Absence of Junctional Rhythm During Successful Slow-Pathway Ablation in Patients With Atrioventricular Nodal Reentrant Tachycardia

Ming-Hsiung Hsieh, MD; Shih-Ann Chen, MD; Ching-Tai Tai, MD; Wen-Chung Yu, MD; Yi-Jen Chen, MD; Mau-Song Chang, MD

Background—The presence of junctional rhythm has been considered to be a sensitive marker of successful slow-pathway ablation. However, in rare cases, junctional rhythm was absent despite multiple radiofrequency applications delivered over a large area in the Koch’s triangle, and successful ablation was achieved in the absence of a junctional rhythm.

Methods and Results—This study included 353 patients with AV nodal reentrant tachycardia (143 men and 210 women; mean age, 50±17 years) who underwent catheter ablation of the slow pathway. Combined anatomic and electrogram approaches were used to guide ablation. Inducibility of AV nodal reentrant tachycardia was assessed after each application of radiofrequency energy. Successful sites were located in the posterior area in 18 (90%) of 20 patients without junctional rhythm during slow-pathway ablation compared with 200 (60%) of 333 patients with junctional rhythm (P<0.001). The fast-slow form of tachycardia was more common in patients without than in those with junctional rhythm (30% versus 3%; P=0.001). At the successful ablation sites, patients with junctional rhythm had a higher incidence of a multicomponent or slow-pathway potential (51% versus 10%; P<0.001), a longer duration of the atrial electrogram (64±8 versus 50±9 ms; P=0.04), and a smaller atrial/ventricular electrogram amplitude ratio (0.29±0.18 versus 0.65±0.27; P<0.001) than those without junctional rhythm. Mean temperatures at successful sites (56±6°C versus 58±9°C; P=0.57) and incidence of transient AV block (2% versus 0%; P=0.86) were similar between patients with and without junctional rhythms. By multivariate analysis, location of ablation sites, atrial/ventricular electrogram amplitude ratio, absence of a multicomponent or slow-pathway potential, and occurrence of the fast-slow form of tachycardia were independent predictors of the absence of a junctional rhythm during successful slow-pathway ablation.

Conclusions—In some rare cases, successful slow-pathway ablation is possible in the absence of a junctional rhythm. (Circulation. 1998;98:2296-2300.)

Key Words: atrioventricular node ■ catheter ablation ■ tachyarrhythmias

Selective radiofrequency catheter ablation of the slow AV nodal pathway has been established as a first-line curative treatment modality in patients with symptomatic AV nodal reentrant tachycardia. Many investigators have used several different methods to perform successful ablation of the slow pathway.1-7 The presence of a junctional rhythm during slow-pathway ablation has been indisputably considered to be the most sensitive but nonspecific marker of successful ablation.8-11 However, the absence of junctional rhythm during successful slow-pathway ablation has not been well described. The purposes of the present study were to investigate electrophysiological characteristics in patients with and those without junctional rhythm and to determine the variables related to the absence of junctional rhythm during successful slow-pathway ablation.

Methods

Patient Population
The present study included 353 consecutive patients with AV nodal reentrant tachycardia. These patients underwent successful radiofrequency catheter ablation of the slow pathway between January 1995 and June 1997. Patients who received ablation of the retrograde slow pathway under ventricular pacing were excluded because it was difficult to observe junctional rhythm while radiofrequency energy was delivered during ventricular pacing. There were 143 men and 210 women included in the present study, and their mean age was 50±17 years (range, 15 to 80 years).

Electrophysiological Test
Informed consent was obtained from all patients, and they were studied in the postabsorptive, nonsedated state after written informed consent had been obtained. Details of the electrophysiological study have been described previously.12,13 Intracardiac electrograms were compared with simultaneous surface electrocardiograms.
filtered at 30 to 500 Hz and simultaneously displayed with surface ECG leads I, II, and V1 on a multichannel oscilloscope (Electronics for Medicine, VR-13, MIDAS 2500, or ART Prucka recording system) and were recorded at a paper speed of 100 to 150 mm/s. The baseline electrophysiological study was performed after antiarrhythmic drugs had been discontinued for ≥5 half-lives; this included determination of the effective refractory periods of the right atrium, the AV node (fast and slow pathways in the antegrade and retrograde directions), and the right ventricle. If tachycardia was not induced in the baseline state, isoproterenol (at graded doses from 1 to 4 μg/min IV) or atropine (0.01 to 0.02 mg/kg IV) was infused to facilitate its induction. AV nodal reentrant tachycardia was diagnosed by previously described criteria; intra-atrial reentrant tachycardia and tachycardia incorporating a midseptal or paraseptal accessory pathway were excluded.14–16

Mapping/Ablation and Junctional Rhythm
The method used for mapping and ablation has been described previously.12,13 The right atrial septum adjacent to the septal leaflet of the tricuspid valve, extending from the ostium of the coronary sinus (posterior) to the recording site at the His bundle area (anterior), was divided into posterior, medial, and anterior regions. To determine the possible anatomic site of the slow pathway, the mapping and ablation catheter tip was initially positioned in the posterior area, then the medial and finally the anterior areas, if necessary. The presumed ablation site was considered optimal if bipolar electrograms obtained from the distal electrodes showed an atrial/ventricular electrogram amplitude ratio of 0.1 to 0.5, with a multicomponent or a putative slow-pathway potential.1,3,7 Radiofrequency energy was applied for 20 seconds after a target site was identified. If AV nodal reentrant tachycardia could not be eliminated after delivery of radiofrequency energy to the optimal sites, areas with different electrogram characteristics were chosen for ablation. The electrode catheter used for ablation had a thermistor embedded in the deflectable 4-mm-tip electrode (7F, EP Technologies, Inc). Radiofrequency energy was delivered from a generator (EPT-1000, EP Technologies, Inc), which supplied continuous, unmodulated sine-wave output at 500 kHz. Power, impedance, and temperature were measured, displayed, and stored during each application of radiofrequency energy via an interface with a microcomputer (NEC DX33–486). The maximum preset temperature was 70°C in every patient. Radiofrequency energy was terminated immediately in the event of impedance rise, displacement of the catheter, an increase in PR interval, or occurrence of AV conduction block.

Junctional rhythm was identified on the basis of an intracardiac electrogram with a low-to-high atrial activation sequence and shorter, irregular cycle length.6–10,13,17 Once junctional rhythm during ablation for 20 seconds was noted, radiofrequency energy was applied again for 60 seconds under high right atrial overdrive pacing. If no junctional rhythm was observed, radiofrequency energy was aborted at 20 seconds, then programmed stimulation was performed to test inducibility of AV nodal reentrant tachycardia. If tachycardia was inducible, application of radiofrequency energy was tried again after the ablation catheter was repositioned. If tachycardia was not inducible, radiofrequency energy was applied for 60 seconds despite the absence of junctional rhythm.

Ablation-Site Electrogram
In the present study, local atrial electrograms at successful ablation sites were divided into 2 forms, a single-component or a multicomponent atrial electrogram (Figure). A multicomponent atrial electrogram was defined as one with several small deflections on the focal atrial electrogram.

Postablation Follow-Up
A complete electrophysiological study was performed 20 to 30 minutes after the ablation procedure to determine the immediate effects of radiofrequency ablation. As described previously,12,13 all patients were observed in the coronary care unit and were monitored by ECG for 24 hours. After discharge from hospital, patients returned to our outpatient clinic 1 week, 1 month, 2 months, and subsequently every 3 months after ablation. Ambulatory ECG monitoring or cardiac-event recording was performed in patients who experienced palpitation or tachycardia.

Analysis of Different Parameters
Data on ablation-site locations (including posterior, medial, and anterior areas), ablation-site electrograms (including amplitude of atrial and ventricular electrograms, atrial/ventricular electrogram amplitude ratio, atrial electrogram duration, and presence of a multicomponent atrial electrogram), forms of tachycardia (slow-fast, fast-slow, or both), mean and maximum temperatures of successful ablation sites, number of radiofrequency applications, and antegrade conduction impairment (AV block or impairment) were obtained for analysis.

Statistical Analysis
All parametric data are expressed as mean±SD. Comparisons of parametric data were analyzed by a 2-tailed Student’s t test. The χ2 test with Yates’ correction or Fisher’s exact test was used to compare nonparametric data in different groups. Univariate and multivariate analyses with a stepwise logistic regression model were performed to analyze variables that could predict the absence of junctional rhythm. A P value < 0.05 was considered statistically significant.

Results
Patient Characteristics
Among the 353 patients with AV nodal reentrant tachycardia who underwent successful slow-pathway ablation, 333 (94.3%) had junctional rhythm during the successful radiofrequency pulses, but 20 (5.7%) did not. Three forms of
tachycardia were found, including slow-fast (319 patients, 90%), fast-slow (16 patients, 5%), and both forms of tachycardia (18 patients, 5%). In patients without junctional rhythm during successful pulses, the fast-slow form of tachycardia was more common than in those with junctional rhythm (30% versus 3%; P=0.001), and the slow-fast form of tachycardia was more common in patients with than in those without junctional rhythm (92% versus 65%; P=0.001). During or after radiofrequency ablation, the incidences of transient AV block during successful slow-pathway ablation were similar between patients with and without junctional rhythms (51% versus 10%; P<0.001).

Other Parameters
Mean (56±6°C versus 58±9°C; P=0.57) and maximum (66±8°C versus 69±5°C; P=0.40) target-site temperatures during successful slow-pathway ablation were similar between patients with and without junctional rhythms (Table). The mean number of radiofrequency pulses used for successful slow-pathway ablation was significantly greater in patients without junctional rhythm than in those with junctional rhythm (51% versus 10%; P<0.001). During or after radiofrequency ablation, the incidences of transient AV block (2% versus 0%; P=0.86) and AV nodal function impairment (1% versus 0%; P=0.91) were similar between patients with and without junctional rhythms (Table).

Predictors of Absence of Junctional Rhythm
By multivariate analysis, location of ablation site (P=0.01; OR, 7.83; 95% CI, 1.52 to 40.51), atrial/ventricular electrogram amplitude ratio (P<0.001; OR, 18.80; 95% CI, 4.87 to

Locations and Electrograms of Successful Sites
More patients without junctional rhythm had successful ablation sites in the posterior area than those with junctional rhythm (90% versus 60%; P<0.001) (Table). The amplitudes of atrial electrograms were similar between patients with and without junctional rhythms during successful slow-pathway ablation (0.19±0.11 versus 0.30±0.20 mV; P=0.10) (Table). However, in patients with junctional rhythm, the amplitudes of ventricular electrograms were significantly larger than in those without junctional rhythm (0.77±0.27 versus 0.50±0.28 mV; P=0.02). Furthermore, the atrial/ventricular electrogram amplitude ratios were significantly larger in patients without junctional rhythm than in those with junctional rhythm (0.65±0.27 versus 0.29±0.18; P<0.001). The duration of the atrial electrogram was significantly longer at the successful ablation sites in patients with junctional rhythm than in those without junctional rhythm (64±8 versus 50±9 ms; P=0.04). At the successful ablation sites, a multicomponent atrial electrogram was more common in patients with than in those without junctional rhythm (51% versus 10%; P<0.001).

Electrophysiological Characteristics in Patients With and Without Junctional Rhythms During Successful Slow-Pathway Ablation

<table>
<thead>
<tr>
<th>Ablation-site location</th>
<th>JR(+) (n=333)</th>
<th>JR(−) (n=20)</th>
<th>Univariate Value</th>
<th>Multivariate Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior</td>
<td>200 (60%)</td>
<td>18 (90%)</td>
<td>&lt;0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>Medial</td>
<td>130 (39%)</td>
<td>2 (10%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>3 (1%)</td>
<td>0 (0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ablation-site electrogram</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A amplitude, mV</td>
<td>0.19±0.11</td>
<td>0.30±0.20</td>
<td>0.10</td>
<td>0.7</td>
</tr>
<tr>
<td>V amplitude, mV</td>
<td>0.77±0.27</td>
<td>0.50±0.28</td>
<td>0.02</td>
<td>0.1</td>
</tr>
<tr>
<td>A/V ratio</td>
<td>0.29±0.18</td>
<td>0.65±0.27</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>A duration, ms</td>
<td>64±8</td>
<td>50±9</td>
<td>0.04</td>
<td>0.1</td>
</tr>
<tr>
<td>Multicomponent A</td>
<td>200 (51%)</td>
<td>2 (10%)</td>
<td>&lt;0.001</td>
<td>0.002</td>
</tr>
</tbody>
</table>

A indicates atrial electrogram; V, ventricular electrogram.
Values are expressed as mean±SD or number (%) of successful ablation sites with [JR(+) or without [JR(−)] junctional rhythm.
72.60), absence of a multicomponent or putative slow-pathway potential ($P=0.002$; OR, 19.13; 95% CI, 3.07 to 119.30), and tachycardia form (fast-slow form) ($P=0.01$; OR, 9.12; 95% CI, 1.94 to 42.86) were independent predictors of the absence of junctional rhythm during successful slow-pathway ablation.

Discussion

Major Findings

The major findings of the present study are as follows: (1) successful ablation sites in patients without junctional rhythm during slow-pathway ablation were located mostly in the posterior area; (2) atrial/ventricular electrogram amplitude ratios were significantly larger in patients without junctional rhythm than in those with junctional rhythm; (3) a multicomponent or a putative slow-pathway potential was rarely seen in patients without junctional rhythm; and (4) absence of junctional rhythm was more frequently noted in patients with the fast-slow form of AV nodal reentrant tachycardia.

Possible Mechanism of Absence of Junctional Rhythm With Successful Ablation

In the present study, successful ablation sites were located in the posterior and medial areas in almost all patients; however, successful sites were located mostly in the posterior area, far from the His bundle, in patients without junctional rhythm. Furthermore, the atrial/ventricular electrogram amplitude ratio at successful ablation sites was significantly larger in patients without than in those with junctional rhythm. These findings suggest that successful ablation sites were closer to the atrial aspect of posterior AV junctional tissue in patients without junctional rhythm. This area of posterior input into the AV node is very complex, and the atrial electrograms may differ at different points along the pathway. Therefore, the different atrial electrograms seen when this area is mapped in patients with or without junctional rhythm may represent different target sites along this pathway. The other possibility is that the slow AV nodal pathways in these patients without junctional rhythm may be different from those in patients with junctional rhythm. This hypothesis could explain why junctional rhythm was so difficult to induce in some patients.

Furthermore, the present study showed that the form of tachycardia was significantly different between patients with and without junctional rhythms. In patients without junctional rhythm during slow-pathway ablation, the incidence of the fast-slow form of tachycardia was higher than in those with junctional rhythm. Previous study has also shown that most of the retrograde slow pathways are in the lower anatomic location of Koch’s triangle, which is different from the antegrade slow pathways. Thus, ablation of the retrograde slow pathway had a lower incidence of junctional rhythm because the successful ablation sites were far from the His bundle area.

A multicomponent atrial electrogram, which is characterized by a sequence of multiple small deflections, is produced by nonuniformly anisotropic tissue. In nonuniformly anisotropic tissue, defined by Spach and Josephson, conduction through atrial and ventricular myocardium is much slower and characteristically produces a prolonged, multiphasic extracellular electrogram. In animal studies, the atrial myocardium adjacent to the ostium of the coronary sinus, which served as the posterior input into the AV node, was associated with fractionated electrograms or double atrial electrograms similar to slow-pathway potentials. In human studies, Niebauer et al found that slow-pathway potential or multicomponent atrial electrograms were recorded at many locations around the tricuspid annulus in the right atrium, and the prevalence was significantly higher at the posterior septum than at other right atrial sites. However, a multicomponent atrial electrogram was present only in 10% of our patients without junctional rhythm, and successful sites were located mostly in the posterior area. Thus, the tissue characteristics of these slow pathways may be different from those in patients without junctional rhythm.

Relation Between Junctional Rhythm and Ablation-Site Electrogram

Although Jackman et al found a discrete slow-pathway potential at nearly all successful ablation sites, there have been several conflicting reports discussing the different prevalences and definitions of these potentials. Haissaguerre et al reported that during ablation of the slow pathway with discrete slow potentials used as a guide, 78% of 64 patients developed junctional rhythms. Kelly et al demonstrated several independent predictors of successful ablation, including the occurrence of junctional rhythm (93%) during ablation and the presence of a discrete slow-pathway potential (81%) in the successful ablation site. In the present study, a multicomponent atrial electrogram was present in 49% of successful ablation sites (172 patients), and the prevalence of a multicomponent atrial electrogram was significantly higher in patients with than in those without junctional rhythm. These reports suggest that junctional rhythm occurs frequently in the presence of a multicomponent atrial electrogram or slow-pathway potentials.

Several studies reported that a longer duration of atrial electrograms was seen at the successful ablation site in patients with AV nodal reentrant tachycardia. In the present study, the duration of atrial electrograms was significantly longer in patients with junctional rhythm than in those without junctional rhythm during successful slow-pathway ablation. The duration of atrial electrograms would be longer in the presence of a multicomponent atrial electrogram. Therefore, the duration of atrial electrograms was significantly longer in patients with junctional rhythm because they had a higher incidence of multicomponent atrial electrograms.

Study Limitations

This was a retrospective study, and therefore we could not study several variables that would have furthered our understanding of the electrophysiological mechanism in patients with or without junctional rhythms during slow-pathway ablation. However, a prospective study would have been difficult to perform because the incidence of absence of junctional rhythm was very low. Therefore, we looked for different characteristics in these 2 groups of patients with the hope that our results would prove instructive in the future.
Radiofrequency Ablation of Slow Pathway

The number of radiofrequency pulses was smaller in patients with junctional rhythm than in those without junctional rhythm. This finding may be related to several factors, including the fact that easy induction of junctional rhythm results in early ablation success. On the other hand, the use of a greater number of pulses produces more severe tissue edema, after which more pulses are required to perform successful ablation.

Clinical Implications

The major clinical implication in the present study is that in rare cases, successful slow-pathway ablation can be achieved in the absence of junctional rhythm with unusual atrial electrograms. We were able to deliver radiofrequency energy for a longer duration, although we could not induce a junctional rhythm or standard atrial electrograms during ablation after systematic mapping. This could decrease procedure and fluoroscopic times.

Conclusions

Patients without junctional rhythm during successful slow-pathway ablation predominantly had posterior locations of the ablation site, larger atrial/ventricular electrogram amplitude ratio, shorter duration of the atrial electrogram, and a lower incidence of a multicomponent or slow-pathway potential than patients with junctional rhythm. Thus, in some rare patients with AV nodal reentrant tachycardia, successful slow-pathway ablation is possible in the absence of junctional rhythm during radiofrequency applications.

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