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Laser Ablation Of Atrial Fibrillation: Mid-term Clinical Experience

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Abstract

Background: Atrial Fibrillation is known to account for one third of all the strokes caused in the US in the population above the age of 70. Patients treated with the surgical Cox MAZE operation have been shown to have a 150 fold decrease in the incidence of stroke over an 18 year period. However, the original Cox MAZE although extremely successful in treating atrial fibrillation and decreasing the incidence of strokes was not performed widely because of complexity and invasiveness of the procedure. A variety of alternative energy based curative ablation strategies are now available for more minimally invasive therapeutic management of atrial fibrillation (AF). In this communication, we report our clinical experience in AF therapy utilizing laser energy ablation technology.

Methods: Fifty two consecutive AF patients underwent concomitant or isolated ablation prior to any coexisting cardiac procedures that included CABG (coronary artery bypass surgery, MV (mitral valve) or AV (aortic valve) repairs. All patients had an epicardially based ablation pattern with basic lesions being en bloc box type pulmonary vein isolation which included the antral surface of the left atrium, directed ganglionectomies of the the right anterior and inferior ganglions, posteriomedial ablation of the IVC (inferior vena cava), and a right isthmus ablation. Twenty seven patients had ligation of their left atrial appendage, 14 patients had resection of the ligament of Marshall, and three patients had endocardial placed lesions of a mitral annular connecting type lesion. In order to maintain the patients in normal sinus rhythm (NSR), electrical cardioversion and anti-arrhythmic drugs were employed as required.

Results: At a median follow-up of 250 days, 44 of the total 52 patients (84.6%) exhibited NSR.. No complications or mortality were reported due to the laser procedure.

Conclusion: Laser ablation was successfully and safely used for endocardial and epicardial AF ablation concomitant to other cardiovascular procedures and in the lone atrial fibrillation treatment utilizing a two port thoracoscopic approach.

Introduction

The operative success rate of the classical Cox-Maze procedure remains unparalleled when comparedto other surgical options available to cure AF [Cox, 2000]. Critical challenge still persists in surgical practice when AF has to be treated concomitantly with co-existing cardiovascular problems [Melo, 1997]. Under these situations, Cox's scalpel based Maze procedure substantially elevates operative complexity and mortality. Due to these concomitant surgical "risks", a number of alternative strategies utilizing energy sources viz., radiofrequency, microwave, and laser etc have

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been developed and applied clinically [Lee 2001, Sie 2001].

Since December 2001, our clinical team has concentrated, more specifically, on employing microwave energy for therapeutic ablation of patients with AF and then since 2004 on laser energy as well. The purpose of this article was to evaluate the peri- and post-surgical outcomes for initial patients who underwent concomitant and isolated laser atrial ablation surgery.

Methods

Patient Enrollment and Demographics

Between November 2004 and June 2006, 52 consecutive permanent AF patients (38 men and 14 women; mean age: 68±12 years), who had an average left ventricular ejection fraction of 47 ± 15 %, underwent microwave ablation prior to concomitant open chest cardiac surgeries. The mean AF duration for our population set was 46 + 27 months. A summary of patient demographics is shown in table 1. Lone atrial fibrillation procedures utilizing a two port thoracoscopic access was performed in 21 patients. Combination procedures consisted of CABG in 16 patients, AV intervention in 9 patients, and MV intervention in 8 patients. The patients were classified with an average NYHA value of 3.125. A significant amount of our population, i.e. 65%, had congestive heart failure problems (n=34). Similarly, hypertension was recorded in 36 (69%) of our patients. All patients were consented through a formal IRB protocol.

Pre-operative Management

62% patients (32) were in pre-operative anti-arrhythmic drug therapy, 52% (n=27) employed β-blocking drugs, while 46% (n=24) of the patients utilized anti-coagulants. The average NYHA classification of the patients was 3.125. All patients had evaluations of their coronaries and cardiac valves prior to acceptance for lone AF treatment. Upon admission, baseline 12-lead electrocardiogram, basic chemistry panel 7, chest radiography and transthoracic echocardiography were performed. All patients underwent transesophageal echocardiography the day prior to surgery or in the operating theater after the induction of anesthesia to exclude the presence of left atrial thrombus. Patients were ordinarily diuresed twenty four hours prior to surgery to facilitate right atrial de-

Men/Women, (n)	**38/14**
Age, yrs	68± 12, yrs
LA Diameter, mm	3.8+2.1, mm
Duration of AF, months	46 + 27, months
NYHA Class	3.125
LV EF%	47±15%

Table 1 Patient demographics and success rates in the overall group, the lone AF group, and the overall concomitant cardiac intervention group

	Patient Population	NSR (Success Rate)	AF
Total Population	52	44 (84.6%)	8
Lone AF Group	21	18 (86%)	3
Concomitant Group	31	26 (84%)	2

Table 2 Success rate in eradication of AF in the CABG, MV, and AV cases

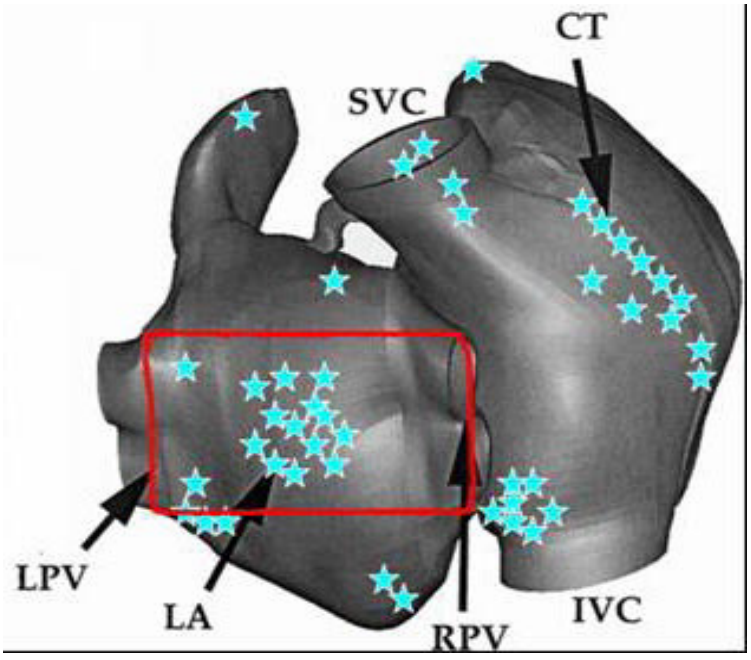
	Patient Population	NSR (Success Rate)	AF
CABG	16	14 (88%)	2
MV Cases	8	9 (89%)	1
AV Cases	7	9 (78%)	2

compression in the scope type surgeries. Patients were also treated with perioperative steroids for twenty four hours to lessen the impact of inflammation in perioperative recurrence of atrial fibrillation.

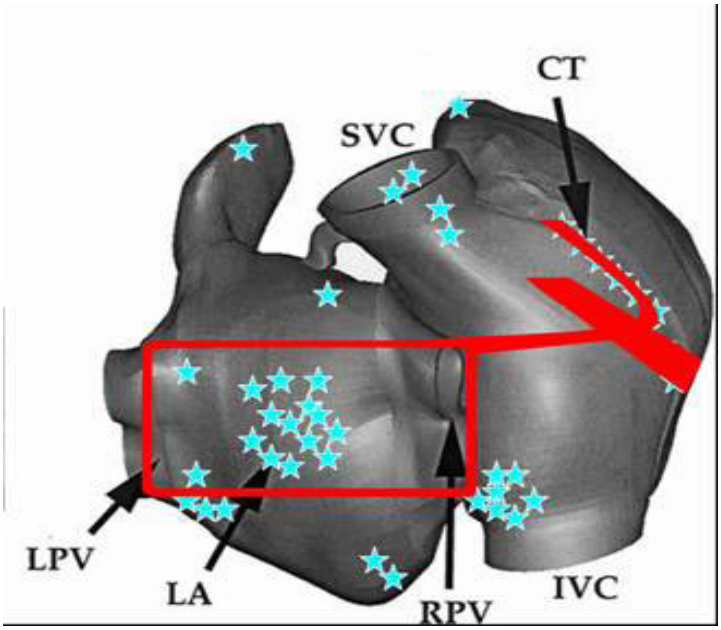
Operative Strategies

Off-pump, epicardial ablation procedure was performed in all 52 patients and endocardially added lesions in 6 of the patients who were undergoing a mitral valve procedure. During these operations, the Encircle laser energy device (Edwards Lifesciences) was used for both epicardial and endocardial ablations. All of the patients had a basic lesion set of an epicardially based ablation pattern with basic lesions being en bloc box type pulmonary vein isolation which included the antral surface of the left atrium, directed ganglionectomies of the the right anterior and inferior ganglions, posteriomedial ablation of the IVC (inferior vena cava), and a right isthmus ablation. Care was taken to ensure that all lesions were closed loop lesions with no open end. These ablations consisted of direct application of laser energy to the gangl ons as well as isthmus with the ganglions being clearly visible epicardial surface structures which is also demonstrated in the diagrams attached; directed ganglionic ablations in this manner have been seen in our practice to have improved our overall results over the prior 5 years. The ganglion ablations all demonstrated classic reflex bradycardia/tachycardia upon initiation of directed laser ablation which then resolved upon successful completion of ablation of the ganglionic plexus. Pulmonary vein isolation was tested with both entrance and exit block testing after ablation. Entrance block was demonstrated with a two electrode sensing catheter placed both inside and outside the pulmonary vein isolation box demonstrating more than a five fold differential in measured potentials and at least a 200 ms conduction delay. Exit block testing was performed with a pacing catheter placed within the isolation box at 10 joules of energy. Entrance block was obtained on all patients demonstrating successful completion of the pulmonary vein isolation; however, exit block could only be successfully confirmed in 41 of the 52 patients even with repeat ablations. Twenty seven patients had ligation of their left atrial appendage performed when there was shown to be a low flow state and when the left atrial appendage was safely accessible for ligation. 14 patients had resection of the ligament of Marshall during the time of this study based on other centers' proposals for the possibility of improved success rates but was not continued when this was not seen to be the case. Six patients had endocardially placed lesions of a mitral annular connecting

Figure: Diagrams of Ablation Pattern

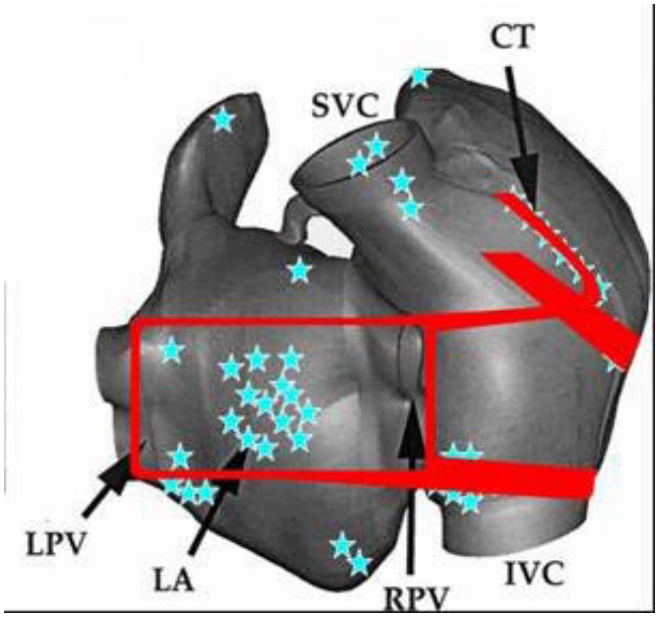


Pulmonary Vein Box Isolation



Directed right anterior ganglion ablation on Crista Terminalis and connected to box lesion set

Directed Right Inferior Ganglion Ablation and Left Inferior Ganglion ablation with ablation line crossing the Coronary Isthmus and attaching to the original box lesion set



Abbreviations:
AF : Atrial Fibrillation
NSR : Normal Sinus Rhythm
CABG : Coronary Artery By-pass Grafting
MV : Mitral Valve
AV : Aortic Valve
SVC : Superior Vena Cava
IVC : Inferior Vena Cava
LAA : Left Atrial Appendage
PV : Pulmonary Veins
TV : Tricuspid Valve
EF : Ejection Fraction
RF : Radiofrequency

type lesion which were in patients who already had a left atriotomy for access to the mitral valve during the course of the procedure. The most effective lesion set encompasses the full enbloc box type pulmonary vein isolation, directed R and L ganglionectomies, directed partial isthmus ablation, and the addition of a mitral annular connecting type lesion. Unfortunately, the addition of a mitral annular connecting type lesion requires a more invasive approach of utilizing extracorporeal circulation and the opening of the left atrium whereas all of the other aforementioned base lesions can be done epicardially either in combination with other cardiac surgery or even with just two 1 cm. thoracoscopic incisions as in the case of lone atrial fibrillation surgery.

Post-Operative Medication

Patients were discharged on anti-arrhythmic drugs and anti-coagulants for a period of 2 months. The anti-arrhythmic drug administration was discontinued after 9 weeks in the case of documented stabilized NSR. One month after discontinuation of anti-arrhythmics, patients were then monitored with an event monitor for one month whereupon a decision was then made with regards to cessation of anticoagulant medication.

Post-Operative Patient Management and Followup

During the hospital stay all the patients were monitored with continuous electrocardiography. Electrical cardioversion was carried out in patients who failed spontaneously to convert to sinus rhythm at the end of the ablation procedure and in whom pharmacological cardioversion was unsuccessful.

Statistical Analysis

Within group comparisons among the variables were carried out using Student's-t test analysis. Statistical significance was accepted at a p-value < 0.05.

Results

Our overall experience reports restoration of stable sinus rhythm in 44 out of 52 patients (84.6%), post-operatively, at a median follow-up of about 250 days. More specifically, of the 16 CABG patients, 14 (88%) were free from AF. 8/9 (89%) MV intervention patients and 7 of 9 AV repair patients (78%) were successfully converted to NSR. 18 /21 (85%) of the lone AF patients were successfully converted to NSR long term. In looking at the ad itional individual lesions of LA appendage ligation, 23/27 patients were found in NSR; ligament of Marshall resection, 10/14 patients were in NSR; and all six of the mitral patients with mitral annular connecting lesions were in NSR. The patients in NSR were all taken off antiarrhythmics and had documented maintenance on NSR two months post cessation of antiarrhythmics utilizing a 21 day event monitor prior to being documented as successful treatment. Any occurrence of atrial fibrillation or flutter lasting more than 5 minutes in length was defined as failure of therapy. Five of the 52 patients developed atrial flutter within the first two months post procedure with three resolving either spontaneously or post cardioversion and two patients went on to require additional catheter intervention. There were no reports of occurrences of stroke or any in hospital complications in our patient population. We had two deaths in the epicardial ablation group which was not attributable to the laser ablation but to an end stage hepatic failure which occurred 3 weeks after multiple procedures including a cardio-myopathy resection, AVR, MVR, and TVR; and other complications of the concomitant surgeries being performed. Overall, the average post-operative length of stay was 2.8 days with 20 of the 21 lone AF patients having only a one day length of stay. Four patients from the epicardial group and three patients from the endocardial group were successfully electrically cardioverted on an outpatient basis after going back into AF postoperatively. Three of the patients had pacemakers implanted for managing bradycardia or sick sinus syndrome but these were all in the concomitant surgery group; none of the lone AF patients required pacer insertion. Three patients from the epicardial group had spontaneous conversion to NSR on medication.

Discussion

Atrial fibrillation is the most common sustained cardiac arrhythmic disorder that substantially elevates the risk of morbidity and related mortality

[Benjamin 1998]. In early 90's, Cox and his team introduced a scalpel incisional based procedure as a curative therapy for AF [Cox 1991]. The MAZE therapy had a curative success rate of as high as 98% but more interestingly as recently reported by Damiano, et al there was only one CVA event in that population over an eighteen year period whereas there would have been 150 expected events in the atrial fibrillation population. The technical complexity of the Cox-Maze operation has led to multiple attempts to replace the cutand-sew incisions with energy incisions using RF, cryo-energy, microwave and laser. We decided to operate utilizing microwave energy for AF management due to its demonstrated safety and the reported ease and effective use in both beating as well as arrested cardiac configurations, in presence, or absence of pump support [Williams 2002]. Over the past year and a half we have begun incorporating laser energy in the 980 nm wavelength energy for ablation therapy.

Thomas et al [2003] compared the epicardial and endocardial linear ablation using handheld monopolar RF devices. They reported that blood cooling at the endocardial surface significantly depressed the lesion depth. They concluded that lesions were unlikely to be transmural when performed either epicardially or endocardially if the tissue thickness was greater or about 4 mm and that prolongation of the duration of ablation from 1 to 2 minutes did not result in a significant increase of lesion depth. The relatively limited penetration depth of epicardial RF lesions undermines the use of RF for beating heart epicardial ablation. Furthermore several serious injuries associated with monopolar RF devices have been reported [Gillinov 2001]. The above limitations and safety issues have prompted surgeons to use newly developed bi-polar RF based devices [Gillinov 2002].

Similarly, during epicardial cryoablation the heating at the endocardial wall by the circulating blood was found to pose a significant effect on lesion formation [Kubota 2002]. In order to achieve an acute electrical isolation of the pulmonary veins following cryoablation, the flow in the left atrium was reduced by snaring both vena cavae and the cardiac tissue was cooled down to about 20°C prior to cryoablation [Kubota 2003].

In this report we have shown that off pump epicardial ablation appears to be equivalent to endocardial ablation in terms of NSR restoration and is quite successful with the use of laser energy. This result further demonstrates the effectiveness of laser energy when applied epicardi ally off pump. To our knowledge microwave and laser energies are the only energy sources which are being routinely used to perform off pump epicardial ablation through small port accesses at the time of this study. Radiofrequency belt sources are now available for port access as well.

It was reported that the patients who underwent the Cox-Maze procedure showed a significant decrease in the secretion of atrial natriuretic peptide (ANP) [Yoshihara 1998]. Since the atrial appendage is the main source of ANP we elected to oversew the LAA instead of completely excising it.

Limitations

Although a base lesion set is performed in all patients of this series, many patients did have additional lesions performed as well as LAA ligation. The individual numbers do not provide enough data to be able to discriminate the various additional lesions and their enhancement of successful atrial fibrillation treatment. However, the primary purpose of this paper is not to discuss the various lesions sets but to merely demonstrate the ability of using laser energy to safely create the lesions.

The followup time is over a median of 250 days which is limited because of the time period that was able to be studied; this paper gives enough followup so as to demonstrate safety and short to midterm efficacy but does not provide long term efficacy data which will be followed up in the future.

Conclusion

Laser energy was successfully and safely used for endocardial and epicardial AF ablation concomitant to other cardiac surgeries. There was no difference between epicardial and endocardial ablation outcomes in terms of NSR restoration. Based on our own promising results and experiences of other, all patients with a history of AF who are presenting for surgical treatment of other cardiac diseases can benefit from laser therapy. To mini-

mize morbidity, after ruling out any LAA thrombosis, the off pump epicardial approach is recommended for most patients. Furthermore, based on the known stroke risks and quality of life impairment associated with AF, the laser ablation procedure should be extended to most of the patients with stand-alone AF.

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