The Heart Surgery Forum #2001-98765
4 (4):340–345, 2001

Online address: www.hsforum.com/vol4/issue4/2001-98765.html

The Electrocautery Maze – How I Do It

(#2001-98765 … August 23, 2001)

Prasanna Simha M, P. S. Seetharama Bhat, N. Prabhudeva

Sri Jayadeva Institute of Cardiology, Bangalore, India

Dr. Simha

ABSTRACT

Background: The Cox Maze III procedure is the standard operation for the surgical cure of atrial fibrillation. Its wide spread use is limited by the extensive nature of the procedure. The surgical diathermy device is a radio frequency generator and can be used to create surgical lesions, which cause interruption of the basic flutter cycle that initiates/maintains atrial fibrillation.

Methods: We describe the initial results in 25 cases where we used an ordinary surgical diathermy unit to create bi-atrial lesions creating an electrocautery maze during concomitant mitral valve surgery.

Results: There was a 96% conversion to sinus rhythm. This has remained stable over a follow-up of a mean of 3.5 years. There has been an associated return of left atrial transport function and a significant reduction in left atrial size.

Conclusion: The electrocautery maze appears to be a simple, effective, and quick method to cure atrial fibrillation.

INTRODUCTION

The Cox Maze III procedure is the standard benchmark for atrial fibrillation surgery [Cox 1995]. It has the highest reported conversion rate to sinus rhythm with re-establishment of atrial transport function [Cox 2000]. The major reason for its limited use is the extensive nature of the procedure and the multiple suture lines giving rise to possible troublesome bleeding apart from the increase in cross clamp time.

Radio frequency current has been used to create lesions in the heart and has been used in electrophysiology labs to create transmural burns. A diathermy unit is a radio frequency generator and initiates hemostasis by thermal energy dissipation. The cut and suture technique in the Cox Maze is primarily a method to enforce a blockade of the electrical wavefront [Cox 1991]. We describe here a method using the creation of lesions by an ordinary unipolar surgical diathermy unit for creating linear lesions akin to the Cox Maze procedure to create a pathway to break the basic flutter cycle. The method described obviates the necessity of extensive surgical expertise, cryoprobes or radio frequency catheters. We hope that this simple technique will make the procedure a simpler one to adapt without additional costs and equipment. The paper describes our initial experience in the first 25 cases and their intermediate term follow up.

Submitted August 17, 2001; accepted August 23, 2001.

Address correspondence and reprint requests to: Dr Prasanna Simha M, No 33 "Shri", Between 2 and 3 cross, Sampige road, Malleswaram, Bangalore 560 003, India, Phone: (91) (80) 3364618, Email: psimha@satyam.net.in

MATERIALS AND METHODS

Patients with chronic atrial fibrillation (greater than six months) and left atrial size greater than 5.5 cms with associated mitral valve disease were selected. Left atrial size was measured on the transthoracic echocardiogram at the time of aortic valve closure in the M-mode echocardiogram in the parasternal long axis view. Patients received mitral valve surgery (repair/commisurotomy/replacement), with concomitant tricuspid or aortic surgery being performed (Tables 1 and 2, ◉). The cautery maze procedure was performed on them as described below.

All patients were placed on conventional cardiopulmonary bypass (CPB) with bicaval venous cannulation (SVC cannula being passed through the right atrial appendage) and ascending aortic cannulation. On total CPB, a trial of cardioversion (in patients who did not have left atrial clot) was made and all patients who did not cardiovert were included as members for the study. Twenty-five such patients were selected. On normothermic bypass with the non cross-clamped perfused beating heart, the right atrium was opened. The initial cautery lesions were placed using the "spray mode" of an ordinary cautery pencil connected to a diathermy machine (Valley Lab Force 40 S™ Valleylab, Inc., CO or Excalibur Plus PC™, Conmed Corp., NY) set at 40 watts and using the coagulation – spray setting. The output waveforms were as follows:

Valleylab Force 40 S™ – 500 kHz damped sinusoidal bursts with a repetition frequency of 31.25 kHz, rated load of 300 ohms and power output being 40 watts.

Conmed Excalibur Plus PC™ – 540 kHz damped sinusoidal bursts with a repetition frequency of 20 kHz, a rated load of 500 ohms and power output being 40 watts.

The theoretical energy delivery is approximately 40 Joules for every second of cauterization.

Lesions were created by slow progression of the pencil such that the tissue blanched when the cautery arc was moved against the tissue.

Table 1. Table showing the preoperative profile of the selected cases.

Preoperative profile		
Mitral stenosis (MS)	4	16.00%
mitral stenosis + tricuspid regurgitation (TR)	4	16.00%
Mitral regurgitation (MR)	3	12.00%
MS + MR +TR	9	36.00%
MS + MR + Aortic Stenosis +TR	3	12.00%
MS + Aortic regurgitation (AR) + TR	1	4.00%
MR + AR +TR	1	4.00%
LA appendage clot	4	16.00%
LA appendage + body clot	4	16.00%
LA size (mean)	7.0 cm	5.5 - 8.2 cms

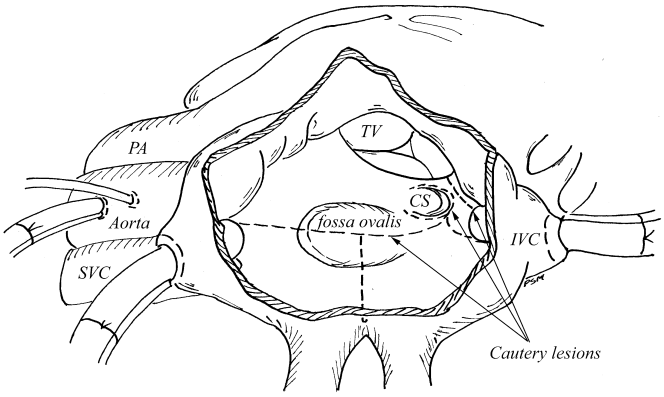

Figure 1. Figure showing the electrocautery lesions placed via a right atriotomy. (CS - coronary sinus, TV - Tricuspid valve and PA - Pulmonary artery)

The right atrial lesions were as follows:

1. From the posterior wall of the SVC – RA Junction (just caudal to the level of the SA node), down across the fossa ovalis to the IVC cannula veering towards the mouth of the coronary sinus and burning the inferior mouth of the coronary sinus including as much of the ostium as possible (Figure 1, ◎).
2. From the IVC burning the atrial isthmus and proceeding to the tricuspid valve orifice at 5 o'clock (Figure 1, ◎).
3. From the middle of lesion 1 laterally towards the atrial wall, burning the atrial "Crista" and proceeding further laterally to meet the atriotomy (Figure 1, ◎). The right sided lesions are performed on the beating perfused heart primarily to see the effect of ablation on the right side. Nearly 60% of cases revert to sinus rhythm or develop a slowing of the heart rate and intermittent P wave formation. The lesion at the coronary ostium can be precisely placed and thus heart blocks can be avoided.
4. From the superior end of the atriotomy to the right atrial appendage stopping at the cannulation orifice and then restarting at the diametrically opposite point and continuing the lesion towards the dome of the left atrium. While placing this lesion, care must be taken to specifically search for the sinus node artery and the interrupt the cautery lesion for 3 mm on either side of the artery.

Table 2. Table showing the concomitant procedures performed along with the cautery maze.

Procedures	
open mitral valvotomy (OMV)	4
OMV + Tricuspid annuloplasty	4
mitral valve repair	3
mitral + tricuspid (TV) valve repair	8
mitral valve replacement + TV repair	1
mitral + aortic + TV repair	1
mitral + aortic valve replacement+ TV repair	4
Total	25

The yellow fat pad indicating the area of the sinus node should be assiduously searched for and avoided during the placement of all lesions (Figure 2, ◎).

The retrograde cannula is placed back into the coronary sinus. Any tricuspid procedure that has been planned is performed. The atriotomy is closed and the heart is arrested with antegrade cold blood cardioplegia. During this period, if there is no left atrial thrombus, the left atrium is ligated externally with a silk/linen ligature.

The left atriotomy is done after dissecting the interatrial (Sondergaard's) groove extensively (vertical left atriotomy). Any left atrial thrombus is evacuated and all lamellar thrombus in the atrial body is assiduously evacuated. The mitral valve procedure is performed. (Table 2 lists the procedures done in addition to the cautery maze.) If the left atrial appendage has not been ligated previously, it is now ligated externally.

The cautery lesions are placed while controlled warm retrograde normokalemic reperfusion is being done. The lesions are placed circumferentially at one centimeter from the pulmonary vein orifices. A lesion touching each of the previous lesions and the mitral annulus at 5 o'clock connects all four lesions. (On a practical basis, if the gap between the left superior and inferior pulmonary vein is small, a common lesion can encircle both pulmonary veins). A lesion is placed from this outer lesion to the ligated left atrial appendage. In giant left atria with atrial diameter more than 7 cms, an optional cruciate lesion is placed within the circum-pulmonary vein lesion (Figure 3, ◎).

The left atriotomy is then closed. The heart is de-aired and the patient is weaned off CPB in the routine manner.

Transesophageal echocardiography was done routinely in all the patients. Atrial and ventricular wires were placed in all patients. Care was taken to place the atrial wires as high as possible to enable sinus node recovery time studies.

Patients who were in sinus rhythm were put on an infusion of amiadorone (10 mg/Kg/24 hours) and then an oral amiadorone 200 mg/day for three months, and then stopped.

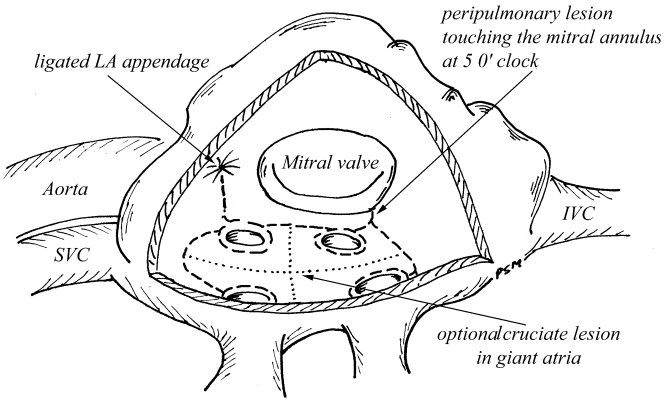

Figure 2: Figure showing the epicardial lesions placed on the surface of the right and left atrium.

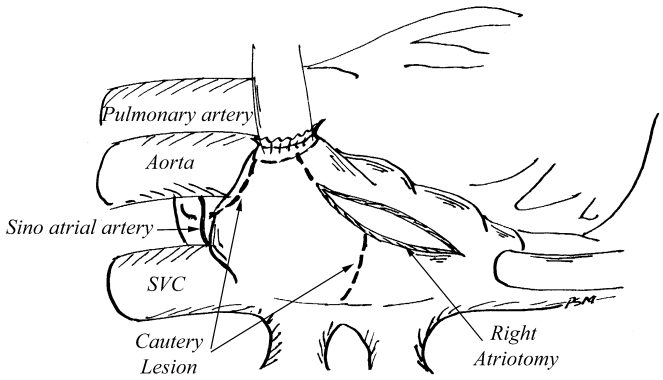

Figure 3: Figure showing the electrocautery lesions placed via a left atriotomy.

Patients who had nodal rhythm were given intravenous aminophylline (18 mg/Kg/24 hours) with an initial 200-mg bolus on CPB, if there was nodal rhythm, and temporary atrioventricular pacing was instituted as and when required.

All patients underwent 24 hour Holter monitoring before discharge (postoperative day 10). All the converters had 24-hour Holter monitoring and were labeled as successful converters if they had no atrial fibrillation episodes lasting for more than 30 seconds in a 24-hour monitoring period.

All patients underwent intra-operative transesophageal echocardiography and transthoracic echocardiography postoperatively to evaluate atrial transport function predischarge and at three and six months and yearly thereafter. Transmitral flow velocities were measured with pulse Doppler echocardiography with a sample volume positioned at the level of the mitral tips in apical four chamber view using a Sonos 1500 (Hewlett Packard, Andover, MA) echocardiography machine for peri-operative TEE and Sonos 2500 (Hewlett Packard, Andover, MA) echocardiography machine for postoperative echocardiograms. Effective left atrial transport function was considered to have returned if there was an "A" wave on the trans mitral Doppler with a velocity of more than 40 cm/sec.

The first 10 patients also had sinus node recovery time (SNRT) studies done. The normal limit for SNRT was taken as 1,400 milliseconds and the corrected SNRT value (CSNRT) was considered normal if less than 525 milliseconds [Narula 1972].

All patients who were not on coumadin for valve replacement (i.e., repairs) were placed on 150-mg enteric-coated aspirin life long.

Statistical analysis was done using the Epi Info 2000 (Ver 1.0.3) statistical package [Dean 2000]. Paired observations (LA size) were analyzed with the paired "t" test. All confidence intervals were set at 95%.

RESULTS

The mean follow up of the patients is 3.5 years (range = 3.2 – 3.8 years).

Electrical sinus rhythm

Twenty-four of 25 (96%) patients converted to electrical sinus rhythm on the table. One patient had nodal rhythm on release of the cross clamp but converted to sinus rhythm on giving a bolus of aminophylline on CPB. One patient who was in sinus rhythm initially slipped into atrial fibrillation on postoperative day four and subsequently reverted to sinus rhythm spontaneously on day eight and remained in sinus rhythm thereafter.

One patient did not convert to sinus rhythm, but persisted to have a controlled rate without the need of additional pharmacological agents

The first 10 patients (all converters) had SNRT studies done. All of them had normal SNRT/CSNRT values.

All 24 converters had successful conversion to sinus rhythm on Holter monitoring and transient atrial fibrillation did not exceed five seconds in any patient.

None of the patients needed insertion of a permanent pacemaker.

Atrial Transport Function

All converters (24/24) had return of right atrial transport function on table. This persisted post operatively. Twenty (83.33%) patients had a return of left atrial transport function on table. An additional three patients had return of left atrial function by postoperative day 10. The remaining patient had return of atrial transport function on the third month transthoracic echocardiogram. This was the patient who had transient postoperative atrial fibrillation. Thus, by the third month all converters had return of left atrial transport function. The mean left atrial "A" wave velocity was 71.8 cms/sec (Standard deviation (SD) = 17.4 cm/sec) (Table 3, ◎). The above changes have persisted on follow up.

Left Atrial size

The mean preoperative left atrial (LA) size was 7.0 cms (SD = 0.75 cm). This reduced to a mean size of 4.3 cm (SD = 0.45 cm) at three months. This reduction in LA size was statistically significant (mean change in LA size = 2.65 cm, SD = 0.62 cm and $p < 0.001$) (Table 3, ◎). This may be due to cor-

Table 3. Table showing the postoperative profile of the patients.

Postoperative profile		
Converters	24/25	96.00%
LA size postoperative (3 months)	4.3 cm	3.8 - 5.3 cm.
Left atrial "A" wave velocity (mean)	71.8 cm/sec	42 - 104 cm/sec

rection of the mitral lesion and efficient atrial emptying. This reduction in atrial size was achieved without any atrial tailoring/resection.

The single non-converter did not return to sinus rhythm but has a controlled rate and does not require additional rate controlling drugs.

Thromboembolism

None of the 24 converters has suffered a thromboembolic episode. The single non-converter has also not suffered from a thromboembolic episode.

The average time taken to perform the electrocautery maze was three minutes. The right atrial lesions were performed on a beating perfused heart on total cardiopulmonary bypass and atrial closure was done during cardioplegia delivery. The left atrial lesions were conveniently made during the period of controlled warm normokalemic retrograde reperfusion. Thus, there was no significant increase in the cross clamp/ischemic time.

None of the patients had fluid retention in the postoperative period necessitating diuretic therapy.

DISCUSSION

Atrial fibrillation has been a major problem in cardiac surgery. Apart from the subjective sensation of an irregular heart beat, the thromboembolic potential and the loss of atrial boost can be detrimental. The loss of the atrial boost may be of great consequence post CPB. Every surgeon has faced a situation of atrial fibrillation with fast ventricular rate in low output where any form of rate control compromises hemodynamics and inotropes only seem to worsen the situation. An uncontrolled rate can also predispose to tachycardia induced myopathy.

The Cox Maze procedure seems to be the best procedure for restoring sinus rhythm and atrial function. Its wide spread use is limited by the perceived complexity of the procedure and the time taken to perform the procedure especially when associated with complex intracardiac procedures. A simplified procedure using the basic "Maze" principle would be useful.

Historically, radio frequency ablation performed by electrophysiologists were first done using the regular cautery (diathermy) machines "borrowed" from the operating room [Shoei 1991]. Surgeons had previously used radio frequency energy (electro-coagulation) intra-operatively to ablate a localized area of the right ventricle in a patient with incessant ventricular tachycardia [Petitier 1971]. Further refinements in these machines were primarily made to estimate the precise amount of energy delivered, duration of energy delivery, along with methods to cool/limit heating of the catheters as these ablations were being performed in a blood filled heart without any cardiac support. Electrocautery using microbipolar forceps and cryo probes has been described [Patwardhan 1997]. The lower rate of conversion (75%) may be due to the inability of the bipolar forceps to create a varied spectrum of lesions as dictated by local atrial anatomy. This may prevent the creation of a complete maze. The procedure, which we have described, uses exclusively a monopolar cautery and no cryo-lesions.

Cardiopulmonary bypass and direct visualization permits direct assessment of the induced lesion. Direct damage to blood elements and tissue explosion is avoided when the cavity is devoid of blood. We believe that using the same radio frequency generator of yore in an open-heart setting could provide an adequate method to create radio frequency lesions precisely and thus perform an electrocautery maze. This equipment is available in every cardiac surgical operating room and permits easy application without the necessity of any other additional equipment and catheters. It has been quick, easy to perform, and reproducible in our hands. It has eased perioperative management and permitted atrial fibrillation correction even after complex valve reparative procedures without prolonging CPB time significantly.

The striking reduction in atrial size and efficient atrial transport achieved may have been due to effective reduction in atrial pressure and efficient atrial emptying. Reduction in atrial size would also improve long term posterobasal ventricular function. This was achieved without any atrial tailoring procedures. Various surgeons have performed atrial reduction surgeries in an attempt to create a peri-pulmonary venous disconnection and reduce the atrial tissue volume and thus the substrate for atrial fibrillation [Batista 1995, Winlaw 1998]. We believe that efficient return of sinus rhythm begets sinus rhythm. This causes a return of atrial size if the atrial pressure is normalized.

We believe that since we only ligated the atrial appendages and did not excise them, there may have been less alteration in the levels of atrial natriuretic hormone. This may have prevented accumulation of fluid postoperatively.

This study is limited by its non-comparative and non-blinded nature.

REFERENCES

1. Batista RJV. Retrograde warm blood cardioplegia for difficult cardiac surgical problems (heart autotransplantation). Warm heart surgery (Edward Arnold, London, 112-8, 1995).
2. Cox JL. Surgical treatment of atrial fibrillation. IV: Surgical technique. J Thorac Cardiovasc Surg 101:584-92, 1991
3. Cox JL, Boineau JP, Schuessler RB, et al. Modification of the maze procedure for atrial flutter and atrial fibrillation. I. Rationale and surgical results; J Thorac Cardiovasc Surg 110:473-84, 1995.
4. Cox JL, Ad N, Palazzo T, et al. Current status of the Maze procedure for the treatment of atrial fibrillation. Semin Thorac Cardiovasc Surg 12:15-9, 2000.
5. Dean AG, Arner TG, Sangam S, et al. Epi Info 2000, a database and statistics program for public health professionals for use on Windows 95, 98, NT, and 2000 computers. Centers for Disease

Control and Prevention, Atlanta, GA, 2000.
6. Narula OS, Samet P, Javier RP. Significance of the sinus node recovery time. Circulation 45:140, 1972.
7. Patwardhan AM, Dave HH, Tamhane AA, et al. Intraoperative radio frequency microbipolar coagulation to replace incisions of Maze III procedure for correcting atrial fibrillation in patients with rheumatic valvular disease. Eur J Cardiothorac Surg 12:627-33, 1997.
8. Petitier H, Polu J.M, Dorlinet B, et al; Tachycardie ventriculaire irreductible traitment par electrocoagulation apres localisation du foyer. Arch Mal Coeur 64:331, 1971.
9. Shoei K, Stephen H, Anna RG, Michael AL, Michael ER, Grace DG, Ronal S. Comparison of catheter ablation using radio frequency versus direct current energy: biophysical, electro-physiological and pathological observation. (JACC, Vol 18, No 4, 1091 – 7, 1991).
10. Winlaw DS, Farnsworth AE, Macdonald, et al. Left atrial reduction: the forgotten Batista. Lancet 351:879-80, Mar 21, 1998.

REVIEW AND COMMENTARY

1. Editorial Board Member SG14 writes:

The authors mention a significant reduction of atrial size. Is it only due to increased atrial function or is it also related to the suturing technique while closing the atrial? Is there a difference in atrial size between early postoperative and after three months?

Author's Response by Prasanna Simha:

We did not do any atrial tailoring procedures. The technique of going through the dissected Sondergaard's groove is unlikely to reduce atrial size. There was some reduction in size at post operative day 10 (statistically insignificant), but by the third month reduction in atrial size was statistically significant.

2. Editorial Board Member L023 writes:

This is an interesting study on use of "diathermy" machines to produce radio frequency transmural thermal burns in the atria. However, it should be put into perspective in terms of the potential risks of using these machines as opposed to machines with feedback mechanisms.

a) No data is provided as to whether transmural thermal injuries were created.
b) Spontaneous cardioversion of pre-operative rhythm is not uncommon following mitral valve surgery at the time of hospital discharge. However, at one-year follow-up, as few as 21% of patients originally in atrial fibrillation remain in sinus rhythm. The 96% maintenance of sinus rhythm at three-year follow-up are therefore good results. How many of these patients are still on amiodarone at this time?
c) The principle of radio frequency energy ablation is to produce a confluent transmural linear line of cellular death by raising tissue temperature to greater than 55°C thereby, similar to a surgical incision, preventing electrical conduction. The reason for the development of specific radio frequency generators for this procedures has been to build in feed back control systems in order to monitor and control the energy delivered - thereby ensuring a fully transmural lesion without a risk of perforation. This "diathermy" method has no monitoring at all. How do the authors ensure that a fully transmural lesion has occurred, as surface endocardial blanching does not indicate a similar temperature on the epicardial surface? Have the authors done any trials to determine that full thickness transmural lesions occurred?
d) The authors' statement that the entire procedure took approximately three minutes for presumably all thermal lines to be made is fairly rapid, suggesting that the "pencil" is moved extremely rapidly. Do the authors keep the pencil stationary at all, and approximately how fast is it moved over, for example, a 1 cm length?
e) The thermal line configuration used by the authors is not similar to the Maze III procedure, as in the Maze III procedure the sinoatrial node artery is not at risk. Why did the authors elect to use a line configuration that appears to be more similar to the Maze II configuration?

Author's Response by Prasanna Simha:

a) We had created lesions on the right appendage and excised them during decannulation prior to starting the trial and found that 40 Watt setting caused transmural colliquative necrosis. This was not obtained with 20 or 30 Watt settings. We also had tried using the 20-Watt setting but found it did not work clinically. We did not include this data as we felt that this data is anecdotal.
b) Amiadorone was given only for a period of three months and then was stopped in all patients. Amiadorone was given primarily to ensure decreased atrial automaticity to offset the increased atrial tissue conduction speed that can cause transient atrial fibrillation despite adequate maze lesions. This was done to ensure maintenance of sinus rhythm postoperatively at all times to ease hemodynamic management in sick left ventricles. We also feel that since sinus rhythm begets sinus rhythm, addition of amiadorone, even though only three months, ensures maintenance of sinus rhythm and early return of atrial function. We also feel that multimodal attack of atrial fibrillation (maze + amiadorone + optional atrial pacing) ensures a controlled sinus rhythm throughout the immediate postoperative period and makes it smoother. We believe the efficient return to sinus rhythm is also a surrogate marker for completeness of the lesions as it is known that inadequately performed Maze procedures can result in a lower conversion rate to sinus rhythm.
c) We agree that feedback systems may be used but this would result in higher costs. We wanted to develop a cost efficient, easily reproducible and quick method. Since the spark mode arc is employed in an empty heart, alteration in conductivity (due to blood and charring) is typically avoided and the rate of progression of the cautery is primarily determined by blanching. This is approximately at the rate of around 1-2 seconds per centimeter.
d) The cautery is never kept stationary as it has to be moved as soon as the tissue blanches. Inspection on the opposite side easily demonstrates the transmural nature of the burn visually. We have not encountered perforations while using this method.
e) The lesion near the sinus node artery was placed as it was found that this lesion usually caused a sudden conversion

to sinus rhythm while placing the right atrial lesions. We chose to keep this lesion as we had "visual comfort" when sinus rhythm was restored during the right sided lesions itself prior to arresting the heart. This lesion is extended as far as possible medially and is stopped short of the ascending aorta.

3. Editorial Board Member IG23 writes:

The authors should state the time frame of this experience (rather narrow time ranges at follow-up, 3.2-3.8 years) and how the selection of these 25 cases was done.

Author's Response by Prasanna Simha:

The 25 cases were selected over a six-month time frame, hence the narrow time range. The above study was subsequently terminated to permit a trial of comparison of different "lesser maze" configurations to avoid opening the right atrium during mitral surgery. The 25 cases were done consecutively in all cases of atrial fibrillation for those who were having atrial fibrillation for more than six months, an LA size of more than 5.5 cms scheduled for surgery, and did not convert to sinus rhythm with an attempt at cardioversion on CPB. The study was terminated on acquisition of 25 such cases.

4. Editorial Board Member JZ39 writes:

Were there any MI's - especially in the circumflex distribution? Did they see any phrenic nerve paralysis from the cautery in and around the pulmonary veins?

Author's Response by Prasanna Simha:

We did not encounter any MI's. The peripulmonary lesion was made to touch the mitral annulus only at 5 o'clock to limit any chance of significant circumflex coronary artery injury.

We did not encounter any phrenic nerve injury and we did not see any diaphragmatic stimulation during the placement of peripulmonary vein lesions.

5. Editorial Board Member MD125 writes:

What was the "pencil" diathermy probe used — the standard " knife" tip or "ball" tip?

Author's Response by Prasanna Simha:

The pencil diathermy probe used was the ordinary "knife" tip and not a ball electrode. The tip actually does not come in contact with the tissue after the spark arc-gap is established. For this a knife tip would be better than a ball tip.