Impact of Left Atrial Size Reduction and Endocardial Radiofrequency Ablation on Continuous Atrial Fibrillation in Patients Undergoing Concomitant Cardiac Surgery: Three-Year Results

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Background and aim of the study: **The study aim was to evaluate the efficacy of left atrial (LA) size reduction combined with radiofrequency (RF) ablation in the treatment of continuous atrial fibrillation (AF), by comparative analysis of the outcomes of patients undergoing RF ablation with and without LA size reduction.**
Methods: **A total of 46 patients with continuous AF and cardiac disease underwent cardiac surgery and RF ablation alone (group I, n = 20) or combined with LA size reduction (group II, n = 26). Patients were followed for three years postoperatively, with evaluation of cardiac rhythm, neurological complications, LA size (by echocardiography) and atrial contractility.**
Results: **At three years after surgery, sinus rhythm (SR) was restored in 61.1% and 70% of patients in groups I and II, respectively. Mean LA diameter was reduced from 60 ± 15 mm to 57 ± 5 mm in group I, and from 69 ± 19 mm to 55 ± 6 mm in group II. The overall three-year survival was 90% in group I, and 88.5% in group II. Three-year freedom from stroke was 88.9% and 86.2% in groups I and II, respectively. Two patients in each group received transvenous permanent pacemaker implantation. Atrial contractility was recovered in all patients with stable SR.**
Conclusion: **LA size reduction improves SR conversion rate after RF ablation for continuous AF in patients undergoing concomitant cardiac surgery.**

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Atrial fibrillation (AF) is an epidemiologically significant problem that affects approximately 2% of the general population, and more than 6% of those aged >65 years (1,2). The development of AF is associated with several factors, including age, hypertension, heart failure, mitral valve disease, and increased left atrial (LA) dimension (3,4). An increase in LA size in the presence of AF has been associated not only with an increased risk of stroke but also increased mortality (5).

Although the classic maze procedure is the 'gold standard' for eliminating AF, it is not frequently performed because of its complexity and invasive nature (6,7). In attempts to reduce surgery time and to simplify the technique, modifications of the original maze procedure have been developed, including the application of radiofrequency (RF) energy. Reports of the sinus rhythm (SR) recovery rate after RF ablation are wide-ranging, from 63 to 77% (8,9). Moreover, the success or failure of RF ablation was determined by LA size as a significant variable (10,11).

The study aim was to evaluate the efficacy of LA size reduction combined with RF ablation in the treatment of continuous AF, by comparing outcomes in patients who underwent RF ablation, with and without LA size reduction.

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Clinical material and methods

Patient population

Between October 2000 and April 2003, 46 consecutive patients with continuous AF of more than one year's duration and concomitant cardiac disease were included in this prospective randomized study. The study was undertaken with the approval of the local Ethics Committee, and informed consent was obtained from all patients.

The patients were randomized consecutively to undergo either RF ablation (group I; 10 men, 10 women; mean age 64 ± 6 years; range: 42 to 78 years) or RF ablation and LA size reduction (group II; 10 men, 16 women; mean age 62 ± 11 years; range: 50 to 73 years), combined with procedures to correct concomitant cardiac disease. A LA diameter >50 mm was defined as enlargement of the atrium. Preoperatively,

the LA diameter was 60 ± 15 mm in group I patents, and 69 ± 19 mm in group II. The left ventricular ejection fraction in these patients was 59 ± 16% and 61 ± 15%, respectively.

Minimally invasive surgical access was used in eight patients of group I and in 10 patients of group II.

Surgical procedure

The surgical approach for conventional cardiac surgery was via a median sternotomy. All operations were performed with the patient on cardiopulmonary bypass (CPB) with moderate hemodilution and moderate hypothermia (30-32°C).

The minimally invasive technique was performed through a small right anterolateral thoracotomy in the fourth intercostal space. These patients also underwent CPB with moderate hemodilution and moderate hypothermia. The right femoral vein and artery were used for cannulation, and myocardial protection was afforded with cold (14°C) blood cardioplegia.

The surgical technique for LA size reduction was performed as described by Scherer et al. (12). Size reduction was achieved by closure of the LA appendage from the inside with a double running suture. The same suture plicated the left lateral atrial wall to the roof of the left pulmonary vein inflow, thus reducing the distance between the mitral annulus and the upper edge of the vein inflow to 2 cm. The septum was plicated by placing stitches across the fossa ovale.

Radiofrequency ablation

Radiofrequency ablation was performed using a previously described technique (13). Radiofrequency energy was used to create long continuous endocardial lesions under direct vision. A T-shaped probe 1 cm in length (Osypka, S-000065, Grenzach, Germany) was used to deliver the RF energy (30 W, 30 s for each lesion). RF ablation was performed using a continuous sinusoidal unmodulated waveform and delivered in unipolar mode (Osypka, HAT 200S).

Lesions included separate right- and left-sided pulmonary vein isolation. Another two ablation lines were added from the posterior mitral annulus to the atriotomy, and from the left auricle to the left pulmonary vein isolation line. The large atriotomy connected the pulmonary vein isolations in order to avoid macro-reentrant circuits.

The concomitant surgical procedures for each group are detailed in Table I.

Follow up

Cardiac rhythm was monitored after surgery until discharge. During the first three postoperative days, rhythm disturbances were evaluated by the physician at the authors' intensive and intermediate care unit, using a continuous monitoring electrocardiogram (ECG) system (Hellige Marquette Solar 8000 Patient Monitor; Marquette Medical Systems, Milwaukee, WI, USA). Thereafter, until discharge, pulse control was monitored twice daily by the physician. A 12-lead ECG recording was performed once daily from postoperative day 4 until discharge, and also in each case of clinical symptoms of rhythm disturbances.

During the early postoperative period, atrial arrhythmias were treated with amiodarone for at least 30 days, but after discharge from hospital the anti-

Table I: Concomitant procedures.

Procedure	Group I	Group II
Mitral valve repair	6 (30)	11 (42.3)
MVR	2 (10)	5 (19.2)
Mitral valve repair + CABG	3 (15)	1 (3.9)
MVR + CABG	1 (5)	1 (3.9)
AVR	2 (10)	2 (7.7)
CABG	2 (10)	1 (3.9)
MVR + AVR + CABG	1 (5)	-
MVR + Tricuspid valve repair + CABG	1 (5)	-
MVR + AVR + Tricuspid valve repair	1 (5)	-
AVR + CABG + Aortic aneurysm repair	1 (5)	-
AVR + CABG	-	2 (7.7)
Mitral valve repair + Aortic valve conduit	-	1 (3.9)
MVR + Aortic valve repair + Aortic aneurysm repair	-	1 (3.9)
Mitral valve repair + Tricuspid valve repair (reoperation)	1 (3.9)	

Values in parentheses are percentages.
AVR: Aortic valve replacement; CABG: Coronary artery bypass grafting; MVR: Mitral valve replacement.

arrhythmic therapy was at the discretion of the cardiologist. Anticoagulation was also at the discretion of the cardiologist, but was recommended for three months if not otherwise required (e.g., mechanical valve, AF). The follow up dates of data acquisition were postoperative day 1, before discharge, and at three and six months, and one and three years after surgery. The patients were followed both by direct contact and through discussions and records of referring physicians. A medical and clinical history and an ECG were performed at each follow up date. At the one- and three-year follow ups, additional Doppler echocardiography was performed in order to evaluate cardiac chamber dimensions. The LA superoinferior diameter was measured from the apical four-chamber view.

At the three-year follow up atrial transport function was quantified using pulsed Doppler echocardiography. The transmitral flow velocities were measured, with a sample volume being positioned at the level of the tip of the atrioventricular (AV) valve in the apical four-chamber view. Peak velocities of the early E wave and of the late-filling A wave were determined as the average of three consecutive beats.

Statistical analysis

Data were presented as mean ± SD. Continuous variables were tested with the Mann-Whitney test for unpaired data, and categorical data were tested with Fisher's exact test. A p-value <0.05 was considered to be statistically significant.

Results

Operative outcome

The mean surgery times were 276 ± 66 min and 297 ± 88 min in groups I and II (p = NS), respectively, while CPB times were 144 ± 34 min and 168 ± 55 min (p = NS). The mean cross-clamp time was 104 ± 23 min in group I, and 107 ± 26 min in group II (p = NS).

Postoperative period

One patient in group I (5%) and three patients in group II (11.5%) died from low cardiac output (p = NS). One patient in group II complained of progressive dysphagia several days after surgery; gastroscopy revealed a small esophageal perforation and the patient was successfully treated conservatively.

The number of patients in SR decreased during hospitalization. Postoperatively, SR was documented in 12 group I patients, and in 15 group II patients. Five group I and six group II patients required atrial pacing due to sinus node dysfunction. Atrioventricular sequential pacing for postoperative AV block was required in three patients in group I, and in five of group II. Before discharge, SR was achieved in 73.7% of group I patients, and in 69.6% of those in group II (p = NS).

Follow up

There was one late sudden cardiac death in group I, and three patients in group II were lost to follow up. The overall three-year survival was 90% in group I and 88.5% in group II (p = NS).

One dual-chamber pacemaker (DDD) for persistent AV block was implanted in group I, and two in group II. A sinus bradycardia developed in one group I patient, who received a single-chamber pacemaker (AAI).

The SR recovery rate at three and six months was 57.9% in group I and 68.2% in group II (p = NS). At one year, 61.1% of group I patients and 77.3% of group II had a documented SR (p = NS). The SR recovery rate at three years was 61.1% in group I and 70% in group II (p = NS) (Table II).

At the one-year follow up, one patient in each group had suffered a stroke, and one transient ischemic attack (TIA) was observed in group I. All three patients were in SR and receiving anticoagulation therapy (warfarin) because of valve replacement (two patients with mitral valve replacement, one patient with aortic valve replacement (AVR) combined with coronary

Table II: Cardiac rhythm during the follow up period.

Rhythm	Discharge		3 months		6 months		1 year		3 years	
	Group I	Group II	Group I	Group II	Group I	Group II	Group I	Group II	Group I	Group II
Sinus rhythm	14 (73.7)	16 (69.6)	11 (57.9)	15 (68.2)	11 (57.9)	15 (68.2)	11 (61.1)	17 (77.3)	11 (61.1)	14 (70)
Atrial fibrillation	5 (26.3)	7 (30.4)	8 (42.1)	7 (31.8)	8 (42.1)	7 (31.8)	7 (38.9)	5 (22.7)	6 (33.3)	5 (25)
Intermittent AF	-	-	-	-	-	-	-	-	1 (5.6)	1 (5)
	1 died (5)	3 died (11.5)	-	1 lost to FU	-	-	1 died (5.3)	-	-	2 lost to FU

Values in parentheses are percentages.
FU: Follow up.

artery bypass grafting). At the three-year follow up, one additional stroke and one additional TIA were observed in group II. Between the one- and three-year follow ups these two patients had recurrence of AF and developed mild to moderate mitral valve insufficiency after an initial successful mitral valve repair and LA enlargement. The patient with the TIA was receiving anticoagulation therapy (warfarin) because of AVR combined with mitral valve repair. The three-year freedom from stroke was 88.9% in group I and 86.2% in group II (p = NS).

Details of anti-arrhythmic and anticoagulation therapy, and cardioversion events during the follow up period, are listed in Table III.

At the one-year follow up, LA diameter (evaluated by echocardiography) was reduced from 60 ± 15 mm to 55 ± 8 mm in group I, and from 69 ± 19 mm to 51 ± 8 mm in group II. At the three-year follow up the LA diameter was 57 ± 5 mm in group I and 55 ± 6 mm in group II (p = NS).

In all patients in SR, atrial contraction was detected with transthoracic Doppler echocardiography. All control examinations performed at three years after surgery showed an effective contraction of the left atrium in both groups. The mean A-wave and the mean E/A ratio were 0.8 ± 0.3 m/s and 1.4 ± 0.1 in group I, and 1.0 ± 0.4 m/s and 1.6 ± 0.5 in group II (p = NS).

Discussion

The relationship between the atrial area available for the macro-re-entrant circuit and the effective refractory period of the atrial myocardium is an important factor for the development and maintenance of AF (7). An enlarged left atrium (>60 mm) is known to be a determining factor in the development and maintenance of AF, even if it is unclear whether the increase in LA size occurs as a result of AF or contributes to its development (3).

The surgical ablation of AF by the application of RF energy is based on the concept of preventing functional macro-re-entrant circuits (14). The SR conversion rate after RF ablation for AF is wide, and ranges from 63% to 77% (8,9). However, a large proportion of patients do not regain SR after RF ablation. In a series reported by Chen et al. (10), the mean postoperative atrial diameter of patients who regained SR was significantly smaller than that of patients who did not regain SR after RF ablation. Likewise, the postoperative reduction of LA diameter to a critical size (which appeared to be 45 mm) is important for restoring and maintaining SR after RF ablation (10). These facts would therefore suggest the importance of minimizing LA size to eliminate AF.

In the present study, a surgically simple and effective method to reduce LA size, and hence to restore SR, was evaluated as an adjunct to RF ablation in patients with continuous AF undergoing concomitant cardiac surgery. During the early postoperative period, all patients in both groups converted to SR, including transient AAI and DDD pacing. As has been reported for other studies, approximately one-third of the present patients had recurrence of AF before discharge, with the majority of recurrences being observed within three months after surgery, after which the heart rhythm was stabilized (8,15).

At the one-year follow up, 61.1% of patients in group I had a documented SR. Adding the LA size reduction technique, the postoperative LA size decreased from 69 mm to 51 mm, and the SR recovery rate increased to 77.3%, including those patients with permanent pacemaker implantation (AAI, DDD). Between the one- and three-year follow ups, one group I patient and two group II patients had recurrence of AF. The latter two patients developed mild to moderate mitral valve insufficiency after initial successful mitral valve repair, and showed an increased LA diameter of 4 mm between the two follow up examinations.

Previously, the importance of LA size reduction to restore and maintain SR after mitral valve surgery was described. Left atrial size reduction, added to mitral valve surgery, was effective in 63% of patients with continuous AF, and restored the predominant sinus rhythm (12). This technique might also play a significant role in the restoration of normal geometric size and wall stress to these large atria. It is believed that the concept of restoring normal atrial geometry is additive to restoring SR.

One minor limitation of the present study was the small number of patients and the lack of telemetric

Table III: Anti-arrhythmic and anticoagulation therapy and cardioversion events.

Therapy	3 months		6 months		1 year		3 years	
	Group I	Group II	Group I	Group II	Group I	Group II	Group I	Group II
Cardioversion	1	3	1	1	-	-	-	-
Amiodarone	11	9	8	8	3	5	-	-
Warfarin	15	19	13	16	10	10	8	4

monitoring when patients were discharged. Atrial fibrillation often remains under-diagnosed, as it is often asymptomatic or intermittent and, therefore may not be detected on standard 12-lead ECG or even 24-h ECG recording. Standard ECG identified AF in 2.7% of the present patients at hospital admission, and in 4.1% of the remaining patients within five days. Holter monitoring disclosed AF in 5% of patients with a normal standard ECG, whereas seven-day ECG monitoring detected AF in 5.7% of patients with a normal standard ECG and normal Holter monitoring (16). Therefore, intermittent AF remains undiagnosed in approximately 10.7% of patients with documented SR at 12-lead ECG.

Although surgical ablation of AF using an endocardial RF approach allows the recovery of SR and atrial function in the large majority of patients, there is a small - but definite - risk of esophageal perforation. For example, Doll et al. (17) reported an incidence of esophageal perforation of 1% after intraoperative left atrial RF ablation. The perforations occurred in patients undergoing a minimally invasive approach, but the risk factors could not be identified (17). Recently, Gillinov et al. (18) described a single case of esophageal perforation after left atrial RF ablation in a patient with in whom a partial upper sternotomy approach had been used, although the patient's small body size may have partially contributed to this injury. Several surgical centers have used temperature-controlled RF ablation without causing esophageal injury (19,20). In the present patient (who was of normal body size), mitral valve repair combined with LA reduction and RF ablation was performed through a minimal right anterior thoracotomy. All mitral valve repair patients underwent transesophageal echocardiography (TEE) either intraoperatively or during the immediate postoperative period. Hence, the small esophageal perforation identified in the present patient might have been secondary to TEE, a rare complication to this procedure (21), or to RF ablation.

In conclusion, LA size reduction improves the SR conversion rate after RF ablation. Both, RF ablation alone and when combined with LA size reduction allow a durable recovery of atrial function in the large majority of patients with continuous AF having concurrent open-heart surgery. It is possible that a more aggressive approach might be considered for patients with continuous AF, and even in those in whom failure to restore SR following a surgical approach might be predicted.

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