Recent Topics on the Surgical Treatment for Atrial Fibrillation

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After the introduction of endocardial radiofrequency catheter, only two arrhythmias, atrial fibrillation and ischemic ventricular tachycardia require surgical procedures. In this review, we describe recent advancements and problems of surgical treatment for atrial fibrillation.

On the basis of multiple-circuit re-entry theory, Cox developed the maze operation with the aim of interrupting the re-entry circuit. Although this procedure has become the gold standard technique for the surgical treatment of atrial fibrillation with approximately 90% success rate, several modifications have been made over time. To obtain a more physiological atrial transport function, radial approach technique or bilateral appendage-preserved maze procedures were developed and to simplify surgical procedures, maze operation with cryoablation or radiofrequency-ablation were created. Other topics are concerned with surgical target or approach to atrial fibrillation. Ectopic focus theories from pulmonary veins have been widely recognized recently and the surgical isolation of pulmonary veins orifices is performed with various energy sources. In addition to standard cut-and-sew surgical technique, cryoablation, unipolar or bipolar radiofrequency ablation, or microwave ablation were induced with endocardial or epicardial approach for the achievement of less invasive cardiac surgery.

As atrial fibrillation leads to frequent mortality, cardiac surgeons have to treat atrial fibrillation with other cardiac disease more frequently to obtain better quality of operative results. (Ann Thorac Cardiovasc Surg 2004; 10: 277–80)

Key words: atrial fibrillation, maze operation, PV isolation, atrial-esophageal fistula, microwave ablation

Introduction

After initial success of curative operation for WPW syndrome, almost all arrhythmias refractory to medication had been indicated to anti-arrhythmic surgery. But after the introduction of endocardial radiofrequency catheter ablation and its progress during the past decade, only two arrhythmias are left for cardiac surgeons to perform surgical procedures. One is atrial fibrillation and the remain-
Over the past 50 years, multiple-circuit re-entry has been the dominant conceptual model of atrial fibrillation. On the basis of multiple-circuit re-entry theory, Cox developed the maze operation with the aim of interrupting the re-entry circuit. After the improvement of his procedures, the maze III operation has become the gold standard technique for the surgical treatment of atrial fibrillation. Recently its success rate is reported as approximately 90%. However, the maze procedure isolates the pulmonary vein area and results in discordant activation in certain adjacent left atrial segments, which affects left atrial function. To obtain a more physiological atrial transport function, several modified maze procedures were tried by Japanese cardiac surgeons. Nitta and associates developed a radial approach technique. In this technique the atrial incisions radiate from the sinus node toward the atrioventricular annular margins to allow a more physiologic atrial activation sequence and parallel the atrial coronary arteries to prevent blood supply to most atrial segment.

Isobe and co-worker developed a bilateral appendage-preserved maze procedure. The atrial appendage is known as the main source of atrial natriuretic peptide (ANP). If both atrial appendages could remain intact though the maze operation, secretion of ANP would be maintained better after surgery. This procedure improved not only atrial transport but also atrial natriuretic peptide secretion, and it simplified the maze operation itself, without decreasing the effectiveness against atrial fibrillation. In his series sinus rhythm was restored in 95.7% of patients.

Although maze operation cures atrial fibrillation in the majority of patients, it has not been a widespread application because of the complexity of the procedure and risk associated with multiple incisions in a posterior structure such as the left atrium. Consequently an easier and safer maze procedure was required. The first simplified maze procedure was performed by Kosakai. He used cryo-surgery, instead of the standard cut-and-sew technique, for atrial fibrillation in patients with mitral valve disease. He is a pioneer to extend the indication of maze operation. From the computational intraoperative mapping, they found regular and repetitive activation which originated in the left atrial appendage and/or orifice of the left pulmonary vein. On the basis of these findings surgical procedures, including resection of the left atrial appendage and/or cryoablation of the left pulmonary vein, were applied on the breakthrough site of the repetitive activation. They reported that 83% of patients maintained sinus rhythm for an average of 24.8 months after operation. Haissaguerre also demonstrated that paroxysmal atrial fibrillation originated from ectopic beat around the pulmonary veins in 94% of patients, and he reported the successful application of radiofrequency catheter ablation at these focal sources.

Nowadays these ectopic focus theories from pulmonary veins are widely supported by results of both catheter ablation and surgery. Ectopic foci from other sources, such as the ligament of Marshall and the superior vena cava may be also important as an initiation of atrial fibrillation. However the main target for cardiac surgeons is pulmonary veins which are the most common source of focal activity. Melo used radiofrequency-induced contiguous left atria lesion lines around pulmonary veins for pulmonary vein isolation and achieved restoration of sinus rhythm in 71% of the patients. A similar approach for surgical isolation of pulmonary veins with cryoablation was reported by Sueda. In his series 83% of patients were in sinus rhythm at a mean follow-up of 8 months. After the surgical success by Melo and Sueda, numerous cardiac surgeons reported their modified isolation procedure.

**Atrial-esophageal fistula after radiofrequency ablation**

Mohr reported the results of curative treatment of atrial fibrillation with intraoperative radiofrequency ablation in
234 patients. A median sternotomy was used in 43% of patients and video assistance procedures through a right lateral mini-thoracotomy was used in 56.3% of patients. In this series endocardial radiofrequency ablation was performed in a unipolar mode between the hand-held probe and an external back-plate electrode. At a median follow-up of 6 months, 81.1% of their patients were in sinus rhythm, and at 12 months, 72.5% of patients. However three patients (1.2%) experienced life threatening complications of esophageal injury with a left atrial-esophageal fistula after surgical ablation. Two of them had successful reoperations, but one patient died of severe cerebral infarction due to air embolism after atrial-esophageal fistula. It has been suggested that the injury was related to the transesophageal echocardiographic probe, and he mentioned that removal of the probe before delivery of radiofrequency energy should prevent esophageal injury. Gillinov also described a case report with fatal esophageal injury during surgical radiofrequency ablation. Because of the high risk of esophageal injury Mohr stopped performing this procedure at the Leipzig Heart Center and is now looking for a safer ablation method.

Introduction of microwave ablation

Microwave energy during open heart surgery has been thought to be effective as the source energy of ablation. However no data from prospective randomized trial using microwave energy are available. Schuetz performed the first randomized trial which indicates that microwave ablation is a safe and highly effective treatment in permanent atrial fibrillation. In the treatment group, 91.7% of patients were successfully converted to sinus rhythm by using microwave ablation therapy, whereas only 31.5% of patients converted to sinus rhythm in the control group. At a 12-month follow-up, there was a significantly higher percentage free from atrial fibrillation in the treatment group compared to the control group (80% vs. 33%). Microwave heating has a potential advantage over radiofrequency heating in the depth and volume of the heart tissue. Therefore this equipment may result in higher probability of transmural ablation lesions. Although esophageal injury due to microwave has not been reported, thermal endocardial approach should be avoided in thin patients with delicate tissue. Even using microwave energy, if we choose the surgical an endocardial approach, an electrophysiological check of the conduction block could not be carried out until release of the aortic clamp and a beating heart. Therefore the epicardial approach has been required for clinical use.

Advantages of epicardial approach

Maessen et al. carried out the beating-heart epicardial approach with microwave energy in 24 patients which allows immediate evaluation of conduction block. They reported that all procedures but one were completely successful on the beating heart and 20 of 23 patients were converted in sinus rhythm at the latest follow-up. The epicardial approach for surgical ablation may offer some advantages such as reduction of cardiac ischemic time, better handling of anatomic variation, avoiding unnecessary left atriotomy, and more apt for a non-invasive thoracoscopic approach. Currently it is also thought to be superior to percutaneous catheter ablation with respect to the length of procedure time, creating a continuous lesion line, handling of anatomical variation, anatomical accuracy of catheter position, and prevention of pulmonary vein stenosis. Although esophageal injury has not been reported with microwave, Manasse presented another troublesome case with an extremely severe complication after microwave epicardial ablation. He experienced the injury of the left main coronary trunk by incorrect placement of the epicardial probe. In this case an urgent coronary bypass surgery was required. Cardiac surgeons have to take extreme care to avoid damaging the zone surrounding the left main coronary trunk.

New bipolar radiofrequency ablation

Gillinov demonstrated the usefulness of the bipolar radiofrequency ablation system, which includes a bipolar radiofrequency clamp. In his series this device was used in 112 patients for pulmonary vein isolation, creation of right atrial lesion, or both. As a result, surgery using this device has proven to be a rapid and safe procedure without any device-related complication. All patients left the operating room with sinus rhythm or junctional rhythm and 68% of patients returned to sinus rhythm at 6 months ECG follow-up. The success rate seems to be lower than the other procedures, but to determine the long-term success rate of this method, additional experience and patient follow up are necessary. Gillinov estimates the importance of proper application of the clamp to make continuous transmural ablation lesions. This new operative method will be widely accepted in patients both with off-pump coronary artery bypass and lone atrial
fibrillation.

Atrial fibrillation is the most common complication after coronary bypass surgery. The US government has a billion dollar problem treating this post-operative arrhythmia. After introduction of a drug eluting stent anticipating extremely lower re-stenosis for coronary intervention, cardiac surgeons must treat not only coronary disease but also atrial fibrillation associated with coronary disease. Although indication for surgical treatment of atrial fibrillation is limited, simultaneous coronary and anti-arrhythmic surgery is expected in the future.

References