Prediction of Clinical Recurrence of Atrioventricular-Nodal Reentrant Tachycardia (AVNRT) After Successful Slow Pathway Ablation

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Background

Even after successful slow pathway (SP) ablation for atrioventricular-nodal reentrant tachycardia (AVNRT), there may be clinical recurrence in certain patients and it is clinically important to be able to predict that.

Methods and Results

In 97 patients with common type AVNRT, the effective refractory period (ERP) of the fast pathway (FP), SP-ERP, and prolongation of the atrio-His (AH) interval (ΔAH) at the time of jump-up phenomenon were investigated. In patients with residual SP, parameters were re-evaluated in a similar manner. SP was successfully ablated and AVNRT was not inducible in all the patients, but residual SP was observed in 54 of the 97 patients, and there was late clinical recurrence in 10 patients (10/54 patients with residual SP and 0/43 without residual SP, p=0.002). The changes in FP-ERP before and after ablation (ΔFP-ERP) did not differ between recurrent and non-recurrent patients. Among the patients with residual SP, ΔSP-ERP did not differ between the groups. However, the changes in ΔAH before and after ablation (ΔΔAH) were larger in non-recurrent (24±30 ms) than in the recurrent patients (4±7 ms, p=0.042).

Conclusions

In patients with AVNRT, the residual SP and changes in ΔAH after successful SP ablation might be useful indices of clinical recurrence. (Circ J 2004; 68: 558–562)

Key Words: Atrioventricular nodal reentrant tachycardia (AVNRT); Clinical recurrence

Radiofrequency catheter ablation is a feasible and useful therapeutic procedure for atrioventricular nodal reentrant tachycardia (AVNRT), but although electrophysiologic studies (EPS) show high success rates for the procedure, 0–14.6% of cases have clinical recurrence during the follow-up period of 1–45 months even after successful slow pathway (SP) ablation.1–11 Several investigators have reported that some electrophysiologic parameters at the time of the first session of SP ablation (eg, residual SP1–4 residual single echo beat2,4 and no junctional beats during ablation2) may be useful for predicting the recurrence of AVNRT, but general consensus has not yet been established. In the present study, several electrophysiologic parameters at the time of SP ablation in cases of AVNRT, especially the changes in the conduction patterns through the atrioventricular node (AVN), were evaluated and compared with the presence of clinical AVNRT recurrence.

Methods

Patients and EPS

Between November 1995 and December 2001, 132 consecutive patients with common type AVNRT underwent SP ablation. Of these, 2 patients still showed inducible AVNRT after ablation and 1 patient had advanced AV block during the 48 h after ablation. Excluding these 3 patients, 129 patients successfully completed the SP ablation procedure and for this study, we selected 97 patients who had demonstrated inducible AVNRT and also showed dual or multiple AVN physiology in the atrial extra-stimulations. After informed consent was obtained, the EPS was performed in the fasting state without any sedative medications. Antiarrhythmic drugs were discontinued for at least 5 half-lives before the ablation. Three 5F quadripolar electrode catheters were introduced via the femoral vein, and were positioned against the high right atrium (HRA), the His bundle region, and the right ventricular apex (RVA) under fluoroscopic guidance. One 5F decapolar catheter was introduced into the coronary sinus via the jugular vein. Between 1995 and 1998, patients’ data were analyzed on a paper recording at 100 mm/s (Model VR-13, Biomedical Systems, USA), and between 1999 and 2001 data were stored for analysis on optical disks using a computer-recording system and were analyzed on screen (Cardio Lab System, Marquette, MI, USA).

Basic Study and Diagnosis

Single-extra-stimulation and incremental pacing were performed at the HRA and RVA sites for the basic electrophysiological evaluation. Prolongation of the atrio-His (AH) interval of not less than 50 ms in response to the shortening of the coupling interval of the premature atrial stimulus by 10 ms was defined as the ‘jump-up’ phenomenon of the AH interval.13 When the single atrial stimulus could not induce the AH jump-up, a double-atrial-extra-stimulus protocol was performed to achieve shorter premature coupling intervals.11 AVNRT was diagnosed in accordance with the following criteria: (1) the jump-up phenomenon of the AH interval after single or double atrial
stimulus, (2) induction of narrow QRS regular tachycardia without the participation of an accessory pathway, and (3) simultaneous activation of the atrium and ventricle during tachycardia. The second criterion was confirmed by single-ventricle scanning during tachycardia and sinus rhythm to exclude orthodromic AV reciprocal tachycardia involving an accessory pathway. Patients were excluded from eligibility for common type AVNRT if they were considered to have slow-slow AVNRT with lower common pathway based on the finding of a retrograde atrial activation sequence during tachycardia or based on the comparison of ventricular-atrial intervals during tachycardia and ventricular pacing. When tachycardia could not be induced in the basic state, isoproterenol (ISP) was infused intravenously at a dose rate of 0.2–0.5 μg/min per kg to increase the basic sinus rate by 20–25%, and the same stimulation protocol was repeated.

**SP Ablation**

After the basic EPS, a 7F quadripolar steerable ablation catheter with 4 mm-tip (Marinr, Medtronic, USA) was introduced through the femoral vein. The catheter tip was initially positioned along the tricuspid annulus anterior to the ostium of the coronary sinus. In the lowest one-third of the area between the recording site at the His bundle and the ostium of the coronary sinus, the optimal ablation site was determined under guidance of the Asp potential as described by Jackman et al with an A/V ratio of 0.1 to 0.5. Radiofrequency energy was delivered with a temperature controlled ablation unit (Atakr RF Ablation system, Medtronic) at 60°C during sinus rhythm. If a junctional beat was recognized within 10 s, the energy delivery was continued for 1 min, and was terminated immediately in the cases showing an impedance rise or any signs of AH block. After each ablation procedure, the pacing protocol was repeated to evaluate the inducibility of AVNRT. When AVNRT was still inducible, the ablation catheter was repositioned to a more superior region along the tricuspid annulus and the ablation procedure was continued. The ablation procedure was considered to be successful when AVNRT could not be induced 10 min after the last delivery of radiofrequency energy. In the post-ablation study, ISP was infused only when it had been needed for AVNRT induction in the basic state before the ablation (n=14). Single atrial echo beat or jump-up of the AH interval was allowed to remain.

**Electrophysiologic Parameters**

**Fast Pathway (FP)-Effective Refractory Period (ERP)**

The ERP of the FP of the AVN that caused the jump-up phenomenon.

**SP-ERP**

The longest coupling interval of the atrial extrastimulus that failed to propagate to the His bundle. In patients in which atrial ERP was longer than the SP-ERP, the atrial ERP was used as a conservative estimation of the SP-ERP.

**ΔAH**

The prolongation of the AH interval at the time of jump-up. It was calculated by subtracting the AH interval before the jump-up from that after the jump-up phenomenon. This parameter was practically considered to be the difference in conduction times between the fast and slow pathways. In patients with triple AVN pathways, the AH prolongation at the first jump-up was regarded as \( \Delta AH \).

**ΔFP-ERP**

The change in FP-ERP caused by successful SP ablation. It was calculated by subtracting FP-ERP at the baseline before the ablation from FP-ERP after the ablation (Fig 1).

**ΔSP-ERP**

The change in the SP-ERP of the patients with residual SP after successful SP ablation. It was calculated by subtracting SP-ERP at the baseline before the ablation from SP-ERP after the ablation (Fig 1).

**ΔΔAH**

The change in AH observed after successful SP ablation. It was calculated by subtracting \( \Delta AH \) at the baseline before the ablation from \( \Delta AH \) after the ablation (Fig 1).

All parameters were recorded and evaluated at a basic cycle length of 600 ms. Elimination of the slow pathway was defined as disappearance of the AVN jump-up phenomenon observed before ablation. The presence of the AVN jump-up phenomenon before and after ablation was investigated under identical protocols. Therefore, the patients undergoing double atrial premature stimulation...
An "of p<0.05 was considered to be statistically significant."

Tests were used to compare the data between groups. A value of p<0.05 was considered to be statistically significant.

Recurrence of AVNRT

Among the 129 cases of AVNRT with successful SP ablation, there were 6 cases of early revival and 10 of late clinical recurrence. Among the 97 patients, 4 patients showed early revival and 10 showed late clinical recurrence during the follow-up period of 59±16 months (range: 9–80 months). All episodes of late clinical recurrence were characterized by the symptom of palpitation, and were confirmed electrocardiographically. Tachycardia that recurred after ablation showed a similar cycle length (392±42 ms) to that before ablation (393±41 ms), and the QRS and P waves on the electrocardiogram were similar to those before ablation. In patients with acute revival, the slow–fast form of AVNRT was reconfirmed electrocardiographically. Tachycardia that recurred after ablation showed a similar mean cycle length (80±18 ms) to that before ablation (80±18 ms), and the QRS and P waves on the electrocardiogram were similar to those before ablation.

**Results**

Recurrence of AVNRT

Among the 129 cases of AVNRT with successful SP ablation, there were 6 cases of early revival and 10 of late clinical recurrence. Among the 97 patients, 4 patients showed early revival and 10 showed late clinical recurrence during the follow-up period of 59±16 months (range: 9–80 months). All episodes of late clinical recurrence were characterized by the symptom of palpitation, and were confirmed electrocardiographically. Tachycardia that recurred after ablation showed a similar cycle length (392±42 ms) to that before ablation (393±41 ms), and the QRS and P waves on the electrocardiogram were similar to those before ablation. In patients with acute revival, the slow–fast form of tachycardia after ablation showed a similar mean cycle length (425±70 ms) to that before ablation (395±33 ms).

**Early Revival and Late Clinical Recurrence of AVNRT**

The appearance of AVNRT after successful SP ablation was classified into 2 categories.

1. Early revival, defined as AVNRT in response to atrial premature stimulation performed 30 min after the last radiofrequency energy delivery. Patients with early revival of AVNRT underwent a repeat ablation procedure and were excluded from the long-term follow-up protocol.

2. Late clinical recurrence, defined as spontaneous recurrence of AVNRT during the long-term clinical follow-up.

**Statistical Analysis**

The data were expressed as the mean value ± SD. Comparisons of the electrophysiologic data were performed using the analysis of variance. Two-tailed unpaired Student’s t-tests were used to compare the data between groups. A value of p<0.05 was considered to be statistically significant.

**Table 1 Patients’ Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>No-recurrence (n=83)</th>
<th>Acute revival (n=4)</th>
<th>Clinical recurrence (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>43±19</td>
<td>40±18</td>
<td>45±22</td>
</tr>
<tr>
<td>Male/female (n)</td>
<td>46/37</td>
<td>2/2</td>
<td>6/4</td>
</tr>
<tr>
<td>RF number (n)</td>
<td>4±5</td>
<td>5±1</td>
<td>5±3</td>
</tr>
<tr>
<td>Energy (W)</td>
<td>3±4</td>
<td>34±3</td>
<td>34±2</td>
</tr>
<tr>
<td>Absence of junctional rhythm (n)</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Transient AV block (n)</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FP-ERP at baseline (ms)</td>
<td>319±35</td>
<td>308±49</td>
<td>312±17</td>
</tr>
<tr>
<td>SP-ERP at baseline (ms)</td>
<td>298±40</td>
<td>290±58</td>
<td>308±21</td>
</tr>
<tr>
<td>SP-ERP, FP-ERP (post-ablation) (ms)</td>
<td>–20±23</td>
<td>–18±33</td>
<td>–45±14</td>
</tr>
<tr>
<td>SP-ERP, FP-ERP (post-ablation) (at baseline) (ms)</td>
<td>257±42</td>
<td>248±46</td>
<td>250±28</td>
</tr>
<tr>
<td>Delta AH at baseline (ms)</td>
<td>92±30</td>
<td>94±19</td>
<td>87±26</td>
</tr>
<tr>
<td>Residual SP post-ablation (n)</td>
<td>41*</td>
<td>3</td>
<td>10*</td>
</tr>
<tr>
<td>Echo beat post-ablation (n)</td>
<td>33†</td>
<td>3</td>
<td>9†</td>
</tr>
<tr>
<td>Triple AVN pathway at baseline (n)</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 2 Electrophysiological Data of the Patients With a Residual Slow Pathway**

<table>
<thead>
<tr>
<th></th>
<th>No-recurrence (n=41)</th>
<th>Acute revival (n=3)</th>
<th>Clinical recurrence (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP-ERP at baseline (ms)</td>
<td>321±47</td>
<td>317±55</td>
<td>312±17</td>
</tr>
<tr>
<td>FP-ERP post-ablation (ms)</td>
<td>317±48</td>
<td>313±42</td>
<td>308±21</td>
</tr>
<tr>
<td>ΔFP-ERP (ms)</td>
<td>–5±14</td>
<td>–32±1</td>
<td>–45±15</td>
</tr>
<tr>
<td>SP-ERP at baseline (ms)</td>
<td>253±40</td>
<td>250±56</td>
<td>250±28</td>
</tr>
<tr>
<td>SP-ERP post-ablation (ms)</td>
<td>258±62</td>
<td>237±55</td>
<td>243±26</td>
</tr>
<tr>
<td>ΔSP-ERP (ms)</td>
<td>4±61</td>
<td>–13±12</td>
<td>–7±18</td>
</tr>
<tr>
<td>ΔAH at baseline (ms)</td>
<td>90±26</td>
<td>85±9</td>
<td>87±26</td>
</tr>
<tr>
<td>ΔAH post-ablation (ms)</td>
<td>114±33*</td>
<td>100±20</td>
<td>91±23*</td>
</tr>
<tr>
<td>ΔAH (ms)</td>
<td>24±30*</td>
<td>15±22</td>
<td>4±7*</td>
</tr>
</tbody>
</table>

**Table 1:** Patients’ Characteristics

**Table 2:** Electrophysiological Data of the Patients With a Residual Slow Pathway

RF, radiofrequency; FP, fast pathway; ERP, effective refractory period; ΔFP-ERP, FP-ERP (post-ablation) minus FP-ERP (at baseline); SP, slow pathway; ΔAH, prolongation of the AH interval at jump-up point; AVN, atrioventricular node. *p=0.002, †p=0.007.
was recognized in all of the 10 recurrent patients (100%), and in 41 of 83 non-recurrent patients (49%, p=0.002). A single echo beat in the post-ablative state was recognized in 9 of the 10 recurrent patients (90%), and in 33 of the 83 non-recurrent patients (40%, p=0.007). There was no difference in the existence of triple AVN pathways in the baseline study among the 3 groups.

Table 2 shows the FP-ERP, SP-ERP, and ∆AH in patients with residual SP, revealing that there were no differences in either FP-ERP, before or after ablation, or in ∆SP-ERP among the 3 groups. Further more, no differences were observed in SP-ERP before or after ablation, or in ∆SP-ERP among the groups. Although ∆AH before ablation did not show a significant difference between the groups, ∆AH in the post-ablative state was longer (114±33 vs 91±23 ms, p=0.047), and the ∆∆AH was larger (24±30 vs 4±7 ms, p=0.042), in non-recurrent patients than in late clinical recurrent patients.

Fig 2 shows the distributions of ∆FP-ERP and ∆∆AH in patients with residual slow pathway (SP; n=54). ∆FP-ERP and ∆AH were determined by subtracting the baseline values from the post-ablation values. Data of individual patients with (●) late clinical recurrence (n=10), (□) acute revival (n=3), and (♦) without recurrence (n=41).

Table 3 Prediction of the Acute Revival or Late Clinical Recurrence of AVNRT

<table>
<thead>
<tr>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual SP post-ablation</td>
<td>92.9</td>
<td>50.6</td>
<td>24.1</td>
</tr>
<tr>
<td>Echo beat post-ablation</td>
<td>85.7</td>
<td>60.2</td>
<td>26.7</td>
</tr>
<tr>
<td>Residual SP with ∆∆AH ≤40 ms</td>
<td>92.9</td>
<td>67.5</td>
<td>32.5</td>
</tr>
<tr>
<td>≤30 ms</td>
<td>85.7</td>
<td>69.9</td>
<td>32.4</td>
</tr>
<tr>
<td>≤20 ms</td>
<td>85.7</td>
<td>72.3</td>
<td>34.3</td>
</tr>
<tr>
<td>≤10 ms</td>
<td>85.7</td>
<td>75.9</td>
<td>37.5</td>
</tr>
<tr>
<td>≤0 ms</td>
<td>35.7</td>
<td>86.7</td>
<td>31.3</td>
</tr>
</tbody>
</table>

AVNRT, atrioventricular nodal reentrant tachycardia; SP, slow pathway; ∆∆AH, ∆AH (post-ablation) minus ∆AH (at baseline); PPV, positive predictive value; NPV, negative predictive value.

In contrast, residual SP with ∆∆AH≤10 ms showed high sensitivity (85.7%) and high specificity (75.9%) for predicting acute revival or late clinical recurrence.

Discussion

End-Point of the SP Ablation Procedure

After successful SP ablation, AVNRT is reported to recur in 0–14.6% of patients.1–11 In the present study, late clinical AVNRT recurrence was observed in 10 of 129 patients (7.8%), therefore being able to predict the recurrence of AVNRT after the ablation procedure is important. Some investigators have suggested that complete elimination of SP conduction is a desirable goal,1 but there are cases of broad SP and sometimes it may be difficult to achieve this end-point.18 We ablated the SP by targeting the Asp potential and followed the classical end-points of Jackmann et al16 and Haissaguerre et al10 As a result, we achieved complete elimination of SP conduction in 44.3% of the patients. If SP ablation was continued in patients with residual SP, complete elimination of SP might have been achieved, but it is questionable whether continuous SP ablation should be carried out from the standpoint of avoiding AV block and prolonged X-ray exposure.18,19

Electrophysiologic Parameters for Predicting AVNRT Recurrence

The electrophysiologic parameters that are considered to be useful for predicting AVNRT recurrence are residual SP;1–4 residual single echo beat;2,4 no junctional beats during
ablation;20 the location of the ablation site6 and the morphology of the A wave.2 Concerning the relationship between residual SP and AVNRT recurrence, some investigators who have used ISP after ablation have suggested that residual SP is not a risk factor for recurrence.3–11 Others who have used ISP or atropine after ablation agree that it is a risk factor.2–4 Therefore, general consensus on the risk factors for AVNRT recurrence has not been established. Several parameters for evaluating the characteristics of residual SP conduction after ablation have been reported: changes in SP conduction (ie, the decrease of 1:1 conduction ability10,16) or a small ERP window between the fast and slow pathways could be negative predictors for AVNRT recurrence. Therefore, a specific change in the characteristics of SP conduction may be predictive for recurrence. In the present study, among the patients showing residual SP, those with late clinical recurrence showed ΔΔAH of 4±7 ms, and 24±30 ms in those without recurrence (p=0.042, Table 2), which indicates that the patients with a smaller change in ΔAH after ablation, especially with ΔΔAH≤10 ms, have a higher incidence of recurrence (Table 3). In contrast, no recurrence or acute revival was observed in patients with ΔΔAH of more than 40 ms (Fig 2). It was not clear why there were the changes in the SP conduction properties after ablation (eg, ΔAH prolongation). However, the reasons might include modification of SP by radiofrequency energy or an additional SP was uncovered by the elimination of the targeted SP. Prolongation of the ΔAH indicates that this additional SP had a slower conduction property than the ablated SP, which might prevent it from constructing an active reentrant circuit, resulting in lower recurrence.

Clinical Implications

The rate of recurrence of AVNRT after SP ablation was lower when (1) the SP was eliminated completely or (2) the ΔAH was prolonged by more than 40 ms after ablation in patients with residual SP. The ΔΔAH is a simple and useful marker for predicting AVNRT recurrence in patients with residual SP.

Study Limitations

First, it was difficult to completely equalize the autonomic state before and after ablation procedure, especially when ISP was used. We consider that the evaluations after ablation may have been influenced by autonomic change. Second, the ΔAH could be related to changes in the FP-AH as well as those of the SP-AH. In addition, SP-AH was measured at different stimulation intervals in patients showing different FP-ERP after ablation. Although there was no significant correlation between ΔFP-ERP and ΔΔAH (r=−0.22, NS, Fig 2), changes in FP-AH and SP-AH at the different stimulation intervals were not clear in our data. The third limitation is that we did not use ISP in the 52 of 83 non-recurrent, 3 of 4 acute revival and 4 of 10 recurrent patients after the post-ablation study. Because there were some recurrent patients who did not undergo the post-ablation ISP study, other SP conduction characteristics and the inducibility of AVNRT, including using ISP, should be especially evaluated in patients with little change in AAH after ablation. The fourth limitation was the ΔAH measurement in patients with triple AVN pathways. We considered measurement of parameters at the first jump-up point might not be useful in all cases of multiple AVN SP, but SP related to clinical tachycardia should be evaluated.

References