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Editorial

The surgical maze in the treatment of atrial fibrillation: the Mayo Clinic approach

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La operación del laberinto en el tratamiento de la fibrilación auricular: el abordaje de la Clínica Mayo

La fibrilación auricular (FA) tiene una prevalencia de hasta el 10-15% en los grupos de edad superiores a 80 años. El impacto económico es significativo e incluye el coste de la medicación, hospitalizaciones, terapias agresivas y el tratamiento de las complicaciones. La FA es un factor independiente de muerte y aumenta el riesgo de infarto cerebral. La terapia anticoagulante no está exenta de riesgos. A pesar de todo, el tratamiento principal de la FA es médico. Nuestro abordaje quirúrgico del problema en la Clínica Mayo se refiere en gran parte a los pacientes de cirugía cardíaca con FA asociada.

La intervención diseñada por el Dr. James Cox, conocida como intervención del laberinto *(Cox-maze),* se dirigió a desarrollar un laberinto de lesiones quirúrgicas que resultase en una vía única de propagación desde el nódulo sinusal al nodo AV. Los requerimientos son la ablación de las arritmias, la restauración de la sincronía AV y la preservación de la función de transporte auricular. En la Clínica Mayo hemos realizado más de 500 intervenciones según las incisiones clásicas complementadas con criolesiones en puntos específicos de ambas aurículas. El grupo más importante de pacientes es el de los que tienen cardiopatía valvular y FA asociada. En la Clínica Mayo hemos realizado un total de 443 intervenciones del laberinto entre 1993-2002, con 335 biauriculares, 99 derechas y 9 izquierdas. La mortalidad global fue 1,5%. Las edades oscilaron de 22-83 años. Un 70% de estas intervenciones se realizaron en pacientes con cardiopatía valvular y la mortalidad fue del 1%. La incidencia de FA en la hospitalización fue del 29%, con un 10% de implantaciones de marcapasos. A una media de 42 meses, se registró ausencia de FA en el 88% de los casos. Según análisis de Kaplan-Meier, la tasa de ausencia de FA fue del 90% a los 5 años y del 64% a los 10 años en pacientes con FA preoperatoria aislada, y del 68% a los 5 años y 41% a los 10 años en los pacientes con cirugía valvular y del laberinto asociadas. Uno de los grupos más beneficiados es el de los que presentan disfunción ventricular inducida por taquicardia, ya que la FE mejoró de 43 a 55% ($p < 0,05$). Los pacientes con cardiopatía congénita y FA también se pueden beneficiar de esta intervención.

Se dedican importantes recursos económicos al tratamiento de la FA con diversas fuentes de energía (crioablación, microondas, ultrasonidos y láser) y muy diversos dispositivos de elevado coste, ya que un transductor de ablación por radiofrecuencia cuesta en EE.UU. > 2.000 dólares. Según nuestra experiencia, los pacientes tratados con radiofrecuencia tuvieron 4,5 veces más posibilidades de estar en FA en el momento del alta y 5 veces más durante el seguimiento.

Hay varias conclusiones de nuestra experiencia: la intervención de Cox es segura, eficaz y eficiente en grupos seleccionados. En los pacientes con disfunción ventricular se aprecia mejoría de la función sistólica. En los pacientes con cardiopatía congénita y FA, es eficaz en la prevención de las arritmias tardías. Al asegurarse la transmuralidad, la intervención clásica del laberinto de Cox sigue siendo el patrón-oro en el tratamiento de la FA.

Atrial fibrillation affects 2.3 million people in the United States. The prevalence ranges from several percent during the 5th and 6th decade of life to as high as 10-15% in the 8th and 9th decade according to population studies such as the Framingham study and data from the Mayo Clinic. The economic burden is significant including the cost of medication, hospitalizations, invasive therapies and treatment of complications. Atrial fibrilla-

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tion has been shown to be an independent risk factor for death across all age groups. Atrial fibrillation clearly increases the risk of embolic stroke. The therapy of anticoagulation is not without risk as bleeding complications have been well documented, particularly in elderly patients. Despite these facts, atrial fibrillation remains primarily a medically managed disease. Our surgical approach to atrial fibrillation at the Mayo Clinic deals in large part with patients presenting for cardiac surgery with associated atrial fibrillation. The question we face is: "Should we address or not address the rhythm in conjunction with the planned cardiac surgical procedure?".

The unique surgical solution was developed by Dr. James Cox[1], now termed the "Cox-maze procedure". It has had several many iterations. The original concept was to develop a maze of surgical lesions resulting in a single path for electrical propagation from the sinoatrial node to the atrioventricular node[2]. Three requirements were considered for the surgical technique to be successful: 1) ablation of the arrhythmias; 2) restoration of atrial ventricular synchrony, and 3) preservation of atrial transport function. Two modifications to the original maze were made to minimize chronotropic insufficiency and mechanical dysfunction of the left atrium. The incisions around the sinoatrial node included in the Maze I resulted in chronotropic insufficiency during stress and exercise. Postoperative left atrial dysfunction also occurred as a result of interatrial conduction delay due to the incision across the dome of the atria in the Maze I and Maze II procedure. Modifications of these incisions resulted in the Cox-maze III procedure[3,4]. This is the procedure that we have performed more than 500 times at the Mayo Clinic. We prefer the standard "cut-and-sew" maze operation consisting of the set of lesions described by Cox with cryo-ablation lesions at specific points on both the left and the right atrium. We have instituted two small modifications. On the medial aspect of the right atrium, we avoid incision and apply a linear cryolesion from the cut edge of the appendage to the superior annulus of the tricuspid valve. This avoids cutting the branch of the right coronary artery to the sinoatrial node. We extend the left atrial encircling incision to the orifice of the left atrial appendage. The orifice of the appendage is then closed within the encircling incision. We believe that the advantage of the cut and sew method assures full thickness lesions particularly around the pulmonary veins, recognizing the importance of the pulmonary venous tissue as the originator of atrial fibrillation in many patients.

The largest group of patients undergoing the maze procedure in our series is patients with valvular disease and associated atrial fibrillation who require valve repair or replacement[5-7]. Elimination of the atrial fibrillation allows patients to remain free from chronic anticoagulation if the valve is repaired or a bioprosthesis is used. There are other groups we believe are appropriate candidates for a surgical maze. These include young patients with limiting symptoms, particularly those refractory to medical management. There are patients that prefer a definitive procedure in contrast to a lifetime of medications that have significant side effects. Some patients have a medical contraindication or a strong personal preference to avoid chronic anticoagulation. There is a small group of patients that have suffered a thromboembolic event while anticoagulated. We have also identified several unique groups of patients that may benefit from surgical treatment for atrial fibrillation; patients with left ventricular dysfunction in the setting of tachycardia-induced cardiomyopathy, and patients with congenital heart disease with right atrial dilatation and associated atrial arrhythmias.

A total of 443 maze procedures were performed at the Mayo Clinic during a 10-year period from 1993 to 2002. This included 335 bi-atrial mazes, 99 right atrial mazes, and 9 left atrial mazes. Overall mortality was 1.5%. Of those 335 patients undergoing a bi-atrial maze, the patients were nearly evenly split between those presenting with paroxysmal atrial fibrillation and those with chronic atrial fibrillation. The ages ranged from 22 to 83 years. Seventy percent of maze procedures were performed in patients with valvular heart disease with problems with atrial arrhythmias. Sixty-four percent were intolerant to their atrial arrhythmias. Approximately one-third of the patients had failure of medical treatment. Early mortality was 1%. During hospitalization, atrial fibrillation occurred transiently in 29%, 10% of patients required permanent pacemaker insertion. At a mean follow-up of 42 ± 6 months, the freedom from atrial fibrillation was 88%. By Kaplan-Meier analysis the freedom from atrial fibrillation was lower, 90% at 5 years and 64% at 10 years for patients with preoperative lone chronic atrial fibrillation, and 68% at 5 years and 41% at 10 years for patients with combined maze and valve surgery. Therefore, overall mortality has been very low when patients are selected carefully. The freedom from recurrent atrial fibrillation has been excellent in patients with pre-operative paroxysmal atrial fibrillation but substantially lower in patient presenting in with chronic atrial fibrillation. The freedom from atrial fibrillation in both groups exceeds results reported from catheter based ablative procedures.

As mentioned previously, one of the subgroups that we believe has significant benefit from the surgical maze procedure are those patients with tachycardia-induced

left ventricular dysfunction from atrial fibrillation[8,9]. Of 99 patients who had atrial fibrillation without associated valvular or congenital heart disease, 37 patients had decreased left ventricular function (preoperative ejection fraction 25-55%). Twenty- four patients exhibited symptoms of heart failure. At a mean follow-up of 42 months, only one patient was in atrial fibrillation. In patients with severe left ventricular dysfunction (ejection fraction < 35%) the ejection fraction had improved from 31 to 53%, $p = 0.01$. In patients with preoperative chronic atrial fibrillation the improvement in ejection fraction was from 43 to 55%, $p < 0.05$. The improvement were sustained from discharge to follow-up and correlated with an improvement in functional class. These data compare favorably with historical data in series of patients with decreased left ventricular function undergoing successful cardioversion[10,11]. We believe this is an important subgroup to consider surgical management of the rhythm as an adjunctive procedure to the definitive valve repair or replacement.

Patients with congenital heart disease with atrial arrhythmias and a dilated right atrium appear to benefit from a right-sided modified maze procedure[12]. These are patients with tricuspid valve disease or right-sided congenital heart disease; examples are Ebstein's anomaly[13] and an atrial septal defect. In our series, 99 of these procedures were performed in association with repair of the congenital heart disease. Atrial fibrillation occurred paroxysmally in 81%. The primary cardiac surgical procedures were tricuspid valve repair or replacement in 70 patients, atrial septal defect closure in 39 and pulmonary valve procedures in 18. At discharge 83% were free of atrial arrhythmias, 63% were in sinus rhythm. Early mortality was 6%. Of 83 known late survivors, 93% were free of atrial arrhythmias, 82 of 83 patients were in NYHA class I or II. Clearly maintenance of sinus rhythm contributes to continued good functional class in this subset of patients.

One of the primary impacts of atrial fibrillation surgery is to reduce the stroke rate. Indeed, in results from Washington University there was a markedly reduced risk of stroke in patients with atrial fibrillation undergoing a maze procedure compared to the other extreme of those with atrial fibrillation not undergoing a surgical maze procedure[14]. We have shown this to be true as well. However, there does not appear to be a survival advantage conferred by performing a maze in conjunction with a valve procedure. In an analysis done at Mayo, freedom from stroke or anticoagulant related bleeding was significantly less in patients undergoing a maze procedure compared to operative controls in atrial fibrillation at a mean follow-up of 6 years[6]. This has been confirmed by other groups[15].

There are significant economic resources being spent on research and development for alternative energy sources to perform maze procedures. These energy sources include cryo-thermal probes, radiofrequency probes (unipolar and bipolar), microwave probes, ultrasonic probes, and laser probes. All result in damage to the myocardial tissue, hopefully causing transmural scar, which does not conduct electricity. There are a plethora of devices that have been developed and even more lesion patterns. The goals of these new alternative energy sources are to provide a less invasive approach, shorten the operating time, and simplify the operation. There are several shortcomings compared to the standard cut-and-sew maze. The cost is high because most of the probes are disposable. For example, the cost of a bipolar radiofrequency ablation probe is > $2000 US dollars compared to $50 US dollar cost of the suture required for the cut-and-sew maze and the cryoprobes are reusable. There is local and regional tissue damage, which can be wider and deeper than the standard cut-and-sew method, particularly with unipolar devices which rely on time of application to control the depth of the lesion. The lesion patterns are often different than the Cox-maze III as the energy source delivery system often cannot be manipulated into position to perform the standard lesion set. This variation in lesions sets render the data presented difficult to interpret. We have utilized the bipolar radiofrequency ablation systems with our standardly place cryoablative lesions to perform the bi-atrial Cox-maze III lesions in 56 patients between January 2002 and February 2005. These patients were matched with patients who underwent the standard cut-and-sew method. Matched variables were gender (33 male, 23 female, both), age (67.5 *vs.* 67.2 years), NYHA class (mean 2.28 *vs.* 1.96), atrial fibrillation type (37 paroxysmal, 19 chronic, both), and concomitant mitral valve surgery (37 patients in both). When compared to the matched controls, fewer radiofrequency ablation patients were free from atrial fibrillation at dismissal (64 *vs.* 88%, $p = 0.0039$) and at last follow-up (72 *vs. 91%,* $p = 0.016$*).* Utilizing logistic regression for matched pairs, radiofrequency ablation patients were 4.5 times more likely to be in atrial fibrillation at dismissal (95% CI, 1.8, 10.9), and 5 times more likely to be in atrial fibrillation at follow-up (95% CI, 1.4, 17.3). No other covariate was associated with atrial fibrillation status at hospital dismissal or follow-up.

There are several conclusions that can be drawn from the recent data derived from our series of the surgical maze performed at the Mayo Clinic. The Cox-maze III procedure is safe, effective, and cost effective in selected low-risk patients with atrial fibrillation in association with valvular disease or other cardiac disease requiring surgical intervention. Other patients appropri-

ate for the surgical maze include those with medically refractory atrial fibrillation and contraindications to anticoagulation. These patients will continue to be the minority of patients referred for consideration of surgical arrhythmia therapy. In some patients, atrial fibrillation may be the cause rather than the consequence of left ventricular dysfunction. Systolic function and functional status can be significantly improved with the restoration of sinus rhythm by the maze procedure. The improvement in left ventricular function is similar to that observed with cardioversion and may be better than that achieved with atrial ventricular nodal ablation and pacing. In patients with atrial fibrillation associated with congenital heart disease, a right-sided maze performed in association with cardiac repair of the defect is effective in reducing late recurrent atrial arrhythmias. Improved long-term morbidity is proven in patients undergoing the Cox-maze procedure by reduction of stroke and anticoagulant related bleeding. However, there does not appear to be a significant survival advantage and care must be taken to select appropriate patients. Caution must be in embracing alternative energy sources for replacement of the cut-and-sewn lesions. Because transmurality can be assured, the standard cut-and-sew Cox-maze III procedure remains the gold standard for the surgical treatment of AF.

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