Review

Surgery for Atrial Fibrillation

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Surgical treatment is highly effective in converting atrial fibrillation back to sinus rhythm and significantly prevents thromboembolism postoperatively. Indications for surgery include patients with atrial fibrillation associated with structural heart disease who undergo cardiac surgical procedures, high-risk patients for systemic thromboembolic complications related to left atrial thrombi, patients with failure or recurrence following one or more sessions of catheter ablation, and patients with intolerable symptoms or an impaired quality of life due to atrial fibrillation. The maze and radial procedures cure atrial fibrillation in the majority of patients, however, the procedures are not guided by electrophysiologic findings in individual patients, and thus may include unnecessary incisions in some patients or be inappropriate for other patients. Intraoperative mapping may facilitate determining the optimal procedure for atrial fibrillation in each patient. Surgical procedure for atrial fibrillation consists of isolation of all four pulmonary veins to prevent propagation of the repetitive activation and multiple incisions on the right and left atria to block the reentrant activation. A number of ablation devices have been developed to make a complete conduction block during the past decade. The challenge in atrial fibrillation surgery is in the development and establishment of an off-pump thoracoscopic procedure. Furthermore, intraoperative electrophysiological assessment of the mechanism of atrial fibrillation and verification of conduction block over the ablation line should be established to accomplish a high success rate for atrial fibrillation. (Ann Thorac Cardiovasc Surg 2005; 11: 154–8)

Key words: atrial fibrillation, thromboembolism, cardiac mapping, electrophysiology, ablation device

Introduction

Atrial fibrillation is a life-threatening arrhythmia that carries a high incidence of thromboembolic complications. Surgical treatment is highly effective in converting atrial fibrillation back to sinus rhythm and significantly prevents thromboembolism postoperatively. Indications for surgery include patients with atrial fibrillation associated with structural heart disease who undergo cardiac surgical procedures, high-risk patients for systemic thromboembolic complications related to left atrial thrombi, patients with failure or recurrence following one or more sessions of catheter ablation, and patients with intolerable symptoms or an impaired quality of life due to atrial fibrillation.

Although current surgical procedures result in a high success rate for atrial fibrillation, they are not guided by electrophysiologic findings in individual patients, and thus may include unnecessary incisions in some patients or be inappropriate for other patients. Intraoperative mapping would facilitate determining the optimal procedure for atrial fibrillation in each patient. Development of ablative devices that enable pulmonary vein isolation and creation of linear conduction block on the atria without the use of cardiopulmonary bypass (CPB) is crucial in ben-

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Table 1. Indications for atrial fibrillation surgery

Class I None
Class IIa 1. Patients who undergo surgery for structural heart disease 2. Patients complicated with left atrial thrombosis refractory to thrombolytic therapy or with a history of thromboembolism despite proper anticoagulant therapy 3. Patients with failed catheter ablation for or with recurrence of atrial fibrillation
Class IIb 1. Isolated atrial fibrillation patients with medically refractory intolerable symptoms and a significantly impaired quality of life 2. Patients with medically refractory paroxysmal atrial fibrillation and repeated emergency visits
Class III 1. Patients with severely dilated atria and a severely increased cardiothoracic ratio, with low voltage f-waves on the ECG, in which there is little chance to maintain sinus rhythm and effective an atrial contraction postoperatively

efiting more patients undergoing surgical treatments for atrial fibrillation.

Surgical Indications for Atrial Fibrillation

The guidelines for the surgical treatment of atrial fibrillation, announced by the Japanese Circulation Society in 2001, are shown in Table 1.[1] Although there is no absolute indication (class I) at this moment in time, concomitant surgery for atrial fibrillation is strongly recommended in patients with atrial fibrillation who undergo surgery for valvular, congenital, or coronary artery disease (CAD). The quality of life would be significantly improved postoperatively, particularly in patients who undergo mitral valvuloplasty, valve replacement with bioprosthesis, or surgery for congenital heart disease (CHD) or CAD, because anticoagulant therapy may not be needed in these patients postoperatively. The incidence of thromboembolism and mortality have been shown to decrease in patients who underwent the maze procedure and mitral valve surgery, as compared to those in whom the atrial fibrillation was not treated and remained postoperatively.[2] Surgery for atrial fibrillation is also indicated in atrial fibrillation patients without structural heart disease, but with a history of thromboembolism, such as a cerebral infarction, or with the presence of left atrial thrombi. In the patients who are not successfully treated by catheter ablation for paroxysmal atrial fibrillation or in whom atrial fibrillation recurred after the ablation, surgical treatment should be performed.

Surgery is considered in atrial fibrillation patients who do not have an associated structural heart disease when they have medically refractory symptoms related to atrial fibrillation. Patients with paroxysmal atrial fibrillation can have more severe symptoms, such as palpitations or fainting, than those with chronic atrial fibrillation, because of the sudden onset of the tachyarrhythmia. Surgical treatment should be considered in these patients.

There is a subset of patients who are not indicated for surgery. Those include patients with a severely dilated left atrium, increased cardio-thoracic ratio, decreased amplitude of the f-waves in the V1 precordial lead, or extremely long history of continuous atrial fibrillation.[3] The success rate for atrial fibrillation has been described as being significantly low in these patients, and they have a poor atrial contraction even if sinus rhythm were to resume.

Maze Procedure

The maze procedure was developed by Dr. Cox and his research laboratory in Saint Louis, Missouri.[4] The maze procedure cures atrial fibrillation by isolation of the posterior left atrium including all four pulmonary veins and multiple incisions on the right and left atria. The rationale behind the maze procedure is the confinement of the repetitive activation arising from the pulmonary veins to the isolated posterior left atrium and the interruption of all potential macroreentrant circuits by the atrial incisions. The maze procedure results in a high success rate for atrial fibrillation associated with or without structural heart disease.[5] Cox et al.[6] described that they performed the maze procedure in 306 patients during the period from 1989 to 1999 and 95% of the patients were cured of atrial fibrillation. Most of the patients did not have associated heart disease and 19% of them had had a history of thromboembolic complications prior to the surgery. There was only one patient who developed cerebral infarction late

after the maze procedure even though anticoagulant therapy was discontinued in all patients except for those with mechanical valves. When we take into account the fact that the incidence of cerebral infarction is about 2-5% annually, the maze procedure significantly prevents the thromboembolism by converting atrial fibrillation back to sinus rhythm.

Radial Procedure

Although the maze procedure cures atrial fibrillation in the majority of patients, insufficient left atrial transport function is occasionally seen in patients after the procedure.[7] The possible mechanisms underlying the insufficient left atrial transport function after the maze procedure are the isolated posterior left atrium between the pulmonary vein orifices, discordant activation of neighboring atrial segments across the incisions, delayed activation at the lateral left atrium, and interrupted atrial coronary arteries. The radial procedure,[8] in which the atrial incisions radiate from the sinus node toward the atrioventricular annular margins and parallel the coronary arteries, was developed as an outgrowth of and alternative to the maze procedure in order to preserve a more physiological activation sequence and the atrial transport function.[9,10]

Between October 1997 and December 2003, 100 patients underwent the radial procedure.[11] There were 53 male and 47 female patients and the average age was 62±10 years. Eighty-two patients had valvular heart disease and nine patients were associated with CHD, while the remaining nine patients had no structural heart disease. There were 67 patients with continuous atrial fibrillation and 33 with intermittent atrial fibrillation. Thirteen patients experienced thromboembolic events prior to the surgery. Seven patients had left atrial thrombi present at the time of surgery. There were two surgical mortalities, not related to the radial procedure. The success rate for atrial fibrillation was 91%. A pacemaker implantation was required in six patients. In all the patients who were cured of atrial fibrillation, a significant contraction of the left atrium was detected by transthoracic Doppler echocardiography postoperatively. During the follow up period of up to 74 months (median 35 months), no patients had experienced thromboembolic events. These results suggest that the radial procedure provides a greater atrial transport function and prevents thromboembolism, and thus may represent a physiological alternative to the maze procedure as a surgical procedure for atrial fibrillation.

LA Isolation and PV Isolation Procedures

Although the maze and radial procedures cure atrial fibrillation in the majority of patients, there is no clear evidence that all the incisions are required to cure atrial fibrillation, and not all the incisions are necessarily essential for terminating atrial fibrillation in every single patient. Sueda et al.[12] simply isolated the posterior left atrium without any incisions on the right atrium in 32 patients with permanent atrial fibrillation associated with mitral valve disease, and found that 74% of the patients were cured of atrial fibrillation during a follow-up period of up to three years. They further simplified the procedure in 12 patients to an isolation of the right and left pulmonary veins.[13] The success rate for atrial fibrillation was 75% in the immediate and 83% in the mid-term postoperative periods. Although the success rate for atrial fibrillation by these simplified procedures is lower than the maze or radial procedures, they are advantageous in reducing the blood loss and decreasing the operation time. These clinical results of the simplified procedures have suggested that the pulmonary veins are the source of the abnormal activation maintaining atrial fibrillation in approximately 80% of patients with permanent atrial fibrillation and mitral valve disease, while other electrophysiology causes are the mechanism in the remaining patients.

Map-guided Surgery for Atrial Fibrillation

The traditional paradigm in surgery for cardiac arrhythmias has been the electrophysiological assessment of the arrhythmia followed by the determination of a specific lesion for ablation or a definitive procedure based on the results of the analysis in each patient. However, the maze and radial procedures are not guided by electrophysiologic findings in individual patients, and thus may include unnecessary incisions in some patients or be inappropriate for other patients. As described above, surgical procedures confined to the left atrium or the pulmonary veins have been shown to cure atrial fibrillation in selected patients. However, the success rate for atrial fibrillation by the limited procedures has been less than optimal and the indications for these procedures have not been discussed in association with the electrophysiology of atrial fibrillation.

We sought to determine if intraoperative mapping is beneficial for the surgical treatment of atrial fibrillation.[14,15] A 256-channel three-dimensional dynamic mapping system with custom-made epicardial patch electrodes

was used to examine the atrial activation during atrial fibrillation and to determine the optimal procedure in 37 continuous and nine intermittent atrial fibrillation patients intraoperatively. Surgery for atrial fibrillation was not indicated in three patients in whom the atrial electrograms had a low voltage over a broad area. Concurrent multiple repetitive activations arising from the pulmonary veins or left atrial appendage were observed in all patients. A simple left atrial procedure, consisting of pulmonary vein isolation and left atrial incisions without any right atrial incisions, was performed in eight patients in whom the right atrial activation was passive, and all (100%) were cured of atrial fibrillation. The radial procedure was performed in the remaining 35 patients, and 31 of the patients (89%) were cured of atrial fibrillation. In this subset of patients, 10 exhibited reentrant or focal activation in the posterior left atrium between the right and left pulmonary veins and required an additional linear ablation on the posterior left atrium. The total amount of postoperative bleeding after the simple left atrial procedure was significantly less than after the radial procedure (378±135 ml vs. 711±364 ml, p=0.03). The right and left atrial transport functions were well preserved both after the radial and simple left atrial procedures. These data suggest that the intraoperative mapping facilitates determining the optimal procedure for atrial fibrillation in each patient.

Ablation Devices

Surgical procedure for atrial fibrillation consists of isolation of all four pulmonary veins and placement of multiple incisions on the right and left atria. All these isolation and incisions should result in complete conduction block to prevent propagation of the repetitive activation of the pulmonary veins toward the left atrium and to block the reentrant activation occurring on the atrial wall. Cut-and-sew is the most reliable technique to accomplish the conduction block, however it extends the cardiac arrest and CPB times and increases the risk of bleeding. During the past decade, a number of ablation devices have been developed and tested in animals and humans for their ability to make a complete conduction block. The ideal ablation device is the one that can make transmural necrosis safely, quickly, and if feasible, epicardially without the aid of CPB. Furthermore, the device may be flexible enough to permit the use through a small thoracotomy.

Cryothermia has been used as an ablation energy source in arrhythmia surgery for a long time. Freezing the myocardium down to –60°C or lower results in irreversible necrosis. The necrosis lesion is homogenous and demarcated without scarring and arrhyhmogeneity. It usually takes 1-2 minutes to make a transmural necrosis in the atrial myocardium with nitrous oxide (boiling temperature: –89.5°C). Recently introduced Argon gas (boiling temperature: –185.7°C) can make a deeper lesion with a shorter time.[16)]

Radiofrequency has been extensively used in catheter ablation. It can be used through a unipolar or bipolar device. The application of the energy increases the tissue temperature to 50-55°C or higher to cause irreversible necrosis. The unipolar radiofrequency device is a flexible probe used with a counter electrode patch usually put on the back. A life-threatening complication of esophageal perforation has been reported.[17,18)] The mechanism of the complication is presumed to be due to the collateral damage of the unipolar application of the radiofrequency energy. The incidence of the complication can run up to 1%.

Bipolar application of the radiofrequency energy has been accepted as a safe and effective ablation device for atrial fibrillation surgery during the past years.[19)] The energy is delivered between the electrodes mounted on both sides of the jaws that clamp the atrial tissue in order to make a complete conduction block and to minimize the collateral damage. The impedance between the electrodes is continuously monitored to examine whether a transmural ablation is achieved. The bipolar radiofrequency devices have been mostly accepted as an ideal tool in the on-pump setting atrial fibrillation surgery, usually undergone in the patients who have atrial fibrillation associated structural heart disease.

Microwave is a recently introduced energy source in atrial fibrillation surgery.[20)] The energy is delivered through an antenna placed in the probe. The probe for the microwave energy application can be flexible, and can be used in the thoracoscopic procedure. Pulmonary isolation can be performed using the microwave probe without using CPB and thoracoscopically.

Perspective in Surgery for Atrial Fibrillation

With the aid of ablation devices, the surgery for atrial fibrillation has become a safe and surgeon-friendly procedure. It only takes 20-30 minutes to perform all the maze incisions as a conjunction with a procedure for structural heart diseases. The challenge in atrial fibrillation surgery is in the development and establishment of an off-pump thoracoscopic procedure which should be indi-

cated in the patients with isolated atrial fibrillation. In addition to the development of new ablation devices, intraoperative electrophysiological assessment of the mechanism of atrial fibrillation and verification of conduction block over the ablation line should be established to accomplish a high success rate for atrial fibrillation.

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