Atrial fibrillation (AF) is the most common sustained tachyarrhythmia encountered by physicians. The prevalence of AF in patients over the age of 65 is approximately 6%, and approaches 10% in patients over the age of 85. As the median age of the population in the United States becomes older, the epidemiologic burden of AF in this country will likely increase. Currently approximately 2.2 million people in the United States have AF. AF, while typically not a life-threatening arrhythmia per se, is associated with increased risk of stroke, heart failure, and increased mortality. The stroke risk in patients with AF, for instance, is increased between 5- and 7-fold compared to similar patients without AF.

Therapy for AF can be divided into two major paradigms – rate control and rhythm control. Rate control, as the name implies, focuses exclusively on preventing an uncontrolled, rapid ventricular response rate in the setting of AF. Strategies to achieve rate control typically include either pharmacological agents to slow conduction through the atrio-ventricular (AV) node (i.e. beta-blockers or calcium-channel blockers), or ablation of the AV junction and implantation of a permanent pacemaker. Large prospective randomized trials have validated rate control as a reasonable option in patients with AF, particularly in terms of overall mortality. However, such a strategy does nothing to reduce the stroke risk and loss of AV synchrony seen in patients with AF, and as such, represents a suboptimal strategy in many patients.

The second paradigm, rhythm control, has historically involved the use of antiarrhythmic medications and/or DC cardioversion from AF into sinus rhythm. Antiarrhythmic medications used for the maintenance of sinus rhythm include class I and class III agents. Randomized prospective data has demonstrated that amiodarone, compared to other class III and to class I medications, is the most effective antiarrhythmic drug to prevent AF. Long-term therapy with amiodarone is imperfect, however, due both to limited efficacy and to attendant end-organ toxicities. Recurrence rates in patients treated with amiodarone are approximately 35%. As importantly, amiodarone has dose-dependent effects on thyroid, liver, and pulmonary function. In patients treated with DC cardioversion alone (i.e. without the suppressive effects of anti-arrhythmic medications) AF recurrence is predictably high, with nearly 66% of cardioverted patients developing recurrent AF within 15 months. In part because of the limitations of effective and safe pharmacological therapy for AF suppression, clinicians have sought non-pharmacological interventions to achieve rhythm control.

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Over the past 15 years, techniques for catheter-based ablation of atrial fibrillation have evolved, and now provide a widely accepted therapeutic option for the treatment and potential cure of AF. This chapter reviews that evolution, summarizes current trends in practice, and speculates on the future directions of AF ablation.

Catheter-based Treatment For Atrial Fibrillation

In 1959, Moe hypothesized that AF was due to multiple randomly propagating reentrant waves in the atrium, suggesting that functional reentry was the mechanism underlying fibrillation. In subsequent work by Allessie and others, Moe’s hypothesis was confirmed. AF was demonstrated to require at least 6 to 8 circulating reentrant wavefronts. Maintenance of AF depended both on a critical atrial mass and on conduction velocity and refractory periods in the atrial tissue to support functional reentry.

Catheter ablation for atrial tachyarrhythmias is a relatively recent phenomenon. The propagation of electrical activation from atria to ventricles over myocardial fibers was originally described in 1883. Nearly a century later, Scheinman and colleagues described the first catheter-based ablation procedure – His bundle interruption for the control of ventricular response rates to refractory supraventricular tachycardias. Over the last twenty-five years, catheter ablation techniques have become standard, curative therapy for AVNRT, accessory pathway ablation, and ablation of macro-reentrant atrial flutter. While ablation of the AV junction has long been accepted as a palliative treatment for AF, curative catheter-based therapy has evolved rapidly since the early 1990s. Initial work focused on linear and MAZE-like lesion sets in the right, right and left, and left atria. More recently, the importance of AF triggers (particularly those located in the PVs) has been recognized and targeted.

The Past

Initial ablation attempts to cure atrial fibrillation focused on linear lesions confined to the right atrium. Between 1994 and 1996, Haissaguerre and colleagues investigated the effects of linear lesion sets in patients with symptomatic, drug-refractory AF. 45 initial patients were studied and followed over the long term. Patients initially underwent right atrial ablation only, with either a single ablation line from SVC to IVC over the atrial septum, or multiple lines (longitudinal and transverse) to compartmentalize the right atrium. The procedure led to stable sinus rhythm in 18 of 45 patients (40%) during the procedure. Sustained AF was inducible in 40 of 45 patients, however, and 19 patients underwent repeat ablation of left or right sided atrial flutter or focal atrial tachycardia. After a follow-up period of 11 ± 4 months, only 6 patients were free of AF off anti-arrhythmic drugs, with another 9 patients free of AF on a previously ineffective medication (overall success of 33%). Of 45 patients had significant improvement of their symptom burden with the aid of an anti-arrhythmic medication, while the remaining 21 of 45 patients had no appreciable effect from RA-only ablation. After 26 ± 5 months of follow-up, there was a further reduction in therapeutic benefit, with 7 previous responders (either cure or significant reduction in AF burden) reverting to frequent AF. Successful results with RA-only lesions were seen in only 17 of 45 patients.

Other investigators have prospectively attempted curative lesion sets confined to the right atrium. Natale and colleagues studied 18 patients with symptomatic, drug-refractory AF. While the lesion sets varied somewhat among the patients (seven with two intercaval lesions, ablation of the cavo-tricuspid isthmus, and an anterior RA line; eleven with a single intercaval line, a septal line, and cavo-tricuspid isthmus ablation), the results were generally poor. After a follow-up period of 22 ± 11 months, only 5 of 18 patients remained free from atrial arrhythmia recurrence. Most of the 13 recurrences occurred within two months of the procedure. The particular lesion set did not predict procedure efficacy. Thus, while linear ablation confined to the right atrium to cure AF is attractive from a technical and safety standpoint, multiple trials with intermediate and long-term follow-up have shown it to be a largely ineffective procedure.

Recognizing the limited efficacy of RA-only ablation for AF, several groups began prospective investigations of bi-atrial and left-atrial linear ablation. Haissaguerre performed left atrial ablation in 10 of their 45 patients described above. Linear
ablation in this group terminated AF during the procedure in 8 of 10 patients. In 5 of 10 patients, sustained AF could not be induced after the procedure. Intermediate follow-up demonstrated success in 6 of 10 patients (with two patients requiring ongoing anti-arrhythmic medications).

Between 1996 and 1998, the same group systematically studied bi-atrial linear ablation to cure AF.26 44 patients were enrolled prospectively, the majority of whom suffered from paroxysmal, drug-refractory AF (n=40). 4 patients had persistent AF. All patients underwent a similar ablative procedure. In the right atrium, an intercalav septal line and ablation of the cavo-tricuspid isthmus were made. In the left atrium, linear lesions were applied from the superior PVs to the posterior MV annulus, including the inferior PV ostia. A roof line connecting the two superior PVs was performed in all patients; a septal left-sided line from the right superior PV to the fossa ovalis was performed in 23 of 44 patients.

This complex lesion set was technically difficult, requiring multiple procedures (2.7 ± 1.3) and prolonged fluoroscopy (171 ± 94 min).28 After a follow-up period of 19 ± 7 months, 25 of the 44 patients were successfully treated, 12 patients were significantly improved, and 7 were without improvement. Success rates increased to 37 of 44 patients with the use of antiarrhythmic medications. However, there were clearly important caveats to the study. Only 7 of the patients were treated with a single procedure, while the rest were treated with multiple procedures for AF recurrence, ablation of AF triggers, and/or the ablation of iatrogenic left atrial flutters. Perhaps most importantly, triggers of AF arising from the PVs were identified and ablated in 26 of the 44 patients studied. Given the clear importance of trigger elimination in catheter-based cures of AF (discussed below), these results undoubtedly confounded an analysis of left atrial linear lesions alone as a curative approach to AF. Indeed, ablation of triggering foci and the creation of at least one successful line of block were the two sole predictors of success in the 37 patients with a favorable outcome.

Other linear left atrial lesion sets have been investigated. Swartz and colleagues pursued a catheter-based recreation of the Cox MAZE lesion set; technical difficulty and complication rates limited the widespread application of the procedure, however.30 A much simpler left atrial lesion pattern was investigated prospectively by Pappone and colleagues.31 27 patients with highly symptomatic, drug-refractory, paroxysmal AF underwent biatrial lesion application using a novel (at the time) mapping system. 14 patients underwent biatrial ablation, with three linear lesions in the RA (posterior intercaval; cavo-tricuspid isthmus; septal) and a single, long linear lesion surrounding the PV ostia and connecting to the MV annulus in the left atrium. The left atrial lesion alone was performed in isolation in 5 patients, while the RA lesion set alone was performed in 8 patients. The success and complication rates reported by Pappone and colleagues were relatively good, with 16 of 27 patients entirely asymptomatic from AF (4 on antiarrhythmic medications), and another 4 with markedly reduced symptoms. No acute complications were reported. Success appeared to be predicted by biatrial ablation (85% success v. 50-60% with single-chamber ablation).

The Present

In part because of the limited efficacy of linear ablation alone for AF, and in part because of critically important observations by Haisaguerre of the triggered nature of AF (discussed below), linear ablation alone for AF is currently not widely performed. However, observations made by the groups that pursued linear ablation – unmasked triggering foci in patients undergoing linear ablation, and the development of simple lesion sets around the PV ostia, in particular – continue to inform current catheter-based ablation strategies for AF.

A seminal event in the catheter-based treatment of AF was the observation by Haisaguerre and colleagues that fibrillation could be triggered by rapidly firing ectopic atrial foci.27,32,33 In a series of publications in the mid- and late-1990s, Haisaguerre’s group reported the successful ablation of AF through radiofrequency ablation of focal trigger points. In 1994, they described three patients with atrial tachyarrhythmias.32 In the first patient, a focal, rapidly firing atrial tachycardia mimicked AF on ECG, and was successfully ablated. The second patient had AT-induced AF, again with successful ablative therapy targeting the ectopic trig-
ger. In the final patient of the series, a focal right atrial septal trigger was found and ablated, with marked diminution of AF burden. These initial results were expanded upon by a larger series of patients (n=9), in whom paroxysmal AF was found to be triggered from ectopic atrial foci.\(^{33}\) In three patients, these foci were located in the RA; in the other six patients, triggers were at the ostium of the right (n=5) or left (n=1) PVs. All patients underwent successful ablation, with a mean of 4 ± 4 RF applications. One patient suffered an early recurrence of AF and underwent re-ablation. After 10 ± 10 months of follow-up, there were no observed recurrences of AT or AF.

In a larger, landmark study of 45 patients with symptomatic, drug-refractory paroxysmal AF, Haissaguerre et al reported that all 45 had demonstrable focal atrial triggers.\(^{27}\) Most patients (n=29) had a single triggering site, although as many as four triggering sites were observed. A total of 69 triggering foci were found, the majority of which (31/69) were located in the left superior PV (LSPV). Other frequent sites included the right superior PV (RSPV; 17/69), left inferior PV (LIPV; 11/69), and right inferior PV (RIPV; 6/69). Three ectopic foci were located in the RA. AF induction was spontaneously observed in 36 patients, and was characterized by short bursts of two or more repetitive focal firings (40/45 patients). Ablation of ectopic foci was successfully achieved in 38/45 patients. Short-term recurrence of AF was seen in 2 of the 38 ablated patients. After 8 ± 6 months, 28 of the 45 patients remained free of AF (62%), without the use of anti-arrhythmic medications; 17 patients, including the early failures, had recurrence of AF.

The observation that AF is frequently triggered by ectopic, rapidly firing atrial foci amounted to a paradigm shift in ablative treatment. Surgical and catheter-based strategies to date had focused principally on substrate modification, in an effort to disrupt the maintenance of AF. Many of these strategies involved surgical or ablative isolation of the PV ostia from the body of the left atrium, which may in part explain their effectiveness. Current ablation strategies are focused more on the elimination and/or isolation of AF triggers, although many strategies combine both trigger isolation and substrate modification. Ablation of PV-located triggers has evolved rapidly, from focal to segmental and ultimately to linear ablation lesions.

With the initial observation that AF triggers are predominantly located in the PVs, focal trigger ablation within the veins became more widespread.\(^{27,33-40}\) Quickly, though, the limitations and dangers of this strategy were discovered. The recurrence rates of AF in patients undergoing focal PV trigger ablation was high, due primarily to other PV triggers unrecognized at the time of initial ablation, or to recovery of identified and ablated PV triggers. As importantly, ablation within the PVs led to an unacceptably high rate of PV stenosis.\(^{41,42}\) This complication has serious downstream sequella, including pulmonary hypertension, hemoptysis, dyspnea, and (rarely) death.\(^{43}\) Accordingly, strategies to isolate the PVs, either through segmental or circumferential lesion sets, were developed in an effort to avoid injury to the PVs themselves.

### Table 1. Summary of Clinical Studies of Segmental PV Ablation

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Follow-up (mo)</th>
<th>Overall</th>
<th>Paroxysmal AF</th>
<th>Persistent or Permanent AF</th>
<th>PV Stenosis (&gt;50%)</th>
<th>Stroke</th>
<th>Cardiac Tamponade</th>
<th>Mitral Valve Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haissaguerre et al(^{36})</td>
<td>2000</td>
<td>4 ± 5</td>
<td>51/70 (73)</td>
<td>51/70 (73)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oral et al(^{30})</td>
<td>2002</td>
<td>5 ± 3</td>
<td>44/70 (63)</td>
<td>41/70 (71)</td>
<td>3/12 (25)</td>
<td>0</td>
<td>1 (1.4)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dalsek et al(^{34})</td>
<td>2003</td>
<td>8 ± 3</td>
<td>38/75 (51)</td>
<td>N/A</td>
<td>N/A</td>
<td>6 (9)</td>
<td>0</td>
<td>4 (53)</td>
<td>0</td>
</tr>
<tr>
<td>Mirsche et al(^{27})</td>
<td>2003</td>
<td>14 ± 9</td>
<td>27/313 (36)</td>
<td>N/A</td>
<td>N/A</td>
<td>22 (7)</td>
<td>2 (0.9)</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Arenz et al(^{45})</td>
<td>2003</td>
<td>12</td>
<td>34/55 (62)</td>
<td>26/37 (70)</td>
<td>6/10 (44)</td>
<td>1 (1.4)</td>
<td>0</td>
<td>1 (1.8)</td>
<td>0</td>
</tr>
<tr>
<td>Oral et al(^{30})</td>
<td>2003</td>
<td>6</td>
<td>27/40 (67)</td>
<td>27/40 (67)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mansour et al(^{40})</td>
<td>2004</td>
<td>21 ± 5</td>
<td>22/40 (55)</td>
<td>19/33 (58)</td>
<td>3/1 (43)</td>
<td>0</td>
<td>2 (9)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vasanreddy et al(^{29})</td>
<td>2004</td>
<td>11 ± 8</td>
<td>39/73 (52)</td>
<td>32/42 (76)</td>
<td>7/33 (21)</td>
<td>3 (4)</td>
<td>2 (2.6)</td>
<td>2 (2.6)</td>
<td>1 (1.3)</td>
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<tr>
<td>Overall</td>
<td></td>
<td></td>
<td>52/874 (71)</td>
<td>196/280 (70)</td>
<td>21/70 (50)</td>
<td>32 (4.3)</td>
<td>5 (0.7)</td>
<td>0 (1.2)</td>
<td>1 (0.1)</td>
</tr>
</tbody>
</table>

*Values are given as n (%); success was defined as free of AF recurrence without antiarrhythmic drugs.
*Seven-day Holter monitoring was used to screen AF recurrence.
*Three-dimensional echocardiography was used to monitor ablation in 258 patients.
Segmental PV isolation refers to the application of lesion arcs immediately outside the ostia of the PVs, and is based on the observation that discrete strands of myocardial tissue are found in PV ostia and represent attractive ablation targets. Segmental isolation is typically guided by a lasso catheter inserted into the PV, allowing for identification of the earliest activated region. A second ablation catheter is then used for lesion application. Ablation is performed at the region of earliest activation, with lesions placed outside the PV ostium.

Segmental ablation has been carefully studied in a number of prospective clinical trials (see Table 1), and remains a preferred method of some operators. Oral and colleagues investigated the efficacy of segmental ablation for patients with paroxysmal (n = 58) or persistent (n = 12) AF. In all patients, at least three PVs were targeted (with variable inclusion of the RIPV), with 94% success in acute isolation. Patients were followed for 150 ± 85 days. There was a 70% cure rate (freedom from AF) and 83% clinical improvement rate (freedom from or marked reduction of symptomatic AF) in patients with paroxysmal AF. Those patients with persistent AF had markedly worse results, with only 22% of patients cured of AF. Subsequent data from this group demonstrated inferiority of their segmental approach to circumferential PV isolation (discussed below). A review of the compiled data evaluating segmental PV isolation demonstrates a combined efficacy that reflects the disparities in success rates seen between patients with paroxysmal and persistent AF described by Oral et al. Intermediate-term success with segmental ablation was seen in 196 of 280 patients (70%) with paroxysmal AF, contrasted with 21 of 70 patients (30%) with persistent or permanent AF. PV stenosis remained a significant complication in these collected studies (incidence of 4.3%). Long term data in this group is limited.

Pappone and colleagues have championed an alternative strategy for PV isolation, in which large circumferential lesions are placed around the ostia of the PVs. Several variations of the procedure are practiced: a single long lesion encompassing the ostia of all four PVs; twin lesions around the left and right PV ostia; or four lesions, each targeting a single PV. In each case, lesions are made empirically, rather than targeting particular regions of early PV activation. Success rates using wide, circumferential lesions have been favorable, typically ranging between 56 to 95%.

Pappone and colleagues studied 251 patients consecutively between 1998 and 2000, employing the circumferential approach. The majority of their patients had symptomatic, drug-refractory paroxysmal AF (n = 179), though some patients had permanent AF (n = 72). In most cases, each PV was isolated individually, with circumferential lesions applied > 5 mm outside the PV ostium. Some patients with closely paired or common PV ostia had larger lesions incorporating both ipsilateral PVs. The study reported follow-up data after 10 ± 4.5 months. In 179 patients with paroxysmal AF, 85% were free of AF; in 49 patients with per-

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Table 1. Summary of Clinical Studies of Segmental PV Ablation

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<th>Study</th>
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<th>PV Stenosis (&gt;50%)</th>
<th>Stroke</th>
<th>Cardiac Tamponade</th>
<th>Mitral Valve Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hassaqueur et al.</td>
<td>2000</td>
<td>4 ± 5</td>
<td>51/70 (75)</td>
<td>51/70 (73)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oral et al.</td>
<td>2002</td>
<td>5 ± 9</td>
<td>41/70 (61)</td>
<td>41/70 (74)</td>
<td>0</td>
<td>1 (1.4)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DelMaestro et al.</td>
<td>2002</td>
<td>8 ± 4</td>
<td>35/75 (51)</td>
<td>N/A</td>
<td>N/A</td>
<td>3 (9)</td>
<td>0</td>
<td>4 (53)</td>
<td>0</td>
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<tr>
<td>Marcoux et al.</td>
<td>2003</td>
<td>14 ± 5</td>
<td>27/135 (66)</td>
<td>N/A</td>
<td>N/A</td>
<td>22 (17)</td>
<td>2 (0.6)</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Arndt et al.</td>
<td>2003</td>
<td>12</td>
<td>34/55 (62)</td>
<td>26/57 (73)</td>
<td>8/19 (44)</td>
<td>1 (1.8)</td>
<td>0</td>
<td>1 (1.8)</td>
<td>0</td>
</tr>
<tr>
<td>Oral et al.</td>
<td>2004</td>
<td>6</td>
<td>27/49 (57)</td>
<td>27/49 (57)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mannour et al.</td>
<td>2004</td>
<td>21 ± 5</td>
<td>22/49 (55)</td>
<td>19/23 (53)</td>
<td>3/7 (42)</td>
<td>0</td>
<td>0</td>
<td>2 (9)</td>
<td>0</td>
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<tr>
<td>Vassalreddy et al.</td>
<td>2004</td>
<td>11 ± 8</td>
<td>39/75 (52)</td>
<td>32/42 (79)</td>
<td>7/22 (21)</td>
<td>3 (4)</td>
<td>2 (2.6)</td>
<td>2 (2.6)</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>Overall</td>
<td>–</td>
<td>–</td>
<td>52/140 (71)</td>
<td>196/280 (61)</td>
<td>21/40 (33)</td>
<td>32 (2.9)</td>
<td>5 (0.7)</td>
<td>9 (1.2)</td>
<td>1 (0.1)</td>
</tr>
</tbody>
</table>

Values are given as n (%); success was defined as free of AF recurrence without antiarrhythmic drugs.
*Seven-day Holter monitoring was used to screen AF recurrence.
†Multicardiolo echocardiography was used to monitor ablation in 280 patients.
sistent or permanent AF, 68% were free of AF. Importantly, the procedure appeared to markedly reduce the incidence of PV stenosis (none), and was generally well tolerated (tamponade in 2 patients).

Oral and colleagues have directly compared the segmental and circumferential approaches in a randomized, prospective trial. In 80 patients, all with symptomatic paroxysmal AF, were evenly assigned to segmental or circumferential ablation. Ipsilateral veins were isolated in a single lesion with the circumferential technique. Procedure and fluoroscopy times did not vary significantly between the two groups. Success after 6 months, however, favored the circumferential (88% freedom from symptomatic AF) over the segmental approach (67% freedom from symptomatic AF). Complications did not vary meaningfully between the two groups, and were minimal (single iatrogenic LA flutter).

A recent review summarized the recent clinical trials investigating circumferential PV isolation efficacy (Table 2). Long-term success was seen in 290 of 393 patients (74%) with paroxysmal AF. In patients with persistent or permanent AF, success rates were predictably lower (73 of 149 patients; 49%). Also predictably, the incidence of PV stenosis was markedly reduced compared to focal or segmental ablation (0.4%). Other complications, including tamponade, stroke, and death, were all under 1%. Based in large part on these trials, and on the aforementioned limitations of focal and segmental PV isolation, circumferential ablation around the PVs remains a commonly used technique, either alone or in conjunction with alternative approaches, in the catheter-based treatment of AF.

The Present - Johns Hopkin Hospital

At Johns Hopkins, we have prospectively investigated both segmental and circumferential techniques for AF ablation, publishing both intermediate- and long-term results. We have chosen a stringent definition for success following AF ablation, defined as freedom from AF off all anti-arrhythmic drugs. An important consideration in evaluating clinical trials describing success rates in AF ablation is the often protean and changing definition of success (ranging from reduction of symp-
follow-up of 70%. Success increased to 83% after a re-do procedure.

The Future

There are several promising developments that may impact the near future of atrial fibrillation ablation. These principally include new technologies for lesion set delivery to the pulmonary vein ostia, consistent with current strategies targeting PV triggers. Focused ultrasound, cryoablation, and RF ablation catheters with customized lesion patterns for PV ostia are only some of the emerging technologies that may make PV isolation easier, faster, and safer. Other types of new therapies include the use of robotic ablation systems (Hansen Medical) and Stereotaxis.

It is difficult now to predict the future. However there are three possible strategies that will likely gain significant market share. One of these strategies involves the use of a balloon based ablation system (Focused Ultrasound, Cryoablation, or Laser). If one of these ablation systems gains market release and is shown to shorten procedure time and improve outcomes of AF ablation it is likely that many patients will initially undergo a balloon based ablation procedure. The obvious advantage of this approach is that expensive mapping systems are not required, making this therapy one that can be offered at virtually all hospitals that have based EP equipment. If an initial balloon based ablation procedure fails, or if a patient has long standing persistent AF they would be referred into a larger center with more sophisticated mapping equipment. A second strategy is the more widespread use of robotic or stereotactic ablation systems. If these systems are shown to improve outcomes and shorten procedure time it is possible that they would gain a very significant market share. The obvious advantage of these systems is that they provide the opportunity to automate much of the ablation procedure. And the third strategy that may remain dominant is the continued use of radiofrequency based ablation systems that heavily rely on electroanatomic mapping. At the present time, this latter approach is clear dominant.

It is clear that electrophysiologists are striving to find an ablation system or strategy that will deliver the best outcomes for their patients. At the present time all of the futuristic ablation systems described above are no more than promising possibilities. In order for these new ablation systems to gain widespread acceptance clinical trials will need to be performed which demonstrate increased efficacy, improved safety, and hopefully both shorter procedure times and reduced cost. Even if the first three are achieved, at an increased overall cost, this ablation system / approach will likely gain widespread acceptance.

In addition, there are ongoing trials looking at ablation versus anti-arrhythmic drug therapy for atrial fibrillation. While catheter ablation for AF is currently restricted primarily to patients with drug-refractory, highly symptomatic AF, a number of studies have investigated or are investigating ablation as a first-line therapy. The results of these trials may impact referral patterns for ablation in the near future.

Conclusions

Catheter-based therapies for AF have evolved rapidly over the last 15 years. One of the striking aspects of that evolutionary process has been the discovery of fundamental mechanisms underlying AF, often revealed during the course of clinical investigation. Triggering of AF from ectopic foci, atrial electrophysiological properties permitting arrhythmia maintenance, and the physical and electrophysiological remodeling that occurs in the setting of AF all have been elucidated, in large part, through clinical investigations.

As importantly, the efficacy and risk: benefit ratio of non-pharmacological interventions for AF continues to improve. New modalities of ablation, including ultrasound, laser, microwave, and cryoablation are all subjects of ongoing investigation. Given the rate of progress in AF therapy over the last quarter century, safer and more effective techniques seem certain to emerge over the next 25 years. Given the aging of the population, and the likely attendant flood of patients with AF at our doorstep, such advances are certainly worthy of aggressive pursuit.

References

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