The Maze Procedure- A Surgical Intervention for Ablation of Atrial Fibrillation

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Abstract

Atrial fibrillation may be considered by some to be innocuous; however, the impact of atrial fibrillation can be substantial. Thromboembolic events and strokes are the number one cause of mortality and morbidity. For patients who do not respond to medical therapy for rate and rhythm control and or are unable to take medication to decrease the risk of a stroke or thromboembolic event, the maze procedure offers an alternative treatment intervention. The goal of this surgical procedure is to return the patient's heart rhythm back to normal sinus rhythm while off all anti arrhythmic medication. The following paper discusses the past and present state of the maze procedure as well as briefly addressing the care of the post operative maze patient.

Introduction

Atrial fibrillation is known as the most common of all clinically, sustained heart arrhythmias. According to recent published data, over 2.3 million people in the United States are presently affected with this arrhythmia; however, the prevalence rate is expected to increase to 5.6 million people by 2050[1]. The occurrence of atrial fibrillation is found to be associated with age, race and gender. The prevalence rate for atrial fibrillation for those under the age of 55 is noted to be 0.1% but for those over the age of 80 the prevalence rate is 9%. Caucasians over the age of 50 were affected at a higher rate than blacks and males have double the prevalence rate than females [1,2].

The impact of atrial fibrillation on society can be substantial. Stroke is the most significant complication. In 1978, results from the Framingham Heart Study indicated that atrial fibrillation was found to increase the risk of stroke.[3] Lin et al in 1996, using data drawn from the Framingham Heart Study, determined that atrial fibrillation was associated with more severe strokes.[4] In fact, ischemic strokes associated with atrial fibrillation were nearly twice as likely to be fatal, reoccur more frequently and leave patients with more functional deficits than strokes not associated with atrial fibrillation. [4,5] These findings were recently confirmed by The Centers for Disease Control (CDC, 2006) where they estimate that atrial fibrillation accounts for one-fourth of all strokes in the elderly.[6] Go et al estimate that atrial fibrillation increases the risk for ischemic stroke five fold and accounts for 15% of all strokes in the United States.[1] Furthermore, CDC has noted that the age adjusted death rates when atrial fibrillation is a contributing cause ranges from 13 to 37.9 deaths per 100,000 people living in the United States. [6]

Atrial fibrillation can also affect the quality of life, functional status and cardiac performance. The hemodynamic dysfunction created by the asynchronous rhythm of the heart can be manifested as chest pain, palpitations, dyspnea, fatigue and/or lightheadedness. This mileu of clinical symptoms can lead to easy fatigability and the inability to pursue the activities of daily living. [1,7, 8]

In recent years, the treatment for atrial fibrillation has rapidly evolved. The prior goals of treatment were the utilization of pharmacological agents to control ventricular response rate, prevent the formation of thrombus and reduce the risk for thromboembolic events. However, other interventional approaches have been developed recently to terminate this arrhythmia with the goal to return the patient to normal sinus rhythm. These new approaches include using radiofrequency waves to isolate and ablate the triggering areas around the pulmonary veins (pulmonary vein isolation) and a surgical approach using either the traditional method of cut and sew or radiofrequency and/or cryothermia to ablate the pathways of the arrhythmia (Maze procedure). [9] Currently, these new approaches are meeting with a success rate of 30%-90% dependent on type of procedure and atrial fibrillation (paroxysmal, persistent or permanent) with the surgical approach exceeding a 90% success rate when the full lesion set is applied.[9]

Maze Surgical Procedure

The maze surgical procedure was developed to address four goals: 1) abolishing atrial fibrillation macro re-entrant circuits and reestablishing sinus rhythm, 2) maintenance of A-V synchrony 3) restitution of atrial transport function and 4) elimination of the risk for thromboembolic event [10]. On September 25, 1987, Dr. James

Cox at Barnes Hospital in St. Louis, Missouri performed the first maze procedure. The first generation of the maze procedure involved cutting and sewing ablation incisions to interrupt all macro re-entrant circuits in the atria. The purpose was to allow the sino-atria (SA) node to resume normal activity following surgery and direct the propagation of the sinus impulse through the atria [11, 12]. However, the first generation procedure had two issues: the inability of the patient to generate an increased heart rate in response to exercise and left atrial delay.

Due to these issues, the Maze procedure was modified. The first modification, Maze II procedure, moved the ablation lines further away from the SA node. However, the Maze II was still technically challenging so was further modified to be less technically demanding into what is known today as the Maze III procedure. [13, 14] The Maze III procedure has met with great success as reported by Damiano RJ, etal. [15, 16] The Maze III procedure has shown a significant reduction in cerebrovascular accidents and transient ischemic events due to the high success rate in ablating atrial fibrillation and the amputation of the left atrial appendage as well as fewer pacemaker implantation and improved atrial transport and sinus node function. [13, 14]

However, even with the remarkable success of the procedure, it was not widely adopted by the medical community due in part to its surgical complexity, invasiveness (median sternotomy with division of the sternum) and increased time on cardiopulmonary bypass. Therefore, many physicians sought less invasive and simpler approaches to treat this extremely common arrhythmia. Thus, over the past decade percutaneous catheter ablation performed by cardiologists was introduced and met with moderate success especially for patients with a history of paroxysmal atrial fibrillation, in need of AV

nodal ablation or ablation of atrial flutter in the right atrium. However, procedures in the left atrium, namely pulmonary vein isolation, met with less success and led to possible lethal complications (pulmonary vein stenosis). [9, 14]

However, through continued research efforts, better understanding has emerged of atrial fibrillation induced atrial remodeling and the electrophysiological basis for atrial fibrillation. [17, 18, 19, 20] These findings combined with efforts to address the complexities of the surgical ablation approach have led to another modification of the maze procedure. The new modified procedure, Maze IV, replaces most of the prior incisions with linear ablation lines using newer and easier technologies which include: radiofrequency energy, cryothermy energy and microwave energy. In addition, the ablation lines around the pulmonary veins changed from a box set to a pair set. These changes in technologies and lesion sets reduced the time required to make the lesion set which has lead to shorter operative times and less morbidity. In addition, a full maze procedure can now be performed through a minimally invasive approach (mini-thoracotomy). Furthermore, surgical pulmonary vein isolation can be performed off cardiopulmonary bypass for the group of patients who meet the criteria that their left atrium is less than 5 centimeters and they are experiencing only paroxysmal atrial fibrillation. These recent advances allow more patients to be referred for surgical ablation for lone atrial fibrillation. [21, 22, 23, 24] See Figures1-9

Care of the Maze Surgical Patient

With the increased understanding of atrial fibrillation and the changes in the surgical approach, the care of the maze patient has also evolved. The immediate clinical goal for the post surgery maze patient is stabilization of the patient in the intensive care

unit following established protocols. However, the care of the maze patient also requires the administration of several additional medications unless otherwise contraindicated. These medications include: spironolactone, furosemide, warfarin, metropolol and Cordarone (Figure 10).

Spironolactone and furosemide are ordered to address one of the most frequent complications in the immediate post operative maze patient, excessive fluid retention which has a reported incidence as high as 40%. [25] Severe fluid retention may result in pulmonary edema and symptomatic pleural effusion. The mechanism for the excessive fluid retention is thought to be due to increased plasma argine vasopressin, aldosterone and atrial natriuretic peptide levels secondary to a temporary lack of response of the atrial baroreceptors. The use of spironolactone and lasix help to blunt the response from these hormones.[26] The patients are to continue to take furosemide for 4 weeks and spironolactone for 6 weeks after hospital discharge with instructions to weigh themselves daily, to stop the furosemide if their weight decreases by eight pounds and to have their Na+ and K+ levels monitored closely. Our experience has shown that only 20% of patients need the full 4 weeks of Lasix treatment whereas 80% of our patients require spironolactone for the full 6 weeks.

Cordarone and metropolol are ordered for all cardiac surgery patients for the prevention of post operative atrial fibrillation. The cause of atrial fibrillation after cardiac surgery is still being debated; however, postoperative complications experienced include increased risk of stroke and hemodynamic instability which leads to increased additional treatments, prolonged hospital stay and costs. [27] A recent meta analysis of nineteen studies reported the use of class III anti- arrythmics (Cordarone) decreases the incident to

atrial fibrillation, ventricular tachyarrythnmias strokes and length of stay postoperatively. The mechanism of action for these results occur due to the medications blockade of the sodium channels in the myocardial cell thus slowing the myocardial cell action potential and refractory period. [28] In a recent comparison trial between oral anti-arrhythmic drugs used to prevent atrial fibrillation after cardiac surgery (SPPAF), the investigators reported the use of a class III anti- arrhythmic plus metropolol reduced the rate of atrial fibrillation after cardiac surgery. [29] Routine cardiac surgery patients are maintained on these medications for 10 days after their discharge unless there are contraindications. However, due to the extensive artial remodeling that can occur after the maze procedure, maze surgery patients continue to be at high risk for the redevelopment of atrial fibrillation so these medications are prescribed for at least the first three months after surgery unless contraindicated.

Warfarin (coumadin) is an anti coagulant medication that is usually ordered for all patients who have an atrial arrhythmia. Warfarin's mechanism of action is to interfere with the vitamin K dependent clotting factors II,VII,IX and X leading to their depletion. However, in the maze procedure the left atrial appendage, the area where most clots are formed while experiencing atrial fibrillation, is removed from circulation either by oversewing or disarticulating the left atrial appendage thus reducing the chance of a thromboembolic event and the need for Warfarin after the first three months. [30]

Furthermore, for patients who do not convert to NSR after surgery, electrical cardioversion should be offered. Our policy is for a patient to have had at least 2 different antiarrythmic drug regimens and three different attempts at cardioversion before the stating that the maze procedure failed.

Conclusion

       The advent of the maze procedure has given alternative treatment options for patients whose atrial fibrillation has been medically refractory to prior interventions. However, the additional medication requirements for all maze patients, verification of patients' rhythm status after discharge and once medications have been stopped and consideration for electrical cardioversion for those patients who do not convert to NSR after the maze procedure, require an extensive follow up late into the postoperative course to enhance the success rate. This extensive follow up to determine the success of the maze procedure will require a dedicated team effort.

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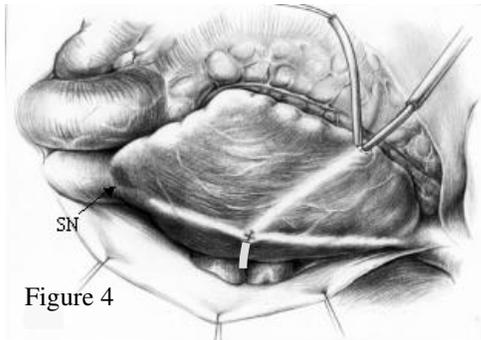
<u>Right Atrial Lesions</u>

Figure 1
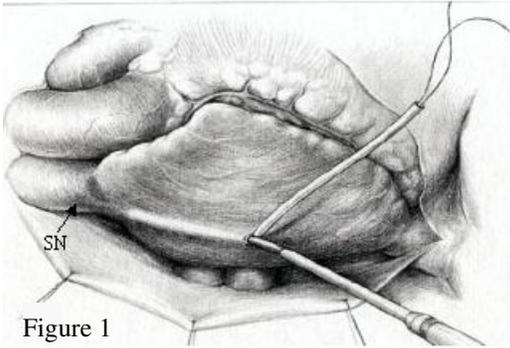
A purse-string suture is placed in the posterior-lateral right atrium and a linear cryoprobe is inserted through the purse-string into the inside of the right atrium. A cryolesion is placed in a cephalad direction into the postero-lateral aspect of the superior vena cava (SVC) orifice and away from the SA node (Figure 1).
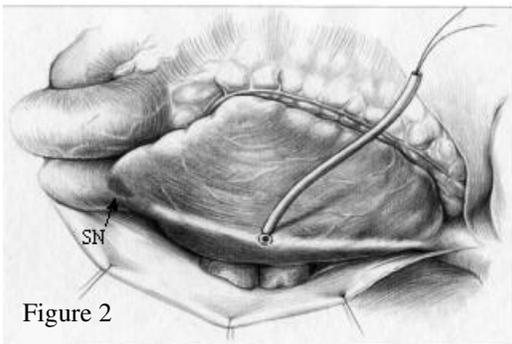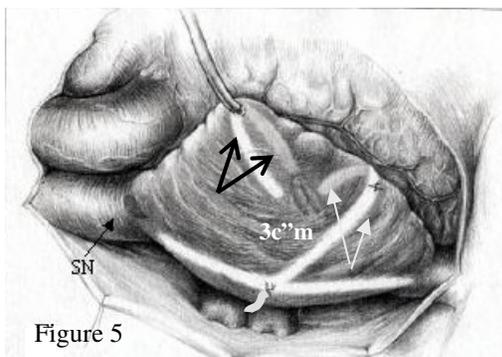

Figure 2

Using the same purse-string suture, a second cryolesion is placed into the orifice of the inferior vena cava (IVC) to complete the longitudinal lesion from the SVC to the IVC (Figure 2).
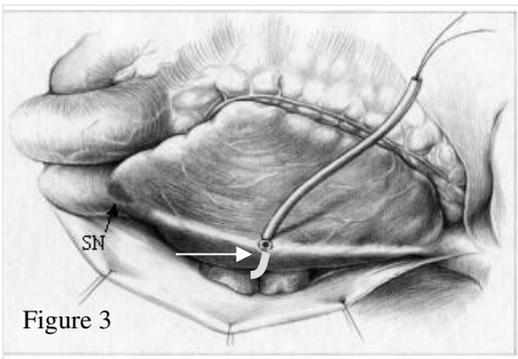
Figure 3

Through the same purse-string a third lesion is made along the lateral wall of the right atrium down to inter-atrial septum and the right pulmonary veins is placed (Figure 3-closed arrow).


Figure 4

The first purse-string suture is tied and a second purse-string is placed near the AV groove of the free-wall of the right atrium. The cryoprobe is inserted through this second purse-string suture to create the linear "T" lesion across the lower right atrium (Figure 4).


Figure 5

Using the same purse-string suture, the cryolesion is extended down to the level of the tricuspid valve annulus at the junction of the anterior and posterior commissures (Figure 4 and 5 – closed white arrows).The second purse-string suture is then tied and a third purse-string suture is placed in the right atrial appendage. A lateral right atrial cryolesion is placed from the tip of the atrial appendage towards the previously placed "T" lesion, leaving at least 3 cm between its tip and the "T" cryolesion. Using the same purse-string suture in the right atrial appendage, a cryolesion is placed from the appendage down to the antero-medial tricuspid valve annulus at the septal commissure (Figure 5 – open arrows).

Left Atrial Lesions

Figure 6
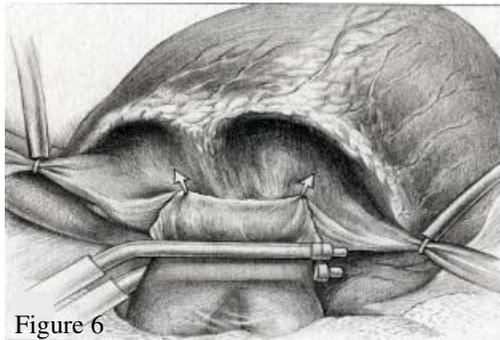
The inter-atrial groove is dissected completely and the right superior and right inferior pulmonary veins are dissected free circumferentially. One linear cryoprobe is placed posterior to the right pulmonary veins as they enter the left atrium. A second identical cryoprobe is placed on the anterior surface of the veins in the same plane. The cryoprobes are then "squeezed" together firmly and two-minute cryolesion is created by freezing with both probes. This result is a transmural cryolesion around the orifices of the right pulmonary veins. A left ventricular vent is placed via the right superior pulmonary vein (Figure 6).
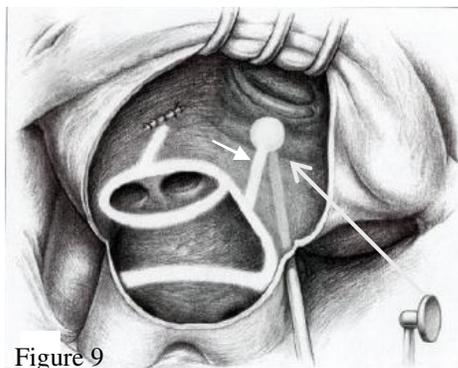

Figure 7
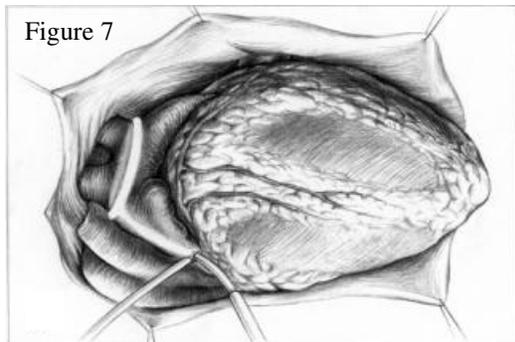
The ventricular apex is then retracted in a cephalad direction out of the pericardium using the left hand to expose the intra-pericardial segments of both left pulmonary veins. After minimal dissection around the left pulmonary veins, the two cryoprobes are "clamped" around both left pulmonary veins as they enter the left atrium posteriorly and cryothermia is applied to both probes. The result is a circumferential, transmural cryolesion around the orifices of the left pulmonary

veins. A purse-string suture is then placed in the tip of the left atrial appendage and a linear cryoprobe is inserted inside the atrial appendage with its tip placed into the orifice of the left superior pulmonary vein to create a linear lesion. The cryoprobe is then withdrawn and the left atrial appendage is excluded from the rest of the left atrium by stapling or suturing the base of the appendage from the outside (Figure 7).

Figure 8
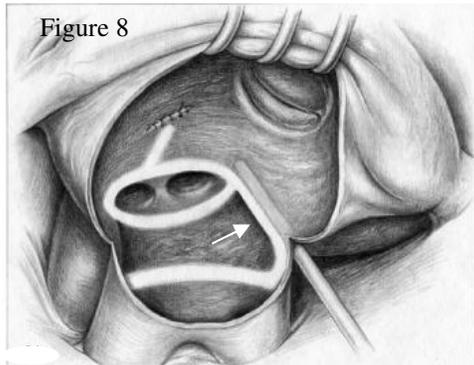
A standard left atriotomy is performed after placement of the aortic cross clamp and instituting cardioplegic arrest. A lesion connecting the inferior right and left inferior pulmonary veins is performed using the linear cryoprobe (Figure 8). As mentioned, epicardial pulmonary vein isolation can be replaced by endocardial box lesion to isolate all four pulmonary veins, it is then when the left atrial appendage is over sawn from the inside.

Figure 9

Creating a lesion from the pulmonary veins connecting line down to the posterior mitral valve annulus with the linear cryoprobe and ablation of the coronary sinus with the 15mm right angle probe concludes the procedure (Figure 9 - arrows). Cryoablation of the coronary sinus is performed on the epicardial surface (open arrow).
This technique decreases the aortic cross-clamp time by reducing the number of cryolesions that are necessary after opening the left atrium to three for those that are marked with arrows in figures 8-9.

Figure 10: Patient Management Post Maze procedure

Preoperative:
1) Keep antiarrhythmic drug (AAD) treatment without any change
2) Coumadin / Heparin – Patients should be switched to IV Heparin from Coumadin

Operative:
1) Very careful with O_2 in patients with therapeutic levels of Amiodarone
2) TEE to rule out LA thrombus or PFO if attempting to perform the procedures or part of it off-bypass
3) CPB weaning – Avoid B_1 agonists if possible

Postoperative:

- *Antiarrhythmic Therapy*
1. No AAD if patient in Nodal/Slow Sinus Rhythm (resume when patient regain NSR of 65-70bpm)
2. Maintain K+>4 and Mg+>2 at all time
3. AAD of choice Amiodarone (Prevention and treatment)

Treatment of Post operative AF:
1. If AF relapses – Attempt rate control with IV Verapamil 5 mg followed Amiodarone Load (IV followed by PO) or may follow the Cardiazem Protocol as outlined in the Guideline for the Prevention and Treatment of Atrial Fibrillation. Then PO Amiodarone 400mg BID for 5 days, followed by 200 BID for 5 days and 200mg QD.
   - Unstable patients or patients in whom rate control was not achieved should be electrically cardioverted.
2. Other AAD choices are:
   - Betapace (Sotalol)
   - Pronestyl+Digoxin

- *Nodal rhythm management*
1. NO AAD!
2. Atrial ECG every day
3. A-paced
4. Diuresis (aggressive)
5. PPM not before postoperative day 7

- *Diuretics*
1. Aggressive especially in patients with longstanding AF and large atria
   - IV Lasix (if patients urine output <1.5 cc/kg/min) first 24-36 hours (Do not use Dopamine)

- IV Lasix 40 mg BID for 48 hours
- PO Lasix 40 mg BID for 2 weeks
- PO Lasix 20 mg BID for 2 weeks
- PO Aldactone 25 QD for <75kg and 50 QD for the rest. (maintain for 6 weeks)
- Weight monitoring following stopping diuresis
- Patients should be instructed to stop the Lasix in case of 8 pounds decrease in body weight

- ***Anticoagulation.***
1. Patients with indications other then the Maze procedure – for life
2. All other patients for 3 months, unless have documented arrhythmia and or LA smoke (by echo), these patient should be kept on coumadin until the problems have resolved.

AF prevention and Follow-up post discharge

1. All maze patients should be discharged with AAD for 3 months
2. The drug of choice is Amiodarone
3. Consider Cardioversion 2-3 wks. Postop, if the patient was discharged in AF.
4. If the patient has a relapse of their atrial fibrillation, they should be evaluated for cardioversion and changed to another AAD. Continuation of the AAD should then continue for at least 6 months.
5. All patients should have holter monitoring at 4 to 6 weeks after AAD discontinuation for documentation of NSR.