Long-term results after ablation for long-standing atrial fibrillation concomitant to surgery for organic heart disease: Is microwave energy reliable?

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Objective: Microwave ablation has been reported as efficient for the surgical treatment of long-standing atrial fibrillation. However, the influence of ablation lesions on long-term results is not known.

Methods: From August of 2000 to November of 2003, 41 patients underwent a left atrial endocardial microwave ablation procedure after a Cox-Maze–like lesion set for long-standing atrial fibrillation concomitant to surgery for valvular or coronary artery disease. Mitral valve surgery alone or combined was performed in 31 cases (75.6%). The mean diameter of the left atrium was 7.19 ± 1.44 cm. The mean duration of preoperative atrial fibrillation was 4.7 ± 3.6 years. Patient follow-up was conducted by means of direct clinical examination, electrocardiography, and transthoracic echocardiography. The mean follow-up was 5.37 ± 0.91 years.

Results: Patient follow-up was achieved in 82% of cases (n = 28). Seven patients (17%) died during follow-up. Stroke was the cause of death in 1 patient with persistence of atrial fibrillation. Major complications occurred in 4 (14.3%) of the patients that were related to the persistence of atrial fibrillation. At 5 years follow-up, 39.3% of patients (11/28) were in sinus rhythm. Seventeen patients (60.7%) were in New York Heart Association classes I and II, and 11 patients (39.3%) were in New York Heart Association class III at the time of follow-up.

Conclusion: In our experience, left atrial endocardial microwave ablation for long-standing atrial fibrillation after a Cox-Maze–like ablation lesion set during surgery for organic heart disease is not a reliable method of achieving long-term conversion to sinus rhythm.

With the renewed interest in the surgical treatment of atrial fibrillation (AF) energized by the introduction of alternative energy sources, microwave energy has been deemed to be safe and effective. However, little is known about microwave ablation as it relates to its long-term efficacy when used to perform the Cox-Maze procedure. As part of an ongoing study, our prospective database was reviewed to evaluate the long-term freedom from late AF recurrence in 41 patients who underwent a left-sided Cox-Maze lesion set using a microwave device as the alternate energy source at the Großhadern Medical Center.

MATERIALS AND METHODS

Between August of 2000 and November of 2003, 41 patients at the Großhadern Medical Center underwent an endocardial left atrial microwave ablation procedure for persistent AF concomitant to open surgery for organic cardiac disease. The study was approved by the ethics committee of the Großhadern Medical Center, and informed consent was obtained from each patient. There were 21 female and 20 male patients with a mean age of 66.4 ± 10.3 years (range 37–81 years). All patients had long-standing AF with a preoperative duration of more than 1 year. No case with paroxysmal AF was included in the study. The following concomitant procedures were performed: mitral valve surgery (n = 26; 63.4%), aortic valve surgery (n = 6; 14.6%), coronary artery surgery (n = 2; 5%), tricuspid valve repair (n = 1; 2.4%), mitral and aortic valve surgery (n = 4; 9.8%), mitral valve and coronary artery surgery (n = 1; 2.4%), and aortic valve and coronary artery surgery (n = 1; 2.4%).

A microwave system (AFx Inc, Fremont, Calif) was used for the ablation. The generator delivers a continuous energy flow (2.45 GHz), which allowed for variable power output ranging between 35 and 75W, adjustable by 5W increments. The Flex 2 probe was used in this study, and it consisted of a 25-mm–long ablation antenna. The temperature of the device was recorded through an embedded thermocouple, and the ablation element was cooled down after 5 to 6 ablations to keep the temperature less than 40°C to prevent overheating and uncontrolled tissue damage.

The microwave energy power setting used to produce each lesion was 40W, with an ablation time of 25 seconds. The number of applications ranged from 17 to 38. The ablation lesion set consisted of a continuous ablation line encircling all 4 pulmonary vein orifices: starting at the level of the mid-mural mitral annulus and going to the left inferior pulmonary vein, then to the left superior pulmonary vein, continuing across the posterior wall of the left atrium to the right superior pulmonary vein, then to the right inferior pulmonary vein, and finally to the mitral valve annulus, and terminating attending at the place the procedure began. The left atrial appendage was excluded by oversewing, and the base of the appendage was surrounded by another continuous ablation line starting from the left superior pulmonary vein.1

All patients underwent arrested heart surgery under cardiopulmonary bypass using a standard procedure via a median sternotomy. The ablation lesion set was performed before valve or coronary artery surgery.

The preoperative and postoperative protocols have been presented in a previous publication.2

Patient follow-up was conducted by means of clinical examination, a recent electrocardiogram (ECC), and transthoracic echocardiographic studies.
Statistical Analysis

In 2004, the Department of Cardiac Surgery at the Großhadern Medical Center changed from the use of microwave to radiofrequency energy-based devices for ablation of AF after some reports suggested a better outcome using radiofrequency. We performed a short-term follow-up after ablation of AF using radiofrequency devices that demonstrated a conversion rate of up to 80%. We had obtained the same results using microwave energy; thus, the question was asked whether the 2 types of energy would have the same results in a long-term follow-up. In answer to this question, we initiated a retrospective study on the patient population who underwent a microwave ablation in the Department of Cardiac Surgery, which is why we can present only the last follow-up data and could not create a Kaplan–Meier curve.

For computer-assisted statistical data analysis, the Statistical Package for the Social Sciences was used (14.0 for Windows; SPSS Inc, Chicago, IL). Values of continuous variables are expressed as mean ± standard deviation. The Student t test was used for parametric variables and the chi-square test was used for categoric variables to calculate probability values. For follow-up variables, the Wilcoxon rank-sum test was calculated.

RESULTS

One-year follow-up results for the first 24 patients have been presented. Long-term follow-up was performed at 5.37 ± 0.91 years (range 3.44–6.74 years). There were 7 deaths during the follow-up period. Stroke was the cause of death in 1 patient. In the remainder of patients, the cause of death was unknown. Of the 34 survivors, 28 patients (82%) were investigated. In all patients, anamnesis, clinical investigation, 12-lead ECG, and transthoracic echocardiography were performed. One patient with persistent AF had a stroke resulting in hemiplegia. One patient had a transient ischemic attack, and 1 patient had a peripheral embolic event that was successfully treated by embolectomy. Percutaneous catheter ablation was unsuccessfully performed in 1 patient. Long-term restoration of sinus rhythm was documented in 39.3% of patients (11/28). All patients in sinus rhythm were not taking any antiarrhythmic medication. Seventeen patients (60.7%) were in New York Heart Association (NYHA) classes I and II, and 11 patients (39.3%) were in NYHA class III at the time of follow-up. There were no significant differences between the NYHA class of patients in sinus rhythm and those patients with persistent AF. The mean duration of preoperative AF was 4.7 ± 3.6 years (range 1–15 years). The mean diameter of the left atrium was 7.19 ± 1.44 cm (range 4.6–10.5 cm). The left atrial diameter was significantly reduced in all patients, with a mean of 5 ± 0.76 cm in patients with sinus rhythm and 5.1 ± 0.67 cm in patients with persistence of AF compared with the preoperative data: $P = .02$ for the patients in sinus rhythm and $P = .003$ for the patients with persistence of AF. We were unable to demonstrate any statistical significance with regard to risk factors for persistence of AF. Preoperative duration of AF was longer in patients with persistent AF at late follow-up (5.6 ± 4.1 years) compared with the patients in sinus rhythm (3.71 ± 2.6 years), but this was not statistically significant. The type of surgery did not influence the results. At late follow-up, 7 patients were in sinus rhythm after mitral valve surgery and 4 patients were in sinus rhythm after other procedures ($P = .7$).

DISCUSSION

The aim of surgical treatment of AF is to restore sinus rhythm. The success rate is different among published data, varying from 42% to 100%. Among the reasons for the difference in results are the following: different criteria for patient selection, incidence of preoperative paroxysmal AF, incidence of preoperative lone AF, application site of ablation energy (endocardial or epicardial), method to produce the lesions (cut-and-sew or alternative sources of energy), lesion set, and definition of success.

Most surgical ablation procedures are performed concomitantly to cardiac surgery for valvular or coronary artery disease, and most of the patients have persistent, longstanding AF.

The cut-and-sew Cox-Maze procedure is considered the gold standard for surgical treatment of AF. However, the perceived technical complexity and longer procedure times have prevented its widespread adoption into clinical routine. Alternative energy sources, including radiofrequency, microwave, cryoablation, high-intensity focus ultrasound, and laser energy, have been developed to simplify the surgical treatment of AF. The endocardial surface is the most frequent energy application site, and in most cases only the left atrial lesion pattern is performed.

There has been some controversy in the literature as to whether the creation of transmural lesions is necessary to cure AF. However, it is an accepted fact that lesions must create a conduction block to be effective as a treatment for AF. Ablation lines are designed to electrically isolate the triggers in the pulmonary veins or block the macro-reentrant circuits responsible for the propagation of permanent AF. However, the only guarantee of complete and permanent conduction block is a transmural lesion.

In consideration of the above-presented commentaries, the most frequent “ablation-scenario” occurs during surgery for organic heart diseases and the lesions are performed on the endocardial surface of the left atrium. Further, if the energy source used produces transmural lesions, then results should be influenced only by lesion set and patient characteristics.

The left atrial Cox–Maze lesion set was developed to interrupt the multiple wavelet macro-reentry circuits that perpetuate AF and has the best long-term results with a conversion rate to sinus rhythm of approximately 95% at 15 years.
However, numerous studies have shown that preoperative duration of AF and the diameter of the left atrium are important variables that significantly influence the success of the procedure.\textsuperscript{8,9} Frequently mentioned cutoff values are preoperative left atrial diameter less than 6 cm and duration of AF less than 6 years.\textsuperscript{10-12} One can therefore conclude that if preoperative duration of persistent, long-standing AF is not excessive and the enlargement of the left atrium is not extreme, left atrial endocardial ablation using a Cox-Maze–like lesion set with a device capable of producing transmural lesions should have good results. In our experience using microwave energy, the initial conversion rate to sinus rhythm was 80% after 1 year in 24 patients,\textsuperscript{1} but this decreased dramatically to 39.3% after 5.37 years in a larger patient population resulting from the addition of 17 supplementary patients. The diameter of the left atrium was 7.19 cm and the duration of preoperative AF was 4.7 years in our entire patient population. At follow-up, we noticed a significant reduction in the left atrial diameter compared with the preoperative status \(P = 0.02\) in patients converted to sinus rhythm (left atrial diameter at last follow-up: 5 cm) and in patients who remained in AF (5.1 cm). There was no difference regarding this parameter between the 2 groups. On the basis of these results, we assume that surgery for the organic heart diseases led to a significant reduction of the left atrial diameter in both groups. On consideration of these data, we conclude that the dimension of the left atrium did not influence the poor conversion rate of our followed patients. The preoperative duration of AF of 4.7 years in our patient population is a rather short time period compared with other studies, so it cannot be considered as a determinant for the poor conversion rate to sinus rhythm.\textsuperscript{10-12}

The current system of microwave ablation lacks a transmurality feedback mechanism. This is in contrast with the bipolar radiofrequency system, which has an adjustable energy delivery mechanism dependent on tissue thickness and is a reliable indicator for lesion transmurality.\textsuperscript{13} The microwave energy delivery is based on a standard protocol recommended by the company that produces the device, which is based on the results of in vitro or animal experiments. For the Flex 2 device, if microwave energy is applied endocardially, most of the authors use an energy power of 40W with an ablation time of 25 seconds per lesion at a frequency of 2.45 GHz.\textsuperscript{1,14,15} Venturini and colleagues\textsuperscript{16} have suggested higher microwave energy levels (65W) and a longer ablation time per lesion (60 seconds). This setting has also been recommended by the device manufacturers for epicardial application of microwave energy for heating heart ablation of AF.\textsuperscript{17}

The ability of the microwave system to create transmural lesions consistently in the arrested heart of a porcine model was described by Gaynor and colleagues.\textsuperscript{6} They created endocardial atrial lesions at 65W and different durations of 15, 30, 45, 60, 90, and 120 seconds. All lesions were transmural with ablation duration of 90 seconds. The lesions that were not transmural were over the trabeculated areas of the atria. On the basis of their results, Gaynor and colleagues concluded that more prolonged ablation will be required in patients if atrial wall thickness exceeds 4 mm.

In our patient population, the lesion set was similar to the left Cox-Maze cut-and-sew procedure, and the microwave energy power setting used to produce each lesion was 40W, with an ablation time of 25 seconds. It is possible that transmurality was not accomplished in all ablated areas. This could be an explanation for the modest conversion rate to sinus rhythm at 5.4 years. The conversion rate in this patient population was 80% at 1-year follow-up.\textsuperscript{1} To our knowledge, the longest follow-up data after microwave ablation available in the literature is 1 year. The reported conversion rates ranged from 62% to 88%.\textsuperscript{15,18}

There is a paucity of publications reporting long-term ablation results. If the cut-and-sew Cox-Maze procedure is used, the reported results are better. Gaynor and colleagues\textsuperscript{8} reported a success rate of 89.3% at 10 years after the cut-and-sew Cox-Maze procedure. However, 66% of the patients underwent surgery for lone AF. Similar results were reported by Itoh and colleagues:\textsuperscript{19} 98.4% at 5 years and 81% at 12 years. The conversion rate reported by Sie and colleagues\textsuperscript{20} was 73.4% at a follow-up duration of 3.3 years using unipolar radiofrequency energy. The logical question is, should 1-year results be considered definitive regarding conversion rate success, or should follow-up be prolonged to demonstrate persistence of sinus rhythm, especially if transmurality of lesions created during surgery is not certain?

Theoretically, conversion to sinus rhythm should lead to significantly higher reduction in left atrial diameter compared with the reduction of this parameter in patients with persistence of AF after surgical correction of organic heart diseases. However, to our knowledge only 1 study has demonstrated a statistically significant result with regard to this difference.\textsuperscript{14} There are 2 other publications that have documented a significant reduction in left atrial diameter after heart surgery but failed to find any difference between patients with sinus rhythm and patients with AF at follow-up.\textsuperscript{21,22} The patients in these studies underwent surgery because of mitral valve disease. The authors stated that the mitral valve procedures caused a considerable reduction in left atrial size, the magnitude of which was similar in all procedures. This was probably caused by mitral valve correction resulting in left atrial pressure relief. We observed a similar finding in our patient population. The diameter of the left atrium at 5 years follow-up in patients with sinus rhythm did not differ compared with the left atrial diameter in patients with AF with the same follow-up duration. However, preoperative left atrial diameter was larger in patients with AF versus patients who were in sinus rhythm. Overall, there was a reduction of the left atrial diameter in all patients...
postoperatively. We assume that this change resulted as a consequence of the surgical correction of the organic heart disease. In our patient population, conversion to sinus rhythm did not seem to influence the reduction in left atrial size.

LIMITATIONS
This study has several limitations. The small patient population along with the number of patients lost to follow-up may have affected the results. Documentation of pulmonary vein isolation by pacing at the time of surgery may have given an indication of the inability of the device to create transmural lesions acutely. The fact that all patients had long-standing AF and were treated with only a left-sided lesion set also may have influenced the results. Reliance on patient history and ECG to evaluate sinus rhythm may have resulted in an underestimation of AF recurrence. A more accurate method would have entailed the use of a Holter monitor or cardiac event monitor.

CONCLUSIONS
We recognize several factors that influence the success of the Cox-Maze procedure, as outlined above. However, on the basis of our findings, one can assume that a lack of lesion transmularity was a major factor influencing the modest conversion rate to sinus rhythm 5 years postoperatively.

References