A simple way to treat chronic atrial fibrillation during mitral valve surgery: the epicardial radiofrequency approach

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Abstract

Objective: We describe an original radiofrequency ablation technique to treat chronic atrial fibrillation in patients undergoing mitral valve surgery. Most of the procedure is carried out epicardially, in order to avoid an undue increase of surgical time and trauma. Methods: The ablations are performed using a temperature-controlled multipolar radiofrequency catheter. Two encircling lesions around the ostia of the right and of the left pulmonary veins are carried out epicardially, usually before cardiopulmonary bypass. Through a conventional left atriotomy the ablation procedure is completed with two endocardial lesions connecting the two encirclings between them and to the mitral valve annulus. After the mitral valve procedure is performed, the left appendage is sutured. Results: From February 1998 to May 1999, 40 patients with chronic atrial fibrillation (43:151:9 months) underwent combined radiofrequency ablation and mitral valve surgery. Mean left atrial diameter was 56.8 ± 10.7 mm. Mean cardiopulmonary bypass and aortic cross-clamp time were, respectively, 119:126:3 and 76:7 ± 21:0 min. Mean postoperative blood loss was 287.2 ± 186.6 ml. No reexploration for bleeding occurred. One patient died of pneumonia 12 days after operation. No patient needed permanent pacemaker implantation. Mean postoperative hospital stay was 7.3 ± 5.6 days. At follow-up (mean 11.6 ± 4.7 months), 30/39 (76.9%) of the patients were in stable sinus rhythm. All patients in sinus rhythm 3 months after operation recovered both left and right atrial contractility at echocardiographic control (mean 7.3 ± 3.4 months). The left atrial diameter decreased significantly in patients recovering sinus rhythm. Conclusions: Epicardial radiofrequency ablation is a safe means to achieve surgical ablation of atrial fibrillation with a high success rate. The simplicity of the technique and the low procedure-related risk should dictate combined treatment virtually in all patients with atrial fibrillation undergoing open heart operations. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Atrial fibrillation; Radiofrequency ablation; Atrial fibrillation surgery; Arrhythmia surgery; Mitral valve surgery

1. Introduction

Atrial fibrillation (AF) is related to poorer survival rates with respect to sinus rhythm (SR) both in the general population [1] and in patients undergoing heart surgery [2]. The prevalence of AF in patients scheduled for a mitral valve procedure is still between 30 and 84% [3–5]. In the presence of permanent AF the likelihood of SR recovery after a conventional heart operation alone ranges from 4.5 to 36% and is even more unlikely in patients with left atrio-megaly [2].

The combination of a modified maze operation, characterised by an extensive use of right and left atrial incisions, has proven effective in restoring SR but it requires a considerable prolongation of cardiopulmonary bypass (CPB) and aortic crossclamp (ACC) time when performed in combination with other standard open heart procedures. Moreover even when SR is restored after combined valve surgery and maze procedure, recovery of atrial function is below 80% [6,7].

Simplified techniques have been proposed in the last years. Effective treatment of AF by replacing surgical incisions with endocardial cryoablations [8,9] or radiofrequency (RF) application [10] has recently been reported.
We describe an innovative surgical RF ablation strategy to treat chronic AF. RF has been used mainly on the epicardial surface to minimize surgical time and myocardial trauma. Early results in a series of patients undergoing open heart procedures are reported.

2. Material and methods

From February 1998 to May 1999, 40 patients with chronic AF, scheduled for heart valve surgery at our Division, underwent combined intraoperative AF treatment with RF ablation. Mean duration of AF was $43.1 \pm 51.9$ months, ranging from 6 months to 20 years. Patients with paroxysmal AF or with persistent AF lasting less than 6 months were excluded from this study. All patients were affected by mitral valve disease; 11 patients had associated heart diseases (Table 1). All patients had given informed written consent to the procedure.

ECG, chest X-ray and transesophageal echocardiogram (TEE) were routinely performed on admission. Additional ECGs were recorded during recovery and before discharge. Standard 12-lead ECG, TTE and Holter monitoring were performed 1, 3, and 6 months after operation, and then on a yearly basis.

The follow-up period ranged from 3 to 18 months (mean 11.6 ± 4.7 months).

2.1. Surgical technique

After the induction of anaesthesia all patients underwent transesophageal echocardiography (TEE), to detect the presence of left atrial thrombosis.

During the initial experience, surgical ablations were performed with a custom made multipolar, temperature-controlled flexible RF catheter, ablating sequentially on 1 cm-long tips. In the last consecutive 18 patients we used a newly developed surgical device with a 7-tipped active length of 12 cm ablating simultaneously (Therma Line®, Boston Scientific). This radiofrequency catheter allows keeping tissue temperature at a pre-set value during ablation by means of a couple of thermosensors placed on each tip. For the present description, technical data about temperature and time of RF erogation will concern the use of the latter device.

The heart was exposed through a conventional median sternotomy access. The intrapericardial portion of the right pulmonary veins (RPV) was prepared and the RF catheter was passed behind them, placing it on the posterior wall of the left atrium (LA) in a semicircular fashion. In order to avoid contact with the left appendage if it was to be sutured (Fig. 1). After heparin administration, an epicardial posterior hemiencircling ablation line (2 min at 75°C) was performed with both the proximal and the distal ablating tips of the catheter located in the interatrial groove. Then, after cannulation, the heart was lifted toward the surgeon, and the left pulmonary veins (LPVs) were exposed and prepared in the same way. In patients with left ventricular enlargement, this manoeuvre usually required institution of partial CPB. After passing the catheter behind the ostia of the LPVs, a complete encircling epicardial ablation line was performed, requiring 1 or 2 applications (2 min, 75°C). When suture of the left appendage was planned (on a routine basis after the first 15 patients), the LPVs encircling line was prolonged to the base of the auricle.

The heart was arrested by antegrade and retrograde cold blood cardioplegia. A conventional left atriotomy was performed parallel to the interatrial groove, connecting the ends of the RPVs ablation line, thus completing the RPVs encircling. Mitral valve excision or repair was carried out. The ablation procedure was then completed with two endocardial linear lesions (2 min, 65–70°C). The first one was performed between the two encirclings on the posteroseptior atrial wall: since the epicardial encircling ablations are usually not visible on the endocardial surface, the ends of this linear lesion must nearly reach the orifices of the PVs, well into each of the encirclings, not to leave any gap in the lesion set. The second endocardial linear lesion was performed to join the mitral annulus to the LPVs encircling, or to the left appendage if it was to be sutured (Fig. 1). During the last ablation, low flow retrograde cardioplegia was administered to protect the circumflex artery from heat trauma.

The valve or ring prosthesis was then implanted. Before closure of the atriotomy incision, the left auricle was carefully sutured.

In case of redo operation or in presence of intracavitary thrombosis all ablations were performed endocardially, because of the unlikeliness of achieving a transmural lesion by ablating on a thickened epicardial surface or because of

<table>
<thead>
<tr>
<th>Table 1 Preoperative data$^a$</th>
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<tbody>
<tr>
<td>Patients</td>
</tr>
<tr>
<td>M/F</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>AF duration</td>
</tr>
<tr>
<td>LA diameter</td>
</tr>
<tr>
<td>C/T ratio</td>
</tr>
<tr>
<td>NYHA--II</td>
</tr>
<tr>
<td>--III</td>
</tr>
</tbody>
</table>

Associated conditions

- TR: 7 patients
- AR: 2 patients
- CAD: 1 patient
- HOCM: 1 patient
- Prior heart surgery: 5 patients

$^a$Continuous parameters are expressed as mean ± SD; M/F, male/female; AF, atrial fibrillation; LA, left atrium; C/T, cardio/thoracic; NYHA, New York Heart Association; TR, tricuspid regurgitation; AR, aortic regurgitation; CAD, coronary artery disease; HOCM, hypertrophic obstructive cardiomyopathy.
2.2. Perioperative management

Antiarrhythmic prophylactic treatment was carried out on a routine basis. Amiodarone was the first choice antiarrhythmic drug. Administration was begun after the induction of anaesthesia (300 mg i.v. bolus followed by 1200 mg/24 h until the first postoperative day, or until the recovery of peristalsis, when oral administration of 200 mg/8 h was begun; after discharge, a maintenance regimen of 200 mg/24 h was continued). In eight patients with contraindications to amiodarone, propaphenone (five patients), sotalol (one patient) or no medication (two patients) was administered. Antiarrhythmic prophylaxis was discontinued 6 months after the operation. Heparin continuous drip was administered after resolution of postoperative bleeding until therapeutic values of prothrombin time were reached with oral anticoagulants.

2.3. Statistical analysis

Data are expressed as mean ± standard deviation (SD). Student’s t-test for paired data was used to assess the statistical significance of differences between pre and postoperative parameters. A P-value <0.05 was considered significant.

The following preoperative variables were considered for any possible relationship with surgical results: AF duration, cardio-thoracic ratio, and left atrial diameter (LAD).

3. Results

RF epicardial ablation was performed in 33 patients (82.5%). Five patients undergoing reoperation and two patients with documented left atrial thrombosis had a completely endocardial ablation procedure. The left appendage, already obliterated in three previously operated patients, was sutured in 23 of the remaining cases (62.2%).

All patients underwent mitral valve surgery alone or in association with other procedures (Table 2). Fifteen patients underwent mitral valve repair: seven had a posterior leaflet quadrangular resection, six an edge-to-edge repair for prolapse of the anterior leaflet or of both the anterior and the posterior leaflets [12], and two a mitral valve annuloplasty with a prosthetic ring. Five patients had an open-heart commissurotomy. Out of 20 patients undergoing mitral valve replacement a bioprosthesis was implanted in three.

Mean CPB and ACC time were, respectively, 119.1 ± 26.3 and 76.7 ± 21.0 min. No reexploration for bleeding occurred in this series. Mean postoperative blood loss was 287.2 ± 186.6 ml. Six patients (15%) required blood transfusions. One 76-year-old female patient with a previous stroke had a postoperative respiratory failure due to bilateral pneumonia, and died 12 days after operation. One patient had a deep sternal wound infection requiring sternectomy and rectus muscle flap reconstruction. No patient needed permanent pacemaker implantation for postoperative A-V block or sinus node dysfunction.

No case of fluid retention as indicated by pulmonary edema, diffuse peripheral edema or pleural effusion requiring thoracentesis, occurred in this series.

3.1. Postoperative heart rhythm

On postoperative admission to the intensive care unit 38 patients (95%) were either in spontaneous SR or electrically paced in DDD or AAI mode.

During the first month, AF recurred in 22 patients (56.4% of 38 patients). The following parameters were considered for any possible relationship with surgical results: AF duration, cardio-thoracic ratio, and left atrial diameter (LAD).

Table 2

<table>
<thead>
<tr>
<th>Operative data*</th>
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</tr>
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<tbody>
<tr>
<td>MV procedures</td>
<td>40/40 patients</td>
</tr>
<tr>
<td>MV repair</td>
<td>15 patients</td>
</tr>
<tr>
<td>MV commissurotomy</td>
<td>5 patients</td>
</tr>
<tr>
<td>MV replacement</td>
<td>20 patients</td>
</tr>
<tr>
<td>Associated procedures</td>
<td>11/40 patients</td>
</tr>
<tr>
<td>TV annuloplasty</td>
<td>7 patients</td>
</tr>
<tr>
<td>AV replacement</td>
<td>2 patients</td>
</tr>
<tr>
<td>Morrow operation</td>
<td>1 patients</td>
</tr>
<tr>
<td>CABG</td>
<td>1 patients</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>119.1 ± 26.3</td>
</tr>
<tr>
<td>ACC time (min)</td>
<td>76.7 ± 21.0</td>
</tr>
<tr>
<td>Bleeding (ml)</td>
<td>287.2 ± 186.6</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>1.8 ± 3.0</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>7.3 ± 5.6</td>
</tr>
<tr>
<td>Reexploration for bleeding</td>
<td>0</td>
</tr>
<tr>
<td>Permanent PM</td>
<td>0</td>
</tr>
<tr>
<td>Death</td>
<td>1 (2.5%)</td>
</tr>
</tbody>
</table>

* Continuous parameters are expressed as mean ± SD; MV, mitral valve; TV, tricuspid valve; AV, aortic valve; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; ACC, aortic cross clamping; ICU, intensive care unit; PM, pacemaker.
Patients were followed-up for more than 1 year.

Two patients had paroxysmal counterclockwise atrial flutter; both were successfully treated by transvenous catheter ablation, respectively, 6 and 9 months after operation. At 11.6 ± 4.7 months follow-up, 30/39 (76.9%) patients were in SR.

Multivariate analysis failed to show any relationship between preoperative variables and outcome of the ablation procedure.

3.2. Echocardiographic data

At postoperative control (mean TTE follow-up 7.3 ± 3.4 months) the LAD decreased from 56.7 ± 10.2 (preoperative value) to 45.8 ± 7.4 ($P < 0.01$) in patients in stable SR. In patients not recovering SR LAD was 57.0 ± 11.7 preoperatively and 52.5 ± 12.1 at follow ($P: n.s.$).

Doppler analysis of mitral and tricuspid flow demonstrated recovery of both left and right atrial mechanical activity in all patients in SR 3 months after operation.

Table 3 summarizes results in terms of Santa Cruz score, ranging from 0 to 4: (0: AF recurrence; 1: no AF, but no atrial contraction; 2: no AF, but only right atrial contraction; 3: no AF, and bilateral atrial contraction; 4: SR and bilateral atrial contraction) [11]. All 28 patients in stable SR 3 months after operation scored therefore 4, nine scored 0, while the only two patients without evidence of left atrial contractility (score 2), had the echocardiographic assessment performed about 1 month after operation.

4. Discussion

AF is an important determinant for survival [1,2]. SR recovery allows withdrawal of anticoagulant medications when mitral valve repair or valve replacement with a bioprosthesis is carried out. Moreover even in patients on anticoagulant medications after mitral valve replacement with a mechanical prosthesis, intracavitary thrombosis and prethrombotic phenomena are favoured by AF [13]. The detrimental effects of AF are even more pronounced in the presence of high ventricular rate, that can further deteriorate ventricular function in patients with heart valve disease [14].

AF ablation with a simple technique, using intraoperative RF mainly on the epicardial surface during mitral valve surgery, yielded in our experience a 76.9% success rate about 1 year after operation, whereas spontaneous SR restoration following conventional heart surgery occurs in 4.5 to 36% of patients in chronic AF [2].

Several surgical procedures have been proposed to treat AF either isolated or associated with organic heart disease [15–20]. In the last decade, new techniques have been developed and various modifications proposed in order to improve success rate while minimizing surgical trauma and operative risk [8–10].

The common features of these approaches derive from experimental evidences on the pathophysiological mechanisms of AF: (i) Dividing the enlarged atria into smaller areas follows the concept of ‘critical mass’. Based on this, a sufficient number of multiple reentrant wavelets to perpetuate AF cannot coexist without a large, uninterrupted atrial mass; (ii) Joining all ablation or incision lines with venous ostia and the fibrous structures of the heart allows avoiding macroreentry circuits around natural obstacles and through gaps within the ablation pattern [17]; (iii) Encircling of the pulmonary veins results in isolation of potential automatic foci within the venous ostia that have been claimed to be responsible for initiation and maintenance of AF [21].

The RF ablation pattern we describe allows isolating the orifices of the pulmonary veins with epicardial ablations, and creating a continuous line of block connecting the encirclings, the sutured auricle and the mitral valve annulus. Thus, all the conceptual criteria of an effective ablation approach to the left atrium are fulfilled.

Auricle exclusion, initially performed only in patients with relevant atriofibrosis, is now carried out on a routine basis because, besides simplifying the completion of the ablation scheme, it decreases the potential for thromboembolism in case of AF recurrence. Auricle thrombosis and spontaneous echocontrast are in fact not uncommon after valve surgery, even under an appropriate oral anticoagulation regimen [13].

The choice of limiting the ablations to the left atrium is based on recent clinical and experimental evidences. During an intraoperative electrophysiologic study on patients with chronic AF and mitral valve disease Sueda et al. recorded the shortest fibrillatory cycles in the posterior wall of the left atrium [8]. Surgical approaches limited to the left atrium proved to be effective in treating chronic AF both in the experimental setting [22] and in patients undergoing mitral valve surgery [8–10]. Similarly, transvenous RF catheter treatment of paroxysmal AF results in higher success rates.
when lesions are performed on the left rather than on the right atrium [23].

It can be argued that the addition of a surgical right-sided ablation of the isthmus would probably have prevented the two cases of refractory atrial flutter observed at follow-up. We deemed secondary treatment by transvenous RF ablation preferable to an additional right atriotomy and primary ablation during CPB. This approach proved highly effective and devoid of complications. The choice to ablate the right atrium during surgery should probably be based on the reliability of the arrhythmology team backup together with the surgeon’s preference.

The effectiveness of epicardial RF ablation in the treatment of AF has been recently documented in the animal model [24]. Starting in February 1998, we chose to adopt epicardial RF in the clinical setting because of different considerations: first of all epicardial ablation around the PVs allows to perform most of the lesions before ACC. Additionally, being the heat source on the epicardial surface, the risk of ablation-related thromboembolism is virtually abolished. Moreover, the possibility of a complete AF ablation from the epicardium can open the way towards beating heart AF surgery and further on to minimally invasive surgical approaches.

However its use is likely to lead to nontransmural lesions when the epicardial surface is thickened by a prior logistic reaction (i.e. redo operations), and can expose to embolic risk patients with atrial thrombosis. In such instances endocardial ablation under direct vision is strongly recommended.

Our results are comparable with those described in other studies reporting similar series of patients operated on with ‘cut and sew’ techniques such as the different modified versions of the maze operation [6,7,25]. The advantage of our ablation procedure is that besides avoiding undue prolongations of CPB and ACC, no additional incision is required apart from the conventional left atriotomy. This finding, also emerging from previously reported experiences with a simplified left atrial approach using RF [10,11], may account for the absence of haemorrhagic complications and fluid retention in our series, favouring a prompt clinical recovery and a short intensive care and hospital stay. Furthermore, while recovery of left atrial function after mitral valve surgery and modified maze occurs in less than 80% of patients with a restored stable SR [6,7], we recorded a 100% rate of contractility of both atria 3 months after operation. This may be due both to a limited atrial muscle trauma related to RF use and to electrical exclusion (and consequent loss of contraction) of a negligible amount of atrial wall, around the orifices of the pulmonary veins.

Our data suggest that intraoperative RF catheter ablation performed mainly through the epicardium is a low risk, effective procedure to treat AF in patients undergoing heart valve surgery. This technique is extremely simple and reproducible, and therefore can be performed routinely in AF patients, scheduled for open heart surgery.

Further research experience is needed to assess the transmurality of RF lesions performed epicardially and to determine their potential role in the treatment of lone AF.

Acknowledgements

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Appendix A. Conference discussion

Dr P.S. Bhat (Bangalore, India): We have been using a similar sort of an approach for the past 1 year, but we use the diathermy cautery, set it around 40, and we put the incision endocardially, and we have employed it in cases which are undergoing a mitral valve procedure, having an associated tricuspid valve disease also, so that we can employ it in both the right atrium and the left atrium, and, surprisingly, our results are a 100%. Diathermy if set at 40, the success of RF ablation was 100%. We have been following up with a mean follow-up of 6 months, and they have undergone Holter monitoring also, and they are in sinus rhythm. It is very effective, doesn’t cost any extra using diathermy cautery.

Dr Benussi: Excuse me, can you repeat the tool you are using?

Dr Bhat: Diathermy cautery.

Dr S. Schueler (Dresden, Germany): Simple cautery.

Dr Bhat: Simple cautery, without any additional cost to the patient and to the surgeon. I mean, it is very effective. And we had presented our paper in the last Asian Congress in Singapore.

Dr Benussi: Well, I am pretty sure that electrocautery can be effective in ablating atrial fibrillation, but cutting and sewing would be as well. The reason why we chose this radiofrequency catheter is that by providing information about tissue temperature, it can prevent an excessive myocardial trauma to be caused by the ablation. When we first started treating atrial fibrillation in February 1998 in fact, our first goal was to minimize the ablation-related risk.

Dr Bhat: And none of the patients had any associated morbidity attributable to the cautery. It was not, you know, making an incision and stitching it. It was just a cautery, you know, injury over the endocardium, not exactly cutting and suturing it.

Dr Schueler: Do you really think there is such a big advantage in using this technique from the outside rather than from the inside, which you did and others did, and there are other tools available? So if you, in any case, opened the left atrium and you put the patient on bypass and cardioplege the heart, from my point of view this really doesn’t matter, makes not a big difference to add these 5 min of heart-lung machine use.

Dr Benussi: That is a very interesting issue. It is just a matter of choice in the surgical approach. As I repeat, our first target is to prevent any additional surgical risk; this can also be accomplished by avoiding any unnecessary prolongation of aortic cross clamping time through epicardial ablation on the beating heart. But in those seven cases performed endocardially, we did not have any technical problem and completing the ablation scheme was simple all the same. What I think is really interesting in this innovative approach, is the future perspective of a complete epicardial ablation of atrial fibrillation without the need of cardiopulmonary bypass.