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## Institutional report - Arrhythmia

# Medium-term outcome of different surgical methods to cure atrial fibrillation: is less worse?

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### Abstract

Different lesion sets and ablation techniques have been performed. We compared these outcomes in search of the best method. We performed a retrospective analysis of patients who have undergone AF surgery different from the maze III. The surgical lesion sets were pulmonary vein isolation (PVI) alone, left atrial maze (LAM) and bi-atrial maze (BAM) and were made with different ablation techniques. During surgery one patient died due to bleeding of a pulmonary vein. The number of patients in the PVI-, LAM-, BAM-groups was 12, 28 and 26, respectively, with freedom from AF at latest follow-up [ $22.0 \pm 15.6$  (3.1–81.2) months] of 33%, 59% and 60%, respectively. Atrial flutter occurred less in the BAM-group (4%) than in the left-sided procedures (15.4%) ( $P=0.231$ ). Multivariate analysis demonstrated a higher recurrence of AF for PVI alone (OR 4.42, CL 0.95–20.6,  $P=0.0583$ ) and a lower recurrence for the 'cut-and-sew' technique (OR 0.13, CL 0.030–0.60,  $P=0.0084$ ). Left- and bi-atrial maze procedures are equally effective in the suppression of AF, whereas omission of right-sided lesions results in a higher prevalence of atrial flutter. The 'cut-and-sew' technique is superior in terms of freedom from AF compared to bipolar and unipolar radiofrequency.

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**Keywords:** Atrial fibrillation; Rhythm surgery; Maze; Arrhythmia

### 1. Introduction

The classical maze III is highly successful in terminating AF, but it has some drawbacks. We still perform the classical maze III procedure in our department and have reported the results recently [1], but because of its drawbacks we also performed less extensive lesion sets with alternative ablation techniques.

Since the introduction of the maze procedure our understanding of AF has grown enormously. Haissaguerre et al. showed that lone paroxysmal AF is often initiated by ectopic foci originating from the pulmonary veins and that ablating or isolating these foci can cure AF [2]. Recent evidence shows that focal activation in the left atrium close to the pulmonary veins plays also an important role in patients with chronic AF and mitral valve disease [3]. The experience with the surgical left atrial isolation procedure also discloses the important role of the left atrium in the arrhythmogenesis of AF [4]. Therefore, both cardiologists and surgeons are now more and more focusing on the left atrium with special interest in the pulmonary veins [5] and one could expect that left-sided procedures are highly effective.

In search of the best alternative for the maze III, we retrospectively compared three different lesion sets and three different ablation techniques.

### 2. Material and methods

#### 2.1. Study population

Between March 1999 and June 2005, a total of 67 consecutive patients had undergone a surgical procedure for AF different from the classical maze III procedure. Preoperative, perioperative and follow-up data of these patients have been collected from in-patient and out-patient clinic files and a questionnaire was mailed to the referring cardiologists. Two patients were lost to follow-up (97% completeness of follow-up).

#### 2.2. Surgical procedures

Three different types of lesion sets have been applied to eliminate AF: pulmonary vein isolation (PVI) alone, left atrial maze (LAM) and bi-atrial maze (BAM). The LAM consists of a PVI and an ablation line through the left isthmus, but without right-sided lesions. The BAM mimics the classical maze III procedure, but the 'cut-and-sew' technique is replaced by ablation lines. All BAM procedures

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were made with bipolar RF ablation, except for three procedures which had been made with unipolar RF ablation. The BAM procedure resembles strongly the maze IV operation described by Damiano and his group [6]. Amputation of the left atrial appendage was carried out in all procedures. We did not perform intra-operative pacing to test transmural or conduction block of the ablation lines.

### 2.3. Surgical ablation techniques

Over the years different ablation devices have been used to replace the 'cut-and-sew' technique. Unipolar radiofrequency ablation lines were cooled with irrigation (Cardio-plate Surgical Ablation Pen, Medtronic Inc., Minneapolis, MN). The bipolar radiofrequency ablation was made with a non-irrigating system (Atricure, Inc., West Chester, OH) and all cryolesions with a re-usable cryo probe using N<sub>2</sub>O (Erbokryo, Erbe Inc., Tubingen, Germany).

### 2.4. Choice of surgical method

The type of lesion set as well as the ablating technique have been an evolution of available technology and understanding of the arrhythmogenesis of AF. Although the classical maze III was still the standard surgical treatment of AF at our department in this period, we performed surgery for AF other than the classical maze III as a consequence of its drawback.

### 2.5. Anti-arrhythmic management

Patients did not receive standard amiodaron postoperatively for prevention or treatment of AF. Sotalol was first treatment of choice to prevent or treat AF postoperatively. If sotalol was inadequate or not tolerated, the preoperative anti-arrhythmic drugs were given for either rate or rhythm control. At least one electrical cardioversion was performed before hospital discharge if a patient had a relapse of AF. After hospital discharge the anti-arrhythmic treatment was left to the referring cardiologist.

### 2.6. Definitions

We defined 'success' as the freedom from AF after a minimal follow-up of three months after surgery. This time window was chosen because of the time dependent success of procedures for AF [7]. The freedom from AF excludes AF regardless of its type or duration. Rhythm results were based on electrocardiograms and 24 h Holter recordings, but never on symptoms related to AF.

### 2.7. Statistical analysis

All values are expressed as mean  $\pm$  S.D. or percentages. For formal hypothesis testing we computed *t*-tests, ANOVA and Fisher's exact test where appropriate.

Multivariate analysis by means of logistic regression was carried out to determine baseline factors that influence the recurrence of AF at latest follow-up. For this analysis the determinants were age, sex, type and duration of AF, left and right atrial diameters, previous CVA or TIA, left ventricular ejection fraction, number of failed anti-arrhyth-

mic drugs, concomitant surgery for cardiac valve disease and atherosclerotic heart disease, aortic cross-clamp time, cardiopulmonary bypass time and occurrence of in-hospital AF after surgery.

A second multivariate analysis was performed to determine the effect of the different surgical methods on the recurrence of AF at latest follow-up. The determinants were the type of lesion set (PVI, LAM and BAM) and the ablation technique ('cut-and-sew', unipolar radiofrequency and bipolar radiofrequency). All calculations have been performed with SAS v 8.2;  $P < 0.05$  was considered significant.

## 3. Results

### 3.1. Patient demographics and baseline findings

The baseline characteristics are described in Table 1.

The number of patients in the PVI, LAM and BAM-group was 12, 28 and 26, respectively. Fig. 1 displays the distribution of the applied techniques: the 'cut-and-sew' and bipolar RF were the most frequently used techniques. The BAM-group did not consist of any 'cut-and-sew' technique, because this method would constitute the classical maze III.

### 3.2. In-hospital results

One patient died shortly after surgery due to non-repairable damage of the right upper pulmonary vein caused by blunt trauma during positioning of the bipolar radiofrequency device.

Further perioperative results are presented in Table 2.

### 3.3. Mid-term rhythm results

During a mean follow-up of  $22.0 \pm 15.6$  (3.1–81.2) months, two patients died due to congestive heart failure. Time of death was in both cases more than four years after surgery.

Although the difference is not significant, the success at latest follow-up of the PVI-group was lowest: 33% vs. 59% and 60% for the LAM- and BAM-group, respectively, ( $P = 0.176$  for PVI vs. LAM,  $P = 1.000$  for LAM vs. BAM,  $P = 0.170$  for PVI vs. BAM).

The success of the three largest uniform subgroups are: 85% for the left atrial maze made with the 'cut-and-sew' technique ( $n = 13$ ), 40% for the left atrial maze made with 'bipolar RF ablation' ( $n = 10$ ) and 57% for the bi-atrial maze made with 'bipolar RF ablation' ( $n = 23$ ).

Atrial flutter occurred in 4.0% (1/25) of the patients who had undergone a BAM procedure. Patients with only left-sided lesion (PVI- and LAM-group) experienced atrial flutter in 15.4% (6/39) ( $P = 0.231$ ).

### 3.4. Follow-up observations

Freedom from pacemaker at latest follow-up was 94% (61/65). One patient received a pacemaker for a persisting third degree AV-block shortly after his left atrial maze (LAM) procedure with mitral valve replacement. During follow-up, another two patients received a pacemaker for a third degree AV-block and another one for symptomatic bradycardias.

Table 1  
Baseline characteristics of total group of 67 patients and the three different lesion sets for the surgical treatment of AF

	Total <sup>†</sup> n=67	PVI n=12	LAM n=28	BAM n=26	P-value
Male	46 (69%)	7 (58%)	10 (64%)	21 (81%)	N.S.
Age (years)	61.8±10.0	59.6±13.5	61.1±10.3	63.3±7.9	N.S.
Duration AF (months)	76.7±79.1	118±103	74±82	60±58	N.S.
Type of AF					
Paroxysmal	38 (58%)	6 (50%)	19 (68%)	19 (52%)	N.S.
Persistent	19 (29%)	3 (25%)	6 (21%)	9 (36%)	N.S.
Permanent	9 (14%)	3 (25%)	3 (11%)	3 (12%)	N.S.
Number of failed AAD	2.9±1.8	3.3±1.7	3.2±2.0	2.3±1.5	N.S.
Number of previous ECV	2.2±3.0	2.5±3.5	2.0±2.7	2.3±3.3	N.S.
Preoperative TIA	2 (3.0%)	1 (8.3%)	2 (7.1%)	6 (24%)	N.S.
Preoperative CVA	9 (14%)	1 (8.3%)	0 (0%)	1 (4%)	N.S.
LA diameter (mm)	51.5±11.3	54.3±17.2	50.4±10.1	51.1±9.2	N.S.
RA diameter (mm)	57.9±7.4	59.5±7.7	56.8±6.9	57.8±8.4	N.S.
LVEF (%)	50.1±8.5	48.3±2.8	48.4±8.0	52.8±9.4	N.S.
Concomitant AF	60 (90%)	10 (83%)	23 (82%)	26 (100%)	N.S.
MV disease	45 (67%)	10 (83%)	17 (61%)	17 (65%)	N.S.
TV disease	3 (4.5%)	1 (8.3%)	1 (3.6%)	1 (3.8%)	N.S.
AoV disease	8 (12%)	2 (17%)	4 (14%)	2 (7.7%)	N.S.
CABG	17 (25%)	0 (0%)	6 (21%)	11 (42%)	*0.008

\*

Table 1 represents the baseline characteristics of all patients and its three subdivisions of lesion sets (exclusive pulmonary vein isolations (PVI), the left atrial maze procedures (LAM) and the bi-atrial maze procedures (BAM)).

LVEF, left ventricular ejection fraction; CABG, coronary artery bypass grafting; AAD, anti-arrhythmic drugs; ECV, electric cardioversion; LA, left atrium; RA, right atrium; MV, mitral valve; TV, tricuspid valve; AoV, Aortic valve; N.S. = not significant.

<sup>†</sup>The total group includes one patient who died shortly postoperative. This patient is excluded in the subgroups.

At latest follow-up, 46% of the patients who were free from AF were free from anti-arrhythmic drugs. Freedom from oral anticoagulation was 44% for patients who were free from AF and did not have a mechanical valve. Freedom from CVAs or TIAs was 100% (after hospital discharge). Echocardiographic follow-up showed a significant decrease of the right and left atrial diameter (Table 3).

### 3.5. Multivariate analysis

Multivariate analysis of the baseline characteristics showed that the recurrence of AF at latest follow-up is higher for patients with mitral valve disease (OR 4.04, CL 1.08–15.1,  $P=0.038$ ) and lower for patients of male gender (OR 0.16, CL 0.044–0.61,  $P=0.0069$ ).

Multivariate analysis for the surgical methods revealed a higher recurrence of AF at latest follow-up after PVI

(OR 4.42, CL 0.95–20.6,  $P=0.058$ ) and a lower recurrence of AF for the 'cut-and-sew' technique (OR 0.13, CL 0.030–0.60,  $P=0.0084$ ).

## 4. Discussion

### 4.1. Key results

Although this study lacks power for any significant results between the different ablation sets, it shows that the PVI alone had the lowest success rate, whereas the LAM and BAM procedure scored equally. Secondly, the 'cut-and-sew' technique resulted in a significant higher success than the other techniques.

### 4.2. AF recurrence

Multivariate analysis of the baseline characteristics demonstrated that patients with mitral valve disease had a higher recurrence of AF. This finding can be ascribed to a particular substrate for AF and concurs with our previous results of the classical maze III procedure [1]. In contrast to AF without mitral valve disease, AF with mitral valve disease is often caused by a volume overload of the left atrium [8]. Secondly multivariate analysis of the baseline characteristics also found that male patients had lower failure rate than female ones. The small sample size or a higher incidence of underlying structural heart disease, which could influence the substrate of AF in female patients, could contribute to this gender difference. It is noteworthy to mention that women underwent more frequently mitral valve surgery than men (90% vs. 57%, respectively,  $P=0.0059$ ).

It is unclear whether the low success rate of the PVI has to be ascribed to an unsatisfying method as such or to the

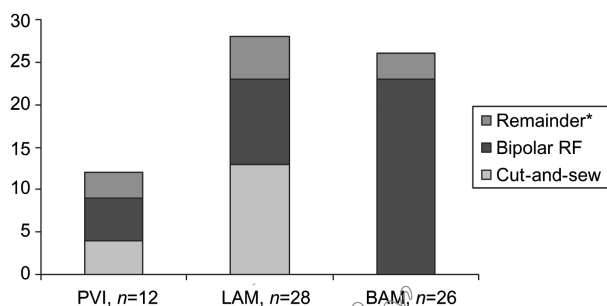


Fig. 1. Surgical methods. The figure displays the different techniques that have been used for the three different lesion sets. PVI, pulmonary vein isolation; LAM, left atrial maze procedure; BAM, bi-atrial maze procedure; RF, radiofrequency. \*Remainder consist of cryotherapy and diathermy ablation techniques for the PVI-group and unipolar radiofrequency ablation for the LAM- and BAM-group.

Table 2  
In-hospital results

	Total n=66	PVI n=12	LAM n=28	BAM n=26	P-value
Duration of ECC (n)	61	11	27	23	
Mean (min)	130±45	102±28	126±42	147±49	†=0.0092
Duration of Aoclamp (n)	61	11	27	23	
Mean (min)	84±36	68±28	83±34	94±41	N.S.
In-hospital AF	58%	25%	74%	56%	N.S.
Transient AV-block (n)	64	12	28	24	
1	9.4%	8.3%	7.1%	13%	N.S.
2	3.1%	0%	7.1%	0%	N.S.
3	14%	8.3%	7.1%*	25%	N.S.
In total	22%	17%	21%	28%	N.S.
Patients needing pacing (n)	64	12	28	24	
Temporary	39%	17%	25%	67%	†<0.02
Definitive	1.6%	0%	3.6%	0%	
In total	41%	17%	29%	67%	
Duration of hospital stay (n)**	48	10	20	18	
Mean (days)	11.7±4.9	11.1±5.6	10.7±3.2	13.2±6.0	N.S.

ECC, extra corporal circulation; Aoclamp, Aortic cross clamp; n, number of patients.

\*One patient had a permanent third degree AV-block and received a pacemaker.

\*\*Some patients were transferred back to the department of cardiology of the referring hospital.

unfavourable arrhythmic profile of the patients who received this surgical method. These patients had long-standing and mostly permanent AF, more failed anti-arrhythmic drugs, electrical cardioversions and the largest diameters of both atria, and were mostly treated in combination with mitral valve disease. Although the baseline characteristics do not differ statistically (Table 1), PVI alone is probably not the ideal method to apply in patients with chronic and complex AF and a more extensive AF ablative method would be preferable.

#### 4.3. Surgical method: ablation technique

Multivariate analysis shows that the 'cut-and-sew' technique resulted in a significant higher freedom from AF. Whether this is caused by the obtained transmural or by the configuration of pulmonary vein exclusion is unclear.

Table 3  
Echocardiographic results

	Baseline	End of follow-up	P-value
LA diameter (mm)	51.5±11.3	47.2±6.9	0.0042
LA diameter (mm)			
With MVS	55.6±12.0	47.3±7.5	0.0017
Without MVS	44.2±5.1	47.0±4.5	0.5281
LA diameter (mm)			
With success	46.9±7.3	47.3±5.3	0.1337
Without success	56.9±13.1	48.1±7.7	0.0323
RA diameter (mm)	57.9±7.4	53.3±11.9	0.0092
LVEF (%)	50.1±8.5	48.6±10.8	0.0513

Different echocardiographic results before surgery (baseline) and at the end of follow-up. The left atrial diameter presents the long axis in the parasternal view and the right atrial diameter presents the largest available diameter.

MVS, mitral valve surgery.

The non 'cut-and-sew' techniques lack the production of consistent transmural ablation lines or conduction blocks. Even with the bipolar RF ablation device, which gives an indication when a lesion is transmural, about three separate ablations are needed for electrical isolation of the pulmonary veins [9].

With the 'cut-and-sew' technique we excluded all pulmonary veins in one large button. This could cure AF by deminishing the total mass of atrium ('critical mass theory') [10] and is supported by recent data showing that two connecting lesions improves success [11]. Excluding a large patch of left atrium can also exclude a large area of important substrate, but can drastically effect the atrial filling fraction and be potentially thrombogenic.

The superiority of the 'cut-and-sew' method has also been described by Stulak et al. [12]. They showed that patients were five times more likely to be in atrial fibrillation after a 'RF ablation maze III' than after a 'cut-and-sew' maze III.

#### 4.4. Left vs. bi-atrial maze

Freedom from AF of the LAM-group and the BAM-group were comparable (59% vs. 60%, respectively). This outcome suggests that left-sided 'maze-like' procedures have comparable success rates as bi-atrial 'maze-like' procedures; this observation concurs with the report of Deneke et al. [7]. Although encouraging results of left-sided 'maze-like' procedures have been reported by others. We found, however, a trend towards a higher prevalence of atrial flutter in the procedures when right-sided ablation lines were not performed. This outcome was also found by Usui et al. [13].

#### 4.5. Mortality and safety

One patient died shortly after surgery, which was related to the use of the bipolar radiofrequency device. The damage was not caused by the heating of tissue, but by trauma incurred during surrounding of the pulmonary veins. This complication occurred at the beginning of our experience with the bipolar RF device. We are not aware of any reports describing similar events with this device.

#### 4.6. Implications: optimal surgical method

PVI alone can cure AF, but multivariate analysis of this study shows that this lesion set has a significant worse rhythm result. The most important advantage of PVI alone is that it can be performed off-pump, minimal invasive and that it is a short and relative easy procedure in combination with alternative ablation techniques. The specific patient profile which might be suitable for PVI alone waits further exploration.

Because arrhythmogenesis of AF is predominantly restricted to the left atrium and because of the superiority of the ‘cut-and-sew’ technique, our data suggest a ‘cut-and-sew’ left-sided maze procedure with a right atrial approach to prevent flutter or post-incisional macro-reentry. This is supported by the success of 85% of the subgroup ‘cut-and-sew’ left atrial maze which is even comparable with the classical maze III [1]. The left atrial procedure should include an ablation line from the pulmonary vein isolation to the mitral valve and amputation of the left auricle to prevent thrombo-embolic events [14, 15].

Another option would be a hybrid approach with percutaneous catheter techniques to cure or prevent atrial flutter by ablation of the cavotricuspid isthmus.

#### 4.7. Study limitations

The small number of patients in the three groups which we retrospectively compared, weakens the message of this study. Secondly, we used different ablation techniques without preoperative control of the electrical isolation of the pulmonary veins. This could have led to incomplete conduction blocks.

Long rhythm registration during follow-up was not available in all patients.

### 5. Conclusions

Left atrial maze procedures seem to be effective in eliminating AF as are bi-atrial maze procedures, but omission of right atrial ablation lines seems to result in a higher prevalence of atrial flutter. A right atrial ablation should therefore be considered to prevent atrial flutter. The exact patient profile for PVI alone has yet to be determined, but it seems it is less suitable for chronic and complex AF.

This study showed that the ‘cut-and-sew’ technique is superior in curing AF in comparison with the bipolar and unipolar radiofrequency ablation.

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**eComment: Bilateral atrial appendage excision should be performed routinely in the surgical treatment of atrial fibrillation**

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In the paper by Geuzebroek et al. [1], the left atrial appendage was removed in all the patients, and the right atrial appendage was removed in bi-atrial maze (BAM) group.

One of the goals of surgical treatment for atrial fibrillation is to alleviate the risk of systemic thromboembolism by preventing blood stasis in the left atrium, which leads to the development of mural thrombi. Studies have revealed that lower blood flow velocity in the left atrial appendage greatly increases the risk of thrombus formation and the incidence of stroke [2]. Clinical experience, however, documents that although left atrial thrombi

are a common occurrence in atrial fibrillation, right atrial thrombi are not. Differences in the right atrial and left atrial anatomy probably explain these clinical patterns. For example, the orifice of the right atrial appendage is so broad-based that it is not usually thought of as being an orifice at all. Moreover, this wide-open entrance into the relatively shallow right atrial appendage is located immediately adjacent to the stream of blood flow from the superior vena cava into the right atrium and across the tricuspid valve. Therefore, there is little opportunity for stasis of blood within the body of the right atrial appendage, even when the atrium is fibrillating. On the contrary, the orifice of the left atrial appendage is an identifiable anatomic opening in virtually all patients. This narrow orifice leads into a relatively long narrow lumen of the left atrial appendage, which is eccentric to the stream of blood flow from the pulmonary veins to the mitral valve [3]. Therefore, when the atrium is fibrillating, severe stasis of blood in the left atrial appendage is virtually assured and is one of the major factors resulting in thrombus formation in the left atrial appendage. The atrial appendage has been shown to secrete atrial natriuretic peptides [4] and reduced secretion of these peptides has been demonstrated in patients after maze procedure with bilateral atrial appendage excision [5]. This reduced secretion of natriuretic peptides could be one of the mechanisms for the postoperative complication of fluid retention frequently seen after the maze procedure. We believe that to preserve secretion of atrial natriuretic peptides, the right and left atrial appendage should be preserved, but the left atrial appendage should be excluded by an interior or exterior continue

suture line because it is the most common region for development of mural thrombus.

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