

# Current Approach to Surgical Ablation for Atrial Fibrillation



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After 4 decades of innovation, surgical ablation for atrial fibrillation is reconverging on the bi-atrial full maze procedure as the most effective approach. Contemporary studies suggest that surgical ablation confers significant rhythm and survival benefits without additional operative risk. Alternative energy sources have become standard, focused primarily on radiofrequency and cryothermic energy. With full bi-atrial lesion sets, long-term sinus conversion rates may now approach 90%. Bi-atrial cryoablation applied in the full maze pattern produces excellent results, and may provide some advantages in simplicity and efficiency. Surgical ablation for atrial fibrillation is being increasingly applied over time for all categories of cardiac operations. Given the known survival advantages of surgical ablation of atrial fibrillation, this trend of increased adoption may contribute to improving long-term outcomes.

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## MECHANISM AND LESIONS

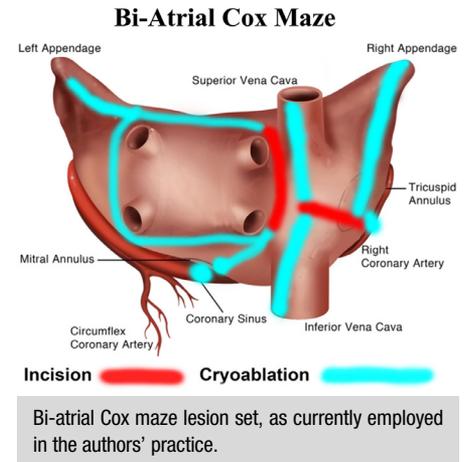
Atrial fibrillation (AF) is the most common adult arrhythmia worldwide. Associated with increased morbidity and mortality, AF has a 5-fold increased risk of stroke and it is responsible for 30% of all strokes.<sup>1</sup> The prevalence of AF is increasing as with increasing life expectancy and age in developed countries.<sup>2</sup> Based on landmark laboratory work to define the mechanism of AF in 1980,<sup>3</sup> Dr James Cox first introduced surgical ablation (SA) of AF as the maze I operation.<sup>4,5</sup> Through ongoing investigation and optimization, the procedure evolved into the maze III and became the gold standard surgical treatment of AF. As alternative energy sources were found to be effective in replacing cut-and-sew lesions, the maze IV procedure was coined to describe the maze III operation performed with radiofrequency and/or cryothermic energy.<sup>4,5</sup>

The pathogenesis of AF is associated with electrical triggers in the pulmonary veins as well as macro re-entry phenomena in dilated areas of atrial tissue. Based on anatomical mapping of both the left and right atria, the concept of the maze

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### Central Message

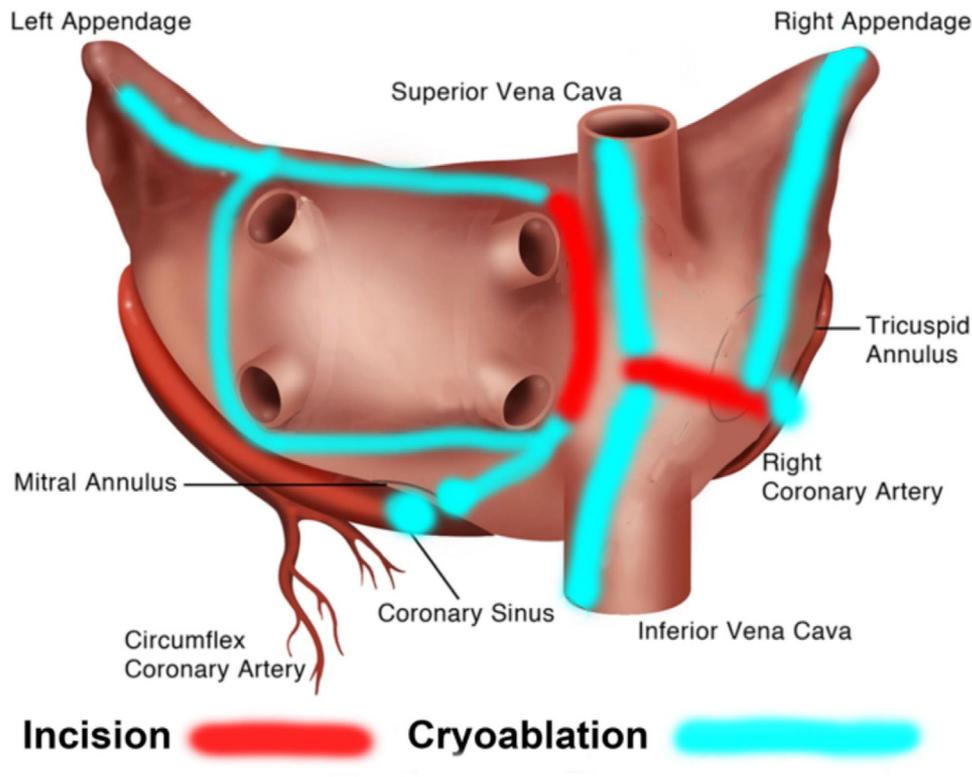
Surgical ablation for atrial fibrillation has clear survival benefits. Development of an evidence-based approach to therapy should be part of a contemporary surgical armamentarium.

operation is to electrically isolate the pulmonary vein triggers, and to create electrically silent maze-like pathways in both atria that prevent macro re-entry.<sup>5</sup> The left atrial lesion set is composed of 7 components: right pulmonary venous isolation, left pulmonary venous isolation, a lesion from the left atrial appendage (LAA) to the left superior pulmonary vein, inferior and superior box lesions in the floor and roof of the left atrium, a mitral isthmus lesion, and the coronary sinus lesion.<sup>5</sup>

Isolation of the pulmonary veins is an integral part of the maze procedure in order to block AF triggers (Fig. 1). The LAA to superior pulmonary vein lesion is done to prevent macro re-entry between the 2 structures along the so-called “Coumadin ridge.” The box lesion connects the superior and inferior aspects of the pulmonary venous isolations to interrupt macro re-entry circuits in the posterior wall of the left atrium. Performing left atrial maze lesions without the epicardial coronary sinus lesion in conjunction with the mitral isthmus line can cause perimitral atrial flutter in 10–15%, and this arrhythmia is often poorly tolerated.<sup>4,5</sup>

The objectives of the right atrial lesions target macro re-entry circuits around the superior vena cava (SVC), around the inferior vena cava (IVC), and the right atrial appendage: superior caval to inferior caval lesion, right atrial T lesion to the

## Bi-Atrial Cox Maze



**Figure 1.** The lesion set for the bi-atrial Cox maze IV procedure.

tricuspid valve annulus, and the right atrial appendage lesion, respectively. The T lesion should be positioned two-thirds down from the superior vena cava orifice and toward 2 o'clock on the tricuspid annulus.<sup>5</sup> Finally, the right atrial appendage lesion may be created by ablating from the tip of the right atrial appendage medially to the tricuspid annulus at 10 o'clock. Recently, Cheema et al described a modification from the vertical right atriotomy toward the tip of the right atrial appendage that readily achieves the same objective.<sup>5,6</sup> If this is utilized, it is essential to avoid the mid right atrial body to mitigate sinus node dysfunction and thus this lesion should be placed along the most anterior aspect of the appendage (Fig. 1). Many surgeons use the bi-atrial cryomaze to approach the complete lesion set. This is performed with 3-minute applications of cryothermic freeze lines, with equivalent outcome benefits.<sup>7</sup> The final step of a complete SA with the maze III or IV is to perform obliteration of the LAA.<sup>8</sup>

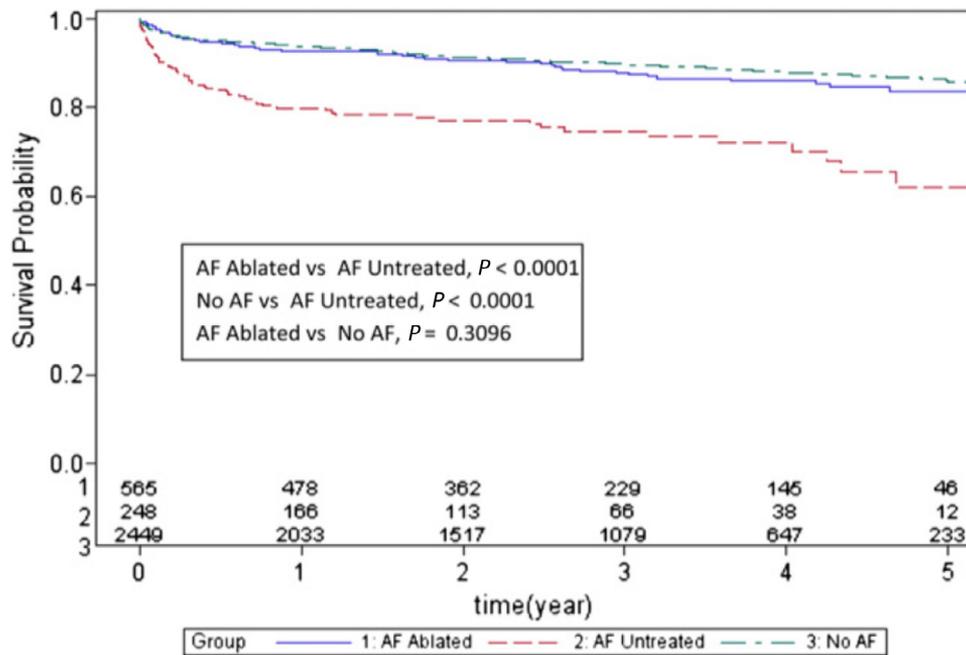
### SA WITH MITRAL VALVE SURGERY

Up to 40% of mitral valve surgery patients experience preoperative AF and other atrial arrhythmias.<sup>2,8,9</sup> Since mitral operations necessitate opening the left atrium, the additional step of performing SA may be relatively straight forward. Most mitral valve patients with AF have risk factors for arrhythmias, such as advanced age and numerous comorbidities. Moreover,

mitral disease often is associated with left atrial enlargement and SA success rates tend to be lower with incomplete lesion sets due to atrial fibrosis and persistent macro re-entry circuits. Thus, bi-atrial maze lesion sets are recommended for persistent AF in all operative categories and achieve the best results in mitral AF patients.<sup>8,10,11</sup>

While SA may modestly increase operative complexity, concomitant SA during a mitral valve procedure is safe and does not increase morbidity and mortality.<sup>8–11</sup> Long-term sinus rhythm and survival is improved with SA, and recent guidelines and expert consensus recommend a IA indication for SA in AF patients undergoing mitral surgery.<sup>8,10,11</sup> The favorable impact on survival with concomitant SA may be related to improved left ventricular function with sinus rhythm, decreased left atrial size, and decreased stroke rates with sinus conversion and LAA management.

In a national clinical registry report, the contemporary rate of SA in AF patients was 48.3% overall, with the highest rates of SA being performed during mitral operations at 68%.<sup>2</sup> Following propensity matching, SA conferred a relative risk of 0.92 for mortality and 0.84 for stroke, respectively.<sup>2</sup> Said another way, SA resulted in a 30-day mortality benefit of 8% and a 16% stroke benefit. In another recent national cohort study, the presence of AF during mitral surgery increased risk-adjusted mortality by 15% (odds ratio = 1.15) with no difference in impact between



**Figure 2.** Propensity-matched assessment of survival benefit of surgical ablation for atrial fibrillation (AF). (From Lee et al.<sup>13</sup>)

paroxysmal and nonparoxysmal AF.<sup>9</sup> However, the performance of a concomitant SA was independently associated with lower mortality (odds ratio = 0.92). Thus, adding SA to mitral valve surgery has now been clearly shown to be associated with a reduction in 30-day operative mortality.<sup>2,9</sup>

Institutional studies have corroborated significant late risk-adjusted survival benefits after SA for AF (Fig. 2).<sup>12,13</sup> Patients achieving sinus rhythm experienced improved survival, whereas SA failures did not. Another study of mitral surgery and SA revealed a perioperative stroke rate of 0.4% and operative mortality of 2.7% with an overall freedom from AF at 1, 5, and 7 years of 90%, 80%, and 66%, respectively, and freedom from embolic stroke at 7 years of 96.6%.<sup>14</sup> In a propensity-matched study, risk-adjusted 10-year survival was found to be 62% in patients with concomitant SA compared to 42% in those with unaddressed AF at the time of mitral operation (adjusted hazards ratio = 0.47;  $P = 0.014$ ).<sup>15</sup> Bi-atrial SA at the time of mitral surgery appears to provide prolonged rhythm advantages over other lesion sets.<sup>16</sup>

When approaching patients with AF at the time of open atrial mitral operations, SA is a guideline-recommended therapy and the most effective lesion set is the full bi-atrial maze IV.<sup>8,10,11</sup>

### SA WITH NONMITRAL SURGERY

Patients with AF undergoing isolated coronary artery bypass grafting (CABG), isolated aortic valve replacement (AVR), or AVR + CABG present the surgeon with a different set of variables for clinical decision-making. The choices are no SA, pulmonary vein isolation (PVI) and epicardial LAA obliteration, or full open atrial SA. Patients undergoing AVR without SA experience increased operative mortality and decreased long-term survival, thus supporting the application of SA to these

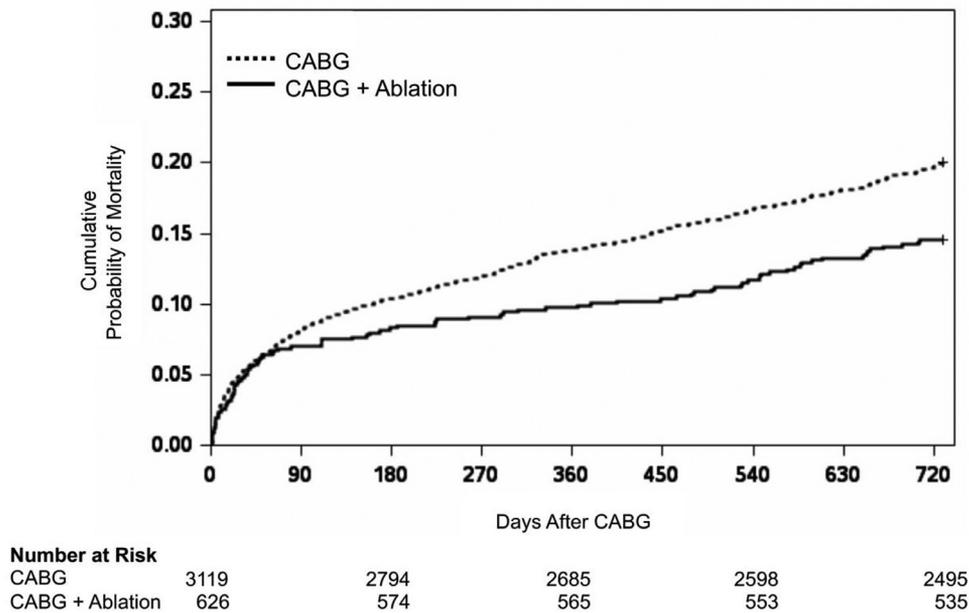
patients.<sup>8,10,11</sup> In multiple observational trials of AVR and coronary bypass (CABG), with or without open SA, no increased mortality was observed with SA.<sup>8,10</sup> The effectiveness of PVI alone in AVR may range between 50% and 80%. While the success rates of bi-atrial maze procedures in these groups have provided superior results, further randomized or clinical registry data are needed.

Similarly, long-term assessments of CABG patients in a national sample observed higher mortality and systemic embolism in patients with preoperative AF compared with non-AF patients, supporting the need for SA.<sup>17</sup> A recent analysis of Medicare CABG patients found that only 17% of CABG patients with AF underwent concomitant SA, and no difference was observed in risk-adjusted operative mortality and perioperative stroke in patients undergoing CABG and SA.<sup>18</sup> However, SA during CABG was associated with improved risk-adjusted late survival and fewer rehospitalizations, with a 29% mortality reduction at 2 years (Fig. 3).<sup>18</sup>

When faced with AF at the time of AVR, CABG, or AVR + CABG, clear guideline-directed advantages exist by adding SA without the addition of operative risk.<sup>8,10,11</sup> For patients with paroxysmal AF, it may be suitable to perform epicardial PVI and LAA obliteration, though full open atrial SA confers better long-term results with nonparoxysmal AF.

### STAND-ALONE SA

Stand-alone SA is considered for patients with symptomatic AF who have failed medical therapy or catheter ablation, and/or exhibit intolerance to oral anticoagulants.<sup>8,10,11</sup> The operative mortality rate for stand-alone SA is low,<sup>2</sup> and most of the data for stand-alone ablation in the literature are derived from minimal invasive approaches.<sup>2,8</sup> This includes



**Figure 3.** Risk-adjusted mortality reduction of 29% with surgical ablation in CABG patients with atrial fibrillation (AF). (From Rankin et al.<sup>18</sup>)

off pump PVI with atrial appendage obliteration by clip or staples as well as minimally invasive full bi-atrial maze IV operations. Numerous approaches have been evaluated: minimal invasive hybrid procedures, bilateral minithoracotomy or thoracoscopic PVI, unilateral right thoracoscopic box lesions with PVI, and the “convergent procedure” complimented by hybrid ablation.<sup>4,9,11</sup> In stand-alone patients, AF cure rates in paroxysmal, persistent, and long-standing persistent AF with nonmaze procedures have been only 40–70%, again inferior to full bi-atrial maze procedures.<sup>11,19–26</sup> For this reason, approaches similar to minimally invasive mitral repair have been developed, in which the full bi-atrial maze operation is performed via right anterior thoracotomy, or robotic approaches. Exceptional freedom from AF rates can be achieved, using minimal access incisions with limited patient trauma (Video).<sup>24–26</sup>

More data are required to inform definitive statements of superiority of 1 technique over another for stand-alone SA. However, patients with paroxysmal AF may do well with minimally invasive epicardial approaches, while patients with non-paroxysmal AF have excellent results with minimally invasive full bi-atrial open Cox maze operations.

**SURGICAL MANAGEMENT OF THE LAA**

The LAA is an important site for clot formation in setting of untreated AF. Exclusion of the appendage can be achieved by epicardial stapling, appendage clips, or endocardial double-layer closer. Recently, Friedman et al performed a retrospective study using Medicare and STS database information, stratifying the population for atrial appendage occlusion vs no occlusion.<sup>27</sup> After statistical risk adjustment, atrial obliteration was associated with significantly lower thromboembolic events, all-cause mortality, and composite of end points. Stroke rates,

however, were not different. In another retrospective administrative study, appendage obliteration seemed to lower stroke and mortality rates in patients with preexisting AF.<sup>28</sup> Current catheter-based ablation guidelines recommend continuation of oral anticoagulation following ablation, yet there are currently no clear guidelines for the management of the postoperative SA patient. In fact, the recent 2017 Heart Rhythm Society consensus statement<sup>10</sup> acknowledged that there is little to no evaluable evidence for or against the merits of anticoagulation following SA when the LAA has been surgically obliterated and thus in the absence of current evidence, the decision to anticoagulate and the duration of treatment should be made on an individual basis weighing the risks and benefits of anticoagulation in the postsurgical patient. Current management practices are variable postoperatively, ranging from 3 to 6 months of oral anticoagulation. Following the Heart Rhythm Society consensus<sup>10</sup> of individualizing postoperative SA management, some centers have injected equipoise in the management of patients with successful SA and LAA obliteration by doing so without postoperative oral anticoagulation, achieving longitudinal stroke rates of less than 1% and prompting the need for more clinical experience and evidence on this issue.<sup>26</sup>

Obliterating the LAA during SA is a singular opportunity to impact stroke prevention and long-term survival.<sup>8,11,27,28</sup> Therefore, LAA obliteration should be considered an essential element of the surgical approach to AF.

**SUMMARY**

SA is effective in recovering sinus rhythm in all categories of cardiac surgical patients with AF. For patients in AF, operative risk is not increased with SA and there may be mortality advantages conferred by adding SA to a concomitant operation,

particular with mitral surgery. More importantly, the addition of SA appears to significantly improve late survival. Minimally invasive surgical approaches to bi-atrial SA are now fully validated, and offer excellent long-term outcomes with low mortality and morbidity. Finally, obliteration of the LAA at the time of SA probably decreases thromboembolic risk and enhances long-term survival. All surgeons should be familiar with SA techniques as part of the current armamentarium in cardiac surgery.

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