SURGERY FOR ATRIAL FIBRILLATION

Gerald M Lawrie
From Methodist DeBakey Heart & Vascular Center, Houston, Texas

INTRODUCTION & HISTORY

Atrial fibrillation (AF) is a common and serious arrhythmia that traditionally has been treated with antiarrhythmic drugs and warfarin for anticoagulation. Patients often are symptomatic. Normal cardiac function may be impaired due to loss of atrioventricular synchrony and the abnormal irregular ventricular activation. Despite the widespread use of medical therapy in these patients, a recent 21-year follow-up study of patients with AF treated medically showed no improvement in mortality risk over time and in fact showed a substantial excess risk of death.1 Thus, the goal of intervention has shifted over the last 30 years from efforts to improve ventricular rate control while leaving the atria in atrial fibrillation to attempting to permanently "cure" atrial fibrillation and restore the atria to sinus rhythm.

The late 1970's and early B0's ushered in a variety of new invasive surgical procedures. Cox initially developed the "left atrial isolation" procedure designed to confine the atrial fibrillation to the left atrium and allow the heart to beat in sinus rhythm from the right atrium.[24] Guiraudon created the "corridor procedure" that joined the sinus node to the atrioventricular node with an isolated strip of right atrial wall.5 In both procedures, the left atrium continued to fibrillate and posed a continued risk of thromboembolism. Open surgical ablation of the atrioventricular node with cryothermia and pacemaker implantation was performed by us in the late 1970's in selected patients who had difficulty controlling their heart rate through medical therapy. This latter procedure was soon superseded by catheter ablation of the His bundle that was reported by Scheinman in 1982.[6] Warfarin continued to be required for "rate-controlled" atrial fibrillation.

The development of a surgical cure for atrial fibrillation was delayed due to the erroneous belief that it was a microreentrant arrhythmia. The initial breakthrough in understanding the mechanism of atrial fibrillation was first achieved by Dr. James Cox and his electrophysiologist colleagues at Duke and then at Washington University. In a series of elegant experiments on dogs and humans, the precise patterns of atrial activation in atrial flutter and fibrillation were elucidated. A mapping computer with 256 electrodes on right and left atrial arrays clearly demonstrated that atrial fibrillation was a macroreentry arrhythmia and that microreentry and automaticity were not present in established atrial fibrillation.[3,4] This was consistent with the earlier work published by Allessie on the mapping of atrial flutter in the isolated heart model, which demonstrated that multiple macroreentrant wave fronts were present during atrial flutter.[7]

Thus, surgical efforts were directed toward creating a series of atrial incisions that would allow normal activation of the entire left and right atria but would prevent propagation of macroreentrant circuits. The specific areas considered at high risk of supporting macroreentry were the vena caval orifices, the base of the left atrial appendage, the four pulmonary veins, the interatrial septum, and the tricuspid orifice. These studies and subsequent clinical experience led to the development of the Cox-Maze III procedure, which was introduced into clinical practice in 1991 and continues to be the "gold standard" for cure of atrial fibrillation.

Even with the high cure rate reported by Dr. Cox and confirmed by other centers, the Cox-Maze procedure was never widely adopted. This was due in part to a perception that it was difficult to learn. It also was a significant surgical procedure: Dr. Cox initially performed the operation by making multiple and extensive full-thickness atrial incisions that then had to be sutured.3•4 The introduction of new technologies such as high frequency ultrasound (HIFU) and bipolar radiofrequency devices has greatly simplified this process and made it easier to apply as a combined procedure in patients with atrial fibrillation and structural heart disease such as coronary or valvular lesions. Despite the surgery's safety record and long-term cure rate of over 95%, however, the need for an open surgical incision and the now-outdated perception of it being a "major" undertaking continues to limit its application as a freestanding procedure.

TYPES OF ENERGY USED FOR SURGICAL ABLATION OF ATRIAL FIBRILLATION

The most common forms of ablative energy used in surgery for atrial fibrillation are high frequency ultrasound (HIFU), radiofrequency energy, and nitrous oxide-based cryorherapy (-80 degrees C). Each has advantages and disadvantages. All are capable of producing areas of localized complete myocardial ablation, which produces complete electrical block in these areas without excessive weakening of cardiac structural integrity. The large size of the lesions produced by surgery dwarf chose produced in the EP laboratory. Applied from the epicardium, the HIFU lesions are about one centimeter wide and are designed to be deeply transmural through three sequential applications

of ultrasound energy at three depths of penetration. Radiofrequency energy is always applied in the surgical setting by a bipolar clamp with long jaws. The risk of collateral damage to structures such as the esophagus is thereby minimized. Cryocherapy is applied wirh a probe that produces lesions 25 mm in diameter and 3-5 mm in depth. These can be applied from rhe endocardium and/or epicardium, as needed.

CATHETER ABLATION OF ATRIAL FIBRILLATION

The studies of Cox and his colleagues were primarily concerned with what is now termed permanent atrial fibrillarion.3.[4] In 1998, Haissaguerre et al. reported that in many patients with paroxysmal atrial fibrillation, automatic foci within or near the pulmonary vein orifices reproducibly initiated paroxysmal atrial fibrillation.[8] Subsequent studies have confirmed the importance of the left aerial tissue adjacent to the pulmonary vein orifices in the initiation and perpetuation of atrial fibrillation. In about 15% of patients, atrial fibrillation arises from macroreentrant circuits in the right atrium.

The seminal contribution of Haissaguerre et al. has led to a massive resurgence of interest in rhe ablation of atrial fibrillation by catheter-based techniques. These usually employ unipolar radiofrequency energy to produce "lines of block" on che left atrial wall and pulmonary veins that resemble the left atrial elements of the Cox-Maze procedure. The majority of pacients rreated to date by catheter ablation have had paroxysmal aerial fibrillation and relatively normal-sized atria. There still remains no unanimity about rhe sire or extent of "lesions sets" needed to produce reliable catheter ablation of paroxysmal atrial fibrillation. The initial efforrs directed toward ablation of individual foci identified by catheter mapping within the veins or at their orifices have led to some cases of pulmonary vein srenosis. Thus the lesions sets reported by various centers range from a single direct ablation of an automatic focus in a pulmonary vein to essentially a left-sided Maze procedure with encircling pulmonary vein lesions and a limb of ablation to the mitral annulus.

LIMITED SURGICAL APPROACHES

In response to the advent of catheter techniques, surgeons have developed less invasive techniques for ablation of atrial fibrillation. The complete Cox-Maze procedure can now be performed without cardiopulmonary bypass by using a combination of HIFU and bipolar radiofrequency ablation through a short midline incision. Another technique empl$_{oys}$ small bilateral thoracotomies, which allows epicardial bipolar radiofrequency ablation of the pulmonary vein junctions with the left atrium. This produces complete encirclement of the pulmonary veins bilaterally, although access for additional lesions is limited.

RESULTS

Few areas of medicine have posed such difficulty in determining the outcome of invasive catheter or surgical procedures as has the evaluation of atrial fibrillation therapy. Many reports have failed co distinguish between preoperative paroxysmal versus permanent atrial fibrillation and che duration of symptoms. The presence or absence of structural heart disease and left atrial size are also important determinants of success. Antiarrhythmic drug use is sometimes not specified. Definitions of success have varied from no arrhythmia reported by the patient to extensive post-operative monicoring.

Many different lesions sets have been proposed for boch surgical and catheter interventions, but they are often nor properly described in reports and frequently misnamed. For example, the "mini-Maze procedure" is a pure localized pulmonary vein isolation procedure, while the description of post-ablation medication status of patients is frequencly inadequate. Finally, because many episodes are asymptomatic, it is especially difficult to ascertain whether or not paroxysmal atrial fibrillation has been cured.

RESULTS OF THE COX-MAZE PROCEDURE

In contrast to the foregoing, excellent long-term data is available regarding outcomes for the full Cox-Maze procedure. Multiple reports extending more than 10 years after operation have consistently demonstrated greater than 90% drug-free cure rates for the classic full "cue and sew" Cox-Maze procedure.[4,9-11] It is important to note that the final evaluation of success rates after open heart surgical application of these techniques must wait at least three months. After surgery, the atria routinely develop inflammatory changes chat predispose chem to early pose-operative aerial fibrillation despite a successful ablation.[10,12] The Cox-Maze III carries a small incidence of need for permanent pacemaker implantation.

There have been two recent meta-analyses evaluating the efficacy of the Cox-Maze III surgery for curing atrial fibrillation. Khargi et al. reported on 3,832 patients from 48 studies and compared a variety of surgical techniques with the "cut and sew" Cox technique.[13] For the 2,279 patients treated with radio-frequency, cryorherapy, or microwave energy, che cure rate was 78.3%. For the 1,553 patients treated by the standard technique, the cure rate was 84.9%. However, these patients were younger and had more paroxysmal AF and less organic heart disease. The second study by Barnett and Ad anal$_{yz}$ed data from 69 studies describing 5,885 patients.14 They observed that patients who underwent biatrial ablations had a higher three-year cure rate (87-92%) than those with only left atrial lesions (73-86%). These studies suggest that the classic Cox-Maze III procedure continues to be the gold standard, with more than 90% of patients cured of AF in experienced centers. Lesser procedures such as

surgical pulmonary vein isolation only, left aerial isolation, and left-sided Maze procedures can be expecred to have cure races in che 70-80% range.

MITRAL VALVE REPAIR AND ATRIAL FIBRILLATION

Ac rhe Merhodisc DeBakey Heare & Vacular Center, atrial fibrillation surgery is routinely combined with mitral valve repair. The aerial fibrillation is usually permanent or persistent. For patients wich permanent aerial fibrillation who receive a micral reparative procedure, chis holds the promise of eventual disconrinuacion of warfarin therapy if rhe atrial fibrillation is cured. Furthermore, two studies have shown cardiac hemodynamic performance to be enhanced by conversion to sinus rhythm. In patients with congestive heart failure and low ejection fraction, Haissaguerre demonstrated significant improvement in ejection fraction after successful catheter ablation of atrial fibrillacion.15 Schaff also demonstrated improvement in ejection fraction in patients undergoing surgical Maze procedures.[16] The improvement was greatest in patients with the worst ejection fractions.

Our standard surgical approach to combined mitral valve repair and aerial fibrillation ablation uses HIFU ro create a full encircling lesion of the pulmonary veins chat is chen connected to the mitral annulus. The left aerial appendage is resected, and the orifice at the base of rhe resected left atrium is connected to the pulmonary venous encircling lesion by sharp extension into the left superior pulmonary vein. Radiofrequency energy is used to join the superior and inferior vena cavae along the crista terminalis. This is a very small addition to the surgical procedure and is well tolerated even in high-risk patients.[17,18] A full Cox-Maze III procedure is still often performed in younger patients. HIFU cannot be used on redo operations where prosthetic valves or coronary bypass grafts are near the atrioventricular groove. In these cases, rhe same lesions are created bur radiofrequency energy is employed throughout.

Alrhough pose-operative conduction disturbances requiring permanent pacing were seen in earlier patients, the earlier right-sided incisions in the Cox-Maze I and II procedures were modified co minimize chis risk.[3,4,9-11] Mose patients who require pacemakers after rhe current Cox-Maze III have had preexisting conduction system disease such as is seen in rhe sick sinus syndrome.

Since rhe initial application of the Cox-Maze procedure, concerns have been raised as co whether atrial rransporc function is eliminated by the multiple incisions in rhe atria. Many of the patients with long-standing permanent atrial fibrillation and large atria already have impaired aerial coneracrility preoperacively. Studies utilizing echocardiography and, more recently, cardiac MRI have dearly demonstrated persistence of aerial contraction and transport function although at less than normal strength. The eransmural atrial incisions used in earlier transmural procedures did interrupt blood supply, whereas the currently used ablative techniques maintain vascularity.

After rhe atria have healed and sinus rhythm is documented as the established rhythm, warfarin can be discontinued. This elimination of the risk of stroke further suggests that atrial transport function, while depressed, is sufficient to prevent thrombus formation in the atria. The routine removal of the left aerial appendage also conrributes to this reduction.

FUTURE CONSIDERATIONS

Alchough inrraoperarive mapping scudies of AF formed the foundation of AF surgery and the development of the Cox-Maze III procedure, ic is rarely emplo y e d now as a clinical tool.3 Harada et al. studied 12 patients in whom repetitive activation arising from the left aerial appendage and/or left pulmonary veins was observed.19Nitta et al. studied 46 patients intraoperatively with a 256 channel system, observing widespread activation in three patients who were not treated surgically.[20] Left-sided incisions were used in eight patients in whom the right atrium showed no primary foci, with 100% cure. The remaining 35 patients required more extensive surgery based on the mapping findings. Given the difficulty in analyzing patients with AF who receive intervention, further clinical study of these patients is unlikely ro elucidate the optimal surgical procedure for future patients. Inrraoperarive mapping findings could greatly accelerate this process.

SURGERY AFTER FAILED CATHETER ABLATION

Up until che present, electrophysiologists and surgeons have tended to manage atrial fibrillation using completely separate pathw'ys : either a catheter or surgical track. Although surgery is a significant intervention, it is an extremely safe, shore procedure with a high cure rate. Catheter-based therapies are still major interventions under general anesthesia, lasting sometimes for many hours and associated with significant failure rates.

It seems reasonable to consider surgery in patients whose AF was significant enough to require one or two attempts at ablation. If unsuccessful, we feel that the option of surgical ablation should be discussed with the patient.

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