Efficacy and Safety of an Irrigated-Tip Catheter for the Ablation of Accessory Pathways Resistant to Conventional Radiofrequency Ablation

Teiichi Yamane, MD; Pierre Jaïs, MD; Dipen C. Shah, MD; Mélèze Hocini, MD; Jing Tian Peng, MD; Isabel Deisenhofer, MD; Jacques Clémenty, MD; Michel Haïssaguerre, MD

Background—Radiofrequency catheter ablation of accessory pathways (APs) is very effective in all but a minority of patients. We examined the usefulness and safety of irrigated-tip catheters in treating patients with APs resistant to conventional catheter ablation.

Methods and Results—Among 314 APs in 301 consecutive patients, conventional ablation failed to eliminate AP conduction in 18 APs in 18 patients (5.7%), 6 of which were located in the left free wall, 5 in the middle/posterior-septal space, and 7 inside the coronary sinus (CS) or its tributaries. Irrigated-tip catheter ablation was subsequently performed with temperature control mode (target temperature, 50°C), a moderate saline flow rate (17 mL/min), and a power limit of 50 W (outside CS) or 20 to 30 W (inside CS) at previously resistant sites. Seventeen of the 18 resistant APs (94%) were successfully ablated with a median of 3 applications using irrigated-tip catheters. A significant increase in power delivery was achieved (20.3±11.5 versus 36.5±8.2 W; P<0.01) with irrigated-tip catheters, irrespective of the AP location, particularly inside the CS or its tributaries. No serious complications occurred.

Conclusions—Irrigated-tip catheter ablation is safe and effective in eliminating AP conduction resistant to conventional catheters, irrespective of the location. (Circulation. 2000;102:2565-2568.)

Key Words: catheter ablation □ Wolff-Parkinson-White syndrome □ radiofrequency

Catheter ablation therapy using radiofrequency (RF) current delivered through conventional catheters is extremely effective for curing patients with Wolff-Parkinson-White syndrome, but a minority of accessory pathways (APs) still cannot be ablated.1-4 Reasons for failure are variable and include nonoptimal mapping or insufficient lesion size. An experimental study5 showed that deeper and wider lesions can be made with irrigated-tip catheters, and the efficacy and safety of such lesions was recently demonstrated for the ablation of atrial flutter.6 We investigated the usefulness and safety of irrigated-tip catheters in a consecutive series of patients with APs resistant to conventional ablation.

Methods

Patient Population
Between October 1996 and April 2000, 314 APs in 301 patients (178 men; mean age, 45±13 years) were treated by RF catheter ablation at our institution. These APs were distributed as follows: 158 in the left free wall, 24 in the right free wall, 21 in the anterior septal space (right side), 18 in the middle septal space (15 on the right and 3 on the left), 67 in the posterior-septal space (40 on the right and 27 on the left), and 26 inside the coronary sinus (CS) or its branches.
attempts) to minimize the risk of inducing venous narrowing/occlusion, which would prevent catheter access distally. Before designating an AP as resistant to conventional catheters, every ablation approach proposed for the resistant AP was attempted, including (1) changing the site of ablation to the other side of the annulus, (2) changing from the endocardial to epicardial (transvenous) approach, (3) switching from the right to left side (septum) or from the retrograde aortic to transseptal (left free wall) approach, and (4) delivering longer durations of RF energy (up to 30 s).

Irrigated-Tip Catheter Ablation

The irrigated-tip catheter (Cordis-Webster Thermocool, D-curve) was used for ablation at the best endocardial or epicardial resistant sites (earliest activity) where conventional RF delivery had been unsuccessful (Figure 1). In cases with synchronous endocardial and epicardial activity, RF applications were performed endocardially. The protocol, which was previously demonstrated to be clinically safe, consisted of temperature-controlled RF delivery (a power limit of 50 W with a target temperature of 50°C) for 15 s, which was continued for up to 60 s if AP block occurred. Inside the CS, a power limit of 20 to 30 W was used with a target temperature of 50°C. Normal saline (0.9%) was infused through the irrigated-tip catheter with a Gemini IMED pump (battery powered to avoid 50-Hz line noise) at a rate of 17 mL/min during RF delivery. Between applications, a flow rate of 3 mL/min was used to maintain patency. For each application, the achieved power, temperature, and impedance were noted every 10 s. In patients who were treated inside the CS, direct venography was performed before and immediately after the ablation procedure using a 5F Amplatz catheter (Cordis Europe) advanced from the femoral vein. Patients were discharged 2 or 3 days after the ablation procedure. During this period, they systematically underwent physical examination, daily 12-lead ECG, postablation echocardiography, and Holter recording, and stress testing. After discharge, they were regularly followed by the referring physician.

Figure 1. Demonstration of tracings at ablation site with conventional and irrigated-tip catheters in patient with AP inside middle cardiac vein (patient 17). In each panel, both bipolar (ABL) and unipolar (UNI) local electrograms were simultaneously recorded during sinus rhythm with 4 surface ECGs (leads I, II, III, and V1) and an endocardial electrogram from high right atrium (HRA). Left, Ablation at shortest local atrioventricular interval with QS unipolar morphology failed to eliminate AP conduction because of very low delivered power (4 W), which was limited by high catheter tip temperature (60°C). Middle, RF application with irrigated-tip catheter targeting previously resistant site (same site showing same local electrogram) allowed an increase of delivered power to 20 W (at 45°C tip temperature), resulting in elimination of AP conduction (right).

Figure 2. Bar graphs comparing physical parameters during RF applications using conventional catheters (white bar) and irrigated-tip catheters (black bar) in 3 regions where resistant APs were located. In each region, values of both initial impedance (A) and tip temperature (C) were significantly reduced by use of irrigated-tip catheter compared with conventional catheter and resulted in significant increase in delivered power (B). Although power output in CS (and its branches) was lowest because of low blood flow, a significant increase of power delivery (>3×) was observed in CS with saline irrigation. Both mean values and SDs are shown below each column. Septum indicates middle/posterior septal space; CS, coronary sinus or its branches. *P<0.05 and **P<0.01.

Irrigated-Tip Catheter Ablation

Statistical Analysis

All values are expressed as mean±SD. Statistical analysis was done using Student’s t test (paired or unpaired) or χ² analysis. One-way ANOVA followed by Scheffe’s post-hoc test was also used when comparing >3 groups. Differences of P<0.05 were considered statistically significant.

Results

Catheter ablation with a conventional catheter failed to eliminate the conduction of 18 APs in 18 patients among 314 APs in 301 patients with Wolff-Parkinson-White syndrome (5.7% of APs). All but 1 of the 18 patients (patient 14) demonstrated manifest preexcitation. Ten patients (56%) had previously undergone unsuccessful ablation elsewhere. The resistant APs were distributed as follows: 6 (of 158 total; 3.8%) were located in the left free wall, 5 (of 85 total; 5.9%) were in the middle/posterior septal space (3 on the right and 2 on the left side), and 7 (of 26 total; 27%) were in the CS. There were no resistant APs in the right free wall (of 24 total) or anterior septal space (of 21 total). The incidence of
resistant APs in the CS was significantly higher ($P < 0.0001$) than that in the left free wall or middle/posterior septum.

Patient characteristics and the ablation results from the 18 patients with resistant APs are summarized in the Table. RF application using the irrigated-tip catheter successfully eliminated AP conduction in 17 of 18 patients (94%; Figure 1). Among 8 left-sided APs, transseptal and retrograde aortic approaches were used in 3 and 5 patients, respectively.

Significant differences were observed between conventional and irrigated-tip catheters in the mean values of the initial impedance, maximum delivered power, and tip temperature ($P < 0.01$). Although 3.4 ± 2.6 applications of RF energy were needed to complete AP block with irrigated tip catheters, 5 of the 7 APs (71%) in the CS were eliminated by only a single RF application. Significantly fewer RF applications with an irrigated-tip catheter were required for AP block in the CS (1.6 ± 1.0; $P < 0.05$) compared with the left free wall (5.0 ± 2.4).

Figure 2 shows the mean values of initial impedance, maximum power, and tip temperature for conventional and irrigated-tip catheters in the 3 regions with resistant APs. In each region, a significant difference in maximum delivered power output was observed between conventional and irrigated-tip catheters; the average increment was maximum in the septum and CS (20 W) compared with that (9 W) for the left free wall.

No early or late complications arose in patients treated with irrigated-tip catheter RF ablation. Audible pops were noted twice with conventional catheters and once with an irrigated-tip catheter. CS venography showed no abnormalities in 5 of the 7 patients with resistant APs inside the CS; however, in 2 patients in whom irrigated-tip catheter ablation was performed inside the middle cardiac vein, luminal irregularities (patient 3) and branch stenosis (≈90%; patient 17) were observed at the ablation sites. No symptomatic or electrocardiographic recurrences of AP conduction were observed during a mean follow-up of 15.3 ± 10.5 months.

### Discussion

The main finding of this study was that the use of irrigated-tip catheters using a moderately high power delivery is effective and safe for the small subset of APs resistant to conventional ablation. The incidence of these resistant APs was 5.7%, which is comparable to the rate noted in other studies, and they were more common inside the CS.

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age, y</th>
<th>Sex</th>
<th>AP Location</th>
<th>PRT, min</th>
<th>Result</th>
<th>No. of RF Applications</th>
<th>Impedance, Ω</th>
<th>Maximum Power, W</th>
<th>Temperature, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Conv</td>
<td>Irrig</td>
<td>Conv</td>
<td>Irrig</td>
</tr>
<tr>
<td>1</td>
<td>37</td>
<td>F</td>
<td>LFW</td>
<td>280</td>
<td>S</td>
<td>14</td>
<td>3</td>
<td>111.1</td>
<td>80.7</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>M</td>
<td>LFW</td>
<td>210</td>
<td>S</td>
<td>11</td>
<td>7</td>
<td>119.7</td>
<td>84.7</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>F</td>
<td>CS (MCV)</td>
<td>225</td>
<td>S</td>
<td>16</td>
<td>3</td>
<td>143.9</td>
<td>107.9</td>
</tr>
<tr>
<td>4</td>
<td>67</td>
<td>M</td>
<td>LFW</td>
<td>220</td>
<td>S</td>
<td>13</td>
<td>8</td>
<td>114.8</td>
<td>93.5</td>
</tr>
<tr>
<td>5</td>
<td>58</td>
<td>M</td>
<td>LFW</td>
<td>210</td>
<td>S</td>
<td>10</td>
<td>6</td>
<td>114.6</td>
<td>91.0</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>M</td>
<td>RPS</td>
<td>440</td>
<td>U</td>
<td>25</td>
<td>15</td>
<td>118.5</td>
<td>96.3</td>
</tr>
<tr>
<td>7</td>
<td>26</td>
<td>F</td>
<td>RPS</td>
<td>210</td>
<td>S</td>
<td>23</td>
<td>2</td>
<td>119.5</td>
<td>105.0</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>M</td>
<td>LPS</td>
<td>250</td>
<td>S</td>
<td>21</td>
<td>3</td>
<td>87.7</td>
<td>72.2</td>
</tr>
<tr>
<td>9</td>
<td>31</td>
<td>M</td>
<td>CS (MCV)</td>
<td>125</td>
<td>S</td>
<td>5</td>
<td>1</td>
<td>136.3</td>
<td>90.0</td>
</tr>
<tr>
<td>10</td>
<td>37</td>
<td>M</td>
<td>LFW</td>
<td>130</td>
<td>S</td>
<td>11</td>
<td>2</td>
<td>109.4</td>
<td>80.0</td>
</tr>
<tr>
<td>11</td>
<td>27</td>
<td>M</td>
<td>RMS</td>
<td>150</td>
<td>S</td>
<td>16</td>
<td>9</td>
<td>126.8</td>
<td>93.1</td>
</tr>
<tr>
<td>12</td>
<td>29</td>
<td>M</td>
<td>CS (MCV)</td>
<td>60</td>
<td>S</td>
<td>6</td>
<td>1</td>
<td>139.5</td>
<td>96.0</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>M</td>
<td>LFW</td>
<td>160</td>
<td>S</td>
<td>11</td>
<td>4</td>
<td>107.7</td>
<td>84.8</td>
</tr>
<tr>
<td>14</td>
<td>25</td>
<td>M</td>
<td>CS (MCV)</td>
<td>105</td>
<td>S</td>
<td>5</td>
<td>1</td>
<td>109.0</td>
<td>80.3</td>
</tr>
<tr>
<td>15</td>
<td>39</td>
<td>M</td>
<td>CS</td>
<td>120</td>
<td>S</td>
<td>8</td>
<td>1</td>
<td>135.8</td>
<td>95.0</td>
</tr>
<tr>
<td>16</td>
<td>52</td>
<td>M</td>
<td>CS</td>
<td>125</td>
<td>S</td>
<td>7</td>
<td>3</td>
<td>128.6</td>
<td>83.0</td>
</tr>
<tr>
<td>17</td>
<td>23</td>
<td>F</td>
<td>CS (MCV)</td>
<td>70</td>
<td>S</td>
<td>5</td>
<td>1</td>
<td>152.0</td>
<td>108.0</td>
</tr>
<tr>
<td>18</td>
<td>65</td>
<td>M</td>
<td>LPS</td>
<td>110</td>
<td>S</td>
<td>10</td>
<td>2</td>
<td>117.0</td>
<td>100.3</td>
</tr>
<tr>
<td>Median</td>
<td>37</td>
<td></td>
<td></td>
<td>155</td>
<td></td>
<td>11</td>
<td>3</td>
<td>119</td>
<td>92</td>
</tr>
</tbody>
</table>

| Mean        | 38.9   | 177.8 | 12.1 | 3.4† | 121.8 | 91.2 | 20.3 | 36.5 | 58.3 | 42.8 |
| SD          | 15.1   | 90.5  | 6.1  | 2.6† | 15.6  | 10.2 | 11.5 | 8.2  | 2.3  | 3.2  |

Conv indicates conventional catheter; irrig, irrigated-tip catheter; LFW, left free wall; MCV, middle cardiac vein; RPS, right posterior septum; RMS, right middle septum; LPS, left posterior septum; PRT, procedure time; S, success of procedure with irrigated-tip catheter; U, unsuccessful result; M, male; and F, female.

* $P < 0.01$

†Value was calculated excluding data from patient 6, who had unsuccessful ablation.
Failure of conventional ablation can result from either suboptimal mapping, a nonaccessed insertion site, or limited lesion size, and a reliable distinction between these factors cannot be clinically obtained. However, when the earliest activity was found within the CS (compared with the endocardium), fewer applications and lower powers were required for successful ablation, suggesting a “true epicardial” AP, whereas in patients with earlier or synchronous endocardial activity, the AP may have been more “intramyocardial,” thus requiring higher amount of power. With a conventional temperature-controlled mode of RF delivery, the electrode temperature in the presence of low local convective cooling by flowing blood enforces a reduced power output and, therefore, reduces lesion size. Irrigating the ablation electrode by dissociating the delivered power from the local convective cooling allows the delivery of a higher and more stable amount of power, permitting the creation of larger lesions.5

The major concern with irrigation is the potentially lethal risks of tamponade or coronary injury related to deeper lesions and popping. The absence of complications in this and another study6 may be due to a reasonable power limit in the range of power delivered with conventional techniques. The power limit was set at 50 W in the free wall (resulting in a mean delivered power of ~40 W) and at 20 to 30 W for the CS. However, the potential dangers of higher delivered power, as well as the limited incidence of APs resistant to conventional ablation, support the use of irrigated-tip catheters as backup therapy only for resistant cases.

Limitations
Only a small number of patients were treated with irrigated-tip catheters in this series and, in view of this, continued evaluation is needed to assess its long-term safety. In addition, the temperature setting of 60°C selected for conventional catheters is a limitation considering that an increment in the target temperature (to 70°C) may have resulted in a higher rate of successful conventional ablation, particularly in the left free wall.

Conclusions
APs resistant to conventional RF ablation were observed in 5.7% of all APs and were more common in the CS. Irrigated-tip catheter ablation successfully eliminated all but 1 of these resistant APs without any serious complications, irrespective of their location.

References
Efficacy and Safety of an Irrigated-Tip Catheter for the Ablation of Accessory Pathways Resistant to Conventional Radiofrequency Ablation

Teiichi Yamane, Pierre Jaïs, Dipen C. Shah, Mélèze Hocini, Jing Tian Peng, Isabel Deisenhofer, Jacques Clémenty and Michel Haïssaguerre

*Circulation*. 2000;102:2565-2568
doi: 10.1161/01.CIR.102.21.2565

*Circulation* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2000 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/102/21/2565

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Circulation* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Circulation* is online at:
http://circ.ahajournals.org/subscriptions/