

Intraoperative endocardial microwave ablation for treatment of permanent atrial fibrillation during coronary artery bypass surgery: 1-year follow-up

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KEYWORDS

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Aims Operative treatment of atrial fibrillation was initially performed as a maze operation in combination with mitral valve surgery or as a stand-alone procedure. The introduction of simplified ablation procedures led to the extension of operative atrial fibrillation treatment.

Methods and results In 102 consecutive patients, endocardial microwave ablation was performed during coronary artery bypass surgery alone ($n = 42$) or in combination with valve surgery ($n = 60$). Patients were divided according to lesion line concept (the initial single lesion line concept connecting the pulmonary veins with the mitral valve annulus was replaced by a box lesion line concept including the left atrial appendage) and the complexity of the procedure. Patients were followed prospectively at 1, 3, 6, and 12 months post-operatively. Survival rate was 95.8% at 30 days and 88.5% after 1 year. There were no device-related complications. At all follow-ups, approximately 10% more of the patients with the first lesion line concept and coronary bypass operation alone showed stable sinus rhythm in contrast to the combination procedures. With the new lesion line concept, patients were significantly more often in sinus rhythm at 1-year follow-up (74% vs. 52%; $P = 0.0026$).

Conclusion Our results demonstrate that endocardial microwave ablation can be performed in combination with coronary artery bypass grafting with excellent conversion rate to sinus rhythm after 1 year without increasing the surgical risk for patients with permanent atrial fibrillation.

Introduction

The maze procedure, which represents the gold standard for surgical treatment of atrial fibrillation, was performed in combination with mitral valve surgery or as a stand-alone procedure by Cox.^{1,2} Before new ablation techniques, such as endocardial microwave ablation, were introduced into the armamentarium of surgical therapy of permanent atrial fibrillation (pAF), it was not usual to combine ablation with coronary bypass surgery. In our centre, we began surgical therapy of atrial fibrillation combined with coronary bypass grafting in 1997. Initially, this was using the Cox-Maze III procedure. Then we switched to endocardial ablation in combination with mitral valve surgery first with radiofrequency energy, and since 1998 with microwave energy.^{3–7}

To overcome the lack of experience with ablation treatment during coronary bypass operations, a pilot study with microwave ablation (MICRO-PASS) was performed in 1999 and 2000 with acceptable conversion rate to sinus rhythm, which encouraged us to extend the indication.⁵

Methods

Between December 1998 and December 2003, 102 consecutive patients undergoing elective coronary artery bypass grafting (CABG) ($n = 42$) or in combination with mitral valve surgery, aortic valve surgery, ASD closure, tricuspid valve repair ($n = 60$) with pAF,⁸ were included in this prospective registry study (Table 1). All patients underwent endocardial microwave ablation. All operations used extra corporeal circulation with arrested heart by crystalloid cardioplegia (Custodiol® HTK solution, Dr F. Köhler Chemie, Alsbach-Hähnlein, Germany) in normothermia.

Patients without pAF were excluded. Other exclusion criteria were: emergency operations, stroke in the last 3 months, acute myocarditis, congestive heart failure [New York Heart Association

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Table 1 Patients' characteristics					
	All patients	CABG isolated L1	CABG isolated L2	CABG combined L1	CABG combined L2
Number	102	30	12	29	31
Male/female	68/34	26/4	9/3	17/12	16/15
Age (years)	70.4 ± 5.8	70.7 ± 5.4	68.8 ± 6.4	71.8 ± 5.0	69.3 ± 6.5
Range	52.0–83.5	60.2 ± 79.5	56.1 ± 79.9	63.1 ± 83.5	52.0–78.4
pAF (years)	6.8 ± 8.2	6.1 ± 6.3	8.9 ± 5.6	5.4 ± 8.9	8.3 ± 9.8
Range	0.1–43.7	0.1 ± 20.8	0.5–20.9	0.1–43.7	0.1–42.2
LVEF (%)	56.6 ± 13.5	53.2 ± 12.2	60.8 ± 9.7	58.7 ± 12.3	55.6 ± 15.1
Range	20–83	32–73	45–70	45–80	20–83
LAD (mm)	49.7 ± 9	46.8 ± 7.7	49.2 ± 5.0	53.1 ± 10.7	49.4 ± 8.0
Range	30–97	30–65	42–60	41–97	40–70

LVEF, left ventricular ejection fraction; LAD, left atrial diameter in parasternal view; CABG isolated L1, isolated CABG with first lesion concept; CABG isolated L2, isolated CABG with second lesion concept; CABG combined L1, combination CABG with first lesion concept; CABG combined L2, combination CABG with second lesion concept.

(NYHA) class IV], pregnancy and nursing, known drug abuse, or conditions rendering the patient unable to give informed consent.

On the day of admission for operation anti-arrhythmic medication was stopped. Post-operatively, all patients received Sotalol to stabilize rhythm and were anticoagulated with Phenprocoumon with a target INR of 2.0–3.0 or 3.0–4.0 in case of mechanical mitral or aortic valve replacement, respectively. After discharge, the patient's general physician or cardiologist managed their anti-arrhythmic and anticoagulation therapy. In all patients who showed stable sinus rhythm on Holter electrocardiography at the 3-month follow-up and who had no mechanical valve, anticoagulation with Phenprocoumon was discontinued and replaced by aspirin. Also Sotalol was stopped after 3 months and replaced by a conventional β -blocker regardless of the rhythm outcome.

Follow-up examinations were carried out in all patients after 1, 3, 6, 12, and 24 months; this involved conducting 24 h Holter electrocardiography and transthoracic echocardiography. A study nurse followed-up all patients, the data for whom were entered into the study register.

The benefits and risks of ablation were explained to all patients at least one day before the operation and only patients who gave informed consent were included. The patients also agreed to the anonymous inclusion of their data in a registry for scientific evaluation.

The AFx microwave surgical ablation devices (Flex 2 and since 2001 Flex 4, AFx Inc., Fremont, CA, USA, now Guidant) were used to produce linear lesions on the endocardial surface of the left atrium. This device was designed to allow the application of microwave energy to tissue through an antenna. Details of the method have been described previously.⁹

The first 59 patients underwent ablation according to Allesie's lesion line concept.¹⁰ The procedure starts under direct view at the posterior mitral valve annulus going to the left pulmonary vein, ending in the vein about 1 cm away from the orifice. The next lesion line starts at the same spot but on the contralateral side of this vein. At the end, the lines connect all pulmonary veins (Figure 1).

For the next 43 patients, the course of the lesion lines was modified. The left atrial appendage was included in the line concept and the pulmonary veins were isolated.¹¹ The line starts at the apex of the left atrial appendage. The pulmonary veins of each side were isolated creating a box lesion around the veins. Another line connects these boxes. Finally, the box around the left pulmonary veins is connected to the line coming from the left atrial appendage leading to the posterior mitral valve annulus. At the end of the ablation procedure, a running suture closes the left atrial appendage from inside (Figure 2).

If the operation procedure required opening the right atrium, for example ASD closure, tricuspid valve repair, or redo operation,

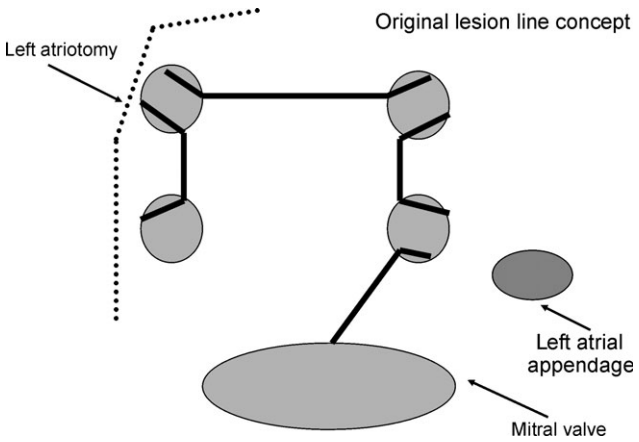


Figure 1 Line concept I.

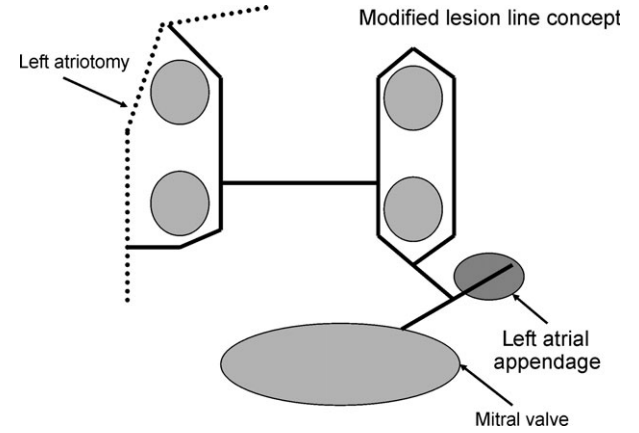


Figure 2 Line concept II.

an additional ablation of the cavo-tricuspid isthmus was carried out. In these cases, a trans-septal access to the left atrium was used.

The mean value $\pm$ standard deviation was given for all continuous data, and percentage frequency with classified data. The χ^2 square test according to Brandt and Snedecor was used for group comparison. P -values < 0.05 indicate a statistically significant difference between groups.

Table 2 Operative data

Type of operation	n
CABG alone	42
CABG + mitral valve repair	18
CABG + mitral valve replacement	8
CABG + mitral valve replacement + aortic valve replacement	3
CABG + mitral valve repair + tricuspid valve repair + ASD closure	1
CABG + mitral valve repair + tricuspid valve repair	3
CABG + mitral valve repair + ASD	1
CABG + aortic valve replacement	8
CABG + aortic valve replacement + mitral valve replacement + tricuspid valve repair	2
CABG + aortic valve replacement + mitral valve replacement + ASD closure	1
CABG + aortic valve replacement + mitral valve repair	2
CABG + ASD closure	6
CABG + ascending aorta replacement	1

ASD, atrial septal defect.

Results

One-year follow-up was complete for 96 patients (in six patients with combined treatment, follow-up continues). The additional time for the ablation procedure requires 10–20 min. No device-related adverse events occurred.

Operative data are presented in *Table 2*. Mean number of distal anastomoses was 2.4 in all patients and 2.9 in patients with CABG, respectively. Thirty-day mortality was 4.2% and 1-year survival was 88.5%.

The reasons for early mortality were heart failure ($n = 3$) and stroke ($n = 1$). During the follow-up period seven patients died due to septic-toxic shock ($n = 1$), stroke ($n = 1$), heart failure ($n = 2$), and pneumonia ($n = 3$) (*Table 3*).

All patients with sinus rhythm demonstrated good biatrial transport function shown in the analysis of the E- and A-wave in echocardiography. There were no changes in the E-A ratio either in the left ($P = 0.520$) or in the right atrium ($P = 0.865$) (*Table 4*).

Differences according to the type of operation (isolated or combined procedure) are listed in *Table 5*. At all follow-up visits, patients with CABG alone had an approximately 10% higher rate of sinus rhythm than the patients with combined procedures (*Table 5*). The success rate for conversion to sinus rhythm was higher in patients who had an ablation procedure following the second line concept. However, this trend failed to be statistically significant.

Patients were analysed on the basis of the line concept employed and the complexity of the procedure. This showed that patients who had undergone a combined procedure benefited most from the use of the new line concept (*Table 6*). At the 1-year follow-up, conversion rate to sinus rhythm was 74%, whereas it was only 52% in patients who had an ablation following the first line concept ($P > 0.0026$).

Twenty-one of the 96 patients (24%) required permanent pacemaker implantation (13 dual chamber and eight single chamber) at the 1-year follow-up. Two of the patients already had a single chamber pacemaker before the operation, which was changed to dual chamber.

Table 3 Number of patients in sinus rhythm after 90, 180, and 360 days for the whole group

	30 days	90 days	180 days	360 days
Whole group ($n = 96$)	92	90	86	85
Deaths	4	2	4	1
Sinus rhythm	66.3%	71.1%	68.6%	64.7%
Permanent atrial fibrillation	30.4%	22.2%	27.9%	29.4%
Atrial flutter				
Typical	3.3%	4.4%	1.2%	2.4%
Atypical	0.0%	2.2%	2.3%	3.5%

Discussion

In 1999, a total of 2052 coronary bypass operations were performed in our institution. Ninety-three of these patients had pAF. So the prevalence of pAF in patients who were referred to our institution for isolated CABG procedures was 4.54%.

Compared with others, this is rather high. Quader *et al.*¹² report a prevalence of only 0.96% for a similar group of patients. One possible explanation may be that our patients were even older than the patients of other centres (70.4 years vs. 59 years).^{13,14}

In our patients, we were unable to observe any additional risk by combining endocardial microwave ablation with CABG. This is confirmed by Quader *et al.*,¹² who, in a risk analysis of 46 984 patients, recommended additional operative ablation treatment for patients with pAF who undergo CABG.

Raine *et al.*¹⁵ came to the same conclusion for patients with pAF who require mitral valve surgery.

Depending on the line concept and the type of procedure, the success rate for patients with pAF who underwent microwave ablation was between 52 and 83%. Our results demonstrate that the new lesion line concept is superior to the original one, especially in patients who undergo complex procedures ($P = 0.0026$). The key criterion for success is restoring sinus rhythm. Nevertheless, some patients reverted to atrial fibrillation during follow-up after having early post-operative sinus rhythm. Similar results were observed in patients following radiofrequency ablation in combination with mitral valve surgery;¹⁶ success rate fell from 80% early post-operatively to 60% after 1 year. The modified line concept seems to be an opportunity to overcome this problem. In our cohort, the patients who had undergone ablation as part of a combined procedure using the modified line concept had no recurrence of atrial fibrillation during follow-up. Nevertheless, these are only short-term results for this kind of surgery and they have to be confirmed in long-term follow-up.

Success rates for endocardial ablation vary from 65 to 93%,¹⁷ which is lower than that described for the standard maze procedure (>90% sinus rhythm at 1 year). This may be explained by different selection of patients.¹⁸ We included all patients with pAF, irrespective of its duration, history, patient's age, or left atrial diameter. This may lead to a higher failure rate, when compared with well-selected patients in the traditional maze procedure,

Table 4 Atrial transport function in patients with sinus rhythm (E/A-ratio in transthoracic echocardiography in four chamber view)

Day	30	90	180	360
Right atrium, A/E	0.83 ± 0.24	0.80 ± 0.24	0.85 ± 0.33	0.77 ± 0.25
Left atrium, A/E	0.51 ± 0.08	0.62 ± 0.32	0.56 ± 0.21	0.55 ± 0.14

Table 5 Frequency of sinus rhythm divided according to type of operation and line concept

	<i>n</i>	90 days	180 days	360 days
CABG, isolated				
Sinus rhythm	42	78%	74%	72%
Deaths	3	1	2	0
<i>P</i> between isolated and combined procedure		0.0417	0.2778	0.0531
CABG, combined				
Sinus rhythm	54	65%	67%	59%
Deaths	8	5	3	0
First lesion concept	59			
Sinus rhythm		68%	66%	62%
Deaths	4	3	0	1
<i>P</i> between first and second lesion concept		0.2077	0.2823	0.2324
Second lesion concept	37			
Sinus rhythm		76%	73%	70%
Deaths	7	3	4	0

Table 6 Frequency of sinus rhythm divided according to line concept and complexity of procedure

	<i>n</i>	90 days	180 days	360 days
First lesion concept				
CABG, isolated	30			
Sinus rhythm		75%	75%	71%
Deaths	2	1	1	0
<i>P</i> between first and second lesion concept		0.1649	0.7471	0.7528
Second lesion concept				
CABG, isolated	12			
Sinus rhythm		83%	73%	73%
Deaths	1	0	1	0
First lesion concept				
CABG, combined	29			
Sinus rhythm		59%	59%	52%
Deaths	2	2	0	0
<i>P</i> between first and second lesion concept		0.0366	0.0423	0.0026
Second lesion concept				
CABG, combined	25			
Sinus rhythm		73%	74%	74%
Deaths	6	3	3	0

where only 40% of patients were in pAF.² Nevertheless, it has to be emphasized that a success rate of 52% for endocardial microwave ablation in combination with isolated CABG is higher than the previously described spontaneous conversion rate to sinus rhythm after CABG without ablation, which is in the range of 7–27%.^{7,19–24}

During the 1-year follow-up, 13 of 96 patients (13.5%), who had preoperative AF with bradyarrhythmia, showed

sinus bradycardia and/or chronotropic incompetence after ablation and received a dual chamber pacemaker system with rate modulation.²⁵ Our incidence of post-ablation pacemaker implantation is comparable with others, which are between 4 and 14%.^{15,26–28}

At the beginning of 2004, we changed our strategy in the treatment of the recurrence of atrial fibrillation in the post-operative period. If atrial fibrillation recurs, we no longer

Table 7 Number of electrical cardioversions

	10 days	30 days	90 days	180 days	360 days	All	Ratio per patient
CABG isolated L1 (n = 30)	18	4	0	0	3	25	0.83
CABG isolated L2 (n = 12)	4	2	0	0	0	6	0.5
CABG combined L1 (n = 29)	20	12	3	1	2	38	1.3
CABG combined L2 (n = 31)	6	1	2	3	0	12	0.38

perform immediate electrical cardioversion, but we delay it to the sixth post-operative week. This explains why patients receiving the initial lesion line concept surgery had significantly more electrical cardioversions than patients with the subsequent lesion line concept (Table 7). Our first experience with this suggests a marked reduction in post-ablation pacemaker implantation.⁶

Limitations of the study

As the study was not a randomized design, the better results obtained with the lesion line concept in the second phase of the study may reflect a more experienced and better surgical performance when compared with the first study phase rather than the real superiority of the method.

Although this study is a retrospective review of prospectively collected data, it is likely to suffer from the inherent limitations of observational studies on non-randomized patient groups.

Conclusion

In conclusion, our results indicate that even in patients who were primarily referred for coronary bypass surgery, additional endocardial microwave ablation can be performed successfully in treating pAF. Sinus rhythm conversion rate is very acceptable and was improved by the modification of the ablation line concept.

The next step should be the evaluation of isolated epicardial microwave ablation to enable the treatment of atrial fibrillation without opening the left atrium.

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