

## Surgery for Atrial Fibrillation

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### Abstract

Atrial fibrillation is the most common sustained cardiac arrhythmia and is associated with significant morbidity and mortality. Surgical treatment is the most effective means of curing atrial fibrillation. The classic Cox maze procedure eliminates atrial fibrillation in more than 90% of patients and has remained the gold standard in surgery for atrial fibrillation. Despite being highly effective, the complexity of the procedure and long operating time associated with the operation has prevented its widespread application by surgeons. Advances in the understanding of the pathogenesis of atrial fibrillation and development of new ablation technologies have fuelled renewed interest in and development of surgical ablation procedures for atrial fibrillation. These new procedures are simpler and easily reproducible and cure atrial fibrillation in approximately 80% of patients. This article reviews the development of surgery for atrial fibrillation and our experience with the radiofrequency Cox maze III procedure.

Ann Acad Med Singapore 2004;33:432-6

**Key words:** Bipolar, Maze, Radiofrequency

### Introduction

Atrial fibrillation is the most common sustained cardiac arrhythmia.<sup>1</sup> The overall prevalence of atrial fibrillation is 0.4%.<sup>2</sup> This increases with age, reaching 3% to 5% in those over 65 years<sup>3,4</sup> and 9% in those over 80 years.<sup>5</sup> Atrial fibrillation is more common in patients with structural heart disease, and these patients make up most of the atrial fibrillation population.<sup>4</sup> The most common conditions associated with atrial fibrillation are coronary artery disease, valvular (mainly mitral) heart disease, congestive heart failure and hypertension. More importantly, 30% to 50% of patients undergoing mitral valve surgery are affected by atrial fibrillation.<sup>6-8</sup>

Atrial fibrillation is associated with significant morbidity and mortality. It is an independent risk factor for death with a relative risk of 1.5 for men and 1.9 for women.<sup>9</sup> Because of loss of effective atrial contraction and consequent stasis of blood in the atria, particularly the left atrial appendage, patients with atrial fibrillation have an increased risk of thromboembolic complications. The risk of stroke in patients with atrial fibrillation is 5 times greater than in age-matched controls and atrial fibrillation is responsible for as many as 15% of all strokes.<sup>9,10</sup>

The failure rate of medical antiarrhythmic therapy for atrial fibrillation is 50% at 1 year and 84% at 2 years.<sup>10,11</sup>

Medical treatment therefore focuses on ventricular rate control and anticoagulation. This, however, is cumbersome and exposes patients to significant risk of haemorrhagic complications.<sup>12</sup>

### Historical Background of Surgery for Atrial Fibrillation

Atrial fibrillation is associated with 3 detrimental sequelae: (1) an irregularly irregular heartbeat that causes patient discomfort and anxiety; (2) loss of synchronous atrioventricular contraction which compromises cardiac haemodynamics; and (3) stasis of blood flow in the left atrium, which increases vulnerability to thromboembolism.<sup>13</sup> While early attempts at surgical control of medically refractory atrial fibrillation restored a regular rhythm, they failed to address one or more of these problems. The earliest and simplest approach was atrioventricular node ablation and pacemaker insertion. This provided rate control, but did not restore atrioventricular synchrony and still left the patient susceptible to thromboembolism. The development of catheter-based techniques by Scheinman and associates<sup>14</sup> made the procedure less invasive, but did not alter the aforementioned shortcomings. In 1980, Williams et al<sup>15</sup> reported the left atrial isolation procedure which confined atrial fibrillation to the left atrium while restoring the rest of the heart to sinus rhythm. While the procedure

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unexpectedly restored normal cardiac haemodynamics, continued fibrillation in the left atrium left the patient vulnerable to systemic thromboembolism. In 1985, Guiradon et al<sup>16</sup> introduced the corridor procedure. Based on the observation by Garrey<sup>17</sup> that sustained atrial fibrillation requires a critical mass of tissue, this procedure was designed to isolate a strip of atrial tissue between the sinus node and the atrio-ventricular node that had insufficient mass to permit fibrillation. Like left atrial isolation, the corridor procedure still leaves a substantial amount of atrial tissue fibrillating and therefore poses a continued risk of thromboembolism. In view of the shortcomings of these procedures, efforts were initiated to design a true surgical cure for atrial fibrillation based on the anatomic-electrophysiological basis of atrial fibrillation and flutter.

### Electrophysiology and Development of the Maze Procedure

In 1962, Moe<sup>18</sup> proposed a multiple wavelet hypothesis as the basis for atrial fibrillation. This theory that atrial fibrillation was caused by multiple random re-entrant wavelets was later verified by Boineau et al<sup>19,20</sup> and Allesie et al.<sup>21</sup> Using epicardial electrode templates, computer-generated activation maps of the atria during atrial fibrillation demonstrated that macro re-entrant circuits were responsible for the entire spectrum of atrial arrhythmias. The results of human studies as summarised by Cox<sup>22</sup> demonstrated that re-entrant circuits responsible for atrial flutter most often involved the right atrium alone, whereas in complex atrial fibrillation, multiple re-entrant circuits were identified throughout both atria. This was consistent with the multiple wavelet hypothesis of Moe. Given the complex and fleeting nature of re-entrant circuits responsible for atrial fibrillation, efforts were focussed on developing a generalised procedure that would interrupt all potential macro re-entrant circuits without requiring individualised intraoperative mapping. After extensive laboratory investigation, the first successful Cox et al<sup>23</sup> maze procedure was performed in September 1987. Studies on the first 32 patients who underwent the procedure identified 2 undesirable sequelae: (1) inability to generate an appropriate tachycardic response to exercise in two-thirds of patients and (2) occasional absence of left atrial transport. This resulted in 2 modifications, culminating in the Cox maze III procedure. In the largest series of 346 patients undergoing the maze procedure, Cox et al<sup>24</sup> reported an operative mortality of 2%, a cure rate of 99% and only 2% requiring postoperative antiarrhythmic medication. Temporary postoperative atrial fibrillation was common, occurring in 38% of patients, but did not diminish the long-term results.<sup>25</sup> Similar excellent results in restoration of sinus rhythm, low risk of late stroke and very low operative morbidity and mortality have been reported in several

major, high-volume centres.<sup>24,26-28</sup> Despite the good results, however, the Cox-maze procedure has not gained widespread application because of its perceived complexity and time-consuming nature. Few patients are referred for surgery of lone atrial fibrillation and even in patients requiring cardiac surgery for other reasons, surgeons are reluctant to add the maze procedure.

### Recent Advances in Atrial Fibrillation Surgery

In recent years, there has been a dramatic resurgence of interest in surgical treatment of atrial fibrillation. This has been brought about by 2 main factors: understanding that the pulmonary veins and left atrium are critical in initiation and maintenance of atrial fibrillation and the development of ablation tools that use alternative energy sources to facilitate rapid and safe creation of lines of conduction block.<sup>29</sup>

Recent mapping studies in the sheep heart point to a primary local generator, such as a single small re-entry circuit or ectopic focus.<sup>30,31</sup> In human studies, up to 94% of patients with paroxysmal atrial fibrillation have been shown to have their arrhythmia originate from ectopic foci in the pulmonary veins.<sup>32</sup> Indeed, catheter ablation of pulmonary vein foci has proven effective in ablating paroxysmal atrial fibrillation.<sup>33,34</sup> While these observations demonstrate the importance of the pulmonary veins in patients with paroxysmal atrial fibrillation and challenge the conventional view that all atrial fibrillation results from multiple re-entry circuits, their role in persistent and permanent atrial fibrillation is less clear.

In tandem with better understanding of the electrophysiology of atrial fibrillation, new ablation tools have been developed to facilitate surgical ablation of atrial fibrillation. These instruments create long linear lesions that block conduction using alternate energy sources such as radiofrequency, cryotherapy, microwave, ultrasound and laser. The clinical experience amongst these is greatest with radiofrequency energy. Radiofrequency energy uses an alternating current to heat tissue resulting in thermal injury.<sup>35</sup> The efficacy of this modality is well established in catheter-based arrhythmia ablation<sup>33,34</sup> and has led surgeons to apply radiofrequency energy directly to the heart during cardiac surgery. The lesion sets applied by surgeons vary considerably, but results are similar with atrial fibrillation being ablated in 70% to 80% of patients.<sup>36-38</sup> To date, most radiofrequency procedures have been performed with monopolar systems. This has several inherent drawbacks. Because of the unfocussed nature of the energy delivery, heat is conducted to the surrounding tissue increasing the risk of injury to neighbouring structures such as the oesophagus.<sup>39,40</sup> It is also virtually impossible to ensure consistent transmural lesions. In contrast, the more

recently developed bipolar radiofrequency clamps address these limitations and allow creation of more precise and uniform lesions. Built-in algorithms in the bipolar system ensure transmural lesions with incremental delivery of radiofrequency energy till there is no further drop in impedance of the clamped tissue.

### National Heart Centre Experience

From July 2001 to November 2003, 56 patients (32 men and 24 women; mean age,  $58 \pm 11$  years) underwent the radiofrequency Cox-maze III procedure while undergoing concomitant cardiac surgery at the National Heart Centre. All patients who have a history of atrial fibrillation and are in atrial fibrillation at the time of surgery for their primary cardiac problem are considered candidates for the radiofrequency maze procedure (Fig. 1). We use a saline irrigated radiofrequency system (Cardioblate, Medtronic Inc, Minneapolis, MN). In our first 46 patients, we used a monopolar probe while our most recent 10 patients have undergone the radiofrequency maze procedure with a combination of monopolar and bipolar probes. Concomitant surgery include 49 mitral valve procedures (14 repairs and 35 replacements), 19 tricuspid valve procedures (17 annuloplasties and 2 replacements), 6 aortic valve replacements, 6 coronary artery bypasses, 5 closures of atrial septal defects or patent foramen ovale and 2 reduction atrioplasties. The radiofrequency maze procedure was performed to achieve the full bi-atrial lesion set of the classical Cox maze III procedure as described by Sie.<sup>36</sup> Freedom from atrial fibrillation and flutter after radiofrequency maze procedure (Fig. 2) was 96% immediately after surgery, 58% at 1 week, 56% at 1 month, 72% at 3 months, 80% at 6 months, 74% at 1 year, 80% at 1.5 years and 79% at 2 years postoperatively (Fig. 3). Freedom from atrial fibrillation levelled off after 6 months. There were 2 early postoperative deaths, both unrelated to the radiofrequency maze procedure. None of the patients suffered injury to neighbouring structures in our series. There is a high incidence of recurrent atrial fibrillation in the first 6 months. It has therefore been our practice to leave



Fig. 1. Preoperative ECG showing atrial fibrillation.



Fig. 2. ECG after radiofrequency maze procedure.

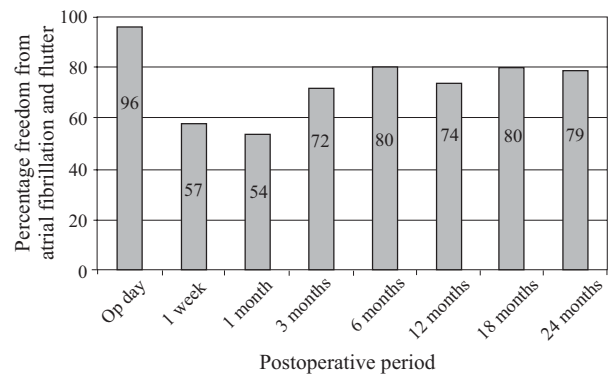


Fig. 3. Freedom from atrial fibrillation and flutter after radiofrequency maze procedure.

patients on antiarrhythmic medication for 6 months and continue anticoagulation for up to 1 year after surgery. No patient has had an embolic stroke during the follow-up period. In contrast, however, 1 patient succumbed to a haemorrhagic stroke 5 months after mechanical aortic valve replacement. He was in sinus rhythm. Anticoagulation in this patient was in the therapeutic range and necessary for the mechanical valve prosthesis. One patient early in our series developed atrial flutter several months after surgery. The flutter was localised to the isthmus and was successfully ablated with a trans-catheter approach. Following this experience, we modified the isthmus portion of the radiofrequency lesions and have not had subsequent problems with recurrent atrial flutter.

Our experience with the radiofrequency Cox-maze III procedure has been positive both with the monopolar, and especially the combined monopolar and bipolar system. Our early experience suggests that sinus rhythm is more stable in the first 6 months after combined monopolar and bipolar radiofrequency maze procedure as compared to monopolar alone, although success rate at 6 months is still 80%. This is likely a result of achieving more consistent transmural lesions with less contiguous atrial myocardial injury and inflammation when using the bipolar clamp. With less than 20 minutes of additional cardiopulmonary bypass time required for the procedure, the radiofrequency Cox maze III has become our standard surgical treatment for patients with atrial fibrillation undergoing cardiac surgery.

### Indications for Atrial Fibrillation Surgery

Patients with chronic atrial fibrillation secondary to valvular heart disease have a low chance of gaining sinus rhythm after corrective valve surgery alone.<sup>41</sup> There is negligible additional morbidity associated with the radiofrequency maze procedure in patients who are undergoing concomitant cardiac surgery in our series as the extra cardiopulmonary bypass time required is short and

the procedure does not add significantly to the complexity of the operation. We therefore consider all patients who are in atrial fibrillation at the time of surgery candidates for the radiofrequency maze procedure. Patients with highly symptomatic paroxysmal atrial fibrillation that is refractory to medical treatment are also candidates for the procedure.

The benefit of restoration of sinus rhythm is expected to be greatest in patients who would otherwise have a long exposure to the risks of anticoagulation such as young patients undergoing mitral valve repair. To date, only patients undergoing concomitant cardiac surgery are considered for the maze procedure. As results improve with changing technology, the indication for radiofrequency maze procedure may extend to include patients who have contraindications to anticoagulation or who have symptomatic, medically resistant, lone atrial fibrillation.

There are no absolute contraindications to the radiofrequency maze procedure. Patients who have sick sinus syndrome documented prior to surgery are warned of an increased chance of requiring a permanent pacemaker after surgery, but will still be considered. Extremely high-risk patients who need quick surgery are a relative contraindication for the radiofrequency maze procedure.

## Summary

Surgery remains the most effective cure for atrial fibrillation. With new ablative technologies, surgery for atrial fibrillation is now simple and easily reproducible. Results of newer procedures still lag behind the classical cut-and-sew Cox maze III procedure and this may preclude its application for lone atrial fibrillation. However, when applied to patients who have atrial fibrillation in association with other cardiac disease requiring surgery, we are presented with an opportunity to cure large numbers of patients with atrial fibrillation.

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