Surgical Treatment of Atrial Fibrillation via Energy Ablation

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Case presentation, patient 1: Permanent atrial fibrillation with mitral incompetence requiring a mechanical prosthesis. A 57-year-old man underwent mitral valve repair for myxomatous mitral valve disease 10 years ago. During the past 3 years, he has been in permanent atrial fibrillation (AF) and has been taking warfarin for anticoagulation. He has had moderate residual mitral valve incompetence that has progressed to severe incompetence with associated left ventricular dilatation requiring further mitral surgery. Should intraoperative ablation also be performed to treat the AF?

Case presentation, patient 2: Symptomatic idiopathic intermittent AF. A 48-year-old man presented with a 3-year-long history of intermittent AF. During each AF episode, he was not able to work; otherwise, he was in good health and had no other cardiac disease. During the past 12 months, he has twice undergone cardioversion to relieve AF that persisted for >7 days. His rate control with pharmacological therapy was variable but generally satisfactory. Antiarrhythmic drugs (sotalol, amiodarone, and flecainide) were tried unsuccessfully for control of the AF burden. Percutaneous catheter ablation of the pulmonary vein orifices was tried on 2 separate occasions, and the patient experienced freedom from AF for 3 weeks after each procedure before the AF returned.

Case presentation, patient 3: Symptomatic intermittent AF due to hypertrophic cardiomyopathy. A 39-year-old woman presented to the emergency department in pulmonary edema associated with AF, with a ventricular response of 140 bpm. Pharmacological rate control was successful, but she remained in congestive cardiac failure. Echocardiography revealed hypertrophic cardiomyopathy. She underwent cardioversion to sinus rhythm, and further echocardiography demonstrated an outflow tract gradient of 50 mm Hg. She was maintained on β-blocker therapy but re-presented on multiple occasions in AF and congestive heart failure, prompting monthly cardioversion. Catheter-based mapping and pulmonary vein isolation were unsuccessful.

Background

AF is the most frequently occurring cardiac arrhythmia, affecting up to 9% of people >80 years old.1 Patients in AF have an increased risk of both mortality and stroke and can have appreciable discomfort and anxiety.2,3 Concomitant heart disease (eg, mitral valve insufficiency) increases the likelihood of a patient having AF.1 Surgery to treat AF aims to improve cardiac efficiency, reduce the risk of thromboembolic stroke, and eliminate the need for warfarin, thus decreasing the chance of anticoagulant-related bleeding. The surgical treatment of AF was pioneered by James Cox in the 1980s and evolved into the Maze III procedure.4 The Maze III procedure involves numerous atrial incisions that form a maze-like pattern, with the scar tissue providing a conduction block to interrupt propagation of the arrhythmia. Cox estimated that the technical difficulty of performing the Maze III procedure is “9.5 on a scale to 10.”5 Despite a high level of safety and efficacy, the procedure has had “little direct effect on the absolute number of

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patients cured of atrial fibrillation.”

Creating the maze pattern with energy ablation rather than incisions has simplified the procedure and increased its application.

**Energy Ablation**

Energy sources used for intraoperative ablation include cryotherapy, radiofrequency, microwave, laser, and ultrasound. Traditional cryotherapy systems used nitrogen for cooling, but newer instruments use argon or helium, which allows lower temperatures to be reached. Radiofrequency probes may be unipolar or bipolar, with bipolar probes having a reduced risk of damaging adjacent structures such as the esophagus. Irrigated radiofrequency probes have greater efficiency because the cooling effect on the surface of the tissue drives the focus of energy deeper into the tissue and prevents char accumulation on the surface. Microwave energy creates deeper lesions than does radiofrequency energy in a similar length of time and may have more potential for epicardial application. Laser and ultrasound energy are still relatively new energy sources, but both may produce transmural lesions even through epicardial fat. Provided the ablation creates transmural lesions and complete conduction block, there is probably little difference between the types of energy used.

**Lesion Set**

The Maze III lesion set that uses surgical incisions is the “gold standard,” with freedom from AF of up to 97% at 10 years’ follow-up. The more extensive the lesion set, the greater the probability of abolition of AF but with the penalty of reduced atrial transport. Recently, Cox suggested that the essential parts of the Maze III lesion set are lesions encircling the pulmonary veins either in isolation or together, a lesion between an inferior pulmonary vein and the mitral annulus, and a lesion joining the coronary sinus and the inferior vena cava (Figure). This is considered the minimal lesion set, although the right atrial lesion may be applied more to prevent late atrial flutter than to cure AF. Few clinical studies have directly compared lesion sets, limiting the evidence available for the minimal ablation set. The required lesion set also is likely to vary for patients with different types of AF; paroxysmal AF usually originates in the pulmonary veins, whereas permanent AF may not rely on the pulmonary veins for continuation. Thus, it is likely that paroxysmal AF can be cured by limited ablation of the pulmonary veins, whereas permanent AF requires a more extensive lesion set.

**Atrial Appendages**

Both the right and left atrial appendages are excised in the Maze III procedure. During intraoperative ablation, the surgeon typically closes or removes the left atrial appendage to prevent thromboemboli in the event of postoperative AF. Removal of the right atrial appendage may not improve the efficacy of the procedure in reducing AF, and retention of this appendage reduces the postoperative fluid retention resulting from preservation of atrial natriuretic peptide function.

**Surgical Times**

Compared with cardiac surgery alone, intraoperative ablation significantly increases bypass and cross-clamping times; however, energy ablation significantly reduces the bypass and cross-clamping times as compared with the Maze III procedure. No studies with intraoperative ablation have reported increases in complications related to the longer bypass times; however, the studies have involved relatively small numbers of patients.

**Atrial Contractility**

Atrial ablation with ligation of the atrial appendages reduces atrial function relative to normal controls in sinus rhythm. The clinical significance of this reduction has not yet been accurately assessed. Transthoracic Doppler echocardiography has been the most frequently used method of measuring atrial contraction after AF surgery, although its clinical usefulness has not been established. The cutoff points used for Doppler echocardiography also appear arbitrary, with the presence of any A wave through an A-wave velocity ≥10 cm/s considered to be effective atrial contraction. Cox has suggested atrial contraction be measured with a battery of tests including echocardiography, MRI, or atrioventricular pacing versus ventricular pacing at the same paced rates.

**Sinus Node Dysfunction**

Paroxysmal AF associated with sinus node dysfunction is called *sick sinus syndrome*. The sinus node dysfunction may not be apparent preoperatively but becomes so postoperatively. Sinus node dysfunction also occurs after correction of AF due to valve disease; this can improve up to 1 year postoperatively. There does not appear to be any increase in pacemaker requirement after intraoperative ablation versus cardiac surgery alone.

**Safety of Intraoperative Ablation**

When intraoperative ablation as a concomitant procedure is compared with
cardiac surgery alone, no difference is seen in mortality rates between the groups.\textsuperscript{21} If the surgery is effective and the patient is restored to sinus rhythm or an atrially paced rhythm, then the long-term result should be a reduced risk of mortality and morbidity from stroke and anticoagulant-related bleeding.

A significant problem with the Maze III procedure is the risk of bleeding from the multiple atrial incisions. Replacement of the incisions with ablation is likely to decrease blood loss, and a reduced risk of bleeding complications after cryotherapy versus Maze III surgery has been reported.\textsuperscript{24} A reduction in the risk of stroke is a major goal of AF surgery. The Maze III procedure reduces the long-term incidence of stroke,\textsuperscript{25} but studies with longer follow-up periods are necessary to confirm whether similar results are found after intraoperative ablation.

Other structures may be damaged during intraoperative ablation. The esophagus lies immediately adjacent to the left atrium and can be injured during posterior wall ablation. The result—esophageal perforation—is usually fatal.\textsuperscript{26–28} The surgeon should be cognizant of the esophagus when ablating the left atrium, particularly when using devices with unfocused energy. Damage to the circumflex artery as a direct result of the ablation also has been reported after cryotherapy ablation,\textsuperscript{29} radiofrequency ablation,\textsuperscript{30} and epicardial microwave ablation.\textsuperscript{31}

**Clinical Treatment Considerations**

**Patient 1**
If valve repair is possible, then intraoperative ablation also should be performed. In patient 1, however, a mechanical valve with ongoing warfarin anticoagulation probably would be required, which means that one of the advantages of the surgery would be negated. Mitral valve replacement alone would result in a spontaneous return to sinus rhythm in \( \approx 26\% \) of patients,\textsuperscript{32} whereas significantly more patients (\( \approx 70\% \)) would be in sinus rhythm after atrial ablation. Patients in sinus rhythm have a reduced risk of overall mortality;\textsuperscript{33,34} hence, patients are likely to benefit from atrial ablation, even if they must continue to take warfarin.

Any commercially available energy source may be used, depending on the experience of the surgeon. A lesion pattern would be recommended including the pulmonary veins, a line to the mitral annulus, and the right atrial isthmus, plus resection or closure of the left atrial appendage. Intraoperative ablation is less effective in patients with large left atria,\textsuperscript{9} and a reduction in atrial size also may be advised via reduction atriotomy.\textsuperscript{35}

Although most patients eventually revert to sinus rhythm, in the early postoperative period a high proportion may have self-limiting atrial tachyarrhythmias. Antiarrhythmic drugs may be given for a few weeks or months after the surgery to treat these arrhythmias but should be discontinued thereafter.

After ablation, patients usually continue taking warfarin for a period of time, but no consensus exists on how long this period should be or the preconditions that must be satisfied for it to be stopped. Some studies have stopped anticoagulation provided a patient was in sinus rhythm, but it is preferable for patients to have both sinus rhythm and effective atrial contraction before discontinuing warfarin.

**Patient 2**
When there is no need for another cardiac procedure, it may be difficult to recommend open-heart surgery for lone AF because of the 20% failure rate reported in most studies. Furthermore, some atrial function may be lost after the surgery, even if it is performed with minimally invasive techniques. These less-invasive techniques include minimal access,\textsuperscript{36,37} off-pump surgery,\textsuperscript{36} or surgery with robotic assistance.\textsuperscript{38–40} If patients do remain in paroxysmal AF, however, then they are likely to progress to permanent AF over time.\textsuperscript{41} Thus, it is desirable to perform ablation, although the ideal technique in cases of lone AF remains in doubt.

**Patient 3**
Patient 3 underwent septal myectomy plus biatrial radiofrequency ablation, but she died of low cardiac output in the early postoperative period, despite sinus rhythm and echocardiography demonstrating a low left ventricular outflow gradient and symmetrical left ventricular contractility. In patients heavily reliant on normal atrial contractility, the small reduction in contractility associated with atrial arrhythmia surgery may be poorly tolerated. Although the onset of AF in hypertrophic cardiomyopathy patients is a poor prognostic indicator, more than one third of such patients tolerate AF reasonably well, and the majority benefit from atrial arrhythmia surgery. For patients who are severely intolerant of AF, however, cardiac transplantation may be a better option.

**References**


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