Thoracic and Cardiovascular Surgery

Surgical Treatment of Atrial Fibrillation: A Look into the Future

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The surgical treatment of atrial fibrillation began in 1987, when Dr. James Cox introduced the maze procedure. This operation proved to be extremely effective in curing atrial fibrillation and preventing its most dreaded complication, stroke. However, many surgeons found the operation to be too difficult and invasive. Over the last 5 to 10 years, various groups have tried to develop less invasive approaches using a number of different energy sources to create linear lines of ablation to replace the surgical incisions. This has led to a plethora of new operations for this arrhythmia. There is significant confusion in the literature at the present time as to what is the best lesion pattern and what is the best energy source. It is our feeling that a great deal of this confusion is due to our lack of understanding of the mechanisms of atrial fibrillation and the effect of ablation technology on atrial hemodynamics and electrophysiology. Future progress will require a better understanding of this arrhythmia and continued research into the safety and efficacy of ablation devices.

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The first effective operation for atrial fibrillation (AF) was introduced in 1987 by Dr. James Cox at Barnes-Jewish Hospital in St. Louis, Missouri.[1-3] This operation, the Cox maze procedure, involved creating a myriad of incisions on both the right and the left atria. The incisions were designed to block the multiple macroreentrant circuits felt to be responsible for AF. Although this theory of AF since has been proven to be incorrect in many instances, the Cox maze procedure was extremely effective at curing AF. The final iteration of this procedure was termed the Cox maze III procedure. From 1988 to 2001, 198 consecutive patients underwent this operation at Barnes-Jewish Hospital.[4] One hundred twelve operations were for lone AF, and 86 were concomitant with either valvular or coronary surgery. Mean follow-up was 5.4 ± 2.9 years, with a range from 6 months to 14 years. The freedom from recurrent AF was 97% in the concomitant group at 10 years and 92% in the lone maze group at 14 years (Fig. 1). Eighty percent of the patients in the lone group were both drug-free and off antiarrhythmic drugs at last follow-up. In the concomitant group, 73% were both drug and arrhythmia free. At last follow-up, only 12% of the patients in the lone group were on anticoagulation. There was only one late stroke, and this was in a patient who had no evidence of recurrent AF. This high success rate has been replicated by a number of other groups around the world.[5-7]

Unfortunately, few surgeons adopted the Cox maze III procedure. It required cardiopulmonary bypass and an arrested heart and was a lengthy operation. The mean cross-clamp time required to perform a lone Cox maze III procedure at our institution was 93 ± 34 minutes.[4] Moreover, the procedure had significant morbidity. Pacemakers were required in 15% of patients. The median length of stay was 9 days in the lone group and 12 days in the patients undergoing a maze with concomitant cardiac procedures.

Ablation-Assisted Atrial Fibrillation Surgery

The shortcomings of the Cox maze III procedure led to interest in developing less invasive surgical approaches to AF. The principal strategy of groups around the world has been to replace the surgical incisions with linear lines of ablation using a variety of different energy sources.[8-11] Cryosurgery, radiofrequency energy, microwave, laser, and high-frequency ultrasound all have

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been used, both experimentally and clinically, for the surgical treatment of AF.[12] The various technologies can be organized into two major groups: those that use a unipolar energy source and those that use a bipolar clamp.

The unipolar energy sources (cryosurgery, unipolar radiofrequency energy, microwave, laser, ultrasound) all share a common weakness. These energy sources radiate either heat or cold from a single source. With the exception of high-frequency ultrasound, the energy is unfocused. None of the devices give the surgeon an indication of when the ablation results in a transmural lesion. Because most were released clinically without accurate dose–response curves, this led to occasional collateral cardiac and extracardiac damage with these devices.[13-15] Moreover, unipolar energy sources have had difficulty creating transmural lesions when used from the epicardial surface on the beating heart.[16-19] This is because the circulating intracavitary blood pool makes transmural lesions difficult. For instance, with microwave energy, our laboratory has shown a direct relationship between the depth of lesion penetration and the degree of intracavitary blood flow.[20] Ultrasound is the one unipolar source that results in a focused delivery of energy. Thus, it potentially has the ability to create transmural lesions on the beating heart. Ultrasound has the disadvantage of having a fixed depth of penetration. This can be a problem because of the variability of atrial wall thickness in pathological states.

Bipolar radiofrequency ablation has been able to overcome some of these shortcomings.[21-24] Because energy is delivered between two closely approximated electrodes embedded in a jaw of a clamp device, the energy is focused and results in discrete lesions. The energy is confined within the jaws of the clamp, eliminating the possibility of collateral cardiac or extracardiac damage. By measuring the tissue conductance between the two electrodes, algorithms have been developed that have accurately predicted lesion transmurality. This allows these devices to tailor the energy delivery to the physiological characteristics of the tissue being ablated. Finally, bipolar ablation has the advantage of shorter ablation times when compared with unipolar devices. Five to six centimeter linear ablation lines can be made clinically in 10 to 20 seconds, whereas most unipolar devices require minutes to create a transmural ablation. The weakness of these devices is that they can only ablate tissue that can be clamped within the jaws of the device. This has limited the potential lesion sets, particularly on the beating heart. These devices have also been incapable of fully ablating the right and left atrial isthmuses and have required adjunctive unipolar ablation to perform a complete Cox maze lesion set.

Our group has used bipolar radiofrequency ablation to replace most of the lesions of the cut-and-sew Cox maze III procedure.[25-28] This new operation has been termed the Cox maze IV and preserves virtually the entire lesion set (Figs. 2 and 3). As of August 1, 2006, we have performed this operation

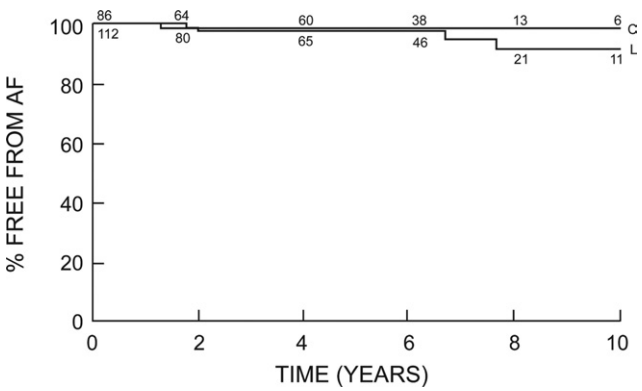

Figure 1 Freedom from recurrent AF. Kaplan–Meier survival analysis of freedom from recurrent AF. The numbers on each line indicate the number of patients at risk. There was no difference in the long-term estimate of freedom from AF between the lone maze group (L) and the concomitant group (C; $P = 0.64$).

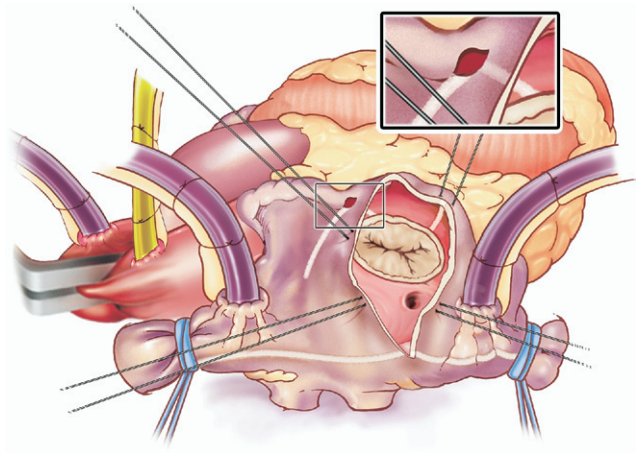

Figure 2 Illustration of right atrial lesion set. White lines indicate radiofrequency ablation. Cryoablation is used to complete the ablation line on the tricuspid valve annulus. (Color version of figure is available online at http://journals.elsevierhealth.com/periodicals/ystcs.)

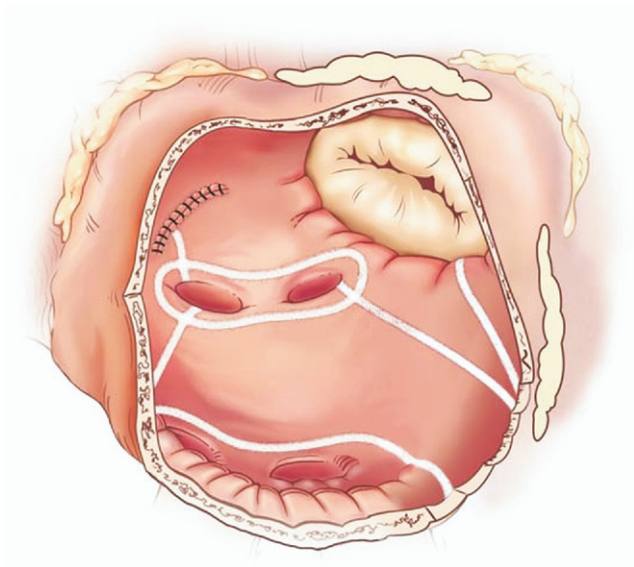

Figure 3 Illustration of left atrial lesion set. White lines indicate radiofrequency ablation. Cryoablation is used to complete the ablation line on the mitral valve annulus. (Color version of figure is available online at http://journals.elsevierhealth.com/periodicals/ystcs.)