

A Novel “Box Lesion” Minimally Invasive Totally Thoracoscopic Surgical Ablation for Atrial Fibrillation

Qiu Zhe Guo, ¹MD, Da Zhu, ¹MD, Zhi Xuan Bai, ¹MD, Jun Shi, ¹MD, Ying Kang Shi, ¹MD, Ying Qiang Guo, ¹MD

Abstract

Introduction: Minimally invasive surgical ablation is an emerging alternative method to catheter ablation and the full surgical maze procedure for nonpharmacologic treatment of atrial fibrillation (AF). We present a totally thoracoscopic “box lesion” radiofrequency ablation procedure in patients with paroxysmal or persistent AF. **Materials and Methods:** From June 2011 to October 2012, 14 patients with lone paroxysmal (n = 7) or persistent AF (n = 7) were enrolled in this study. Procedures were performed through 3 5-12 mm holes on each side of the chest wall. A bipolar ablation device was used to create a box lesion in the posterior wall of the left atrium that encircled the 4 pulmonary veins (achieving bilateral pulmonary vein/posterior left atrial wall isolation). Perioperative complications were recorded for all patients. Freedom from AF was assessed by 24-hour Holter monitoring every 3 months or during symptoms of arrhythmia. **Results:** The ablation was successfully performed in all patients, with median operation time of 128 minutes (range, 45 to 180 minutes). No operative mortality or morbidity were noted during the study period. Freedom from AF was achieved in 12 patients (85.7%) during follow-up (median follow-up 9 months). One patient with persistent AF was shifted to paroxysmal AF. No atrial flutter or atrial tachycardia was noted during the follow-up. **Conclusion:** These early results show that totally thoracoscopic surgical ablation using a unique “box lesion” procedure for persistent or paroxysmal AF is a feasible and effective method with good short-term results. Further study is necessary to validate this result.

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Introduction

Atrial fibrillation (AF) is the most common and severe cardiac arrhythmia. It affects 0.4% to 1% of the general population, and the prevalence of AF,¹ which increases with age, is 8% in people aged over 80. About three-quarters of the cases are non-valvular AF. The risk for stroke in AF patients is 5 times higher than that of the non-AF population. Maintaining sinus rhythm has been shown to be superior to heart rate control in this arrhythmia in reducing the incidence of stroke and other cardiovascular events. But the success rate of drug-only therapy or catheter ablation in maintaining sinus rhythm in AF patients does not exceed 60%.² The traditional surgical “cut-and-sew” Cox maze III procedure is the most successful treatment

for the management of AF, and has a cure rate of 95%.³ But this procedure requires sternotomy, cardiopulmonary bypass (CPB), and a complex series of incisions into the myocardium. The complexity of this technique and the risks involved in its use have prevented wide application of the procedure.

As substitutes for the Cox maze III procedure, a variety of surgical ablation procedures that rely on minimally invasive techniques to achieve isolation of the pulmonary veins, the primary source of ectopic foci in AF, have been developed.^{4,5} Unfortunately, none of these procedures are likely to be as effective as the traditional Cox maze III procedure. One reason is that isolation of the posterior left

¹Department of Cardiovascular Surgery, West China Hospital, Sichuan University, People's Republic of China

Address for Correspondence: Dr Guo Ying Qiang, Department of Cardiovascular Surgery, West China Hospital, Sichuan University, 36th Guoxue Road, Chendu, 610041, Sichuan, People's Republic of China.

Email: drguoyq@hotmail.com

atrial wall is not included, and the posterior left atrial wall, in addition to the pulmonary veins, is considered to play a significant role in the initiation and maintenance of AF.⁶ In the present study, we report our initial experience with, and short-term results for, a newly developed minimally invasive technique for treatment of AF that uses a bipolar radiofrequency device to create a transmural box lesion that surrounds the posterior left atrial wall and encompasses the pulmonary veins—a procedure that separates the pulmonary veins and posterior left atrial wall as a whole from the rest of the atrium.

Materials and Methods

Patient Enrolment

This study was approved by Clinical Research and Biomedical Ethical Committee of West China Hospital Sichuan University. Patients with lone AF (paroxysmal, persistent or permanent) and who had underwent minimally invasive totally thoracoscopic surgical ablation in our hospital were enrolled in the study. The patients involved were all from our clinic and voluntarily chose to undergo surgery after the different treatment options were introduced and explained to them. The classification of paroxysmal and persistent AF followed the Heart Rhythm Society/European Heart Rhythm Association/European Cardiac Arrhythmia Society (HRS/EHRA/ECAS) definitions.⁷ All patients fulfilling either of the following criteria were included in this study: (1) recurrent episodes of AF, and (2) AF refractory to antiarrhythmic drugs. Exclusion criteria were (1) previous pulmonary and cardiac surgery, (2) underlying cardiovascular or pulmonary diseases other than AF, (3) atrial thrombi or persistent left superior vena cava confirmed by transoesophageal echocardiogram. Coronary angiographic analysis was performed if necessary to rule out coronary artery disease. Informed written consent was obtained from all patients.

Surgical Procedure

Procedures were conducted under general anaesthesia under CPB standby conditions. Patients were intubated with a double lumen endotracheal tube in order to achieve lung isolation, and were placed in a supine position with both upper arms dorsiflexed 15° and slightly flexed along the body to facilitate the exposure of the lateral side of the chest wall. A transoesophageal echocardiogram was performed to confirm the absence of left atrial thrombi and persistent left superior vena cava.

After deflation of the right lung, a 5-mm trocar was introduced into the fourth intercostal space in the anterior axillary line and CO₂ insufflation was delivered at approximately 8 to 12 mmHg. A 0° thoracoscope was then

introduced through this port. Two other 5-mm ports were introduced in the third and fifth intercostal space at the anterior axillary line, respectively. The first 5-mm port was then replaced by a 12-mm port which served as the working port (Fig. 1a). The pericardial sac was opened from the superior vena cava (SVC) to the inferior vena cava (IVC) about 2 cm anterior and parallel to the phrenic nerve (Fig. 2). Blunt dissection was performed underneath the SVC and IVC to establish access to the transverse and oblique sinuses, respectively. Two Cardioblade Navigators (Medtronic, Minneapolis, MN, USA) were then put through the sinuses and the right lung was re-inflated (Figs. 2 and 3).

Left-sided Ablation

The left lung was deflated and the same ports as those on the right chest wall were developed on the left chest wall. The pericardium was opened and the tips of the 2 navigators were delivered through the working port (Fig. 1b). Two jaws of the Cardioblade Gemini-s bipolar radiofrequency isolator (Medtronic, Minneapolis, MN, USA) were attached to the tips of the navigators. Under the guidance of the navigators, the 2 jaws of the isolator were then delivered smoothly into the transverse and oblique sinuses respectively (Figs. 2 and 3). When the correct position was achieved, repetitive radiofrequency pulses were applied about 3 to 5 times to achieve transmural ablation. The isolator was then retrieved.

Right-sided Ablation

After re-inflating the left lung and collapsing the right lung, the ablation procedure was repeated by introducing the isolator into the right side of the transverse and oblique sinuses under the guidance of navigators through the right working ports. Repetitive radiofrequency ablations were then applied. When ablations on both sides were completed, a continuous box lesion surrounding the pulmonary veins and posterior left atrial wall was created (Figs. 2 and 3). A single 28-French chest tube was placed in each pleural space through the most inferior ports. The patient was then transferred to the intensive care unit for recovery.

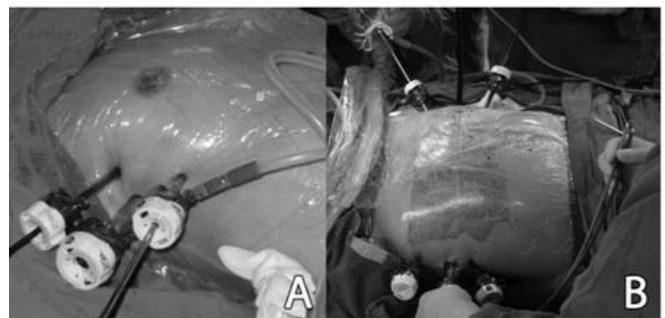


Fig. 1. Location of the ports on each side of the chest wall.

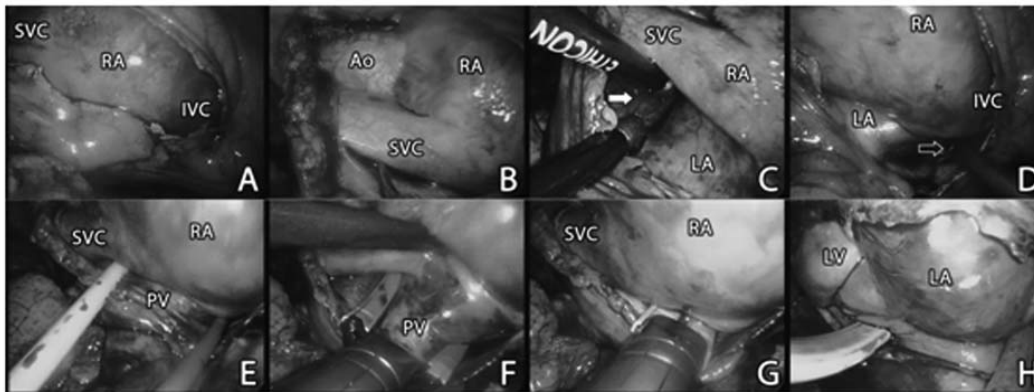


Fig. 2. Continuous intraoperative endoscopic view of the ablation procedure. (a, b) The pericardial sac was opened from the superior vena cava to the inferior vena cava anteriorly and parallel to the phrenic nerve. (c, d) Blunt dissection of the transverse (indicated by the white arrow) and oblique sinuses (black arrow). (e) Two navigators were delivered through the 2 sinuses. (f, g) Right side ablation. (h) Left side ablation. Ao: Aorta; IVC: Inferior vena cava; LA: Left atrium; LV: Left ventricle; PV: Pulmonary vein; RA: Right atrium; SVC: Superior vena cava.

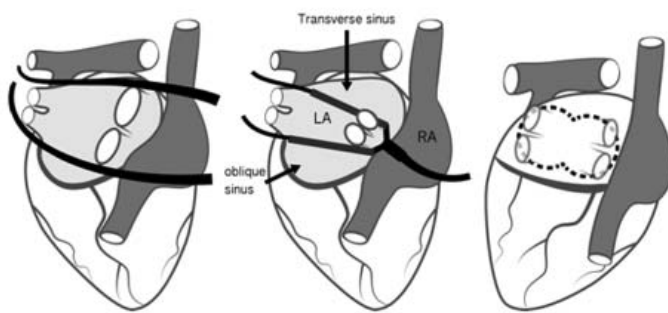


Fig. 3. Schematic drawing of the posterior aspect of the heart. Two navigators were positioned in the transverse and oblique sinuses to guide the ablation device. The dashed line in the figure shows the box lesion created after ablation on both sides.

LA: Left atrium; RA: Right atrium

Postoperative Management

Cardiac rhythm was continuously monitored for 48 hours. Thereafter, daily 12-lead electrocardiograms (ECGs) were performed for the duration of hospitalisation. All patients were given amiodarone (or sotalol if amiodarone was not tolerated) for at least 3 months. In patients who were in stable sinus rhythm, the antiarrhythmic agent was stopped at 3 months. Those who developed persistent AF during the hospital stay underwent cardioversion within 24 hours.

Follow-up

Electrocardiographic follow-up was undertaken at 1 month, 3 months, 6 months, and 1 year after the surgery. A 24-hour Holter test was requested at 3 and 6 months after the surgery, or at any time for patients with normal ECG but symptomatic evidence of recurrence of AF.

Results

Patient Demography and Characteristics

Patient demographic data and characteristics are listed in Table 1 and Table 2. From June 2011 to October 2012, 14 patients (8 male and 6 female) with lone paroxysmal ($n = 7$) or persistent AF ($n = 7$) who had undergone totally thoracoscopic surgery in our hospital were enrolled in the

study. All patients had been unresponsive to or did not tolerate antiarrhythmic drugs. Four patients had had a recurrence of AF after a prior transcatheter endocardial ablation. The median age of patients and median duration of AF were 62 years (range, 41 to 76 years) and 36 months (range, 12 to 204 months) respectively. On echocardiography, the median left atrial diameter was 42 mm (range, 32 to 56 mm) in the parasternal long axis view.

Perioperative Data

The procedure was successfully completed in all patients, with no conversions to sternotomy or thoracotomy. The median procedure time was 128 minutes (range, 45 to 180 minutes). Procedure length was significantly shortened after the first few cases, and the last 3 procedures were completed within 90 minutes. All patients were awakened in the intensive care unit. Thirteen patients were successfully extubated within 6 hours after surgery. A prolonged intubation time occurred in 1 patient with a long history of smoking and deterioration in lung function, and this patient was not extubated until 18 hours after the completion of surgery. The median postoperative stay was 7 days. Eight patients had a postoperative stay of 7 days, and the others had postoperative stays of 8 to 12 days (Table 3).

Table 1. Patient Demography and Characteristics (n = 14)

Characteristics	n (%)
Gender	
Female	6 (42.9)
Male	8 (57.1)
Age (years)	62 (41, 76)
AF type	
Paroxysmal	7 (50.0)
Persistent	7 (50.0)
AF duration (months)	36 (12, 204)
Left atrial diameter (mm)	42 (32, 56)
Previous catheter ablation	4 (28.6)
Preoperative AADS	
IC II	1 (7.1)
II	2 (14.3)
III	2 (14.3)
No	9 (64.3)

AADS: Antiarrhythmic drugs; AF: Atrial fibrillation

Table 3. Perioperative Data and Surgical Outcomes

Surgical Outcomes	n = 14
Procedure time (range, minutes)	128 (45 to 180)
Extubation time (range, hours)	5 (3 to 18)
Postoperative hospitalisation time (range, days)	7 (7 to 12)
Cardioversion (n, %)	2 (14.3%)
Postoperative sinus rhythm (n, %)	12 (85.7%)
Sinus rhythm at 6-month follow-up* (n, %)	9 (90.0%)
Follow-up (range, months)	9 (1 to 12)

*Four subjects' with follow-up period less than 6 months were excluded. Continuous data are summarised by median and full range. Categorical data are summarised by count and percentage.

Table 2. Patient Demography and Characteristics

Patient No.	Gender	Age (Years)	Atrial Fibrillation Type	Atrial Fibrillation Duration (Months)	LAD (mm)	Previous Catheter Ablation	Preoperative AADS
1	Female	41	Paroxysmal	48	42	Yes	No
2	Female	66	Paroxysmal	120	32	Yes	IC II
3	Female	59	Persistent	204	51	No	No
4	Male	76	Persistent	60	42	No	No
5	Female	51	Paroxysmal	12	40	No	No
6	Male	67	Paroxysmal	36	42	Yes	III
7	Male	62	Persistent	36	41	No	No
8	Male	62	Persistent	24	40	No	No
9	Male	69	Paroxysmal	36	56	No	III
10	Male	62	Persistent	12	51	No	II
11	Male	56	Persistent	12	39	No	No
12	Female	47	Paroxysmal	36	32	No	No
13	Female	56	Paroxysmal	24	39	No	No
14	Male	63	Persistent	96	48	Yes	II

AADS: Antiarrhythmic drugs; LAD: Left atrial diameter

A complication occurred in 1 patient who was readmitted 2 weeks after the surgical intervention due to a medial right pleural effusion shown on x-ray. This patient was then treated with pleurocentesis. There were no perioperative deaths, and no reintubations, blood product infusions or pacemaker insertions were required during follow-up.

Surgical Outcome

Twelve of the 14 patients (85.7%) converted to sinus rhythm immediately after the procedure. The 2 patients who did not convert received electrical cardioversion during hospitalisation and were restored to sinus rhythm. All patients (100%) were in sinus rhythm at discharge and

1 month follow-up. Of the 10 patients who completed 6 months follow-up, 9 (90%) patients were in sinus rhythm. One patient who suffered persistent AF before the surgery had a recurrence of paroxysmal AF at this time. No atrial flutter or atrial tachycardia was observed during the follow-up. The median follow-up time was 9 months (range, 1 to 12 months).

Discussion

This report describes the early results of the first series of patients who had underwent a completely thoracoscopic box lesion procedure for the treatment of AF. This procedure was both safe and effective. A pleural effusion in 1 of the 14 patients was the only adverse effect, and the 6-month follow-up showed a 90% success rate.

AF is an increasingly common disease that affects patient morbidity and mortality. Over the years, hypertension and coronary artery disease have replaced rheumatic heart disease as the major causes of AF. In addition, about 30% of AF cases are not associated with an underlying heart disease. For these reasons, catheter ablation and minimally invasive surgical ablation have emerged as promising new treatment strategies.

Advantages and Disadvantages of Different Energy Sources

Over the past decade, different energy sources for causing ablation have been used to replace the “cut and sew” technique during AF surgery, and they include bipolar and unipolar radiofrequency, cryotherapy, microwave, laser and ultrasound. Of these energy sources, bipolar radiofrequency has been shown to be the most safe and effective in creating transmural linear lesions.⁸ Unipolar radiofrequency ablation has favourable plasticity and can be used in some special areas such as the mitral isthmus, but the continuity and transmural of the lesion cannot be assured. Cryotherapy is less likely to cause thrombosis and damage to the surrounding tissues than other techniques, but treatment using this energy source is time-consuming and has poor efficacy. Microwave ablation has favourable plasticity and is also less likely to cause damage to the surrounding tissues, but the transmural of microwave ablation is poorer than that of bipolar radiofrequency ablation. High-intensity focused ultrasound ablation has favourable transmural, but is likely to cause damage to the surrounding tissues and carries a risk for oesophageal injury. Bipolar radiofrequency ablation, the technique used in this study, can be used for transmural ablation with high efficiency and is less likely to cause damage to surrounding tissues than other techniques. Its disadvantage is that some special areas, such as the mitral isthmus, are difficult to access.

Development of Minimally Invasive Ablation Technique

In 2003, Saltman et al⁹ reported the first totally endoscopic microwave ablation procedure for paroxysmal AF, and a variety of minimally invasive techniques emerged after that. Wolf et al⁴ reported their initial experience of video-assisted thoracoscopic AF surgery in 2005, using bipolar radiofrequency to perform bilateral pulmonary vein isolation. Totally thoracoscopic radiofrequency pulmonary vein isolation was performed by Yilmaz in 2007.⁵ A hybrid procedure combining electrophysiology (EP) mapping, epicardial and endocardial ablation was introduced recently and good success rate in eliminating AF freedom rate was reported.¹⁰

Advantages of Our Procedure in Comparison with Other Minimally Invasive Procedures or Catheter Ablation

The 6-month sinus rhythm restoration rate (90.0%) seen in our study is similar to, or even higher than the results reported in other studies.^{11,12} The main reason for this acceptable result is that we combined the advantages of both bipolar RF and box lesion isolation.

Isolated endocardial and epicardial techniques have the following advantages and disadvantages. Isolated endocardial ablation can be performed percutaneously, is less invasive, and can be performed in regions where epicardial ablation is not feasible. It has favourable repeatability and is not influenced by pericardial or pleural adhesions. However, the continuity and transmural of the lesion cannot be assured, single ablation has a low success rate, radiation damage due to x-ray exposure can occur along with complications such as thrombosis, pulmonary venous stenosis, and atrial oesophageal fistula. Continuity and transmural can easily be accomplished with isolated epicardial ablation, and this method is less likely to cause thrombosis, pulmonary venous stenosis, and atrial-oesophageal fistula. But, epicardial ablation is more invasive than endocardial ablation and requires general anesthesia and endotracheal intubation. In addition, an incision on each side of the chest and alternating one-lung ventilation should be done.

Continuity and transmural of the lesion sets are critical for the therapeutic effect,⁸ and histopathological studies have shown that lesions produced by bipolar RF ablation are more likely to be uniformly transmural than those produced by other energy devices.^{13,14} During our minimally invasive procedure, atrial tissue was clamped by the 2 jaws of the bipolar RF device, and saline irrigation between the compressed tissue and the electrode was performed by the device during delivery of radiofrequency energy in order to cool the tissue and increase the effectiveness of the ablation. The achievement of transmural ablation

was directly detected by a feedback system contained in the device. Compared to other completely thoracoscopic box lesion procedures using microwave or high-intensity focused ultrasound (HIFU),^{9,15} our procedure has a higher single-ablation success rate and fewer complications.

Our box lesion procedure isolated the left posterior atrial wall as well as the pulmonary veins. Cui et al,¹² using bilateral thoracoscopic pulmonary vein isolation, ablation of ganglionic plexi, and left atrial appendage removal, reported a 78.6% success rate 6 months after surgery. However, the left posterior atrial wall was not isolated. The existence of non-pulmonary foci has been correlated with recurrence of AF, and the left posterior atrial wall is the critical site in which these foci are located.⁶ The activation of epicardial ganglionic plexi (GP), which are found primarily in fatty epicardial tissues and ligament of Marshall (LOM), has been implicated as a trigger of lone AF. Additional ablation of GPs and LOM may increase freedom from AF.¹⁶ Some GPs located away from the pulmonary vein-atrial junction are difficult to isolate by bilateral pulmonary isolation but can be included in the box lesion ablation. In addition, the roof line of the box lesion is critical in blocking the LOM. Isolating the entire posterior left atrium with a box lesion in the Cox maze procedure has been shown to produce a higher response rate than making only a single connecting lesion between the pulmonary veins.¹⁷ A high clinical success rate of a box-shaped isolation in the posterior left atrium has also been reported in catheter ablation procedures.¹⁸ Doty et al¹⁹ have used a procedure including the destruction of autonomic ganglia, box lesion RF ablation, and removal of the left atrial appendage, but their procedure is not totally endoscopic and requires thoractomy on each side of the chest. A few studies have reported a less invasive procedure which needs only 3 ports on one side of the chest. However those techniques either did not use bipolar radiofrequency or did not perform a box lesion.

No bleeding, conversion to open procedures, stroke, pulmonary vein stenosis and oesophageal damage was observed during follow-up in our study. In our procedure, radiofrequency energy was delivered through the epicardium and the ablation device was not in contact with the endocardium, therefore thrombus formation was not likely to occur. Pulmonary veins stenosis was also avoided as the ablation was not performed on the pulmonary vein orifice.

Underlying Disadvantages

The hybrid procedure is capable of overcoming the shortcomings of both surgical and catheter ablation techniques and is therefore likely to be more effective, because the conduction block can be confirmed by EP mapping and additional ablation can be performed as

necessary. However, the hybrid procedure will not avoid damage caused by radiation and contrast medium, and its financial cost is higher. In mainland China, patients need to pay part of the hospitalisation cost, and the lower cost procedure of our procedure is therefore an advantage. The major disadvantage of our procedure is that no EP mapping was included. Bidirectional block of the lesion set could only be guaranteed by the feedback system of the device and repeated isolation. But, we have provided a less invasive and more economical way to achieve a acceptable result and avoid the damage caused by radiation and contrast medium of an extra catheter ablation.

One possible disadvantage of our technique is that electrophysiological changes that occur after the procedure might enable the formation of a macro-reentry circuit around the box lesion set. The underlying possibility of atrial flutter was taken into consideration in our study, but was not observed during follow-up.

Another possible disadvantage (but also a possible advantage) of our method is that it does not include amputation of the left atrial appendage. In non-rheumatic AF, most of the thrombus is located in the left atrial appendage.²⁰ Eliminating the appendix will reduce the risk of release of thrombotic emboli. But elimination of the appendix also has disadvantages. According to the study of Kamohara et al,²¹ left atrial appendage exclusion may affect the function of the left atrial reservoir. Also, atrial appendectomy by the maze procedure has been shown to reduce atrial natriuretic peptide secretion and the ability of kidneys to handle fluid load early after surgery.²² And, in studies of minimally invasive epicardial ablation techniques combined with left atrial appendage amputation, the incidence of bleeding and conversion to open procedures has been closely associated with left atrial appendage amputation.^{23,24} In our procedure, no left atrial appendage amputation was performed and this may be one of the reasons for the low complication rate seen. Also, in spite of the fact that the left atrial appendage was left intact, no thromboembolic event occurred during the follow-up.

Study Limitations

Our result reflects our experience on a relatively small number of patients, in a rather limited time period. Only 7 patients were able to finish the 1-year follow-up because the procedure was first used in June 2011. In addition, it was hard to detect every asymptomatic episode of AF using single ECG or Holter tests. However, the study is still ongoing, and more patients will be enrolled and followed for a longer duration, incorporating Holter monitoring for all patients at 6-months and 1-year.

Conclusion

We presented the early results of a new, completely thorascopic, minimally invasive surgery for treatment of AF by creating a unique box lesion around the pulmonary veins that includes the left posterior atrial wall. This procedure is safe, easy to perform and appears to be effective in short-term follow-up. It might be an attractive alternative to antiarrhythmic medication therapy and catheter ablation. Continued long-term follow-up on a large group of patients is still required to establish the sufficiency of the treatment.

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