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Monopolar and Bipolar Radiofrequency Ablation Surgery: 3-Year Experience in 90 Patients with Permanent Atrial Fibrillation

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ABSTRACT

Objective: In our population, permanent atrial fibrillation (pAF) is a serious concomitant problem in patients scheduled for open heart surgery. The high incidence necessitates reliable methods of treating pAF efficiently. We report our 3-year experience with a safe concept of using monopolar and bipolar radiofrequency (RF) ablation procedures.

Methods: Ninety patients (mitral, n = 56; aortic, n = 22; aortic and mitral, n = 1; coronary artery bypass grafting, n = 11) underwent either monopolar (n = 77) or, recently, bipolar (n = 13) RF ablation procedures that produced encircling isolation lesions around the left and the right pulmonary veins (PVs) and a connection line between the two. Amiodarone was given for 3 months after surgery.

Results: Hospital mortality was 2.2%. At follow-up, 75% of the patients were in stable sinus rhythm (SR). Preoperative pAF duration, etiology of heart disease, and type of RF energy application were not predictive of the risk of persisting pAF after surgery. Whereas patients (50 of 90) with small preoperative left atrial (LA) diameters (<56 mm) had SR in almost 90% of cases, large preoperative LA diameters (≥56 mm; 40 of 90 patients) were associated with a significant risk of persisting pAF ($P < .05$).

Conclusion: Particularly in cases of small preoperative LA diameters, isolation of the PVs using either monopolar or bipolar RF ablation procedures in combination with amiodarone therapy represents a safe and efficient option for curing pAF in patients undergoing open heart surgery.

INTRODUCTION

In cardiac surgery, strategies for effective treatment of permanent atrial fibrillation (pAF) are of great interest because pAF is a frequent problem that substantially deteriorates the prognosis [Morris 1995, Benjamin 1998, Jessurun 2000]. The data concerning the incidence of pAF documented as persisting for at least 6 months among all patients scheduled for open heart surgery in our institution between February 2001 and February 2004 are outlined in Table 1. PAF was classified on the basis of the American College of Cardiology/American Heart Association/European Society of Cardiology (ACC/AHA/ESC) practice guidelines [Fuster 2001].

Since Cox [1996] demonstrated that AF can be definitely eradicated, efforts have been made to achieve alternative and, especially, less complex methods for the use of surgical catheter ablation techniques during cardiac surgery. A broad spectrum of these methods have been described [Sueda 1997, Chen 1998, Benussi 2000, Melo 2000, Pasic 2001, Hornero 2002, Khargi 2003, Knaut 2003, Schütz 2003]. We report our experience with monopolar and bipolar radiofrequency (RF) ablation procedures for treating pAF during open heart surgery.

MATERIAL AND METHODS

The etiology of heart valve disease was assessed by clinical history, intraoperative valve examination, and histological analysis. Patients hospitalized for heart valve surgery who had pAF (≥6 months) underwent combined intraoperative AF treatment with monopolar RF ablation. A bipolar RF ablation procedure was performed beginning in March 2003 in coronary artery bypass grafting (CABG) patients and beginning in October 2003 in aortic valve surgery patients with pAF. Patients with any other form of AF (intermittent or pAF <6 months), emergency operation, severely reduced left ventricular function (ejection fraction ≤25%), acute endocarditis or myocardial infarction (≤7 days), severe cachexia (body mass index ≤18), severe intracardiac thrombosis, or extreme left atrial (LA) size were excluded (LA diameter ≥72 mm was assessed as being our limit for the procedure).

Surgical Procedure

Monopolar Radiofrequency Ablation. The surgical procedure has been described previously [Geidel 2003a]. To create endocardial RF ablation lesions, we used 2 almost identical systems: the Thermaline device initially and since January 2002 the Cobra device (both Boston Scientific Corporation,

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Table 1. Incidence of Permanent Atrial Fibrillation (pAF) (≥6 mo) among 3598 Open Heart Cases (n = 129)*

Heart valve operations	10.4%	101 of 973
Mitral	30.0%	71 of 237
Rheumatic	42.4%	39 of 92
Degenerative	27.7%	26 of 94
Endocarditis	18.2%	2 of 15
Ischemic	11.1%	4 of 36
Mitral + aortic	16.6%	5 of 30
Aortic	3.6%	25 of 704
Tricuspid	—	0 of 2
Non–heart valve operations	1.1%	28 of 2.625
Coronary artery bypass grafting	1.1%	28 of 2.559
Miscellaneous	—	0 of 66
Total	3.6%	129 of 3598
P (Fisher exact chi-square test)	<.0001	

*Age, 71.0 ± 8.6 y; pAF duration, 5.6 ± 5.1 y; left atrial diameter, 56.4 ± 7.5 mm.

San Jose, CA, USA). Monopolar RF ablation was performed with 100 W RF power for 120 seconds; the local temperature was set at 70°C. The first lesion line completed isolation of the right pulmonary veins (RPVs) from the inferior to the superior RPV through the left atriotomy. Isolation of the left pulmonary veins (LPVs) was performed with a semicircular ablation line close to the inferior and another one around the superior LPV. These lines were connected by a transverse lesion across the posterior wall of the LA. The LA appendage was sutured from the endocardial side in cases with large left atria (LA diameter ≥56 mm, since July 2003).

Arrangements to avoid thermic esophageal injury were as follows: (1) cachectic patients were excluded; (2) a dry compress was passed behind the LA before delivery of RF energy; (3) the transesophageal echocardiographic probe was removed during the ablation procedure; (4) a flexible ablation probe was used and adapted to the tissue without pressure; (5) local temperature was set at 70°C; and (6) monopolar RF ablation was performed precisely under direct view during conventional open heart valve surgery only.

Bipolar RF Ablation. The surgical procedure has been described recently [Geidel 2003b]. The bipolar AtriCure device (AtriCure, Cincinnati, OH, USA) was used for an almost identical lesion pattern. The device consists of a handpiece, a foot switch, connecting cables, and an ablation and sensing unit (ASU) that (1) delivers RF energy while simultaneously measuring tissue conductance and (2) uses a temperature-sensing mechanism (range, 45°C-55°C). During ablation the tissue is impacted between 2 jaws of the hand piece, and energy is delivered by foot switch. Ablation was finished when the ASU monitor indicated that tissue conductance was below 2.5 millisiemens for at least 3 seconds. After the start of cardiopulmonary bypass, isolation of the RPVs and the LPVs was performed by grasping of the adjacent atrial tissue. A pursestring suture with a tourniquet was set at the posterior wall of the left atrium. The distal jaw was inserted through a small incision in the direction of the LPVs, and RF ablation was performed after clamp closure. The distal jaw was inserted in the direction of the RPVs, and the connection line was completed. The LA appendage was sutured from the epicardial side in patients with large left atria (LA diameter, ≥56 mm; since July 2003).

Perioperative Management, Follow-Up, and Statistical Analysis

The perioperative management has been described previously [Geidel 2003a, 2003b]. Standard 12-lead electrocardiography (ECG) and transthoracic echocardiography were routinely performed on admission (for evaluation of LA diameter) and before discharge. Administration of amiodarone was started before the end of cardiopulmonary bypass and continued for 3 months after surgery. Early recurrence of AF was DC cardioverted after saturation with amiodarone. Patients with CABG, mitral valve (MV) repair, or a bioprosthesis received coumarin for 3 months. Patients with mechanical valves received lifelong anticoagulation. All patients were reexamined 3, 6, 9, 12, 18, 24, and 36 months after surgery by standard 12-lead ECG and clinical examination.

Quantitative preoperative and operative data were normally distributed and described by arithmetic mean ± SD. Qualitative distributed data were presented as absolute frequencies. For pAF and sinus rhythm (SR), the relative frequency among all patients and some subgroups was calculated. Qualitative characteristics were compared using the Fisher exact chi-square test. All *P* values were 2-tailed and interpreted nominally, that is, not adjusted for multiple comparisons. $P < .05$ was considered statistically significant. Analysis was performed with SPSS for Windows 11.5.1.

RESULTS

Ninety patients (mitral, n = 56; aortic, n = 22; aortic and mitral, n = 1; CABG, n = 11) underwent either monopolar (n = 77) or, recently, bipolar (n = 13) RF ablation procedures. All relevant preoperative and operative data are outlined in Table 2. Fifty patients had a small (LA diameter, <56 mm) and 40 patients had a large LA diameter (≥56 mm). All patients left the operating room either externally paced in DDD mode (n = 57) or in regular SR (n = 33). There were 2 (2.2%) cases of hospital mortality (1 cardiac, 1 noncardiac). Early postoperative recurrence of AF before discharge occurred in 48 of 88 patients and was DC cardioverted in 19 of 38 cases. Mean follow-up time up to February 2004 was 15.1 ± 9.6 months (Table 3). Survival at 2 years was 89.6%; late mortality was related to 4 noncardiac and 2 cardiac deaths. At late follow-up, approximately 75% of all patients and almost 90% of those with a preoperative LA diameter <56 mm were in stable SR (Table 3). The rate of SR was significantly higher in patients with small compared with those with large left atria ($P = .002$ and $P = .033$ at 6 and 9 months of follow-up). Preoperative pAF duration, etiology of heart disease, and type of RF energy applied were not predictive of the risk of persisting pAF after surgery. After bipolar RF ablation procedures, 7 of 8 patients were in SR at 3 months.

Table 2. Preoperative and Operative Data (n = 90)*

	Monopolar RF Ablation (n = 77)	Bipolar RF Ablation (n = 13)
Sex, M/F	36/41	8/5
Age, y	70.1 ± 9.3	68.2 ± 6.9
AF duration, mo	65.7 ± 58.1	59.0 ± 60.3
LA diameter, mm	55.9 ± 7.5	45.3 ± 5.4
Ejection fraction, %	59.4 ± 12.3	57.2 ± 11.7
NYHA class	3.0 ± 0.5	2.8 ± 0.4
Primary surgical procedures		
Mitral	25 repair, 21 bio, 10 mech	—
Aortic	17 bio, 3 mech	2 bio
Mitral + aortic	1 bio	—
CABG	—	11
Associated surgical procedures, n		—
Tricuspid valve repair	19	
CABG	7	
Myxoma	1	
Aortic aneurysm	1	
Prior heart surgery	1	
Aortic cross-clamping time, min	100.4 ± 17.3	27.1 ± 21.9
Cardiopulmonary bypass time, min	137.1 ± 20.2	93.4 ± 24.4
Operation time, min	191.6 ± 21.4	176.7 ± 34.1
Thermaline device, n	25	—
Cobra device, n	52	—
AtriCure device, n	—	13
Ablation time	9.0 ± 1.8 min	81.1 ± 25.8 s
Total time of ablation procedures, min†	15.1 ± 4.5	13.4 ± 3.4
Bretschneider cardioplegia, n	77	2
Intermittent cross-clamping, n	—	11
Hospital mortality, n	2	—
Pacemaker implantation, n	1	—

*RF indicates radiofrequency; AF, atrial fibrillation; LA, left atrial; NYHA, New York Heart Association; bio, bioprosthesis; mech, mechanical valve; CABG, coronary artery bypass grafting.

†Including adjustment of the equipment and precise adaption of the probe to the tissue (Thermaline/Cobra) and preparation of the pulmonary veins (AtriCure).

DISCUSSION

Rationale for Surgical Practices for Treating pAF

Reliable and effective strategies for treatment of pAF are of great interest in cardiac surgery because pAF doubles the death rate and increases the risk of stroke 5 times, leads to reduced cardiac output, and leads to the need for systemic anticoagulation with the danger of bleeding [Morris 1995, Benjamin 1998, Jessurun 2000]. The incidence among patients scheduled for open heart surgery is particularly high among those with heart valve disease and is of special importance in MV disease [Geidel 2003a]. That is why most of the recently reported surgical AF ablation data were observed after heart valve (particularly MV) surgery [Sueda 1997, Chen 1998, Benussi 2000, Melo 2000, Pasic 2001, Hornero 2002, Khargi 2003, Knaut 2003, Schütz 2003]. The permanent form of AF is 1 of 2 AF types (permanent and intermittent) and is usually the final mode in which nonpermanent AF culminates [Fuster 2001]. Patients with pAF have atrial fibrillation all of the time without any episodes of SR. The variant clinical presentations of permanent and intermittent AF have caused the establishment of heterogeneous nomenclatures in different countries and led to the use of misleading terms (chronic, paroxysmal, and persistent AF) and resulting difficulty in comparing the success rates of different groups.

In surgical practice, three main energy sources have been favored for creating atrial lesions to cure AF. RF energy has become established for variant treatment strategies and has become the most widely used energy source for AF surgery [Benussi 2000, Melo 2000, Pasic 2001, Hornero 2002, Khargi 2003]. Microwave ablation [Knaut 2003, Schütz 2003] and cryoablation [Chen 1998] have been described as alternatives. In these investigations [Benussi 2000, Melo 2000, Pasic 2001, Hornero 2002, Khargi 2003], RF energy was used without exception in a monopolar fashion for endocardial and/or epicardial ablation techniques with more or less comparable and successful results. However, 2 theoretical deficiencies remain with the application of monopolar RF energy: (1) transmurality of the created lesions is not definitely guaranteed, and (2) rare but fatal complications caused by excessively deep lesions have occurred [Gillinov 2001, Mohr 2001]. Experiences with possibly reliable bipolar RF ablation techniques that guarantee lesion transmurality and continuity and definitely bar extracardiac tissue injury are therefore of great interest.

Many surgeons who used ablation techniques in the past followed more or less closely the principles of the maze procedure, which are PV isolation, reduction of atrial size, and block of reentrant circuits by complex incisions [Benussi 2000, Pasic 2001, Hornero 2002, Khargi 2003]. An ideal lesion pattern should combine (1) slight invasiveness, (2) simplicity, (3) high reproducibility, and (4) saving of time with excellent success rates in almost all cases. The question whether such a lesion pattern is actually applied in practice must be answered in the negative. The mechanisms of AF initiation and maintenance vary and are connected with individual electrophysiological and pathological atrial tissue changes in cases with AF and particularly pAF [Li 1999, Goette 2000, Kawara 2001]. It is possible that individual patients with pAF probably need individual surgical ablation procedures. The relevant questions are the following: (1) Does a lesion pattern exist that can be recommended as a basis and can be completed easily according to the individual pathological or electrophysiological substrate? (2) Can patients be defined who need specific additional ablation procedures?

Haissaguerre et al [1998] described an important pathophysiologic finding. They demonstrated that the initiation of AF originates from rapidly firing foci predominantly located inside the PVs. According to that principle, the concept was developed that isolation of the PVs creating transmural encircling RF ablation lesions around the LPVs and the RPVs should be a sufficient basis for surgical ablation procedures.

Table 3. Follow-up Data: Patients with Stable Sinus Rhythm after Open Heart Surgery and Radiofrequency Ablation Procedures*

	Total (n = 90)	LA ≥56 mm (n = 40)	LA <56 mm (n = 50)	*P* (Fisher Exact Chi-Square Test)
Discharge	59 of 88 (67.0%)	24 of 38 (63.2%)	35 of 50 (70.0%)	.647
3 mo	56 of 77 (72.7%)	21 of 34 (61.8%)	35 of 43 (81.4%)	.073
6 mo	51 of 68 (75.0%)	16 of 29 (55.2%)	35 of 39 (89.7%)	.002
9 mo	46 of 60 (76.7%)	17 of 27 (63.0%)	29 of 33 (87.9%)	.033
12 mo	38 of 51 (74.5%)	14 of 22 (63.6%)	24 of 29 (82.8%)	.194
18 mo	28 of 41 (68.3%)	9 of 16 (56.3%)	19 of 25 (76.0%)	.302
24 mo	17 of 26 (65.4%)	4 of 9 (44.4%)	13 of 17 (76.5%)	.194
36 mo	3 of 5 (60.0%)	1 of 2 (50.0%)	2 of 3 (66.7%)	1.000

*Mean follow-up period, 15.1 ± 9.6 months. LA indicates left atrial diameter.

To save LA function and to bar potential generation of foci, the maze pattern of multiple incisions was reduced to a short connection line between the two. During valve surgery, RF ablation was normally performed from the endocardial side with direct view of the atrial tissue to guarantee continuity of the lesions. A new bipolar RF approach was recently used in primary CABG cases and aortic valve cases. The advantages were less invasiveness and shorter aortic cross-clamping time owing to avoidance of opening of the left atrium. Amiodarone was normally given to reduce postoperative recurrence of AF [Roy 2000].

Evaluation of the Results

Our results conformed to the basic experiences of other researchers [Moe 1962, Allessie 1985, Cox 1996, Haissaguerre 1998]. AF wavelets sustained by foci located inside the PVs were blocked by the created lesions. The described antiarrhythmic protection supported SR [Roy 2000] during the unstable initial stage, which was approximately 3 months. AF recurred soon after ablation surgery because the refractory period of the atrium was still shortened. In the case of AF recurrence, DC cardioversion was recommended, so the influence on the long-term results must be further clarified. Our data indicated that preoperative LA size is of significant concern for the success of the described method. However, it remains uncertain whether the LA size itself is the critical issue. It can be expected instead that cellular, structural morphologic, and, in parallel, electrophysiological changes in the atrial tissues are more marked in cases of progressive enlargement and hypertrophy of the atria [Li 1999, Goette 2000, Kawara 2001]. This electrical and anatomic atrial remodeling is supposed to be the reason for what has been described as "AF begets AF" [Wijffels 1995]. It must be conceded that an additional effect may be that in patients with small left atria the encircling lesions possibly encompassed larger portions of the left atrium in comparison with its overall size than in patients with large left atria in that reentrant circuits in the LA tissue could be interrupted more frequently. In addition, LA reduction has been described as being of advantage for restoring SR in patients with chronic AF and large left atria following MV surgery [Jansz 2003]. However, as a consequence of the described results, since July 2003 the LA appendage has been sutured in patients with large left atria to reduce the risk of thromboembolism.

Even though our patients were approximately a decade older than patients in other studies [Benussi 2000, Melo 2000], surgery was well tolerated. In particular, no case of esophageal injury [Gillinov 2001, Mohr 2001] was observed. Also confirmed was the increase in SR during the first year after surgery [Benussi 2000, Melo 2000, Pasic 2001, Khargi 2003]. It can be suggested that 3-month administration of amiodarone is appropriate but should be handled flexibly.

The described procedures are of slight invasiveness and are easy to perform. Both monopolar and bipolar procedures usually can be performed within 15 minutes. The lesion pattern can be created with monopolar RF energy and with a bipolar approach as well. However, it is still to be shown whether the results with bipolar RF energy are similar to those of monopolar procedures. Because in MV surgery the left atrium has to be opened anyway, we continue to recommend an endocardial ablation technique for these patients. In primary CABG and aortic valve procedures, a bipolar approach seems to be less invasive.

Limitations

For rhythm evaluation, only 12-lead ECG was used. We plan to complete the follow-up data by forming a 24-hour ECG registry to assess the possibility of the presence of nonpermanent AF. The data were not evaluated under randomized and prospective conditions. The groups were not matched, and that limits the evidence. Moreover, the number of procedures was small, particularly in the bipolar group. Further long-term investigations are needed to determine whether these early results can be confirmed.

Conclusion

We believe the described concept is a successful treatment of pAF in patients undergoing open heart surgery. The procedure seems to fulfill all the demands of an effective and easy-to-handle method. It also seems to simplify the treatment of pAF and can be recommended in patients undergoing cardiac surgery. The advantages compared with other techniques are (1) the procedure is easy to practice, and (2) atrial tissue trauma is extremely slight. Our data indicated that, particularly in patients with small left atria, stable SR can be restored in 90% of cases. The evidence, however, was limited by the small number of procedures.

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