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Efficacy of Cut-and-Sew Box Isolation of the Posterior Left Atrium for Treatment of Atrial Fibrillation—Long-term Follow-up after a Modified Maze Procedure

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ABSTRACT

Background: Box isolation of the posterior left atrium is one surgical or catheter ablative approach for treating atrial fibrillation (AF). In such cases, incomplete transmurality or recovery of pulmonary vein conduction after the application of various ablative techniques is considered the main reason for the recurrence of postprocedural arrhythmia. The use of solely cut-and-sew box isolation does not have these disadvantages and therefore demonstrates maximum efficacy for this therapeutic approach.

Methods: We treated 15 patients with both an indication for open heart surgery and AF (2 paroxysmal, 6 short persistent [<12 months], and 7 long persistent [>12 months] cases) with a solely cut-and-sew box lesion. These patients were then retrospectively followed up over the long term with respect to the end point of freedom of atrial tachyarrhythmias >30 seconds.

Results: The median follow-up duration was 42 months (range, 32-84 months). Five (63%) of 8 patients with preoperative paroxysmal or short persistent AF had no arrhythmia recurrence, whereas arrhythmia recurrence was documented in all 7 patients with preoperative long persistent AF.

Conclusions: Despite reliable transmural isolation with cut-and-sew lesions, we observed long-term arrhythmia recurrence in patients who had preoperative paroxysmal or short persistent AF, suggesting that therapy approaches that are more complex than box isolation might be needed for selected patients to achieve long-term stable sinus rhythm, despite the initially paroxysmal or short persistent character of the arrhythmia. A high rate of recurrence in patients with severe structural heart disease and preoperative long persistent AF might indicate that, in general, isolation of the left posterior atrium alone is not an adequate therapeutic approach for these patients.

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INTRODUCTION

Given the pathophysiological denotation of the posterior left atrium to atrial fibrillation (AF) pathophysiology [Kamino 1991; Morillo 1995; Mandapati 2000; Ndrepepa 2002; Bazaz 2003], complete isolation of this area with a "box lesion" has been studied as a possible surgical approach [Sueda 1997; Todd 2003; Guiraudon 2005; Pruitt 2007; Reddy 2008; Voeller 2008] and as a solely catheter-based interventional approach [Ernst 1999; Kumagai 2007; Sanders 2007; Thomas 2007; Lim 2008; Sohara 2009; Tamborero 2009; Yamaguchi 2010] to AF therapy.

To the best of our knowledge, all surgical procedures that have been published to date use additional ablation techniques with different energy sources in combination with cut-and-sew lesions for isolating the posterior left atrium. Therefore, the potential for incomplete transmurality and subsequent incomplete prevention of electrical conduction between the pulmonary veins/posterior left atrium and the rest of the atrium or, alternatively, recovery of a conduction block as a potential cause of recurrence of atrial arrhythmias during follow-up has to be considered in all of these approaches [Ouyang 2005; Lim 2008].

In our hospital, patients with AF and an indication for open heart surgery were treated with solely cut-and-sew box isolation and no further left atrial lesions except for amputation of the left atrial appendage in a modified maze procedure. Owing to the reliable transmural isolation of the pulmonary veins and the posterior left atrium with a solely cut-and-sew box lesion, this treatment for completely isolating the posterior wall of the left atrium with no additional ablation techniques is capable of demonstrating maximum efficacy as a therapeutic approach for AF.

In our current study, patients treated with solely cut-and-sew box isolation of the posterior left atrium were followed up with respect to the recurrence of atrial tachyarrhythmias lasting longer than 30 seconds.

METHODS

Study Population

For our retrospective study, we included 15 patients (12 male, 3 female) who underwent cardiac surgery including

a modified maze procedure between January 2001 and July 2005 in our university hospital. Written informed consent was obtained from all the participants. The study protocol was approved by the local ethics committee.

Cardiac Surgery

The modified maze procedure was always performed with cardiopulmonary bypass and in addition to other cardiac surgery (mostly reconstruction of the mitral valve).

All left and right atrial lesions were applied with a surgical cut-and-sew technique without any additional ablation techniques; pulmonary veins including the posterior left atrium were isolated en bloc ("box lesion"). Both the right and left atrial appendages were amputated, and a cavotricuspid isthmus line was applied surgically. Finally, the atrium was made taut during reattachment of the cut edges. Of note is that no further linear lesions with proarrhythmogenic potential were applied in case the lesions were incomplete. For example, an anterior mitral line or a lateral mitral isthmus line was not applied, either by ablation or by a cut-and-sew technique. Figure 1 shows the left atrial lesions in a schematic made with the help of a 3-dimensional reconstruction of a computed tomography scan of the left atrium.

Follow-up

Pre- and perioperative data and the clinical courses of the patients were retrospectively obtained by analyzing clinical records of our hospital and documents that were brought by the patients or were ultimately requested from general practitioners, external cardiologists, or hospitals in May 2010.

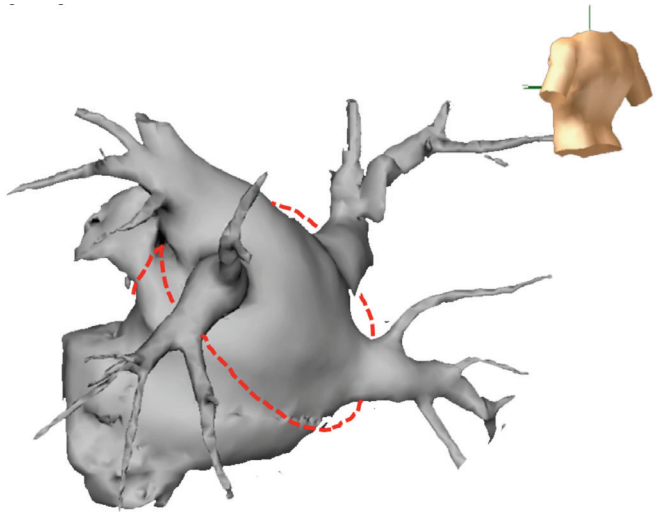

Figure 1. Modified maze procedure. Pulmonary veins including the posterior left atrium were isolated en bloc ("box lesion"). Both right (not shown) and left atrial appendages were amputated, and a cavotricuspid isthmus line (also not shown) was applied. The atrium was made taut during reattachment of the cut edges.

During the follow-up visit in our ambulance, patients were interviewed in detail regarding their history, a 12-lead electrocardiogram (ECG) was recorded, and a transthoracic echocardiography examination was performed. Finally, every patient without an implanted pacemaker underwent a 7-day Holter ECG examination. All but one of the pacemaker patients had a DDD system; therefore, mode switch episodes were used to detect the potential recurrence of arrhythmia in these patients. One patient with a VVI pacemaker also underwent a 7-day Holter ECG examination.

Freedom from recurrence of atrial tachyarrhythmias was defined as a lack of any episodes of atrial tachyarrhythmia lasting >30 seconds during follow-up. AF was defined as short persistent if the arrhythmias lasted for <1 year, and long persistent AF was defined as arrhythmias lasting >1 year. As a valvular genesis of AF was assumed in the majority of our patients ,$CHADS_2$-score was not calculated because this score has been validated only in patients with nonvalvular AF [Gage 2001].

RESULTS

A general summary of the patients' characteristics and the results of our study are given in the Table.

Preoperative Data

At the time of cardiac surgery, the mean age (±SD) of the patients was 69 ± 5.7 years. A combination of structural heart disease and concomitant AF was the indication for cardiac surgery in all patients. Twelve patients who showed mitral valve regurgitation greater than grade III were planned for reconstruction of the mitral valve, and 2 patients had severe aortic valve stenosis with an indication for valve replacement (with a biological valve). An aortocoronary bypass was indicated for coronary heart disease in 1 patient.

Echocardiography revealed that 7 of the patients exhibited severe dilation of the left atrium; 4 patients had mild dilation. Atrial size was not documented preoperatively in the 4 other patients. Left ventricular function was normal in 11 patients and reduced in 4 patients.

Before cardiac surgery, 2 patients experienced paroxysmal AF, and 6 patients experienced short persistent AF. Because of anamnesis and previous clinical findings, we assumed that the remaining 7 patients had long persistent AF.

Before cardiac surgery, all patients received antiarrhythmic drugs (beta-blockers, calcium antagonists, or digitalis glycosides). Two patients were treated with amiodarone in combination with a beta-blocker.

Peri- and Postoperative Data

The mean duration of the cardiac surgery was 260 ± 55 minutes, including a mean cardiopulmonary bypass time of 137 ± 28 minutes and a mean aortic-clamping time of 81 ± 24 minutes.

Complications associated with the surgical intervention occurred in 4 patients: Urgent mitral valve replacement of an initially reconstructed valve was indicated for 1 patient, and 1 patient experienced an intraoperative myocardial infarction that was treated immediately with a coronary bypass.

Overview of the Patients' Characteristics and the Results of the Study*

Preoperative Data		Peri- and Postoperative Data		Follow-up	
Patient age, y	69 ± 5.7	Duration of cardiac surgery, min	260 ± 55	Median follow-up duration, mo	42 (range, 32-84)
		Cardiopulmonary bypass time, min	137 ± 28		
		Aortic clamping time, min	81 ± 24		
AF type, n		Heart rhythm at discharge, n		Heart rhythm, n	
Paroxysmal	2 (13%)	Sinus rhythm	10 (67%)	Sinus rhythm	5 (33%)
Short persistent	6 (40%)	Persistent AF	5 (33%)	Paroxysmal/short persistent AF	3 (20%)
Long persistent	7 (47%)			Long persistent atrial tachyarrhythmias	7 (47%)
Pacemaker	0 (0%)	Pacemaker	2 (13%)	Pacemaker	4 (27%)
Left atrial size, n		Left atrial size, n		Left atrial size, n	
39mm	0 (0%)	39mm	1 (7%)	39mm	2 (13%)
40-50mm	4 (27%)	40-50mm	10 (67%)	40-50mm	10 (67%)
50mm	7 (47%)	50mm	1 (7%)	50mm	2 (13%)
No data	4 (27%)	No data	3 (20%)	No data	1 (7%)
Left ventricular function, n		Left ventricular function, n		Left ventricular function, n	
Normal (LVEF > 55%)	11 (73%)	Normal (LVEF > 55%)	11 (73%)	Normal (LVEF > 55%)	8 (53%)
Mildly reduced (LVEF 45%-54%)	3 (20%)	Mildly reduced (LVEF 45-54%)	3 (20%)	Mildly reduced (LVEF 45-54%)	3 (20%)
Moderately reduced (LVEF 30%-44%)	1 (7%)	Moderately reduced (LVEF 30%-44%)	1 (7%)	Moderately reduced (LVEF 30%-44%)	3 (20%)
Severely reduced (LVEF < 30%)	0 (0%)	Severely reduced (LVEF < 30%)	0 (0%)	Severely reduced (LVEF < 30%)	0 (0%)
No data	0 (0%)	No data	0 (0%)	No data	1 (7%)
Indication for cardiac surgery, n		MV vitium, n		MV vitium, n	
MV regurgitation grade III	12 (80%)	None	8 (53%)	None	8 (53%)
Aortic valve stenosis	2 (13%)	Regurgitation grade I	5 (33%)	Regurgitation grade I	4 (27%)
Coronary heart disease	1 (7%)	Regurgitation grade II	2 (13%)	Regurgitation grade II	2 (13%)
		No data	0 (0%)	No data	1 (7%)
Antithrombotic therapy, n		Antithrombotic therapy, n		Antithrombotic therapy, n	
None	5 (33%)	None	1 (7%)	None	1 (7%)
Aspririn	3 (20%)	Aspirin	6 (40%)	Aspirin	9(60%)
Oral anticoagulation	7 (47%)	Oral anticoagulation	8 (53%)	Oral anticoagulation	5 (33%)
Antiarrhythmics (combination possible), n		Antiarrhythmics (combination possible), n		Antiarrhythmics (combination possible), n	
None	0 (0%)	None	2 (13%)	None	3 (20%)
Beta-blocker	11 (73%)	Beta-blocker	8 (53%)	Beta-blocker	12 (80%)
Digital glycosides	8 (53%)	Digital glycosides	4 (27%)	Digital glycosides	4 (27%)
Calcium antagonists	1 (7%)	Calcium antagonists	1 (7%)	Calcium antagonists	0 (0%)
Amiodarone	2 (13%)	Amiodarone	4 (27%)	Amiodarone	0 (0%)

*Data are presented as the mean SD where indicated. AF indicates atrial fibrillation; LVEF, left ventricular ejection fraction; MV, mitral valve.

Rethoracotomy due to a secondary hemorrhage was necessary in 1 patient. Finally, 1 patient exhibited symptoms of a prolonged, reversible focal neurologic deficit without pathologic findings apparent in a computed tomography scan. A few days after cardiac surgery, pacemaker implantation was indicated for 2 patients with severe sinus bradycardia.

Postoperatively, echocardiographic evaluations showed the left atrium to be of normal size in 1 patient, mildly to

moderately dilated in 10 patients, and severely dilated in 1 patient. The postoperative size of the left atrium was not documented in 3 patients.

Left ventricular function was normal in 11 patients, mildly reduced in 3 patients, and moderately reduced in 1 patient. None of the patients had a severe vitium after cardiac surgery, 2 patients with formerly severe mitral valve regurgitation had moderate mitral valve regurgitation, and another 5 patients still experienced mild regurgitation.

Sinus rhythm was documented immediately after cardiac surgery in 6 of the 8 patients with preoperative paroxysmal or short persistent AF. Two patients had AF that converted spontaneously to sinus rhythm during a postoperative stay in the intensive care unit.

Six of 7 patients with preoperative long persistent AF had sinus rhythm immediately after cardiac surgery or had sinus rhythm restored by electrical cardioversion. While in the intensive care unit, however, 4 of these patients experienced recurrent paroxysmal or persistent AF. Finally, despite multiple electrical cardioversion attempts, sinus rhythm could not be restored postoperatively in 1 patient.

After cardiac surgery, most of the patients were still being treated with beta-blockers, calcium antagonists, or digitalis glycosides. Postoperatively, amiodarone therapy was discontinued in 1 of the 2 patients who had received this drug before cardiac surgery. Amiodarone therapy was continued in the other patient for a maximum of 1 year, as well as in 3 other patients, who were started on amiodarone therapy postoperatively. No other antiarrhythmic drugs besides those mentioned were administered to the patients.

Follow-up

The median follow-up duration between cardiac surgery and the 7-day Holter ECG was 42 months (range, 32-84 months). At follow-up, dilation of the left atrium was mild to moderate in 10 patients and severe in 2 patients. A normal atrial size was documented in 2 patients.

Left ventricular function was reduced mildly or moderately in 6 patients, and it was normal in 8 patients. No vitium was echocardiographically diagnosed in 8 patients, and mild or moderate mitral valve regurgitation was documented in 6 patients. No echocardiographic data were obtained for 1 patient with multiple comorbidities, because she was not able to leave her flat.

At follow-up, no antiarrhythmic therapy was determinable for 2 patients who had experienced short persistent AF preoperatively or for 1 patient with long persistent AF preoperatively. All other patients received beta-blockers and/or digitalis glycosides. No patient was treated with class I or class III antiarrhythmic drugs, including amiodarone.

Analysis of the 7-day Holter ECGs or pacemaker interrogation of the patients with preoperative paroxysmal or short persistent AF revealed recurrence of AF in 1 of 8 patients, whereas freedom from arrhythmia recurrence was documented in the 7 other patients. In addition, there was no clinical evidence for the recurrence of atrial tachyarrhythmias in these patients. During follow-up, however, AF was documented and treated with electrical cardioversion in 2 patients. In summary, freedom from arrhythmia recurrence during follow-up was observed in 63% (5 of 8) patients with preoperative paroxysmal or short persistent AF.

Seven-day Holter ECG analysis or pacemaker interrogation of patients with preoperative long persistent AF revealed persistent atrial tachyarrhythmias in all 7 patients.

In 1 patient, an invasive electrophysiological diagnostic procedure that included electroanatomical mapping of the left atrium was performed 1 year after cardiac surgery. Figure 2 shows that complete isolation of the posterior left atrium was definitely achieved with the cut-and-sew technique.

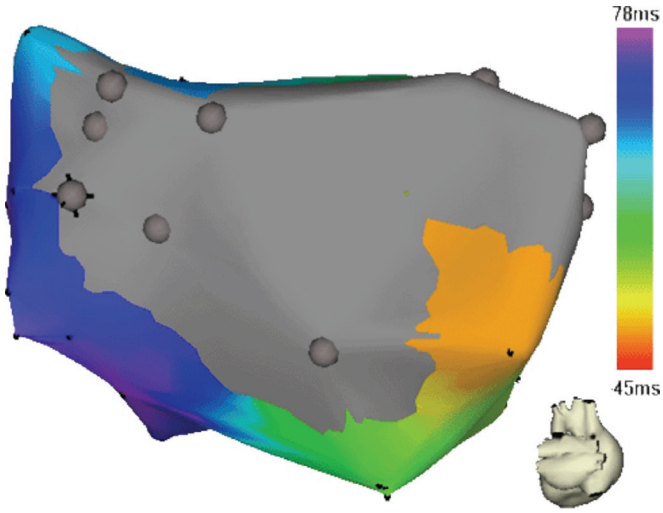

Figure 2. Electroanatomic map (Carto Electroanatomical Mapping System, posterior view; Biosense Webster, Diamond Bar, CA, USA) of the left atrium of a patient with paroxysmal atrial tachycardias at 1 year after cardiac surgery. Complete isolation (scar tissue in gray) of the left posterior atrium including all 4 pulmonary veins was achieved by the cut-and-sew technique.

DISCUSSION

In our study, patients who underwent a modified maze procedure via a solely cut-and-sew box isolation of the posterior left atrium received long-term follow-up for the recurrence of atrial tachyarrhythmias. The high rate of recurrence of atrial tachyarrhythmias in our study population and the serious differences in freedom from arrhythmia recurrence that depended on the preoperative AF type are the main results of our study.

Recommendations for follow-up studies of patients with AF [Calkins 2007] were considered in our study. Because our data were obtained retrospectively, however, all methodologic problems inherent to this study design (nonrandomized fashion, selection bias) and that might have influenced our results have to be considered. Furthermore, because the modified maze procedure has always been performed in combination with other cardiac surgery (especially in patients with paroxysmal or short persistent AF), more pronounced structural heart diseases, and an older age at the time of cardiac surgery, these facts are principal considerations when comparing the success rates of our study with those of studies that were

surgical stand-alone procedures or involved catheter-based ablative isolation of the posterior left atrium.

Freedom from recurrence of atrial tachyarrhythmias might be a result not only of the rhythm surgery itself but also of the successful surgical treatment of the disease that initially indicated cardiac surgery. Wong et al [2006] compared the rates of recurrence of atrial tachyarrhythmias for patients who underwent mitral valve reconstruction with and without a concomitant maze procedure. They found that the rate of achieving a stable sinus rhythm during follow-up was much higher for patients who also underwent a maze procedure. Handa et al. [1999] reported similar results. Thus, rhythm surgery seems to be considerably more important with regard to the rhythmologic outcome of patients than surgical treatment of the cardiac disease [Handa 1999; Wong 2006].

Studies of surgical or catheter-based isolation of the posterior left atrium as a therapeutic approach for AF have reported rates of freedom from atrial tachyarrhythmias during follow-up that range from 40% to 90% [Sueda 1997; Ernst 1999; Todd 2003; Guiraudon 2005; Kumagai 2007; Pruitt 2007; Sanders 2007; Thomas 2007; Lim 2008; Reddy 2008; Voeller 2008; Sohara 2009; Tamborero 2009; Yamaguchi 2010]. Comparing these studies is somewhat problematic, however, because these studies differ in important points, such as patient characteristics, the definition of persistent AF, follow-up duration, the quality of ECG follow-up (from a single resting ECG to a 7-day Holter ECG or event recording to exclude arrhythmia recurrence), the aforementioned differences in technical methods of isolation, and, finally, lesion design. In some instances, additional lines (cut-and-sew or catheter-based) were also used. Furthermore, patients with paroxysmal, short persistent, or long persistent AF were often not observed separately, as they were in our study, even though this division into subgroups would be appropriate, not only for pathophysiological considerations.

To the best of our knowledge, catheter-based ablation has been used in all approaches to date for isolating the posterior left atrium, either alone or in addition to cut-and-sew lesions. It is not clear, however, whether it is possible to create continuous transmural and therefore electrically isolating lesions with the alternative energy sources (such as radiofrequency, cryoablation, or microwave techniques) that are normally used in both catheter-based interventional and surgical approaches to AF treatment. A histopathologic investigation of the atrial myocardium of deceased patients who underwent radiofrequency ablation at some point in their lives revealed transmurality in only 75% of the lesions [Deneke 2005]. In addition, incomplete transmurality and subsequent postinterventional recovery of conduction are considered the main reason for arrhythmia recurrence after the use of ablative isolation techniques [Ouyang 2005]. Unsurprisingly, these mechanisms have also been discussed as the main reason for arrhythmia recurrence in reports of studies of isolating the posterior left atrium as an approach for AF treatment, and they have even been partly proved electrophysiologically [Ernst 1999; Kumagai 2007; Sanders 2007; Thomas 2007; Lim 2008; Sohara 2009; Tamborero 2009]. Because the isolation of the posterior left atrium in our study included only cut-and-sew lesions, possible incomplete transmurality and subsequent postinterventional recovery of conduction cannot explain the recurrence of atrial tachyarrhythmias in our patients.

Ectopic triggers are considered the main pathophysiological mechanisms for the initiation and maintenance of paroxysmal AF and the continuation of short persistent AF [Calkins 2007]. Foci from other areas of the atrium, the coronary sinus, or the superior vena cava that were not included in the initial box isolation might explain the recurrence of arrhythmia in our patients with preoperative paroxysmal or short persistent AF. Alternatively, because we definitely documented AF in all of our patients with arrhythmia recurrence during follow-up, we also cannot exclude the possibility that these patients had precedent undocumented atrial tachyarrhythmias (for example, an atypical left atrial flutter as a consequence of the box isolation approach), which then subsequently remodeled the atrium, thereby favoring the creation of de novo foci that then triggered the recurrence of AF.

In summary, the basic electrophysiological characteristics of the patient's atrium per se, as well as mechanisms produced by the therapy approach, might be responsible for the recurrence of atrial tachyarrhythmias in a patient with preoperatively paroxysmal or short persistent AF.

In our follow-up, the rate of recurrence of atrial tachyarrhythmias depended strongly on the type and duration of the arrhythmia prior to the rhythmologic intervention. Despite the difficult problems, in principle, with comparisons, not only because of the differences in line concepts, surgical approaches, or catheter ablative techniques but also because of the heterogeneity in the patient cohorts, this dependence has also been found in other studies of surgical and catheter-based ablative treatment of AF [Calkins 2007].

The worse results obtained in our study for the patients who had long persistent AF preoperatively might indicate that isolating the posterior left atrium alone is not an adequate therapy for patients with longer persistent AF, despite the use of trusted transmural and continuous lesions.

One reason for the worse outcome of our patients with severe structural heart disease and long persistent AF preoperatively might be insufficient modification of the substrate of the atrium. That is because the atrium is modified by atrial remodeling after prolonged AF, and other, more "substrate-based" mechanisms for arrhythmia maintenance besides ectopic triggering come to the fore [Calkins 2007]. Therefore, modification of the atrium substrate in addition to a box lesion might be necessary for these patients because of other pathophysiologically important mechanisms, such as complex fractional electrograms, AF nests, or autonomic ganglion plexi, which are only partly influenced by box isolation alone [Yamaguchi 2010].

CONCLUSIONS

Despite the reliable approach to transmural isolation via the use of cut-and-sew lesions alone, we observed long-term recurrence of atrial tachyarrhythmias in patients with preoperative paroxysmal or short persistent AF. These results suggest that therapeutic approaches more complex than isolation

of the posterior left atrium are needed in selected patients to achieve long-term freedom from arrhythmia recurrence, despite the initially paroxysmal or short persistent character of the arrhythmia.

The high rate of recurrence of atrial tachyarrhythmias in patients with severe structural heart disease and preoperative long persistent AF in our study suggests that, in general, isolation of the posterior left atrium alone is not an adequate approach to therapy for these patients.

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