Atrial Mapping and Radiofrequency Catheter Ablation in Patients With Idiopathic Atrial Fibrillation
Electrophysiological Findings and Ablation Results

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Background—Knowledge of the electrophysiological substrates and the cure of atrial fibrillation (AF) is still unsatisfactory. The goal of this study was to evaluate the electrophysiological features of idiopathic AF and their relationship to the results of radiofrequency (RF) catheter ablation of AF and the safety and effectiveness of this procedure.

Methods and Results—Sixteen patients with idiopathic AF underwent atrial mapping during AF and then RF ablation in the right atrium. The atrial activation was simultaneously recorded in four regions in the right atrium: high lateral wall (HL), low lateral wall (LL), high septum (HS), and low septum (LS) and in the left atrium through the coronary sinus (CS). In these regions, we evaluated the atrial fibrillation intervals (FF) and the morphological features of AF recordings by Wells’ classification. No complications occurred during RF ablation. Of the 16 patients, 9 (56%) without AF recurrences during the follow-up (11±4 months) were considered successfully ablated. These patients showed a significantly shorter mean FF interval in the HS and the LS (122±32 and 126±28 ms, respectively) than in the HL and LL (159±24 and 156±28 ms, respectively). Moreover, the septum had more irregular electrical activity with greater beat-to-beat changes in FF and a higher prevalence of type III AF than the lateral region. The CS had similar behavior to the septum. Conversely, patients with unsuccessful ablation had an irregular atrial activity in the lateral wall, septum, and CS with no significant differences between the different sites.

Conclusions—Right atrial endocardial catheter ablation of AF is a safe procedure and may be effective in some patients with idiopathic AF. The atrial mapping during AF showed a more disorganized right atrial activation in the septum than in the lateral wall in patients with successful ablation. (Circulation. 1998;97:2136-2145.)

Key Words: fibrillation ■ catheter ablation ■ electrophysiology ■ mapping

Atrial fibrillation is the most frequent supraventricular arrhythmia; despite this, its therapy is still unsatisfactory, probably because of the few data known about atrial mapping during AF in different clinical situations in humans.12 Recently, some studies on animals3,4 and a few in humans5-10 have demonstrated that selective endocardial lesions in the right and/or left atrium may be effective in the prevention of AF. These studies considered a heterogeneous population and used different ablation techniques that consisted of multiple RF lesions in both the right and left atria in most cases. However, the creation of extensive lesions in the left atrium is associated with a theoretical increased risk of thromboembolism.11 Also, to the best of our knowledge, no data are reported concerning the relationship between atrial mapping and the success of the ablation procedure in humans.

The aim of this work was to evaluate in patients with idiopathic AF (1) the electrophysiological features of atrial activation, (2) the possibility of restoring sinus rhythm and preventing recurrences of AF with RF catheter ablation performed only in the right atrium, (3) the safety of this procedure, and (4) the relationship between the results of catheter ablation and atrial mapping. Because the ablation procedure was limited to the right atrium to avoid the risk of thromboembolism, we selected patients with idiopathic AF and, among these patients, those in whom the arrhythmia seemed to be induced by a vagal trigger because in these patients the right atrium might be more directly involved in AF initiation and perpetuation.12-14

Methods

Study Population
Sixteen consecutive patients highly symptomatic for idiopathic AF with a clinical history suggestive of a vagal form as described by Coumel11 and Prystowsky et al16 and refractory to drug therapy (number of drugs, 3±2), including class III drugs in all patients, were studied (Table 1). Mean age was 52±10 years, all but 1 were
men, and a history of AF was present from 7 ± 6 years. In all patients, a close link between the onset of the AF and enhanced vagal tone was present; at the beginning of symptoms, most of the episodes started during the night, after meals, and during rest; no demonstrable organic heart disease was present in any patient. Left and right atria were normal in 9 and 6 patients, respectively, and moderately enlarged in the others. Eight patients had long-lasting episodes (>7 days) defined as persistent, and 8 had paroxysmal AF with daily sustained episodes. Patients with the paroxysmal form had a mean value of 10.5 (range, 2 to 92) episodes per day, and AF was present for a mean of 43.5 ± 16.4% (range, 17% to 55%) of time as evaluated with ECG Holter monitoring.

Electrophysiological Study
All patients gave written informed consent. Antiarrhythmic drugs had been discontinued for at least five half-lives, and no patients had received amiodarone in the preceding 6 months. The electrophysiological study was performed by use of two standard halo catheters (Cordis Webster) with 20 electrodes and an interelectrode distance of 2–8 mm positioned in the right atrium to map the region of the lateral wall of the left atrium adjacent to it. Bipolar digitized atrial electrograms from 20 to 24 endocardial sites and two surface ECG leads were simultaneously recorded (1-kHz sampling frequency, 30- to 500-Hz band-pass filters), displayed on a multichannel recorder, and stored on magneto-optical disks (Cardiolab, Prucka Engineering, Inc). If AF was not spontaneously present, it was induced by an isoelectric space of at least 50 ms. The choice of the limit of F waves the presence of two distinct electrograms clearly separated by an isoelectric space of at least 50 ms. The choice of the limit of 50 ms for the shortest FF interval, which is similar to that used in other studies, and the simultaneous evaluation of the atrial electrograms in the sites adjacent to those analyzed were aimed to reduce the interference of double or fragmented and long-duration electrograms. Both the FF interval durations and the beat-to-beat changes in FF intervals were evaluated. The latter was expressed as the absolute value of the percentage difference to the preceding interval: \( \text{abs}\left[\frac{\text{FF}_{i-1}-\text{FF}_{i}}{\text{FF}_{i}}\times 100\right] \). Second, to grade the higher or lower regularity of the atrial electrograms, we used the classification suggested by Wells et al applied to the periods of 60 seconds used for analysis of FF intervals. The presence and duration of the three different types of AF in each site were expressed as a percentage of the total duration of the analyzed period. This qualitative analysis, although questionable and slightly approximate, was performed to evaluate the presence of a more regular (type I) or more irregular (type III) AF in the different atrial regions and to extend the analyzed period of AF to reduce the bias of the spontaneous fluctuation of AF activation.

The electrophysiologists who evaluated these data were unaware of the part of the atrium analyzed and the results of the ablation. Some months later, the measurements in eight patients were repeated blindly by a second physician to assess the interobserver variability, and in the other eight, the measurements were repeated by the same physician.
Catheter Ablation in Atrial Fibrillation

![Diagram of three linear lesions performed in the right atrium](image)

**Figure 1.** Diagram of the three linear lesions performed in the right atrium. The first was a “septal” line from the superior vena cava (SCV) to the fossa ovalis (FO) to the CS os and from this to the inferior vena cava (ICV) (1). The second lesion was performed in the inferior vena cava–tricuspid valve isthmus (2). The third transversal lesion from the fossa ovalis through the posterior wall to the lateral edge of the tricuspid annulus was performed to compartmentalize the right atrium (3). T indicates tricuspid valve.

Electrophysiologist to evaluate the intraobserver variability. Comparisons of the two analyses were performed by use of the same chunk of recordings with unpaired t test analysis.

**Catheter Ablation**

Catheter ablation was performed by use of either a standard ablation catheter with a 4-mm electrode tip with thermistor (Blazer, EP Technologies) or special catheters with multiple 4-mm electrodes (from four to six), each suitable for RF delivery with thermocouple (Amazr Medtronic). Three linear lesions in the right atrium were performed as described in Figure 1. On the basis of our preliminary observations of the atrial electrophysiological features during AF, the third transversal lesion was not performed in the last four patients. The fossa ovalis was localized with radiological landmarks and transesophageal (Sonos 1000, 5-MHz Hewlett Packard) or intracavitary echocardiography (ClearView Ultra, 20 or 10 MHz, Boston Scientific Corp), which were also used to check the stability and tissue contact of the catheters. RF energy was delivered with Atakr (Medtronic) or EPT 1000 (EP Technologies) generators; RF energy was delivered setting the temperature to 60°C for 60 seconds. No pericardial effusion, an echocardiogram at the follow-up examinations.

The ablation was considered successful if no recurrences of AF lasting >30 seconds were present either with or without previously ineffective drugs during the follow-up.

The patients were then followed up at 1, 3, 6, 9, 12, and 18 months or, in the case of symptom recurrences, with ECG, clinical examination, Holter, and echocardiography; all the patients were taught to use a transtelephonic monitoring device for the first 6 months. The presence of left and right atrial contraction was evaluated with an echocardiogram at the follow-up examinations.

The results of atrial mapping in the patients with the different results of catheter ablation were retrospectively analyzed. For this purpose, the patients were divided into three groups: group A, successful ablation; group B, unsuccessful ablation owing to AF recurrences; and group C, unsuccessful ablation without AF recurrences but with the appearance of new atypical atrial flutter.

Finally, to evaluate a possible injury of vagal innervation, we retrospectively evaluated heart rate variability in a time domain analysis in the nine patients with successful ablation. Using a Del Mar Avionics Strata-Scan 563, we calculated the SD of the NN intervals, considering day (8 AM to 8 PM) and night (midnight to 6 AM) separately.

**Statistical Analysis**

Paired and unpaired t tests were used for statistical analysis. Results were considered to be statistically significant when P<0.05. All data, unless otherwise noted, were expressed as mean±SD. All statistical analyses were performed with the Statistica for Windows statistical program (StatSoft).

**Results**

**Intraobserver and Interobserver Variabilities**

There were negligible intraobserver differences (1% to 2%) in values of FF intervals. Also, no significant interobserver differences were observed in duration of FF intervals (1% to 6%). Moreover, there were no significant intraobserver and interobserver differences in the duration of the three types of AF (2% to 5%).

**Electrophysiological Findings**

We have analyzed 2 periods of 10 seconds, epochs a and b, for a total of 13785 AF beats measured. The following results refer to epoch a. The mean FF interval was slightly longer in the HL and LL (147±31 and 148±29 ms, respectively) compared with the HS and LS (130±30 and 130±29 ms, P<0.05) and the distal CS (130±21 ms, P<0.05). The beat-to-beat changes in FF intervals were lower in the lateral region (HL, 24±12%; LL, 24±12%) than in the other regions (HS, 31±16%; LS, 33±14%; and CS, 30±15%), but the statistical significance was reached only for the HL and LL compared with the LS (P<0.05).

In the lateral right wall, type I and type II AF generally was present (40.1% and 41.7% in the HL and LL for type I and 34.6% and 34.2% in the HL and LL for type II), interrupted by briefer periods of type III AF (HL, 25.3%; LL, 24.1%). Conversely, type II and type III were mostly present in the septum (44.4% and 47% in the HS and LS for type II and 42.4% and 46.3% in the HS and LS for type III) and in the CS (37.5% and 48.5%, respectively), while type I was present for shorter periods (HS, 13.2%; LS, 6.7%; and CS, 14.0%, respectively). In the HL and LL, type I was significantly different with respect to the HS (P<0.01), LS (P<0.01), and CS (P<0.05). Type III AF was present for a shorter period in the HL than in the HS (P<0.05), LS (P<0.05), and CS regions (P<0.05) and in the LL than in the HS (P<0.01), LS (P<0.01), and CS (P<0.05).

**Ablation Results**

The procedure was performed during AF in 13 patients and during sinus rhythm in 3 patients. At the end of the procedure, 4 patients (2 with paroxysmal and 2 with persistent AF) were in sinus rhythm, and AF was no longer inducible. In these patients, the interruption of AF occurred while performing the RF lesion
in the septum, and it was preceded by an organization of the atrial activity in this region (Figure 2). In the other 12, the AF was still present or inducible. The results of RF ablation are summarized in Table 2. The mean duration of the procedure was 308±57 minutes with a mean fluoroscopic time of 40±13 minutes. The mean number of RF pulses was 44±9. In 5 patients, two sessions were performed because of AF or atypical flutter recurrences; another 2 patients refused the second session. No complications occurred in any patients. In the 4 patients in sinus rhythm and no inducible AF, at the end of the procedure, we were not able to demonstrate the presence of a block of the conduction through the lines of lesion evaluated with atrial

**TABLE 2. Results of Radiofrequency Ablation**

<table>
<thead>
<tr>
<th>Group</th>
<th>Patient</th>
<th>Procedure Duration, min</th>
<th>Fluoroscopic Time, min</th>
<th>RF Pulses, n</th>
<th>Atrial RF Lesions</th>
<th>Follow-up, mo</th>
<th>Follow-up Therapy</th>
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<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>300</td>
<td>52</td>
<td>39</td>
<td>S, I</td>
<td>7</td>
<td>Propafenone</td>
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<tr>
<td></td>
<td>2</td>
<td>330</td>
<td>54</td>
<td>36</td>
<td>S, I, T</td>
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<td>Amiodarone</td>
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<tr>
<td></td>
<td>3</td>
<td>290</td>
<td>45</td>
<td>30</td>
<td>S, I, T</td>
<td>12</td>
<td>No drugs</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>300</td>
<td>32</td>
<td>47</td>
<td>S, I, T</td>
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<td>Sotalol</td>
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<tr>
<td></td>
<td>5</td>
<td>390</td>
<td>55</td>
<td>45</td>
<td>S, I</td>
<td>6</td>
<td>No drugs</td>
</tr>
<tr>
<td></td>
<td>6</td>
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<td>S, I, T</td>
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<td>No drugs</td>
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<td>8</td>
<td>300</td>
<td>50</td>
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<td>290</td>
<td>30</td>
<td>56</td>
<td>S, I, T</td>
<td>13</td>
<td>Flecainide</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>360</td>
<td>25</td>
<td>47</td>
<td>S, I, T</td>
<td>13</td>
<td>Digoxin and β-blockers</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>350</td>
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<td>42</td>
<td>S, I, T</td>
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<td>Digoxin</td>
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<td>390</td>
<td>53</td>
<td>54</td>
<td>S, I, T</td>
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<tr>
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<td>300</td>
<td>34</td>
<td>44</td>
<td>S, I, T</td>
<td>19</td>
<td>No drugs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>290*</td>
<td>46*</td>
<td>42</td>
<td>S, I, T</td>
<td>19</td>
<td>AV node ablation</td>
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<td>310</td>
<td>22</td>
<td>35</td>
<td>S, I, T</td>
<td>14</td>
<td>Propafenone</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>340</td>
<td>49</td>
<td>43</td>
<td>S, I, T</td>
<td>19</td>
<td>Digoxin and β-blockers</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>300</td>
<td>50</td>
<td>64</td>
<td>S, I, T</td>
<td>12</td>
<td>No drugs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>230*</td>
<td>37*</td>
<td>32</td>
<td>S, I, T</td>
<td>12</td>
<td>No drugs</td>
</tr>
</tbody>
</table>

S indicates septal; I, isthmus; and T, transversal; A, group of patients with successful ablation; B, group of patients with unsuccessful ablation; and C, group of patients with unsuccessful ablation due to appearance of new atypical flutter.

*Data referred to the second ablation session.
pacing from different sites of the right atrium and CS; in all the patients, a reduction in the amplitude and a fragmentation of the atrial electrograms were generally observed in the sites where RF energy was delivered.

The heart rate variability analysis performed after ablation in the nine patients with successful ablation shows a greater mean RR interval and SD of the NN interval in the night than in the day (897±209 versus 785±124 ms and 90±44 ms versus 66±16 ms, respectively); however, the difference did not reach statistical significance, probably because of the small number of patients.

During follow-up (mean, 11±4 months; range, 4 to 19 months), nine patients (56%) (group A) had stable sinus rhythm, four without any antiarrhythmic drugs and five with a previously ineffective drug (Table 2 and Figure 3). Of the other seven patients (44%), five had AF recurrences (group B) and two episodes of atrial flutter (group C).

All the nine patients with stable sinus rhythm showed preserved atrial contractility evaluated with echocardiography in all the examinations during follow-up. We did not observe any significant difference between the group of patients with successful AF ablation and those in whom the ablation was unsuccessful with regard to the ablation procedure (duration of the procedure, fluoroscopic time, and number of RF pulses). Moreover, echocardiographic findings and clinical characteristics of AF (paroxysmal or persistent) did not present any significant relationship with the results of AF ablation and atrial mapping.

Atrial Mapping and Ablation Results

Patients with successful ablation (group A) showed different electrophysiological features of the AF compared with group B patients in whom the ablation was unsuccessful. The number of patients, expressed as a percentage, with successful ablation with or without previously ineffective drugs and those with unsuccessful ablation. The number of evaluated patients is indicated for each follow-up period.

In Table 5, the mean duration (expressed as a percentage) of the three types of AF in groups A and B for each site are given. Groups A and B did not show any statistically significant difference with regard to the types of AF, except for type III, which was greater in group B than in group A in the HL region (P=0.05), and type I, which was present mostly in the HL region (P<0.05) in group A. As seen with the analysis of the FF interval duration and the beat-to-beat changes in FF interval, group A showed greater organization in the lateral region than in the septum and CS, whereas group B showed no significant differences in the mapped regions (Figure 5). In group A, type I was more present in the HL and LL regions compared with the HS, LS, and CS; however, this is statistically significant only for the HL and LL compared with the HS (P<0.01) and LS (P<0.05) (Figure 6). No significant difference was observed for type II AF. In group A, type III AF was more rarely present in the HL and LL than in the HS (P<0.01) and LS (P<0.01). Only the HL showed a significant difference for type III when the different sites were compared with the CS (P<0.01). In group B, the types of AF were similarly present in the mapped regions with no significant differences.

Comparison Between Epochs a and b

In the total group of 16 patients, no statistically significant difference was observed between epochs a and b for all sites analyzed (HL, 147±31 versus 145±33; LL, 148±29 versus 150±35; HS, 130±30 versus 123±35; LS, 130±29 versus 119±31; and CS, 130±21 versus 119±28, respectively). Moreover, a comparison of epochs a and b did not show...
significant differences in patients with successful (HL, 159±24 versus 157±22; LL, 156±28 versus 166±25; HS, 122±32 versus 117±32; LS, 126±28 versus 115±32; and CS, 132±20 versus 122±26, respectively) and unsuccessful (HL, 122±31 versus 118±37; LL, 128±28 versus 118±35; HS, 128±16 versus 116±34; LS, 127±34 versus 111±32; and CS, 119±23 versus 102±24, respectively) ablation. Similarly, in epoch b, the difference between the septum and the lateral right wall was similar to epoch a. In fact, FF intervals in the lateral right wall were significantly longer than in the septum (HL and LL versus HS and LS, P<0.01) and in CS (P<0.01).

### Discussion

**Atrial Mapping**

Few studies have evaluated atrial activation during AF in humans, and any atrial mapping was generally performed from the epicardium and limited to the free walls, with the other regions of the atria and particularly the septum exclud-
TABLE 4. Differences in FF Durations Between the Mapped Sites in the Group With Successful Ablation (Group A) and the Group With Unsuccessful Ablation (Group B)

<table>
<thead>
<tr>
<th>Mapped Sites</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL vs HS</td>
<td>0.001</td>
<td>0.452</td>
</tr>
<tr>
<td>HL vs LS</td>
<td>0.003</td>
<td>0.619</td>
</tr>
<tr>
<td>HL vs CS</td>
<td>0.001</td>
<td>0.683</td>
</tr>
<tr>
<td>LL vs HS</td>
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<td>0.974</td>
</tr>
<tr>
<td>LL vs LS</td>
<td>0.011</td>
<td>0.916</td>
</tr>
<tr>
<td>LL vs CS</td>
<td>0.004</td>
<td>0.246</td>
</tr>
<tr>
<td>HL vs LL</td>
<td>0.414</td>
<td>0.418</td>
</tr>
<tr>
<td>HL vs LS</td>
<td>0.373</td>
<td>0.872</td>
</tr>
<tr>
<td>HS vs CS</td>
<td>0.200</td>
<td>0.260</td>
</tr>
<tr>
<td>LS vs CS</td>
<td>0.358</td>
<td>0.581</td>
</tr>
</tbody>
</table>

ed.12 Data dealing with the spatial organization of AF are also scarce.1–3,20–22

In this study, performed in patients with idiopathic AF, we observed during AF that different atrial regions showed different electrophysiological behaviors with the simultaneous presence of regions with relatively regular activation and other areas with a completely disorganized atrial activity. The AF pattern showed more regular and organized atrial activity in the right lateral wall, as demonstrated by lower FF beat-to-beat changes and by the higher percentage of type I and lower percentage of type III AF compared with the other evaluated sites, particularly the LS. These data are in accordance with what has been reported by others in different experimental situations.1,20 Morillo et al1 observed longer intervals in the right free wall than in the left free wall in dogs; however, no data are reported for the interatrial septum. Similar results were found with only qualitative analysis by Jais et al.26 who evaluated, although not simultaneously, the regional disparities of endocardial atrial activation in humans in a different kind of population.

This nonhomogeneous electrophysiological behavior may find an explanation in the anatomy of the right atrium, which is a rather complex structure, and in particular in the presence of the crista terminalis. It is conceivable that this anatomic structure, together with the tricuspid ring, may generally work as a functional barrier, isolating the lateral and anterior wall from the other regions of the right atrium and thus preventing the irregular spread in this region of the multiple AF wavelets that have to follow a forced path, forming an almost regular activation front, as suggested for atrial flutter.27 Therefore, this area might be protected from the appearance and/or perpetuation of multiple wavelets and thus, at least in some patients, may not be a critical area for the maintenance of AF but probably a bystander. On the other hand, the more irregular atrial activity recorded in the LS may be related to the finding of increased nonuniform anisotropic characteristics observed in this region by Papageorgiou et al.24 However, we must be aware that we cannot exclude the possibility that the more irregular atrial activity observed in the septum may depend on the fact that the catheter positioned on the right septum may, to some extent, record the wavelets circulating on both the right and left sides of the septum.

Catheter Ablation

There are few data on endocardial catheter ablation of AF.3–10 Recently, experimental studies dealing with AF catheter ablation in animals have been reported.34 Elvan et al3 evaluated AF inducibility after an ablation procedure that mimicked the Maze procedure; on the contrary, Morillo et al3 showed the effectiveness of localized epicardial cryoa blastion in 11 dogs in the site where the shortest FF intervals were recorded.

Few studies5–10 on AF catheter ablation in humans are available, without any information on atrial mapping during AF. Haissaguerre et al5 reported the results of catheter ablation in patients with paroxysmal AF with and without organic heart disease. Their success rate, including patients on antiarrhythmic drugs, was 33% with a procedure limited to the right atrium; the rate increased to 60% with additional ablation in the left atrium.

Extensive ablation, however, especially in the left atrium, may be related to an increased risk of complications such as thromboembolism. To avoid these risks and because AF patients are a very heterogeneous group, we selected patients with idiopathic AF with the clinical characteristics of the so-called “vagal AF.”15,16 In fact, the increase in vagal tone is considered the possible trigger of the arrhythmia, and the effect of the vagal tone seems to be predominant in the right atrium12–14; thus, we supposed that an ablation limited to the right atrium might be effective.

The sites of RF lesions were decided on the basis of two observations. First, some anatomic barriers are already present in the right atrium; the septum is delimited by some of these (superior and inferior vena cava, crista terminalis, CS os, tendon of Todaro) and characterized by the presence in its center of a nonhomogeneous structure, the fossa ovalis. Second, in our experience from previous unpublished data, the septum was the region of the right atrium in which more irregular and disorganized electrical activity was recorded; assuming that this factor might be critical for the maintenance of the AF, our ablation strategy considered a linear lesion in the atrial septum to be the first step. The second lesion was performed in the inferior vena cava–tricuspid valve isthmus because the creation of a lesion from the superior to the inferior vena cava could facilitate the reentrant circuit of atrial flutter.23,25 The third transversal lesion was performed in the first 12 patients in an attempt to compartmentalize the right atrium as described by Haissaguerre et al.5 However, considering the results of the atrial mapping, the transversal lesion was not performed in the last 4 patients; in all of them, the ablation was successful.

In our study, we obtained successful ablation in nine patients (56%); however, only four of them did not use drugs, while the other five still needed drugs to maintain sinus rhythm. The modification of the effect of antiarrhythmic drugs that were ineffective before the ablation may be a sign that the electrophysiological substrate has been modified by the RF lesions. It may be hypothesized that if the lesion created is not continuous enough to block the conduction in
that area, it could be sufficient to reduce the number of wavelets sustaining the arrhythmia; therefore, the drugs may cause a further reduction of the number of wavelets, thus preventing the maintenance of AF.

Although the success rate is not very high, is similar to or higher than that reported in the literature for an ablation limited to the right atrium in humans, and is lower than that reported with a combined right and left approach, our data suggest that a more extensive ablation may be necessary for successful treatment of AF.
show that at least in some patients, catheter ablation in the right atrium only may be effective in the "cure" of AF with a low risk of complications; in fact, in our small group of patients, no major complication occurred.

**Atrial Mapping and Ablation Results**

The aim of catheter ablation of AF should be its cure while limiting the extension of the lesions as much as possible; one of our objectives in this study was to evaluate whether an analysis of the atrial electrophysiological features may lead to the identification of atrial regions that are critical for the appearance and maintenance of the AF, thus limiting the RF delivery to relatively small areas.

When we analyzed the differences between the patients with successful and unsuccessful ablation, we found some interesting findings, particularly their relationship with right atrial mapping. The parameters that we analyzed, which are an expression of different electrophysiological characteristics, are indeed concordant in showing that patients with successful ablation generally present a peculiar pattern characterized by a nonhomogeneity of the atrial activation in different regions of the right atrium; this was less evident in patients with unsuccessful ablation. Considering that in this study, RF was delivered mainly in the septal area and that catheter ablation was more frequently successful in those patients in whom the septum was the region of the right atrium with the shortest FF interval and with the most irregular activation compared with the lateral wall, we might hypothesize that in these patients the lateral wall might be a bystander. These preliminary data suggest that catheter ablation of AF might be guided by the localization of critical areas necessary for the perpetuation of AF, at least in some patients with idiopathic AF. This is in agreement with the hypothesis recently suggested by Konings et al that although the atria as a whole participate in the process of AF, not all the parts of the atria contribute equally to the perpetuation of the fibrillatory process, suggesting that selective ablation of the areas characterized by abnormal conduction patterns may be effective in the treatment of AF. Moreover, the importance of the septum in the perpetuation of AF has been recently highlighted by Kumagai et al, who showed in dogs that a reentrant circuit in the septum may be a major factor in the maintenance of this arrhythmia.

On the contrary, in patients with unsuccessful ablation, both the lateral and the septal regions showed similar irregular activations; therefore, in this case, the lateral wall may be directly involved in the perpetuation of the arrhythmia. Possible explanations of the unsuccessful ablation in these patients may be the difficulty in creating continuous linear lesions in the lateral wall because of the anatomy of this area or the need for either more detailed atrial mapping with the evaluation of more sites or more extensive RF lesions, including the left atrium.

**Study Limitations**

Some limitations are present in this study. The atrial mapping was performed by use of bipolar recordings with a relatively large interelectrode distance (2 mm); a closer interelectrode distance or unipolar recordings would have allowed more precise evaluation of the atrial activation with possible perturbation caused by far-field activation excluded. We used unipolar recordings in the first patients, but the disturbance of the isoelectric line made correct evaluation of the FF intervals difficult.

Other limitations are the small number of atrial sites considered for the analysis of FF interval and AF pattern, which excluded the posterior and anterior wall of the right atrium, and the fact that the activation data of the left atrium were recorded with the catheter positioned in the CS; these activations do not necessarily reflect the left atrial endocardial activation.

Moreover, the analysis of the differences in the electrophysiological features between patients with successful and unsuccessful ablation was only retrospective, and no attempt was made to modify the ablation strategy on the basis of the atrial mapping. The lack of significance of AF type differ-

**TABLE 5. Mapping Results: AF Types**

<table>
<thead>
<tr>
<th>Group</th>
<th>HL AF Type, %</th>
<th>LL AF Type, %</th>
<th>HS AF Type, %</th>
<th>LS AF Type, %</th>
<th>CS AF Type, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I</td>
<td>49.3</td>
<td>38.7</td>
<td>12.0</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>27.9</td>
<td>20.4</td>
<td>14.3</td>
<td>34.1</td>
</tr>
<tr>
<td>B</td>
<td>Mean</td>
<td>15.0</td>
<td>27.1</td>
<td>57.9</td>
<td>22.5</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>23.4</td>
<td>11.3</td>
<td>31.0</td>
<td>24.2</td>
</tr>
</tbody>
</table>

---

**Figure 6.** Duration of the three different types of AF obtained expressed in percentage for all patients, the successful ablation patients (group A), and the unsuccessful ablation patients (group B).
ences in group B might be due to a type B error because of the small number of patients.

Several limitations, although similar to those of the other clinical studies on AF, are present, particularly the difficulty in performing precise measurements of the FF interval when the atrial activation is very irregular and the atrial electrograms are fragmented, as they are in many cases during AF. We were not able to use automatic measurements, thus allowing the analysis of AF in periods of longer duration.

Finally, we cannot exclude the possibility that successful ablation may depend on the lesion of vagal nervous endings, considering the kind of population examined, even if the analysis of heart rate variability suggested a preserved vagal tone modulation as indicated by the day/night difference in the mean RR intervals and standard deviation.

Conclusions

In patients with idiopathic AF, different activation patterns during AF may be simultaneously present; some regions show more regular atrial activity, generally the right lateral wall, while others such as the septum may show very irregular atrial activation. Cather ablation limited to the right atrium may be effective in about half of the patients with idiopathic AF, although most of them still may need previously ineffective drugs. However, this suggests that the electrophysiological substrate was modified. The success of the catheter ablation shows that at least in some patients, the right atrium is primarily involved in the genesis of the AF and that the patients with successful ablation showed a peculiar electrophysiological pattern characterized by more rapid and irregular atrial activity in the septum than in the lateral wall.

A period of 10 seconds seems to be long enough to evaluate nonhomogeneous activation between the different regions of the atria. The qualitative analysis of Wells’ AF type gives concordant results with the measurements of FF interval; therefore, the former analysis, which is much faster than the latter, might be used in the clinical evaluation of atrial activation during AF.

Right atrial catheter ablation has been found to be safe because no complications occurred in any patient. An improvement in atrial mapping is recommended to characterize better this heterogeneous type of arrhythmia and consequently to evaluate whether it is possible to differentiate various type of AF and to identify different ablation strategies.

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