Catheter Ablation for Atrial Fibrillation: Hartford Hospital Experience

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Historical Perspective

A n appreciation of symptoms related to alterations in heart function is not new. Ancient Chinese physicians studied the relationship of the palpable pulse to health as early as the fifth century B.C. Manipulation and/or eradication of symptomatic or harmful cardiac arrhythmias date back to the 17th and 18th centuries when natural pharmacology was used: quinine to quell the fibrillating atria, and foxglove to treat cardiac insufficiency. After some success with these attempts at controlling heart rhythm through pharmacology, a huge discipline and industry was created. Unfortunately, over the ensuing decades, it was learned that these limited successes also had a price. While some patients did quite well and remained free from their symptomatic arrhythmias, many patients succumbed to the unknown evils of products that were poorly understood and even more poorly tested and evaluated.

The first published attempt to surgically alter the heart, and thereby prevent a cardiac arrhythmia was reported in 959. Despite this surgical failure to prevent recurrent ventricular tachycardia, a new and aggressive approach to controlling cardiac arrhythmias was born. It took Guiraudon, and colleagues, another 5 years to describe a surgical procedure aimed not specifically at the arrhythmia—ventricular tachycardia—but at its substrate—a dilated cardiomyopathy.²

In this same decade, in both Europe and America, the development of electrophysiologic-programmed stimulation techniques enabled animal and human studies of multiple arrhythmias, including monomorphic ventricular tachycardia.³ ⁴ With the development of standardized electrophysiologic benchmarks, and the advancement of open heart surgical techniques through the 1970s and into the 80s, a collaborative effort between electrophysiologists and surgeons developed. In 1978, Josephson and colleagues reported the first EP map guided endocardial resection procedure for sustained VT—the first successful nonpharmacologic therapy for a cardiac arrhythmia.⁵ The era of EP guided nonpharmacologic arrhythmia management was born.

In 1981, Gonzalez and Scheinman, et al, described the successful catheter-based elimination of AV nodal conduction in dogs using unfocused D-C energy.⁶ This series of experiments led to the nonsurgical, catheter based, method for control of symptomatic SVT’s (supraventricular tachycardias) in humans. The use of transvenous temporary catheters to deliver an energy source capable of altering or destroying arrhythmic substrate, and thereby ameliorating or eradicating multiple types of arrhythmias took fast hold in the electrophysiologic community.⁷ The DC ablation registry showed that while some patients responded well to this form of energy delivery, it was, nevertheless, a diffusely traumatic technique and resulted in damage to the heart and/or a less than satisfactory cure rate in many patients, limiting its usefulness.

Over the next 10 years, a flurry of activity by surgeons and electrophysiologists in an attempt to cure various forms of reentrant and focal cardiac arrhythmias was reported.²² Industry interest was fueled by the scientific and industrial communities. Improved recording equipment, catheters,
and mapping techniques were developed for this new and exciting field.

While it was clear to the early electrophysiologists and surgeons that arrhythmias could be managed through mechanical means with limited morbidity, there were still significant drawbacks to the delivery of a large amount of unfocussed energy that could result in diffuse injury to the heart. A more focal power source was sought.

S. K. Huang was an early investigator of the use of radiofrequency energy, adapted from surgical electrosurgery systems, to deliver focal desiccating energy and alter conduction at the level of the AV node in an animal model.9,10 Later, this energy source, radiofrequency, was successfully delivered through specialized electrophysiology catheters to locally heat/burn the myocardium around the area of catheter contact. Based on tip size, temperature achieved, and duration of the burn, myocardial lesion size varied, but could be delivered with impressive accuracy, and minimal complications. Employing the mapping techniques developed in the 1970s, 80s, and 90s, the focal delivery of radiofrequency energy was used to successfully eliminate many cardiac arrhythmias. Early successes were seen with catheter-based radiofrequency ablation of anatomic structures, including accessory pathways and the AV node.23–26 With advances in mapping technique (three dimensional electroanatomic, activation, pace mapping, concealed entrainment, VT/scar mapping), successful ablations were being performed not based solely on anatomic structures, but on an understanding of the intractable relationship between mechanism and anatomy (AVNRT, atrial tachycardia, atrial flutter, VT).

A landmark study published by Jais and colleagues appeared in Circulation in 1997, describing the pulmonary veins as a common source for premature depolarizations responsible for triggering episodes of atrial fibrillation.11 This report described the possibility of curing patients with paroxysmal atrial fibrillation with catheter based mapping and ablation techniques. It further verified the “multiple mechanism” hypothesis for atrial fibrillation. Prior to this time, atrial fibrillation was explained by multiple nomadic circulating wavelets within both atria.12 These newer investigators validated the hypothesis that at least some atrial fibrillation was due to a single (or multiple) rapidly firing focus located somewhere in the atria, or in communication with the atria (pulmonary veins).

Not long after this sentinel description others13,27,28 described the electrophysiologic features within the left and right atria for patients with paroxysmal and persistent/chronic atrial fibrillation. Using similar catheters and energy source, but with varying mapping techniques and endpoints, it was shown that paroxysmal and chronic atrial fibrillation could be also eradicated at the end of a radiofrequency catheter. Pandora’s box had been opened.

Demographics

Atrial fibrillation is a heart arrhythmia that affects some two to three million adults in the United States and about 6 million around the world.14 This often disabling arrhythmia usually affects people after the 6th decade of life, and increases in frequency with age. The arrhythmia increases the risk for stroke, congestive heart failure, and death in both men and women.15 Atrial fibrillation is responsible for 15% of reported strokes in the United States alone. Stroke as a result of atrial fibrillation is more commonly seen in the elderly, patients with structural heart disease, and those with other risk factors, including hypertension, diabetes mellitus, coronary artery disease, cardiomyopathy, valve disease, or thyrotoxicosis. The relative risk elevation does not depend on whether the atrial fibrillation is paroxysmal, persistent, or chronic. Interestingly, a reduction in the incidence of age-related stroke is conferred by the drug warfarin, and in some populations by aspirin. Tight control of the INR in warfarinized patients optimizes efficacy and reduces the risk of severe bleeding.

The enormity of atrial fibrillation’s impact on public health in our country is highlighted by its estimated annual cost of 10 billion dollars.16

Recent investigation results hoping to demonstrate that maintenance of normal rhythm in patients with a history of atrial fibrillation would result in freedom from stroke and a lower mortality were surprising.17 In the valuable AFFIRM study, patients were randomized to rate control and anticoagulation; or to antiarrhythmic drug therapy in an attempt to maintain normal rhythm. In an intention-to-treat analysis, there was no difference in stroke rate. There was a trend towards a higher mortality in the rhythm control group (P=0.058).17 While this was felt to be due to a more lax control of anticoagulation in rhythm controlled patients (many of whom had asymptomatic recurrences of atrial fibrillation), it was clear that antiarrhythmic drug management alone to maintain normal rhythm was not optimal.

Interestingly, a report by Kaye, et al, re-analyzing the AFFIRM data from a successful therapy perspective (patients successfully kept in normal rhythm) discovered that mortality and stroke rate were indeed lower in patients who maintained normal rhythm throughout the follow-up period of the study.18 While this observation is provocative, because the study was not designed to analyze the data in such a way, conclusions about the effectiveness of sinus rhythm to reduce stroke and improve mortality could not be firmly made.

Fortunately, it was just at this time that the group from Bordeaux, France described their experiences with focal atrial fibrillation within the pulmonary veins, and a higher than expected long-term “cure” rate from paroxysmal atrial fibrillation.19
Catheter ablation for atrial fibrillation has become available in many advanced centers throughout the world. Scientific reports and collaborations among these laboratories, with the participation of industry, have enabled many interventional electrophysiology laboratories to boast a procedural success rate of approximately 80% in both paroxysmal and persistent/chronic atrial fibrillation patients. While the symptoms of atrial fibrillation appeared to be well controlled after a “successful” ablation procedure, the long-term freedom from the arrhythmia itself and associated stroke is not known. There were many reports of patients with improved quality of life and freedom from symptomatic atrial fibrillation who have subsequently been documented with asymptomatic atrial fibrillation. Follow-up is still too short, and postoperative care has not been standardized in such a way as to analyze large populations of patients and make a statement about the effect of atrial fibrillation ablation on the long-term risk for stroke, and mortality.

While most patients may eliminate chronic antiarrhythmic drug therapy because of successful eradication of symptomatic atrial fibrillation, few electrophysiologists consider this procedure a long-term “cure.” A significant minority of patients will return with other forms of left atrial arrhythmias, (atrial tachycardia or flutter) for a second procedure, weeks or even months after the initial ablation. Further, because of the unknown frequency of asymptomatic paroxysmal atrial fibrillation after a “successful” ablation for atrial fibrillation, many electrophysiologists will recommend long-term warfarin therapy on patients with atrial fibrillation associated risk factors for stroke.

A categorization of the patients with “paroxysmal,” “persistent,” and/or “chronic” atrial fibrillation may guide the electrophysiologist’s selection for treatment and expectation for success: Infrequent and brief episodes of AF with minor symptoms in a patient without heart disease may be perfect for iterant, or daily pharmacological therapy. Asymptomatic persistent/chronic AF in an elderly patient without a bleeding history, who may not be an optimal ablation candidate, may do very well with warfarin therapy and rate control. A patient with a history of symptomatic AF in need of bypass +/- or valve surgery may benefit from the addition of an epicardial surgical “maze” procedure. Patients with drug-refractory, symptomatic atrial fibrillation are frequently referred for catheter ablation.

### Hartford Hospital

**Atrial Fibrillation Ablation Guidelines:**

**Preoperative management:**

1. Warfarin anticoagulation with INR greater than two, for four weeks prior to procedure. INR is checked weekly for a month prior to procedure to ensure adequate anticoagulation. Patients who fail to meet these requirements, and have urgent needs, may receive 24 hours of Heparin, and transesophageal echo (TEE) to rule out left atrial appendage (LAA) thrombus prior to the ablation procedure /
   cardioversion.

2. Warfarin is discontinued three to five days prior to the procedure:
   a. Paroxysmal atrial fibrillation with patient in normal rhythm: warfarin may be discontinued five days prior to procedure without need for heparin or Lovenox as long as nSR is maintained.

   b. For patients with persistent, or recurrent atrial fibrillation during the washout period—bridge anticoagulation therapy using Lovenox 1 mg/kg subcu b.i.d.—to be discontinued 2 hours prior to procedure—may be employed as an outpatient.

   c. Alternatively, patient may be admitted for “drug washout.” Initiation of intravenous heparin therapy begins when the INR is <=2, with PTT of 50 to 70 seconds to be discontinued several hours prior to patient’s procedure.

   d. For patients with inadequate anticoagulation a TEE may be performed one to two days prior to procedure while on (fractionated or unfractionated) heparin therapy.

   e. Three dimensional chest imaging (multislice CT, MRI), chest x-ray invasive or noninvasive coro-

### Table 1.—Atrial Fibrillation Ablations in HH Database

<table>
<thead>
<tr>
<th>Numbers</th>
<th>PAF</th>
<th>2nd Procedures Required</th>
<th>AAD’s Required for NSR</th>
<th>Resistant AF/AT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total—105</td>
<td>57 (54%)</td>
<td>18 (17%)</td>
<td>14 (14%)</td>
<td>14 (14%)</td>
</tr>
<tr>
<td>FY ‘05—60</td>
<td>26 (43%)</td>
<td>6 (10%)</td>
<td>5 (8%)</td>
<td>5 (8%)</td>
</tr>
</tbody>
</table>

### Table 2.—Atrial Fibrillation Complications

<table>
<thead>
<tr>
<th>Numbers</th>
<th>Deaths</th>
<th>*CVE’s</th>
<th>*MI</th>
<th>Tampanade</th>
<th>Vascular Event</th>
<th>*PV Stenosis</th>
<th>Atrial Esophageal Fistula</th>
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<tbody>
<tr>
<td>Total—105</td>
<td>0</td>
<td>1-TIA</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>FY ‘05—60</td>
<td>0</td>
<td>1-CVA</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
nary evaluation, laboratory evaluation, etc. may be performed prior to admission, as appropriate.

**Procedural guidelines:**

1. **Anesthesia:** Conscious sedation or general anesthesia may be used. The decision as to which is most appropriate for the patient is usually a collaborative decision between the electrophysiologist and the anesthesiologist, and depends upon the proposed length of the procedure, airway anatomy, and various comorbid conditions.

2. Procedure done with intracardiac echo (ICE) to help guide trans-septal puncture, and pulmonary vein mapping/ablation, monitor ablation lesions for “bubbles” (excessive heat), pericardial effusion development, and thrombus formation.

3. Transseptal puncture guided by multiplane fluoroscopy, right and left atrial pressure recordings, and ICE.

4. IV heparin is used to reduce the risk of thrombus formation: bolus 80 mg/kg IV may be given after entry into the left atrium is confirmed, with infusion at 15 mg/kg to maintain ACT 300 to 400 seconds—checked every 10 to 20 minutes.

   Alternatively, 5,000 units of intravenous heparin may be given prior to transseptal puncture as is the practice in some laboratories, with the remainder of the bolus given after entry into the left atrium and continuous infusion started at that time (ACT 300-400 sec; check q 10-20 min.).

3. Targeting of one or more rotar sites (persistent atrial fibrillation; Nadamannee 21);

4. Or, a combination of these procedures.

It appears from the literature that the best results are delivered when exit and entrance block of all four veins are demonstrated, and when there is a line of block created from the left inferior pulmonary vein to the mitral annulus. Ability to confirm block at the level of the mitral annulus is difficult. Bidirectional block at the level of the mitral annulus may be required for recurrent left atrial arrhythmias and may require mapping and ablation within the coronary sinus.

Creation of a cavo-tricuspid isthmus line of block is advised but optional depending on the patient’s status and duration of surgery.

**Post ablation hemostasis protocol options:**

1. Use of intravenous iterant protamine in 10 to 20 mg aliquots with monitoring of ACT down to 180 to 220 seconds before sheaths are removed; or,

2. Pulling of sheaths after a patient is extubated and removed from the Interventional Electrophysiology Laboratory is possible if the patient is transferred to a unit which is properly staffed with personnel trained to recover post catheterization/ general anesthesia patients. Sheaths may be removed when the ACT is below 180 seconds.

**Postoperative care:**

Intravenous heparin is started within six hours of leaving the interventional electrophysiology laboratory at between 800 and 1,200 units per hour. PTT may be checked after six hours on continuous infusion/low dose heparin, and PTT thereafter adjusted for 50 to 70 seconds. Five milligrams of warfarin given night of procedure and continued until INR are greater than or equal to two.

On the day after surgery (POD #1), intravenous heparin may be continued, with initiation of Lovenox on POD #2 at 1 mg/kg subcutaneously to be delivered by patient. The patient is usually discharged after self-administering at least two full doses of Lovenox, and being fully ambulatory without any signs of bleeding. They will continue half to full dose subcutaneous Lovenox until INR is greater than two. Concern exists for severe bleeding events on early postop full dose Lovenox, as was seen in four patients in our early experience.

**Figure 1.—Onset of paroxysmal Atrial Fibrillation from a pulmonary vein extrasystole.**

**Atrial fibrillation ablation:**

Available and acceptable ablation procedures include:

1. Pulmonary vein isolation by antral encircling procedure to ensure exit and entrance block (Haissaguerre group) 19 (Figs. 1,2,3).

2. Broad circumferential ablation (Pappone 20)(Figs. 2, 3) or;
Alternatively, intravenous heparin may be continued (PTT 50–70 sec), until INR is greater than or equal to two, then D/C patient on warfain to be checked as outpatient in three to five days, and adjusted to maintain INR.²,³

**Additional Considerations**

**Atrial fibrillation recurrence:**

It is not uncommon for patients to go into postoperative atrial fibrillation on day one to three postablation. Rapid cardioversion with restoration of sinus rhythm while on an antiarrhythmic agent (amiodarone, sotalol, dofetilide) seems to be very useful in maintaining sinus rhythm and allowing optimal remodeling. Atrial fibrillation recurrences within the first 12 weeks post ablation are treated aggressively with rapid cardioversion and medication adjustment, as needed (“the longer the patient is in NSR; the longer the patient is in NSR”). Atrial arrhythmia recurrences which fall outside of this “remodeling period” may need a second ablation procedure; especially if symptomatic.

**Pericardial effusion:**

Post procedural pericardial effusion is not uncommon and appears to occur in 10% to 20% of our patients, although postoperative tamponade has not occurred.

Post pericardiotomy like findings of pericardial and pleural effusions, and low grade fever may result in some mild chest discomfort, and shortness of breath for seven to 14 days postoperatively. Nonsteroidal antiinflammatory drugs or a short course of steroids to relieve symptoms may be useful. Postoperative echo may be necessary to document absence of hemodynamic compromise for continued anticoagulation therapy.

**Shortness of breath:**

About 10% of patients may require three to five days of post op furosemide for diuresis (probably due to decreased local ANP)—after pericardial tamponade has been ruled out by 2D echo. A brisk diuresis generally relieves the shortness of breath, and fluid reaccumulation is unusual. More delayed (weeks to months postop) symptoms of shortness of breath should alert one to the possibility of pulmonary vein stenosis. A chest x-ray, and V/Q scan should be performed immediately. Findings of V/Q mismatch should be followed with a CT angiogram or MRI to differentiate a pulmonary embolus from pulmonary vein stenosis.

**Followup post discharge:**

Follow up at one month, three months, six months, and 12 months.

Ambulatory monitor recording at three months on follow up is usually performed in patients who continue to note
palpitations, or cannot continue long term warfarin therapy.

From the immediate postoperative period to three months, every effort is made to continue an antiarrhythmic agent at therapeutic doses (amiodarone, sotalol, dofetilide) and iterant cardioversions to maintain normal rhythm and allow maximal remodeling. For patients who are particularly symptomatic or who have recurrences beyond three months, repeat ablation may be recommended. For patients who are particularly symptomatic even prior to that time, an early repeat procedure may occasionally be recommended.

Antithrombotic therapy with warfarin is continued in patients who have an elevated risk for stroke (coronary artery disease, abnormal LV function, prior CVE, valve disease, hyperthyroidism, hypertension, diabetes mellitus) even after three months postop, unless there are contraindications. There are currently no data which allow us to conclude that a successful atrial fibrillation ablation results in permanent eradication of atrial fibrillation and flutter, and lowers the extended risk for stroke.

**Hartford Hospital experience:**

Radiofrequency ablation for atrial fibrillation began at Hartford Hospital in the year 2001. Since that time, there have been approximately 250 procedures for the control and eradication of this form of SVT. Tables I and II show results, and complications available from the 105 patients entered into our database, from 2003 to 2005, with complete data on those 60 patients ablated in the year 2005. Note that catheter ablations were predominantly for paroxysmal atrial fibrillation, until recently, when nearly 60% of our patients had chronic/persistent AF; over 85% remain in NSR—70% without the need for antiarrhythmic drugs (AAD).
Of the 105 patients reported with full data sets and followup, 57 had paroxysmal atrial fibrillation and 48 chronic or persistent atrial fibrillation. The initial ablation procedure was successful in 87 patients (83%). Eighteen patients (17%) underwent a second procedure for recurrence of atrial arrhythmia. In the entire group, 91 patients (87% of the 105 patients) remained free of documented and/or symptomatic atrial fibrillation episodes at the followup time. Of these 91 patients, 77 (73% of the 105 patients) did not require antiarrhythmic drug therapy. Fourteen patients (13% of the 105 patients) remain in an atrial arrhythmia (atrial flutter, fibrillation, or tachycardia), despite ablation and medications.

Complications are acceptably low. However, they can be quite serious and include cerebrovascular events (one TIA/one CVA) and pulmonary vein stenoses (two). For this reason, we recommend two prior failures/intolerance of AAD’s before consideration of AF ablation in symptomatic patients.

Exclusions for radiofrequency catheter ablation of atrial fibrillation at Hartford Hospital include congestive heart failure, active angina, severe unstable coronary artery disease documented by angiogram or nuclear imaging, left atrium greater than 6.0 cm, patients with severe mitral regurgitation, patients with large atrial septal defect, patients with recent stroke or myocardial infarction, patients with left atrial thrombus identified by TEE, patients with clotting abnormalities, severe comorbid conditions (malignancy) which would be expected to limit survival to 6 months, congenital anatomical anomalies which might increase risk, or those having concomitant open heart surgical procedures where an epicardial maze-like procedure might be performed.

Conclusion
Atrial fibrillation is a ubiquitous cardiac arrhythmia with significant morbidity, and an associated increased mortality. In the USA alone, it is responsible for over $10 billion in annual healthcare costs. Rate control and anti-coagulation have been shown to improve lifestyle, quality of life, and survival. Maintenance of normal sinus rhythm to treat recalcitrant limiting symptoms (dizziness, fatigue, dyspnea, palpitations) through the use of antiarrhythmic therapy has not proven to be maximally effective or safe for many patients.

With the evolution of catheter based ablation techniques for the treatment of this arrhythmia, cardiologists and electrophysiologists in the new millennium are in a position to recommend radiofrequency catheter ablation as a treatment option for many patients with symptomatic paroxysmal and persistent atrial fibrillation. Whether stroke is reduced and warfarin therapy is obviated, however, has not yet been resolved.

Hartford Hospital has a multidisciplinary and individualized approach to the treatment of this most important cardiac arrhythmia. Through the combined use of pharmacological therapy, the very successful deployment of advanced mapping and ablation techniques for both paroxysmal and persistent atrial fibrillation, and surgical maze procedures during concomitant open heart surgical procedures, a successful treatment option for all patients who suffer from atrial fibrillation is provided.

REFERENCES: