The Cox-Maze Procedure for Lone Atrial Fibrillation
A Single-Center Experience Over 2 Decades

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Background—The Cox-Maze procedure (CMP) has achieved high success rates in the therapy of atrial fibrillation (AF) while becoming progressively less invasive. This report evaluates our experience with the CMP in the treatment of lone AF over 2 decades and compares the original cut-and-sew CMP-III to the ablation-assisted CMP-IV, which uses bipolar radiofrequency and cryoenergy to create the original lesion pattern.

Methods and Results—Data were collected prospectively on 212 consecutive patients (mean age, 53.5±10.4 years; 78% male) who underwent a stand-alone CMP from 1992 through 2010. The median duration of preoperative AF was 6 (interquartile range, 2.9–11.5) years, with 48% paroxysmal and 52% persistent or long-standing persistent AF. Univariate analysis with preoperative and perioperative variables used as covariates for the CMP-III (n=112) and the CMP-IV (n=100) was performed. Overall, 30-day mortality was 1.4%, with no intraoperative deaths. Freedom from AF was 93%, and freedom from AF off antiarrhythmics was 82%, at a mean follow-up time of 3.6±3.1 years. Freedom from symptomatic AF at 10 years was 85%. Only 1 late stroke occurred, with 80% of patients not receiving anticoagulation therapy. The less invasive CMP-IV had significantly shorter cross-clamp times (41±13 versus 92±26 minutes; P<0.001) while achieving high success rates, with 90% freedom from AF and 84% freedom from AF off antiarrhythmics at 2 years.

Conclusions—The CMP, although simplified and shortened by alternative energy sources, has excellent results, even with improved follow-up and stricter definition of failure. (Circ Arrhythm Electrophysiol. 2012;5:8-14.)

Key Words: ablation ■ arrhythmia heart rhythm disorders atrial fibrillation ■ surgery ■ tachyarrhythmias

Atrial fibrillation (AF) is the most common sustained arrhythmia worldwide, with an expected increase in our aging population.1 In addition to the significant morbidity and mortality secondary to hemodynamic compromise and tachycardia-induced cardiomyopathy in some patients, stroke remains the most feared complication.2 AF accounts for ≈25% of strokes in patients >80 years and increases a person’s risk of stroke by 5-fold.3 The limitations of pharmacological therapy, with failure rates as high as 60%, have led to the development and proliferation of interventional approaches in the treatment of AF, including catheter ablation and surgery.4–7

Clinical Perspective on p 14

In 1987, Dr. Cox introduced the maze procedure (CMP) for the surgical treatment of AF at our institution. His surgical approach was designed to block the multiple macroreentrant circuits that were the putative cause of AF.7,8 The final iteration of his cut-and-sew technique, termed the CMP-III, proved to be highly efficacious, with 97% freedom from symptomatic AF, and became the gold standard for the surgical therapy of AF for >10 years (Figure 1).9,10 Although early follow-up was excellent and included 24-hour Holter monitoring, only few patients had ECGs or prolonged monitoring at long-term follow-up.5,11 The end point was generally self-reported freedom from symptomatic AF. Moreover, this procedure was not widely adopted because of its complexity and invasiveness.

The development of alternative energy sources has enabled surgeons to create lines of ablation to replace most incisions of the original CMP-III, which shortened and simplified the procedure.12,13 In our laboratory, bipolar radiofrequency energy was able to create reliable transmural lines of ablation while minimizing the risk of collateral damage to the surrounding tissue.14,15 In 2002, our institution introduced a new iteration termed the CMP-IV, which used bipolar radiofrequency and cryoenergy to replace most of the original incisions.13 Although we initially performed only a single inferior connecting lesion between the ablations isolating the right and left pulmonary veins (PVs), we implemented the final version of the CMP-IV 2 years later, in which the entire posterior left atrium was isolated by adding a superior connecting line, termed the box lesion set (Figure 2 and Figure 3).17 This closely resembled the original cut-and-sew..
lesion set of the CMP-III. In this recent group of patients, a stricter follow-up regimen was implemented, with all patients undergoing electrocardiography or 24-hour Holter monitoring at 3, 6, and 12 months and annually thereafter. Also, the definition of success, as outlined in recent guidelines, was applied.5,11

Although we have previously reported excellent results with the CMP, most of these patients underwent concomitant cardiac surgery procedures.9,10,18,19 Since 1992, our institution performed a stand-alone CMP in 212 patients, reflecting the largest series in the literature. This report evaluates our experience in the surgical treatment of lone AF over 2 decades and compares the outcome of the original cut-and-sew CMP-III with the ablation-assisted CMP-IV.

**Methods**

From April 1992 through October 2010, 212 consecutive patients underwent a stand-alone CMP for the surgical treatment of AF at our institution. AF was defined as paroxysmal, persistent, or longstanding persistent, per recent guidelines.5,11 In the first decade, the CMP-III was performed in 112 patients using the cut-and-sew technique. Since 2002, 100 patients received the CMP-IV, which was performed with a bipolar radiofrequency clamp and cryoprobes. In 72% of patients, the AtriCure Isolator, Isolator I and II, and Synergy series (AtriCure, Inc; Cincinnati, OH) were used. In 28% of patients, the irrigated Medtronic Cardioblate BP and LP (Medtronic, Inc; Minneapolis, MN) were applied. Algorithms measuring tissue conductance or impedance were used to determine the time of ablation and to estimate transmurality. Linear and bell-shaped cryoprobes (AtriCure, Inc) were used and cooled to -60°C for 2 to 3 minutes by nitrous oxide for all ablations.

This study was approved by the Washington University School of Medicine Institutional Review Board. Informed consent and permission for release of information were obtained from all patients.

**Surgical Technique of the CMP-III**

The surgical technique of the CMP-III has been previously described (Figure 1).20 All patients underwent a median sternotomy and cardiopulmonary bypass with bicaval cannulation. The right atrial (RA) incisions were performed on the beating heart and included excision of the RA appendage, a free wall incision, a linear incision from the superior to the inferior vena cava, and a perpendicular incision to the tricuspid annulus. A second incision to the tricuspid annulus was performed from the RA appendage. At the tricuspid annulus, a 3-mm cryoprobe (CCS200, Frigitronics, Inc; Trumbull, CT) was applied.

The left atrial (LA) lesion set was performed under cardioplegic arrest. The LA appendage was amputated, and a standard left atriotomy was performed. The remaining incisions included an encirclement of the PVs, with extension to the mitral annulus, and an atrial septal incision. A cryoprobe was used between the appendage amputation site and the 2 ends of the incision encircling the PVs, as well as over the coronary sinus and at the mitral valve annulus.

**Surgical Technique of the CMP-IV**

The CMP-IV was performed using cardiopulmonary bypass with bicaval cannulation, as previously described.13,17,21 All patients underwent either a median sternotomy (n = 79) or a right minithoracotomy (n = 21).21 All patients underwent intraoperative transesophageal echocardiography, and cardioversion was performed if needed after the presence of an LA appendage clot was excluded. Electric isolation was documented by pacing from each PV to confirm exit block. In all patients in whom pacing could be performed (93%), ablation was continued until exit block was documented from each PV. We routinely applied the bipolar radiofrequency clamp 2 to 3 times and then tested for exit block. This was successful 98% of the time. In patients undergoing a right minithoracotomy, pacing was performed only from the right PVs.

Patients were cooled to 34°C, and the RA lesion set was performed on the beating heart (Figure 2). A single incision was usually made in the RA free wall, but recently a 3 purse-string approach has been adopted to eliminate this incision in patients undergoing a minithoracotomy. All ablations were performed with the bipolar radiofrequency clamp, except for 2 endocardial ablation
lines to the tricuspid annulus, which were performed with a linear cryoprobe. The LA lesion set was performed under cardiopulmonary bypass (Figure 3). The LA appendage was amputated, and the bipolar clamp was used to create an ablation line from this site into 1 of the left PVs. A small left atriotomy was performed, and the remainder of the ablation lines was completed with the bipolar clamp. Cryoablation was used to connect the isthmus ablation line to the mitral annulus. In patients undergoing a right minithoracotomy, cryoablation was more extensively applied to isolate the left PVs and to complete the posterior LA isolation. The LA appendage was oversewn from the inside.21

Postoperative Care and Follow-up
After surgery, antiarrhythmic drugs were administered as soon as the patient restored a normal sinus rhythm. Warfarin was also initiated in all patients, unless contraindicated. If patients developed early tachyarrhythmias, they were administered antiarrhythmic drugs and then electrically cardioverted if needed. If patients were in sinus rhythm, antiarrhythmic drugs were discontinued at 2 months. The patients then underwent prolonged monitoring, and an echocardiogram was obtained, at 3 months. Warfarin was discontinued if patients were free of atrial tachyarrhythmias (ATAs) and an echocardiogram ruled out atrial stasis or thrombus.

In patients who underwent the CMP-III between 1992 and 2001, the clinical profiles and perioperative outcomes were collected prospectively. Follow-up was conducted by office visits at 6 months and included a medical history, a physical examination, 24-hour Holter monitoring, a transthoracic echocardiogram, and dynamic magnetic resonance imaging. The first 69 patients also underwent an electrophysiological study at this time. Because AF could not be induced in 1 patient, this follow-up regimen was discontinued. Long-term follow-up consisted of a retrospective cross-sectional analysis performed in 2001. This included a mailed questionnaire or telephone interview and contact to either the cardiologist or the primary care physician to evaluate recurrence of AF.

In patients who received the CMP-IV since 2002, the clinical demographics and postoperative outcomes were collected prospectively in a longitudinal database. Follow-up was conducted by office visits at 3, 6, and 12 months and annually thereafter. At each visit, a medical history, physical examination, and ECG were obtained. Since 2006, when new follow-up guidelines were established, 24-hour Holter monitoring or pacemaker interrogation was obtained in 95% (62/65) of patients. Late recurrence was defined as any episode of ATAs, including AF, atrial flutter, or atrial tachycardia, that lasted >30 seconds. Any patient requiring an interventional procedure after 3 months postoperatively was deemed a permanent failure. Patients were only considered to be a success if they were both free of AF and free of antiarrhythmic drugs (class I or III).

Data Analysis
Continuous data were checked for normality using the Shapiro-Wilk statistic. Normally distributed continuous data were expressed as mean±SD and 95% CI, nonnormally distributed data were expressed as median and interquartile range (IQR; Q1–Q3), and outcome percentages were expressed as the percentage and 95% CI. Categorical data were expressed as absolute numbers and proportions. Freedom from AF recurrence was calculated by using Kaplan-Meier analysis; clinical profiles were compared using the χ² or the Fisher exact test. The unpaired t test was used to compare normally distributed data, and the Mann-Whitney U test was used for nonnormal data. All data analyses were performed with the SPSS system for statistics (SPSS 11.0 for Windows, SPSS, Inc; Chicago, IL).

Results
Patient Demographics
In the entire series of stand-alone CMP, patients (n=212) were a mean age of 53.5±10.4 years (95% CI, 52.0–54.8 years), with 78% males. The median duration of preoperative AF was 6.0 years (IQR, 2.9–11.5 years), with 48% paroxysmal and 52% persistent or long-standing persistent AF. Of the patients, 13% were in New York Heart Association class III or IV. Transient ischemic attacks or stroke was the reason for surgical referral in 14% of cases. Overall, 20% of patients had experienced previous catheter ablation failure.

Table 1. Patient Demographics

<table>
<thead>
<tr>
<th>Demographics</th>
<th>CMP III (n=112)</th>
<th>CMP IV (n=100)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD (95% CI), y</td>
<td>51 ± 10 (20–77)</td>
<td>56 ± 10 (28–75)</td>
<td>0.002</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>80</td>
<td>76</td>
<td>0.548</td>
</tr>
<tr>
<td>AF duration, median (IQR), y</td>
<td>7.0 (3.2–13)</td>
<td>7.4 ± 6.76 (2.4–10.0)</td>
<td>0.039</td>
</tr>
<tr>
<td>Paroxysmal AF, %</td>
<td>63</td>
<td>31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NYHA class III or IV, %</td>
<td>5</td>
<td>22</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous catheter ablation failure, %</td>
<td>2</td>
<td>40</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

NYHA indicates New York Heart Association.

CMP-III
The patient characteristics are shown in Table 1. The reasons for surgical referral were documented cerebral vascular accidents in 17%, intolerance of medication in 4%, and development of clinical symptoms of the arrhythmia in 79%. Two patients had experienced previous catheter ablation failure.

CMP-IV
Patients who received the CMP-IV were significantly older than those in the CMP-III cohort (P=0.002). There was also a significantly higher incidence of congestive heart failure New York Heart Association class III or IV (P<0.001). This reflects our expanding indications for the CMP into higher-risk patients in the recent era. The incidence of paroxysmal AF significantly decreased in the CMP-IV cohort (P<0.001). The median duration of preoperative AF decreased from 7 (IQR, 3.2–13) years to 6 (IQR, 2.4–10) years (P=0.039). The mean LA diameter measured by echocardiography was 4.7±1.1 cm. The reasons for surgical referral were patients with symptomatic AF in whom medical therapy or catheter ablation had failed (88%) and the occurrence of transient ischemic attacks or stroke (12%). Overall, 40% (40/100) of patients had experienced a mean of 2.6±3.1 (range, 1–6) previous catheter ablation failures. This was significantly higher than in the CPM-III cohort (P<0.001) because catheter ablation has increased during the past decade. The indication for surgery in this subgroup was stroke in 13% (n=5) and clinical symptoms in 87% (n=35). The 60 patients who had not undergone prior catheter ablation were referred because their treating physicians or the patient preferred a surgical approach or because they were believed to be poor candidates for catheter ablation.

Perioperative Findings
The 30-day mortality of the entire series was 1.4% (n=3), with no intraoperative deaths. The mean aortic cross-clamp time was 68±33 minutes. The median length of stay at the
The 30-day mortality was 1.8% (Table 2). One patient died of multisystem organ failure, and one death was caused by acute respiratory failure. The median aortic cross-clamp time was 90 (95% CI, 73.5–105) minutes. The median length of stay at the intensive care unit was 2 (IQR, 1–3.0) days; the median length of hospital stay was 8 (IQR, 6.7–11) days. There were 2 (0.9%) early strokes within 30 days after surgery, and 8% of patients required postoperative pacemaker implantation.

**CMP-III**

The 30-day mortality was 1.8% (Table 2). One patient died of multisystem organ failure, and one death was caused by acute respiratory failure. The median aortic cross-clamp time was 90 (95% CI, 73.5–105) minutes. The median length of stay at the intensive care unit was 2 (95% CI, 1–3.5) days, and the median length of hospital stay was 9 (95% CI, 7–12.2) days. The major complication rate (Table 2) was 10%, which was significantly higher than in the CMP-IV cohort (P=0.004). Early postoperative ATAs were documented in 34% (n=38) of patients. Nine patients (8%) required postoperative pacemaker implantation because of chronotropic incompetence (n=6) or slow junctional rhythm (n=3).

**CMP-IV**

The 30-day mortality was 1% (n=1). There were no intraoperative deaths. The only mortality occurred in a woman who experienced a pulmonary embolism on the day of discharge, despite being fully anticoagulated. The median aortic cross-clamp time was 39 (IQR, 33–46.7) minutes, which was significantly shorter than in the CMP-III group (P<0.001). Of the patients, 78% (n=78) received a complete box lesion set isolating the entire posterior LA. The median length of stay at the intensive care unit was 1 (IQR, 1–3) days, and the median length of hospital stay was 7 (IQR, 6–9.5) days. A single stroke (1%) was the only major perioperative complication. Early postoperative ATAs were documented in 40% of patients. Seven patients (7%) required a postoperative pacemaker implantation for chronotropic incompetence (n=2) or slow junctional rhythm (n=5).

**Late Follow-up**

In the entire series, freedom from AF was 93% and freedom from AF off antiarrhythmics was 82% at last follow-up, with a median follow-up of 2.3 (IQR, 0.9–6.3) years (Table 3). The Kaplan-Meier estimate for freedom from AF at 10 years was 85% (95% CI, 70%–92%; Figure 4). There was no significant difference in late success rate for patients with paroxysmal AF (96%; 95% CI, 86%–98%) versus persistent or long-standing persistent AF (91%; 95% CI, 81%–95%) (P=0.094). Late recurrence occurred at a median time of 1.2 (IQR, 0.9–2.1) years postoperatively. There was 1 late stroke (0.5%), with 80% of patients being off anticoagulation therapy at last follow-up. The late mortality (>30 days after surgery) was 1.4%.

**CMP-III**

The median follow-up was 5.9 (IQR, 2.5–7.8) years and was 88% complete. The freedom from symptomatic AF was 95% (95% CI, 86%–98%) at last follow-up, with a freedom from AF off antiarrhythmic drugs of 83% (95% CI, 68%–88%). There was no significant difference in late success rates for patients with paroxysmal AF (96%) compared with those with persistent or long-standing persistent AF (93%, P=0.556). One late stroke (0.9%) occurred in a patient with restored sinus rhythm who was not anticoagulated. Of patients, 86% were free of anticoagulation therapy at last follow-up. The late mortality (30 days after surgery) was 0.5%.

**CMP-IV**

The median follow-up was 1.0 (IQR, 0.7–2.0) years. No patient was lost to follow-up. Two-year follow-up was

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**Table 2. Perioperative Variables**

<table>
<thead>
<tr>
<th>Variables</th>
<th>CMP III (n=112)</th>
<th>CMP IV (n=100)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPB time, median (IQR), min</td>
<td>163 (145–183)</td>
<td>129 (113–150)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CCT, mean (95% CI), min</td>
<td>90 (73.5–105)</td>
<td>39 (33.2–46.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>30-d Mortality</td>
<td>2 (2)</td>
<td>1 (1)</td>
<td>0.625</td>
</tr>
<tr>
<td>Early ATAs</td>
<td>38 (34)</td>
<td>40 (40)</td>
<td>0.732</td>
</tr>
<tr>
<td>Pacemaker implantation</td>
<td>9 (8)</td>
<td>7 (7)</td>
<td>0.776</td>
</tr>
<tr>
<td>Major complication rate</td>
<td>11 (10)</td>
<td>1 (1)</td>
<td>0.003</td>
</tr>
<tr>
<td>Reoperation for bleeding</td>
<td>3 (3)</td>
<td>0</td>
<td>…</td>
</tr>
<tr>
<td>Early stroke ≥30 d</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>…</td>
</tr>
<tr>
<td>Renal failure</td>
<td>2 (2)</td>
<td>0</td>
<td>…</td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>1 (1)</td>
<td>0</td>
<td>…</td>
</tr>
<tr>
<td>Intra-aortic balloon pump</td>
<td>4 (4)</td>
<td>0</td>
<td>…</td>
</tr>
</tbody>
</table>

Data are given as number (percentage) of each group unless otherwise indicated.

CPB indicates cardiopulmonary bypass; CCT, aortic cross-clamp time.

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**Table 3. Late Follow-up**

<table>
<thead>
<tr>
<th>Variable</th>
<th>CMP III (n=112)</th>
<th>CMP IV (n=100)</th>
<th>CMP III+IV (N=212)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-up, median (IQR), y</td>
<td>5.9 (2.5–7.8)</td>
<td>1.0 (0.74–1.9)</td>
<td>2.2 (0.9–6.2)</td>
</tr>
<tr>
<td>Freedom from AF*</td>
<td>96 (86–98)</td>
<td>90 (81–95)</td>
<td>93 (87–96)</td>
</tr>
<tr>
<td>Freedom from AF off antiarrhythmics*</td>
<td>83 (68–88)</td>
<td>82 (71–89)</td>
<td>82 (75–87)</td>
</tr>
<tr>
<td>Freedom from warfarin*</td>
<td>86 (75–92)</td>
<td>74 (62–83)</td>
<td>80 (72–86)</td>
</tr>
<tr>
<td>Late stroke (&gt;30 d), no. (%)</td>
<td>0 (0.8)</td>
<td>0</td>
<td>1 (0.4)</td>
</tr>
</tbody>
</table>

*Data are given as mean (95% CI).
available on 50% of patients. The freedom from AF was 94% (95% CI, 85%–98%), 93% (95% CI, 69%–99%), 90% (95% CI, 78%–96%), and 90% (95% CI, 68%–99%) at 3, 6, 12, and 24 months, respectively. The freedom from both AF and antiarrhythmic drugs was 72% (95% CI, 60%–81%), 82% (95% CI, 54%–95%), 82% (95% CI, 68%–90%), and 84% (95% CI, 58%–95%) at 3, 6, 12, and 24 months, respectively. In patients receiving a complete box lesion set (n=78), freedom from AF was 96% (95% CI, 87%–99%) and freedom from AF off antiarrhythmic drugs was 86% (95% CI, 74%–93%) after 1 year. This compares with patients receiving a nonbox ablation set (n=22) with a freedom from AF of 77% (95% CI, 49%–93%) and a freedom from AF off antiarrhythmic drugs of 46% (95% CI, 21%–69%) (P=0.004 and P<0.001, respectively). In 40 patients in whom previous catheter ablation had failed, the postoperative freedom from AF was 92% (95% CI, 76%–98%) at 3, 6, and 12 months, respectively. The freedom from both AF and antiarrhythmic drugs was 72% (95% CI, 53%–86%), 86% (95% CI, 67%–95%), and 84% (95% CI, 68%–95%) at 3, 6, and 12 months, respectively. There was no significant difference in success rate off antiarrhythmic drugs for patients with paroxysmal AF (68%) versus persistent or long-standing persistent AF (72%, P=0.886). There were no late strokes. At 12 months, 74% (95% CI, 62%–83%) of patients were free of anticoagulation therapy. The recurrent arrhythmias were atrial fibrillation (80%), atrial flutter (10%), and atrial tachycardia (10%). Four patients reconverted to sinus rhythm after AF was documented previously at follow-up.

Discussion

The CMP has been the gold standard in the treatment of AF, with the highest late success rates of any single-interventional procedure.10,22,23 This surgical approach was developed at our institution and has gone through various iterations to improve and simplify the procedure.7,9,13,24,25 The original CMP-III was empirically designed to interrupt the macroreentrant circuits in both atria, which were thought to be responsible for AF.7,26,27 However, it is now known that there are multiple mechanisms responsible for AF, and this complex arrhythmia is still not thoroughly understood in many patients.28–30 With the anticipated goal to preserve the high success rates of the CMP-III and to decrease invasiveness, the CMP-IV was designed to simplify the operation by using bipolar radiofrequency energy to replace most of the traditional incisions. This energy source was chosen after extensive investigation in our laboratory that demonstrated its ability to reliably create discrete and transmural lesions.15,16 By achieving complete lines of ablations in a matter of seconds, it overcame the major limitations of other energy sources. Furthermore, the focused application of energy within the jaws of the clamp minimized the risk of collateral damage to surrounding tissue that had been reported for unipolar energy sources.31 Because invasiveness is a major concern, the ability to reduce cross-clamp time and enable a minimally invasive approach made the CMP-IV more attractive to patients with lone AF.21 This report of 212 consecutive patients undergoing a CMP for lone AF over almost 20 years demonstrated excellent long-term success rates, with 93% freedom from AF and 82% freedom from AF off antiarrhythmic medication. Only 1 late stroke occurred over a total of 763 patient-years of follow-up, with 80% of patients being free from anticoagulation therapy with warfarin. Considering the adverse effects of warfarin, including the higher risk of anticoagulation-associated intracranial hemorrhage, this is important in improving quality of life.32 However, in a few patients, other indications for anticoagulation therapy were present or developed, despite restored sinus rhythm. The technical complexity of the CMP-III kept it from wide adoption, whereas its invasiveness made catheter ablation the preferred choice of treatment for most patients with drug-refractory, symptomatic, lone AF. Based on isolating the PV, the results of catheter ablation have been variable, with single-procedure success rates between 16% and 84%.6,11,33,34 A recent study from the group of Haïssaguerre et al, who pioneered the isolation of the PV, reported a single-procedure success rate as low as 29% after 5 years.35 Certain patient subgroups have performed particularly poorly, such as patients with long-standing persistent AF and large atria.36,37 A recent review suggested a success rate for a single procedure ranging from 22% to 45% in patients with persistent or long-standing persistent AF.11

Our experience with the CMP defines the long-term results with this procedure. The CMP-III had excellent freedom from symptomatic AF at 10 years. The less invasive CMP-IV has shown significantly shorter operating times and lower complication rates, while resulting in equivalent early freedom from AF, despite more rigid definitions of success and improved follow-up. Presently, the cut-and-sew CMP-III is no longer performed at our institution. The results of this study confirm the efficacy of the CMP-III lesion set. Moreover, the CMP was equally effective for paroxysmal and long-standing persistent AF. It was also effective in patients in whom previous catheter ablation had failed. These results can be achieved with minimal operative risk. Our data would suggest that more patients should be referred for the CMP, particularly symptomatic patients in whom a catheter ablation has failed or who belong to a subgroup who have poor results with catheter ablation.

The need for a pacemaker remains a problem after the Cox-Maze procedure. Although the CMP-IV lesion set might cause a sinus node dysfunction, it is not the only possible mechanism. Most patients requiring pacemakers presented with preexisting sick sinus syndrome. Moreover, AF induces sinus node dysfunction. Although sinus node recovery time seems to normalize after termination of AF, the time course of reverting this electric remodeling is variable, and the risk for pacemaker implantation cannot be completely eliminated. It is possible that eliminating right atrial ablations would decrease the need for postoperative pacemaker implantation; however, this also would likely result in a lower cure rate.

There are several limitations to this report. Although follow-up in the historical series was longer and showed a freedom from symptomatic AF and antiarrhythmics of 83%, few of these patients underwent electrocardiographic or Holter monitoring at 12 or 24 months. With constantly improving follow-up, recent guideline requirements have been met since 2006.5,11,38 The lack of electrocardiographic or
Holter follow-up likely resulted in an underestimation of the long-term failure rate in the CMP-III group. However, the recent CMP-IV cohort has been well monitored, with 24-hour Holter or pacemaker interrogation. This cohort reflects the current standard of surgical treatment and shows excellent success rates that compare favorably with our CMP-III experience. This was particularly true for patients who had an isolation of the entire posterior LA. Our success rate off antiarrhythmic drugs at 1 year in this group was 86%. Moreover, 69% of patients presented preoperatively with persistent or long-standing persistent AF and 40% had previously experienced catheter ablation failure, reflecting a more difficult cohort for successful treatment than the CMP-III group. However, a comparison of the 2 groups remains difficult. A Kaplan-Meier analysis was most suitable to present the results of the entire series because of the difference in follow-up. However, AF is a dynamic end point and reconversion to sinus rhythm after an episode of AF was still shown as permanent failure. To account for this, we presented the recent CMP-IV results as percentage of freedom from AF at various time points. In a previous study, patient-specific variables were adjusted by a propensity analysis, and we showed similar results with the CMP-III and CMP-IV. Finally, the mechanisms for AF recurrence were not well defined. The question remains unanswered whether our failure rate was due to technical difficulties, untreated atrial pathological features, or a focal mechanism of the recurrent ATAs.

This report gives a benchmark for the excellent long-term success rate of a stand-alone CMP and will provide a useful comparison for the myriad of procedures that are performed surgically, including left atrial lesion sets and isolation of the PVs, as well as for new and less invasive approaches under development.

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Disclosures

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References


**CLINICAL PERSPECTIVE**

This study reviews our experience in the surgical treatment of atrial fibrillation (AF) during the past 2 decades in 212 consecutive patients with lone AF. Freedom from AF in the original Cox-Maze III procedure was 93%. However, the procedure was difficult to perform and had a 10% rate of major complications. By using radiofrequency bipolar clamp technology to replace surgical incisions with transmural lesions, we modified the procedure (Cox-Maze IV), essentially maintaining the original pattern of lesions. Our results demonstrate that the procedure is much easier to perform, the time to perform the procedure is reduced, and the major complication rate declined to 1%. The present study shows that freedom from AF is still 90% and even off antiarrhythmics it is 83%. Thus, we were able to maintain the efficacy of the original procedure and make it more accessible to a wider cohort of patients. The Cox-Maze IV represents a therapeutic option for lone AF in patients who have had clinical symptoms despite medical treatment or in whom a catheter ablation has failed, patients who have had a stroke despite anticoagulation therapy, and patients who are not candidates for other therapies. The procedure can be performed with minimal risk. The results of this study also serve as a benchmark for the future development of procedures to treat lone AF.
The Cox-Maze Procedure for Lone Atrial Fibrillation: A Single-Center Experience Over 2 Decades
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