

## A minimally invasive Cox maze IV procedure is as effective as sternotomy while decreasing major morbidity and hospital stay

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**Objectives:** The Cox maze IV procedure has the best results for the surgical treatment of atrial fibrillation. It has been traditionally performed through sternotomy with excellent outcomes, but this has been considered to be too invasive. An alternative approach is to perform a less invasive right anterolateral minithoracotomy. This series compared these approaches at a single center in consecutive patients.

**Methods:** Patients undergoing a Cox maze IV procedure (n = 356) were retrospectively reviewed from January 2002 to February 2014. Patients were stratified into 2 groups: right minithoracotomy (RMT; n = 104) and sternotomy (ST; n = 252). Preoperative and perioperative variables were compared as well as long-term outcomes. Patients were followed up for 2 years and rhythm was confirmed with an electrocardiogram or prolonged monitoring.

**Results:** Freedom from atrial tachyarrhythmias off antiarrhythmic drugs was 81% and 74% at 1 and 2 years, respectively, using an RMT approach and was not significantly different from the ST group at these same time points. The overall complication rate was lower in the RMT group (6% vs 13%,  $P = .044$ ) as was 30-day mortality (0% vs 4%,  $P = .039$ ). Median length of stay in the intensive care unit was lower in the RMT group than in the ST group (2 days [range, 0-21 days] vs 3 days [range, 1-61 days];  $P = .004$ ) as was median hospital length of stay (7 days [range, 4-35 days] vs 9 days [range, 1-111 days];  $P < .001$ ).

**Conclusions:** The Cox maze IV procedure performed through a right minithoracotomy is as effective as sternotomy in the treatment of atrial fibrillation. This approach was associated with fewer complications, decreased mortality and decreased length of stay in the intensive care unit and hospital length of stay. (*J Thorac Cardiovasc Surg* 2014;148:955-62)

Atrial fibrillation (AF) is the most common cardiac arrhythmia with an estimated prevalence of 2.7 to 6.1 million people in the United States. This prevalence is projected to increase to 5.6 to 12.1 million people in the United States by the middle of the century.<sup>1</sup> AF is associated with significant morbidity resulting from loss of synchronous atrioventricular contraction and the need for anticoagulation. Despite anticoagulation, AF has been implicated in up to 15% of all thromboembolic strokes.<sup>2</sup> The Cox maze procedure was developed in 1987 in an effort to surgically treat AF.<sup>3-5</sup> After several modifications, the Cox maze III (CMIII) procedure became the gold standard for surgical treatment of AF during the 1990s.

This technique was performed by median sternotomy and involved extensive cut-and-sew lesions in both the left and right atria. Despite its proven efficacy,<sup>6-8</sup> the CMIII did not gain widespread acceptance because of its technical difficulty and complexity.

The incorporation of new ablation technology has obviated the need for the traditional cut-and-sew technique of the CMIII without sacrificing efficacy.<sup>9</sup> The Cox maze IV (CMIV) procedure, the latest iteration of the procedure, uses bipolar radiofrequency (RF) and cryoablation to significantly reduce the operative and crossclamp times, as well as the complexity of surgical ablation compared with the traditional cut-and-sew CMIII.<sup>10</sup> The simplification of replacing surgical incisions with ablation lines has made the procedure easier to perform and has contributed to the significant increase in the number of AF surgical procedures in North America.<sup>11,12</sup>

In an effort to further reduce operative morbidity, our group has developed a minimally invasive procedure involving a full CMIV lesion set through a 5- to 6-cm right minithoracotomy approach.<sup>13,14</sup> Although early results are promising, the long-term outcomes of this approach have yet to be evaluated.<sup>13</sup> The goal of this series was to directly compare perioperative and late outcomes between sternotomy (ST) and right minithoracotomy (RMT) approaches in a consecutive group of patients undergoing a CMIV procedure.

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**Abbreviations and Acronyms**

AAD	= freedom from atrial tachyarrhythmia off antiarrhythmic drugs
AF	= atrial fibrillation
ATA	= atrial tachyarrhythmia
CCM	= continuous cardiac monitoring
CMIII	= Cox maze III
CMIV	= Cox maze IV
CPB	= cardiopulmonary bypass
ECAS	= European Cardiac Arrhythmia Society
ECG	= electrocardiogram
EHRA	= European Heart Rhythm Association
HRS	= Heart Rhythm Society
ICU	= intensive care unit
LA	= left atrial
LOS	= length of stay
LVEF	= left ventricular ejection fraction
MVR	= mitral valve replacement
PVD	= peripheral vascular disease
PVI	= pulmonary vein isolation
RA	= right atrial
RF	= radiofrequency
RMT	= right minithoracotomy
ST	= sternotomy
STS	= Society of Thoracic Surgeons

**METHODS**

This study was approved by the Washington University School of Medicine Institutional Review Board. Informed consent and permission for release of information was obtained from each participant. All data were entered prospectively into the Society of Thoracic Surgeons (STS) database or a longitudinal database designed by our institution.

**Study Design**

Three hundred fifty-six patients who underwent a CMIV as a stand-alone procedure or with a concomitant mitral procedure from January 2002 to February 2014 were retrospectively reviewed. Patients were considered for a corrective arrhythmia procedure if they met the indications for surgical ablation defined by the recent consensus statement.<sup>15</sup> Concomitant aortic valve procedures and coronary artery bypass procedures were excluded. Patients were divided into 2 groups based on the operative approach and compared. The surgical technique used to perform a minimally invasive CMIV through an RMT has been previously described by our group.<sup>14,16</sup> A non-rib-spreading technique was used to create a 5- to 6-cm thoracotomy. Femoral cannulation and direct aortic crossclamping was performed. A 5-mm 30° endoscope was placed through a separate port through the fifth intercostal space to aid in visualization and minimize the need for chest wall retraction. Major differences between right atrial (RA) lesion sets included the replacement of the right atriotomy performed in the ST approach with a line of bipolar RF ablation in the RMT approach. All other RA lesions were identical between the 2 approaches and were accomplished in the RMT approach by placing either 1 jaw of the bipolar RF clamp or a cryoprobe through 3 separate purse-string sutures placed along the RA. The left atrial (LA) lesion sets were also similar with the exception that left pulmonary vein isolation (PVI) was achieved endocardially with sequential cryoablation

around the left pulmonary veins (Figure 1). In the RMT group, the LA appendage was excluded by oversewing from the endocardial surface as opposed to epicardial excision, which was performed in the ST approach. Contraindications to an RMT approach included a previous right thoracotomy, severe atherosclerotic disease of the aorta, iliac, or femoral vessels, and severely decreased left ventricular ejection fraction (LVEF  $\leq 20\%$ ). All patients scheduled to have an RMT underwent a computed tomography angiogram of the thoracic and abdominal aorta as well as the femoral arteries if they were more than 50 years of age, had risk factors for the development of peripheral vascular disease (PVD), or had evidence of PVD on physical examination.

All lesions within each group were similar with the exception of the addition in 2005 of a superior LA bipolar RF lesion that connected the superior left and right pulmonary veins. The addition of this lesion was added to electrically isolate the entire posterior LA and completed the box lesion set.<sup>17</sup>

Patients were discharged on class I or III antiarrhythmic drugs and warfarin, unless contraindicated; antiarrhythmic agents were discontinued 2 months postoperatively if patients were in normal sinus rhythm. Calcium channel blockers or  $\beta$ -blockers were not considered as antiarrhythmic drugs.

Sixteen preoperative and 18 perioperative variables were compared between the groups (Tables 2 and 3) and were chosen based on their clinical significance or a preliminary analysis of more than 400 variables collected between the STS databases and our institutional AF database. Complications including pneumonia, mediastinitis, need for intra-aortic balloon pump, permanent stroke, reoperation for bleeding, and renal failure requiring dialysis were considered major complications and compared between groups. The overall major complication rate was defined as the aggregate of these complications and compared between groups.

**Follow-up**

Patients were followed prospectively and had an electrocardiogram (ECG) at each follow-up visit. In accordance with the 2006 Heart Rhythm Society (HRS)/European Heart Rhythm Association (EHRA)/European Cardiac Arrhythmia Society (ECAS) consensus statement on catheter and surgical ablation of AF, 24 hours of continuous cardiac monitoring (CCM), which included 24-hour Holter monitoring, pacemaker interrogation, and interrogation of continuous cardiac loop recorders, was obtained at 3, 6, 12, and 24 months.<sup>15</sup> Both overall freedom from atrial tachyarrhythmias (ATAs) and freedom from ATAs off antiarrhythmic drugs (AADs) were calculated. Success at 1 or 2 years was defined as freedom from AF, atrial flutter, or atrial tachycardia while off AADs as assessed from the end of a 3-month blanking period as defined in the HRS/EHRA/ACAS consensus statements.<sup>15,18</sup> Follow-up was available in 95% of patients. At 1 and 2 years after surgery, follow-up was obtained in 77% and 58% of patients, respectively. Of the patients who were available for follow-up, CCM was obtained in 66% at 1 year and 77% at 1 year after 2007. Mean follow-up time was  $2.8 \pm 2.5$  years.

**Statistical Analysis**

Continuous variables were expressed as the mean  $\pm$  standard deviation or the median with the range. Categorical variables were expressed as frequencies and percentages with outcomes compared using the  $\chi^2$  or the Fisher exact test. Continuous outcomes were compared using the *t* test for means of normally distributed continuous variables and the Mann-Whitney *U* nonparametric test for skewed distributions. All data analyses were performed using SYSTAT 13 software (Systat Software, Inc, Chicago, Ill).

**RESULTS****Demographics**

A total of 104 patients (29%) underwent a CMIV procedure through an RMT and 252 patients (71%) underwent CMIV through a sternotomy approach. Of the

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