

Right-Sided Minithoracotomy as a Surgical Approach for the Concomitant Treatment of Atrial Fibrillation

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Abstract

Background: Atrial fibrillation (AF) is the most common arrhythmia diagnosed in humans and therefore causes a high socioeconomic burden. The Cox-Maze IV procedure is the gold standard treatment for atrial fibrillation. Minimally invasive surgery for the treatment of AF is also promising.

Objectives: Our aim is to evaluate the feasibility, safety, and immediate plus medium-term results of concomitant AF ablation therapy in patients undergoing minimally invasive valve surgery through right-sided minithoracotomy.

Patients and Methods: Retrospective data were collected from January 2012 to December 2013. Seventy-five consecutive patients underwent radiofrequency ablation during valve surgery through a right-sided minithoracotomy.

Results: All 75 patients underwent radiofrequency ablation. The pulmonary vein was isolated in 6 (8%) by encircling the left and right pulmonary veins. In 9 (12%) patients, endocardial box lesions were created using a monopolar probe, while in 47 (62.7%), epicardial box lesions were produced with a monopolar probe. Thirteen (17.3%) patients received a box lesion created with a bipolar probe. Finally, in 22 (29.3%) patients, a line of lesions was produced leading up to the posterior mitral annulus. Only 1 (1.3%) perioperative death was observed. At discharge, 43 (57.3%) patients were in sinus rhythm and 30 (40%) were in AF. After a mean follow-up of 21.6 ± 10.1 months, 46 patients (63%) were in a stable sinus rhythm and 27 were in (37%) in AF; 26 (56.5%) patients were free from antiarrhythmic therapy, while 19 (42.2%) were still taking at least one drug.

Conclusions: We can conclude that treatment of AF using a right-sided minithoracotomy approach and RF energy in patients undergoing cardiac surgery for various valve diseases is feasible, safe, and reproducible.

Keywords: Atrial Fibrillation, Minimal Invasive Surgery, Radiofrequency Catheter Ablation

1. Background

Atrial fibrillation (AF) is a supra-ventricular tachyarrhythmia characterized by the presence of a chaotic and non-coordinated atrial activation and is a consequence of mechanical inefficiency. It is the most common type of arrhythmia encountered by cardiologists. In the United States (US) alone, it is estimated that 2.2 million people suffer from AF; this number is expected to increase steadily over the next few decades, exceeding 10 million by 2050 (1). About 40 - 60% of patients undergoing mitral valve surgery will be found to have one form of AF (2, 3). Symptoms of AF include palpitations, chest pain, dyspnea, and fatigue. Stroke is also a frequent life-threatening complication of AF that accounts for 5% of non-coagulated patients every year.

The risk of stroke increases substantially with age, from 1.5% in individuals aged 50 - 59 years to 23.5% for those between 80 - 89 years (4, 5). Medical treatment and electric conversion are the first-line treatment options.

However, medical therapy has its limitations, with failure rates as high as 60%. Furthermore, AF is frequently encountered during cardiac surgery as a concomitant disease in patients undergoing surgery for other reasons (2). In patients with permanent and persistent AF and a large left atrium, mitral valve surgery alone is associated with a low rate of conversion to sinus rhythm during early and long-term follow-up (6). Consideration of these data and the high burden of AF in the general population have led to the search for better treatment options by developing interventional and surgical methods of treatment.

The Cox-Maze III procedure proposed by Dr. James Cox has been the gold standard for the surgical treatment of AF with an efficacy of 97% freedom from symptomatic AF (7). However, the use of the Cox-Maze procedure is restricted due to its complexity, invasiveness, and postoperative complications (8). The Cox-Maze IV, a modified

version of the original Cox-Maze procedure that uses radiofrequency (RF) and cryo energy, was proposed to simplify and shorten the surgical procedure (9). This procedure is performed with the patient on cardiopulmonary bypass with aortic and atrial or bicaval cannulation depending upon the type of primary surgery performed. The decision to perform concomitant RF ablation for AF during open cardiac surgery mainly depends on a risk/benefit assessment of the procedure and the ambition of the individual patient (10). Furthermore, recent recommendations advocate that surgical ablation of AF should be considered in patients with symptomatic AF undergoing cardiac surgery (Class IIa, Level A evidence) (11).

Minimally invasive surgery is becoming an increasingly common practice in cardiac surgery, even for the approach and treatment of complex and/or multiple valvular pathologies. A smaller incision, less tissue dissection and less bleeding are concepts that are rapidly spreading in surgical culture because they mean less pain, less surgical stress, and a faster postoperative recovery (12). More patients are attracted to such methods of treatment due to the greater cosmetic results and lesser emotional impact of minimally invasive surgery.

Along with the technological developments that have allowed such rapid growth of minimally invasive valvular surgery techniques, we have also seen the gradual introduction of new devices on the market dedicated to ablation therapy for AF. Their presence has made it possible to simplify the original Cox-Maze procedure, allowing it to become a routine treatment both in the case of concomitant AF with valvular or other heart diseases as well as in cases of isolated AF (13).

2. Objectives

In this retrospective study, we aimed to evaluate the feasibility, safety, and immediate as well as medium-term results of concomitant AF ablation therapy in patients undergoing minimally invasive valve surgery using right-sided minithoracotomy.

3. Patients and Methods

3.1. Patients

The data were collected retrospectively from January 2012 - December 2013. During this period, 75 consecutive patients underwent surgical treatment of AF with minimally invasive valve surgery through a right-sided minithoracotomy at the FTGM G. Pasquinucci Heart Hospital in Massa, Italy. Our patient population was composed of 43 (57.3%) females and 32 (42.7%) males. The average age of the patients at admission was 66.7 ± 9.8 years; the youngest had an age of 33 years, while the oldest was 86 years old. The average duration of AF

in the overall series was 25.1 ± 22.7 months, with a range of 1 - 98 months.

Our patients were divided into four subgroups according to their clinical presentation: 17 (22.7%) patients with paroxysmal AF, 21 (28%) with persistent AF, 18 (24%) with long-standing persistent AF, and 19 (25.3%) with permanent AF. Although it was conceptually incorrect to include patients with permanent AF for surgical ablation, as these patients had long since abandoned any attempt to restore a normal sinus rhythm and were being treated with oral anticoagulants and anti-arrhythmic therapy alone, it was nevertheless decided to include these patients in this category.

Most of the patients had moderate functional limitations with dyspnea. Twenty-five (33.3%) patients presented as New York heart association (NYHA) Class III or greater. In relation to their rhythm disorder, most patients were in European heart rhythm association (EHRA) Class II-III. Twenty-three (30.7%) patients had a history of at least one attempt of electrical cardioversion, and three (4%) had undergone a previous electrophysiological study with unsuccessful catheter ablation. Fifty patients (66.7%) were suffering from hypertension, 13 (17.3%) patients had a recent and past history of coronary artery disease, 2 of whom underwent coronary artery bypass grafting, and 1 had a history of myocardial infarction.

Most of our patients (73.3%) were on anticoagulation therapy with oral warfarin. Additionally, 88% of our patients were taking some type of antiarrhythmic drugs (digoxin, beta-blockers, calcium channel blockers, amiodarone, and class I antiarrhythmic drugs), while only 9% of patients were receiving no treatment. Eleven patients had been prescribed solo amiodarone compared to 18 patients who were on a combination therapy. The general characteristics of the patients are presented in Table 1.

3.2. Preoperative Evaluation

In addition to other routine necessary investigations, all patients underwent two-dimensional transthoracic echocardiography to evaluate their detailed cardiac morphology, the function of the left ventricle, and any valve pathologies; the left atrial dimensions were also measured. Measurements along the parasternal long axis and from a four-chamber view permitted the determination of a left atrial mean dimension of $48.5 \pm 7.3 \times 52.7 \pm 8.1 \times 63.1 \pm 9.8$ mm. The evaluation of the left ventricular ejection fraction (LVEF) showed a mean LVEF of $55.3 \pm 7.8\%$. The preoperative echocardiographic data are summarized in Table 2.

Moreover, all patients were subjected to coronary angiography in order to exclude any significant stenosis or abnormalities in the coronary arteries.

The estimation of the operative risk was carried out using EuroSCORE. The average value of the logistic EuroSCORE was 5.74 ± 4.65 , and scores ranged from 1.51 - 23.68.

Table 1. General Characteristics of the Patients^a

Variables	Values
Total patients	75
Female	43 (57.3)
Age (range), y	66.7 ± 9.8 (33 - 86)
Weight, kg	74.6 ± 13.8
Height, cm	168 ± 8.9
BSA	1.82 ± 0.3
Hypertension	50 (66.7)
History of coronary artery disease	13 (17.3)
Previous electric cardioversion	23 (30.7)
Previous transcatheter ablation	3 (4)
Previous coronary artery bypass grafting	2 (2.7)
Thyroid disorder	8 (10.7)
Previous neurological deficit	2 (2.7)
NYHA class	2.3 ± 0.7
EHRA class	2.8 ± 0.8
NYHA class >= 3	25 (33.3)
Logistic EuroSCORE (Range)	5.74 ± 4.65 (1.51 - 23.68)
Types of atrial fibrillation	
Paroxysmal	17 (22.7)
Persistent	21 (28)
Long-standing persistent	18 (24)
Permanent	19 (25.3)
Duration of AF since first diagnosis (range), mo	25.1 ± 22.7 (1 - 98)
Rhythm at admission (AF)	48 (64)
Anti-arrhythmic therapy	66 (88)
Digoxin	29 (38.7)
Beta-blockers	34 (45.3)
Calcium channel blockers	7 (9.3)
Amiodarone	11 (14.8)
Anti-arrhythmic drugs of class I	5 (6.7)
Combination anti-arrhythmic treatment	18 (24)

Abbreviations: AF, atrial fibrillation; EHRA, European heart rhythm association; NYHA, New York heart association.

^aValues are presented as mean ± SD or No. (%).

Table 2. Preoperative Echocardiographic Data^a

Variables	Values
LVEF	55.3 ± 7.8
EF < 35%	4 (5.3)
LVIDd, mm	53.3 ± 8.0
LVIDs, mm	35.7 ± 7.3
IVS, mm	11.6 ± 2.4
LV mass, g	235.3 ± 72.4
Left atrial dimensions	
Left atrium, mm	48.5 ± 7.3
Length in 4C, mm	52.7 ± 8.1
Height in 4C, mm	63.1 ± 9.8
More than moderate mitral insufficiency	56 (74.7)
More than moderate mitral stenosis	10 (13.3)
More than moderate tricuspid insufficiency	11 (14.7)
More than moderate aortic insufficiency	5 (6.7)
More than moderate aortic stenosis	7 (9.3)
Right atrium, mm	40.8 ± 7.0
Right ventricle, mm	30.0 ± 6.5
PAPs, mmHg	42.5 ± 12.7

Abbreviations: EF, ejection fraction; IVS, interventricular septum; LVEF, left ventricular ejection fraction; LVIDd, left ventricular internal diameter in diastole; LVIDs, left ventricular internal diameter in systole; LV, left ventricle; PAPs, pulmonary artery pressure in systole.

^aValues are presented as mean ± SD or No. (%).

3.3. Anesthesia and Cardiopulmonary Bypass

We used our standard anesthesia protocol for regular cardiac surgery. Selective endotracheal intubation was reserved for high-risk patients who developed pulmonary complications (Redo cases, patients with chronic obstructive pulmonary disease (COPD), and those with suspicious pleural adhesions). A transesophageal echocardiography (TEE) probe was inserted, and TEE was performed in every patient for preoperative assessment of the valvular pathology as well as intraoperatively and postoperatively to assess the results of the repair, the amount of residual intracardiac air, and any paravalvular leaks in the case of valve replacement.

In all patients, right-sided minithoracotomy (5 - 7 cm) was done at the 3rd or 4th intercostal space at the midclavicular or anterior axillary line for mitral valve and tricuspid valve surgery, respectively, and at the 2nd intercostal space of the parasternal line for isolated aortic surgery (Figure 1). For a better cosmetic result in female patients



Figure 1. Right-Sided Minithoracotomy

who underwent mitral and tricuspid valve surgery, the surgical incision was made at the inframammary fold. Chest retraction was accomplished using a special soft tissue retractor and a rib retractor. Video optics were connected through a working 5.5 mm port introduced in the third intercostal space at the midaxillary line. An additional 7.5 mm working port was introduced in the fifth space on the midaxillary line for the introduction of a vacuum field, a vent, and a cannula for insufflating carbon dioxide into the chest cavity.

After systemic heparinization, direct aortic cannulation was carried at the ascending aorta using Straight Shot (Johnson and Johnson, Inc.) or EasyFlow (Estech, Inc.) aortic cannulas. Venous cannulation was achieved by percutaneous cannulation of the right femoral vein using Seldinger's technique with QuickDraw (Johnson and Johnson, Inc.) or Biomedicus (Medtronic, Inc.) venous cannulas. The correct positioning of the venous cannula into the superior vena cava was guided by TEE. In the case of tricuspid valve repair, venous cannulation was achieved using a double stage RAP FV (Estech, Inc.) venous cannula.

The intervention was conducted under mild hypothermia at 34°C. The cardioplegic cannula was inserted in the ascending aorta, and myocardial protection was obtained using the cold crystalloid cardioplegic solution Custodiol (HTK) with a single 20-mL/kg dose. Every patient underwent the creation of box lesions with a radiofrequency ablation device in addition to the valvular or other cardiac procedure. In all patients, the energy used for the creation of atrial lesions included both monopolar and bipolar radiofrequencies with different modes of delivery. Specifically, the main surgical gestures were made as follows:

- Isolation of the pulmonary veins with four different modes: encircling an endocardial lesion on the left and right pulmonary vein using monopolar RF, an endocardial box lesion to isolate the posterior atrial area with monopolar RF, or creating an endo-epicardial lesion using a bipolar RF source.

- Creation of the mitral line, a line that connects the box lesion or encircles the posterior mitral annulus.

- Exclusion of the left atrial appendage and an ablation line of connection with the left superior pulmonary vein.

The epicardial ablation was performed in a normothermic beating heart on cardiopulmonary bypass; endocardial lesions were created in the arrested heart before performing the valve surgeries. Exclusion of the left atrial appendage was performed by suturing it endocardially using two layers of 4-0 Prolene.

3.4. Follow-Up

All patients underwent periodic follow-up every 3, 6, 12, 18, and 24 months postoperatively. Controls were followed through clinical evaluations and electrocardiograms and also by telephone follow-up. All patients underwent 24-hour Holter ECG monitoring at least once in the 12 months following the procedure to screen out asymptomatic AF episodes; in patients with doubtful clinical symptoms, we performed repeat Holter ECG examinations. All patients underwent echocardiography at least once during the follow-up period.

3.5. Statistical Analysis

Data were expressed as mean ± standard deviation in the case of continuous variables and as percentages for categorical variables. The Kaplan-Meier analysis of survival free from supraventricular tachyarrhythmias and analysis of event-free survival was performed using StatView®.

4. Results

4.1. Perioperative Results

All 75 patients in our series underwent RF ablation of AF using monopolar, bipolar, or both sources of energy. It is worth noting that in over 80% of the sample, the only type of energy used was monopolar RF. Epicardial ablation was carried out in 44% of patients, whereas endocardial ablation was performed in just 21.3%. Furthermore, 34.7% of patients were ablated both epicardially as well as endocardially (Table 3 and Figure 2).

Table 3. Type of Energy Used and Sites of Ablation^a

Variables	Value
Applied energy	
Radiofrequency	75
Monopolar	62 (82.7)
Bipolar	9 (12)
Both	4 (5.3)
Site of ablation	
Epicardium	33 (44)
Endocardium	16 (21.3)
Both	26 (34.7)

^aValues are presented as mean ± SD.

As previously described in the surgical technique section, multiple surgical strategies were adopted for the treatment of AF. Specifically, all 75 patients underwent pulmonary vein isolation (PVI) (Figure 3):

- 6 (8%) by encircling the left and right pulmonary veins antral position
 - 9 (12%) by creating an endocardial box lesion with monopolar RF energy
 - 47 (62.7%) through an epicardial box lesion using unipolar RF energy
 - 13 (17.3%) with a box lesion and bipolar RF energy
- In addition to the isolation of the pulmonary veins, a

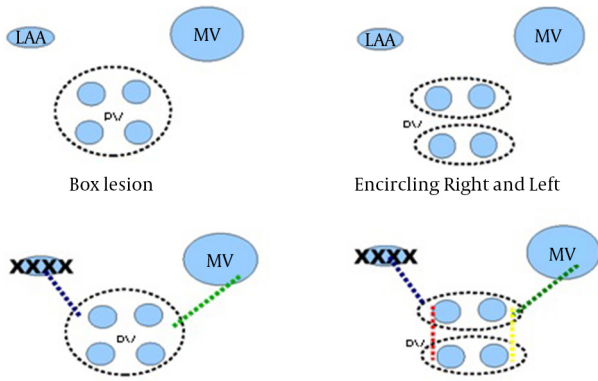


Figure 2. Surgical lesions created during the radiofrequency ablation. LAA, left atrial appendage; MV, mitral valve; PV, pulmonary vein.

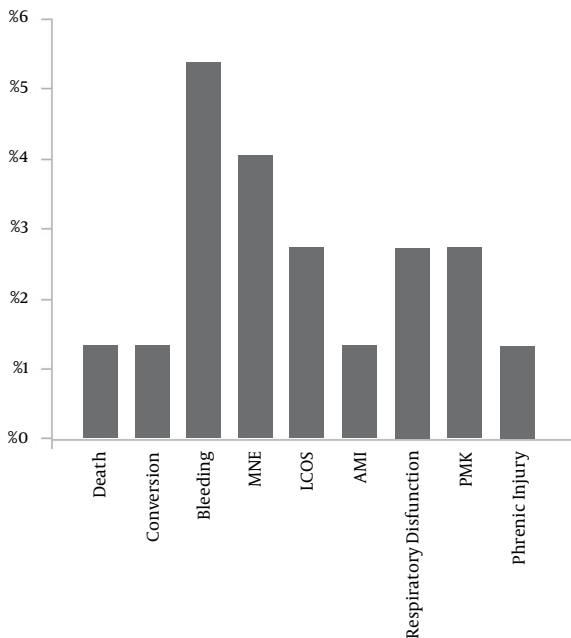


Figure 3. Graph showing in hospital morbidity and mortality. AMI, acute myocardial infarction; ICOS, low cardiac output syndrome; MNE, minor neurological event; PMK, pacemaker.

linear lesion was created in 22 (29.3%) patients towards the posterior mitral annulus. The exclusion of the left atrial appendage was done surgically, and a connecting ablation line between the atrial appendage and the left superior pulmonary vein (LSPV) was created in 12 (16%) patients. A complementing Cox-Maze IV lesion on the left side was performed in only one (1.3%) patient; in another, biatrial Cox-Maze IV was carried out (Table 4).

We divided our patient population into four subgroups for proper treatment strategies on the basis of preoperative atrial fibrillation. Tables 5 - 8 show the preoperative data and surgical strategies of the different groups.

Table 4. Lines of Lesions Created in the Patient Population^a

Variables	Values
PVI	75 (100)
Endocardial encircling of the right and left pulmonary veins with monopolar RF energy	6 (8)
Box lesion	69 (92)
Endocardial box lesion with monopolar RF energy	9 (12)
Epicardial box lesion with monopolar RF energy	47 (62.7)
Bipolar RF energy	13 (17.3)
Mitral line	22 (29.3)
Exclusion of the LAA and the connecting line with the LSPV	12 (16)
Complementing lesion on the left side	2 (2.7)
Cox-Maze IV on the right side	1 (1.3)

Abbreviations: LAA, left atrial appendage; LSPV, left superior pulmonary vein; PVI, pulmonary vein isolation; RF energy, radiofrequency energy.
^aValues are presented as No. (%)

Table 5. Paroxysmal Atrial Fibrillation, Preoperative Data and Ablation Lines Created^a

Variables	Values
Duration of AF, mo	21.3 ± 23.4
Size of the left atrium	
Left atrium, mm	46.4 ± 8
Length in 4C, mm	52.6 ± 9
Height in 4C, mm	61.5 ± 10.1
Pulmonary vein isolation (PVI)	
Box lesion	17 (100)
Endocardial box lesion with monopolar RF energy	4 (23.5)
Epicardial box lesion with monopolar RF energy	11 (64.7)
Bipolar RF energy	2 (11.8)
Mitral line	4 (23.5)
Exclusion of the LAA and the connecting line with the LSPV	1 (5.9)

Abbreviations: AF, atrial fibrillation; LAA, left atrial appendage; LSPV, left superior pulmonary vein; PVI, pulmonary vein isolation; RF, radiofrequency; 4C, four chamber.

^aValues are presented as mean ± SD or No. (%).

Table 6. Persistent Atrial Fibrillation, Preoperative Data and Ablation Lines Created^a

Variables	Values
Duration of the AF, Mo	7.1 ± 3.6
Left atrial size	
Left atrium, mm	50.4 ± 6.3
Length in 4C, mm	54.3 ± 7.3
Height in 4C, mm	64 ± 6.6
PVI	
Endocardial encircling of the right and left sides with monopolar RF energy	1 (4.8)
Box lesion	20 (95.2)
Endocardial box lesion with monopolar RF energy	3 (14.3)
Epicardial box lesion with monopolar RF energy	12 (57.1)
Bipolar RF energy	5 (23.8)
Mitral line	5 (23.8)
Exclusion of the LAA and the connecting line with the LSPV	4 (19)
Complementing lesion on the left side	1 (4.8)
Right sided Cox-Maze IV	1 (4.8)

Abbreviations: AF, atrial fibrillation; LAA, left atrial appendage; LSPV, left superior pulmonary vein; PVI, pulmonary vein isolation; 4C, four chamber.

^aValues are presented as mean ± SD or No. (%).

Table 7. Persistent Atrial Fibrillation of Long Duration, Preoperative Data and Ablation Lines Created^a

Variables	Values
Duration of AF, mo	30.8 ± 22.6
Left atrial size	
Left atrium, mm	47.8 ± 8.1
Length in 4C, mm	52.1 ± 8.1
Height in 4C, mm	62.2 ± 10.6
PVI pulmonary vein isolation	
Endocardial encircling of the right and left sides with monopolar RF energy	3 (16.7)
Box lesion	15 (83.3)
Endocardial box lesion with monopolar RF energy	5 (27.8)
Epicardial box lesion with monopolar RF energy	8 (44.4)
Bipolar RF energy	2 (11.1)
Mitral line	3 (16.7)
Exclusion of the LAA and the connecting line with the LSPV	3 (16.7)

Abbreviations: AF, atrial fibrillation; LAA, left atrial appendage; LSPV, left superior pulmonary vein; PVI, pulmonary vein isolation; RF, radiofrequency; 4C, four chamber.

^aValues are presented as mean ± SD or No. (%).

Table 8. Permanent Atrial Fibrillation, Preoperative Data and Ablation Lines Created^a

Variables	Values
Duration of AF, mo	42.8 ± 20.5
Left atrial size	
Left atrium, mm	49.4 ± 6.8
Length in 4C, mm	52.4 ± 8
Height in 4C, mm	65.6 ± 10.9
PVI	
Endocardial encircling of the right and left sides with monopolar RF energy	1 (5.3)
Box lesion	18 (94.7)
Endocardial box lesion with monopolar RF energy	1 (5.3)
Epicardial box lesion with monopolar RF energy	16 (84.1)
Bipolar RF energy	1 (5.3)
Mitral line	10 (52.6)
Exclusion of the LAA and the connecting line with the LSPV	4 (21.1)
Complementary lesion of the left side	1 (5.3%)

Abbreviations: AF, atrial fibrillation; LAA, left atrial appendage; LSPV, left superior pulmonary vein; PVI, pulmonary vein isolation; RF, radiofrequency; 4C, four chamber.

^aValues are presented as mean ± SD or No. (%).

Among the various data shown, the more substantial differences exist for the higher frequency of endocavitary monopolar lesions (monopolar endocardial encircling + box), for the isolation of the pulmonary veins in persistent AF of a long duration (44.5% compared with approximately 20% of overall cases), and the creation of the mitral line in patients with permanent AF (more than 50%).

The following surgical procedures were performed in association with RF ablation:

- Mitral valve repair: 31
- Mitral valve replacements (MVR): 21
- Aortic valve replacements (AVR): 10
- Mitral valve repair and tricuspid annuloplasty: 9
- Mitral valve replacements and tricuspid annuloplasty: 2
- Combined MVR, AVR, and tricuspid annuloplasty: 2

In two cases, reoperation was required in patients with previous surgical revascularization of the myocardium (i.e. coronary artery bypass grafting). The times required for extracorporeal circulation and aortic cross clamping were 161.5 ± 53 and 100.8 ± 40.4 minutes, respectively.

There was one (1.3%) perioperative death due to uncontrollable bleeding secondary to cardiac rupture in an 82-year-old patient with a logistic EuroSCORE of 22.02 who underwent mitral valve replacement for severe mitral stenosis and insufficiency. There were no further in-hospital deaths. Among the postoperative complica-

tions, we had to implant a permanent pacemaker in two cases (2.7%): one for 3rd degree atrioventricular block and one for AF with a ventricular escape rhythm and non-reversible bradycardia. The other major perioperative complications were as follows (Figure 3):

- Conversion to sternotomy for bleeding: 1 (1.3%)
- Postoperative bleeding: 4 (5.3%)
- Minor neurological event (MNE): 3 (4%)
- Low cardiac output syndrome (LCOS): 2 (2.7%)
- Acute myocardial infarction (AMI): 1 (1.3%)
- Respiratory dysfunction: 2 (2.7%)
- Right-sided hemidiaphragm paralysis due to phrenic nerve injury: 1 (1.3%)

The only intraoperative conversion to sternotomy for bleeding was due to a traumatic lesion at the apex of the left atrial appendage, which was probably created during aortic cross clamping. In the other four cases of chest reopening due to postoperative bleeding, none of the bleeding sites were caused by surgical ablation. One perioperative myocardial infarction also occurred due to involvement of the circumflex artery in a patient undergoing bipolar RF ablation in which a mitral line lesion was created using a bipolar RF probe.

4.2. Mid-Term Results

After a mean follow-up of 21.6 ± 10.1 months (range: 5 - 45 months), 98.6% of patients completed the follow-up, 46 (63%) were in a stable sinus rhythm, and 27 (37%) remained in AF, atrial flutter, or atrial tachycardia. From our analysis of the group of patients with different patterns of AF, we identified the following improvements (Figure 7):

- Paroxysmal AF patients: 14 (82.4%) converted to SR.
- Persistent AF patients: 14 (70%) converted to SR.
- Persistent long-term AF patients: 11 (61%) converted SR.
- Permanent AF patients: 7 (39%) converted to SR.

From a statistical analysis that was carried out by assessing the survival curve of those free from atrial fibrillation or supraventricular tachyarrhythmias, the Kaplan-Meier survival plot showed similar results to the analysis of prevalence. It is clear that the trend and the results in patients with permanent AF are markedly worse than the other subtypes of AF. The outcome was worse after 24 months but was explainable due to the small number of patients with long follow-up periods (Figure 4).

During the postoperative period, cardioversion was needed due to the presence of one episode of persistent AF in 7 (15.2%) out of 45 patients in sinus rhythm at the end of the follow-up. This action significantly changed the Kaplan-Meier curve for arrhythmic-free event survival (Figure 5).

In all 73 investigated patients, a marked improvement in symptoms was observed with an overall reduction in NYHA functional class to 1.2 ± 0.5 from 2.8 ± 1.2 preoperatively (Figure 6).

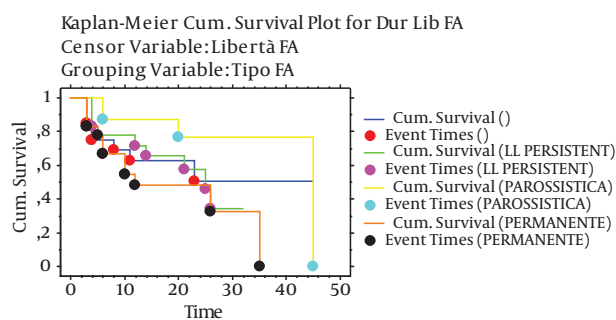


Figure 4. Kaplan-Meier survival curve for freedom from atrial fibrillation and supraventricular tachycardia.

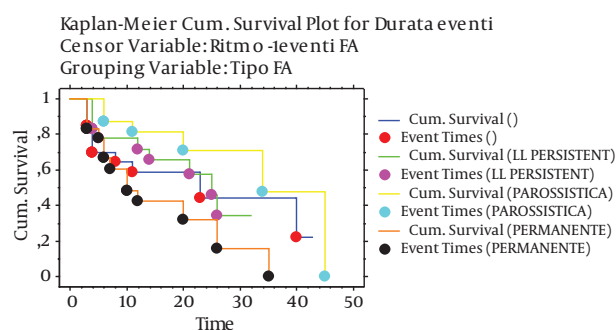


Figure 5. Kaplan-Meier survival curve for event-free survival.

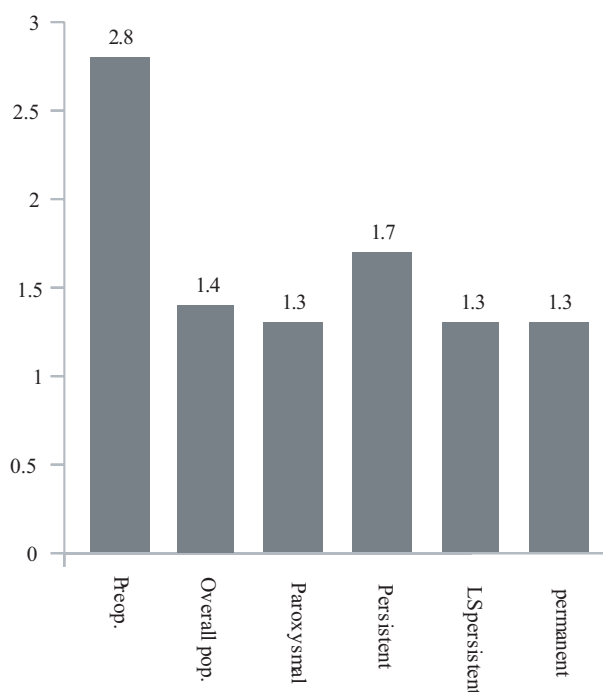


Figure 6. Freedom from symptoms, average EHRA class.

In the overall population, more than 60% of patients were free from antiarrhythmic therapy at the time of the follow-up. When considering the subgroup of patients

who were in sinus rhythm at follow-up, 26 (56.5%) were free from antiarrhythmic therapy while 19 (42.2%) were still receiving treatment with at least one of the following drugs: amiodarone, digoxin, sotalol, non-dihydropyridine calcium antagonists (Figure 7).

There were no other deaths in this study. However, the following postoperative adverse events occurred:

- Three pacemaker implantations
- Two transient ischemic attacks
- One stroke without serious sequelae

One of the two transient neurological events occurred in a patient with residual AF after discharge who was receiving oral anticoagulant therapy, but the patient's INR was not in range. The other TIA and a cerebral stroke occurred 13 and 18 months, respectively, after surgery in patients with a documented stable sinus rhythm who had discontinued antiarrhythmic therapy and oral anticoagulation.

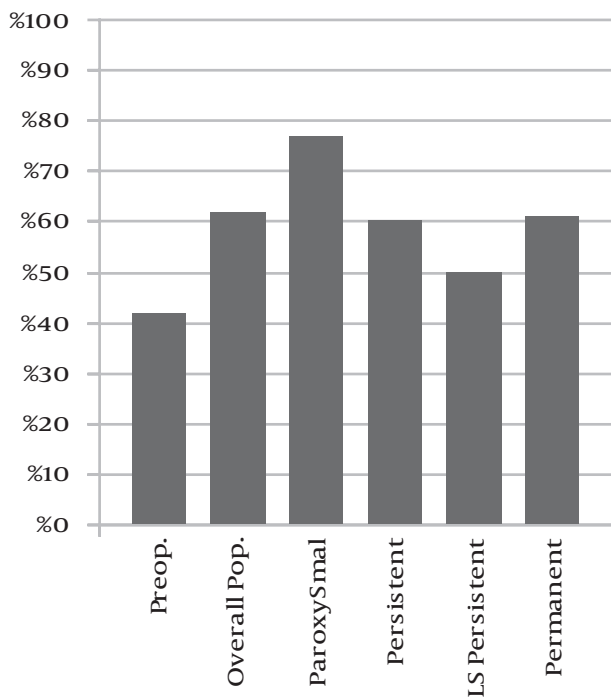


Figure 7. Freedom from antiarrhythmic therapy in the general study population.

5. Discussion

The reason that AF constitutes a preoperative risk factor for early and late mortality in patients undergoing cardiac surgery is still not fully understood. However, a sub-population of cardiac surgical patients suffering from AF seems to show significantly higher co-morbidities in addition to an older age, which tends to influence the result of the surgery (14-16). Although there is disagreement regarding whether a concomitant ablation procedure may improve the survival of patients undergoing cardiac sur-

gery (6, 17), it is evident that the probability of conversion to a stable sinus rhythm in patients with untreated AF is extremely low (5 - 33%) (18). Therefore, whenever necessary, the concomitant treatment of AF through surgical ablation should be considered during the treatment of basic heart disease. Moreover, the recently revised current guidelines indicate surgical treatment of AF in patients with symptomatic AF who are scheduled for heart surgery for other reasons. In asymptomatic patients undergoing heart surgery for other reasons, surgical treatment should only be performed if it can be done with minimal risk. In patients with isolated AF, a minimally invasive approach to surgical treatment can be used following a failed percutaneous procedure (19).

Minimally invasive surgery is currently the gold standard in many centers worldwide for the treatment of mitral and aortic valve disease. Due to the availability and refinement of minimally invasive techniques, more and more patients with complex valvular diseases are seeking this type of treatment. A recent meta-analysis and review of the literature revealed that a minimally invasive approach was not inferior to sternotomy in the treatment of isolated AF as well as for AF in association with other cardiac pathology (20). In the wake of enthusiasm for minimally invasive surgery, numerous authors (13, 21, 22) have developed and described specific surgical techniques for the treatment of AF by minithoracotomy, reporting promising results in terms of perioperative mortality and morbidity as well as freedom from AF at short- and medium-term follow-up, which is similar to our results.

The strength and limitation of our study is that our analysis refers to an overall experience and extremely heterogeneous. However, in our case there was a uniform background; all patients were subjected to ablation alone using RF energy. More than 80% of our population underwent ablation (with different patterns of lesions and different modes) with the exclusive use of monopolar RF, while the remaining group of patients was treated with bipolar RF or a mixed approach. Undoubtedly, some concerns have been expressed about the effectiveness and safety of the use of monopolar RF energy: no monopolar device provides information on the transmuralty of the lesion created (which correlates with the stability of the result) (23). Instead, when bipolar RF energy is used, the measurement of the conduction between the two electrodes has allowed the development of algorithms capable of predicting the desired lesion (24). Gillinov et al. and Laczkovics et al. reported occasional esophageal injury resulting from the dispersion of monopolar energy and described sporadic heart damage following the procedure (25, 26). However, in our series, no such complications occurred in any of the treated patients. A fundamental approach was to remove the transesophageal echocardiography probe in order to avoid having it become a possible discharging pole.

In their in vitro and in vivo study, Bevilacqua et al. high-

lighted some difficulties in creating transmural lesions using a monopolar RF epicardial probe on a beating heart; this problem was attributed to the effect of cooling exerted by the circulating blood. Forty-seven (62.7%) patients were subjected to this type of approach in our study because we were unable to ensure creation of a transmural lesion; to overcome this difficulty, we used a specific device (Cobra Adhere XL) characterized by a vacuum-assisted positioning system, which should minimize these effects, as described in one of our previous publications (21).

Several retrospective studies have acknowledged the use of different techniques and technologies for the treatment of concomitant AF during cardiac surgery, demonstrating variable results with success rates ranging between 65 - 95% (27, 28). In our experience, from the analysis of prevalence, we have shown successful treatment in 63% of the population, which was also confirmed by the Kaplan-Meier survival curve. In addition, we have demonstrated a clear reduction of the EHRA class in patients with residual AF. A majority of the available studies has reported results after a median follow-up of 6 months, while we included data from patients who were followed for an average of 20 months. In fact, we believe that it is unfair to evaluate the stability of the sinus rhythm on the basis of a short monitoring period, i.e. six months.

Nevertheless, there are many factors that may lead to differences in outcome; the technology used and the experience of the surgeons certainly constitute two major issues. However, we believe that the most interesting result is related to the analysis of the lesion sets. Each ablation procedure should begin with proper isolation of the pulmonary veins and eventually lead to a forecast and plan for the addition of further lines of lesions, as originally described by Cox and colleagues (29). Recently, there has been a general consensus that a more extensive set of lesions ensures greater freedom from AF in the long-term (23). Indeed, in a randomized trial, Gaita et al. demonstrated that isolation of the pulmonary veins alone is insufficient to ensure the effectiveness of treatment in patients with permanent AF; several other studies have reported consistent results in patients with persistent AF of a long duration (30, 31). After analyzing our data, we can conclude that all patients underwent pulmonary vein isolation using different methods, but a line of lesions was added to the posterior mitral annulus only in about 30%; additional lesions were created in even fewer cases. A set of complete lesions into the left atrium was produced in only one patient, and a complete biatrial Cox Maze IV was carried out in one other patient.

Independent of the types of lesions, all of our patients reported noticeable clinical improvement; in the subgroup of patients with residual AF, we have shown a significant reduction of the AF burden along with an improvement in symptoms and quality of life. Objectively, there was also a decrease in the EHRA functional class.

5.1. Conclusions

Based upon our data, concomitant treatment of atrial fibrillation through a minimally invasive, right-sided minithoracotomy approach using RF energy in patients undergoing cardiac surgery for various valve disease is feasible, safe, and reproducible. The mortality and hospital morbidity did not differ significantly from those of the general population and are similar to those reported by important studies in the literature. Ablative procedures do not seem to add a substantial risk to the basic procedure of minithoracotomy. Both monopolar and bipolar RF energy sources have been demonstrated to have a good safety profile and acceptable effectiveness.

The results in terms of freedom from atrial fibrillation, atrial flutter, or atrial tachycardia were satisfactory and altogether similar to those of published works to date. However, the technology and the techniques used remain somewhat ineffective in the treatment of atrial fibrillation of a long duration (i.e. persistent and permanent).

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Footnote

Authors' Contribution: Kaushal Kishore Tiwari: concept, study design, data collection, literature review, data processing, manuscript writing; Tommaso Gasbarri: concept, study design, data collection, literature review, data processing, manuscript writing; Stefano Bevilacqua: concept, study design, manuscript writing supervision; Mattia Glauber: concept, study design, manuscript writing supervision.

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