Diagnostic Significance of the Morphological Change in the Atrial Electrogram During Para-Hisian Pacing

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Para-Hisian pacing (PHP), a pacing method to differentiate between conduction occurring over an accessory pathway (AP) from that over the atrioventricular node (AVN), is assessed essentially by comparing the timing in the atrial electrograms. Morphological change in the atrial electrograms is often observed during PHP, but its significance has not been investigated. Prior to the catheter ablation procedure, PHP was performed in 52 patients with an AP and in 36 patients with AV nodal reentrant tachycardia (AVNRT). The morphological change in the atrial electrograms, which was retrospectively assessed between the His bundle and proximal right bundle branch (HB-RB) captured and non-captured beats, was identified in 15 of 52 patients with an AP and in 26 of 36 patients with AVNRT. The atrial electrogram in the 6 of these 15 AP patients changed its morphology without overlapping the ventricular electrogram. All 6 AP patients exhibited a PHP pattern with the presence of 2 retrograde conduction routes, an AP and the AVN. In the patients demonstrating no morphological change in the atrial electrogram, 33 of 37 AP patients and all 10 AVNRT patients had only one retrograde conduction route. Morphological change in the atrial electrogram without overlapping the ventricular electrogram seems to have diagnostic significance indicating the presence of both AP and AVN conduction. (Jpn Circ J 2000; 64: 928–932)

Key Words: Accessory pathway; Atrial electrogram; Catheter ablation; Para-Hisian pacing; Retrograde AV nodal conduction

Para-Hisian pacing (PHP), which is a useful pacing method to differentiate between conduction occurring over an accessory pathway (AP) from that over the atrioventricular node (AVN), is assessed essentially by comparing the timing of the local atrial electrogram of the His bundle and proximal right bundle branch (HB-RB) captured beats with that of HB-RB non-captured beats. Morphological change in the atrial electrogram is often observed during PHP, but its significance has not been investigated except for in our previous case report. The aim of the present study was to elucidate the diagnostic value of these morphological changes as well as their frequency and to discuss the mechanism for the electrophysiological phenomenon.

Methods

Study Population

The study population consisted of 96 patients with paroxysmal supraventricular tachycardia undergoing an electrophysiological study and radiofrequency catheter ablation. There were 51 male and 45 female patients, aged from 14 to 79 years old (mean±SD, 48.6±15.4 years). Orthodromic AV reentrant tachycardia was induced in 55 patients with Wolff-Parkinson-White (WPW) syndrome (manifest WPW, 21; concealed WPW, 33) including a patient with permanent form of junctional reciprocating tachycardia (PJRT). Forty-one patients were found to have AVN reentrant tachycardia (slow/fast form AV nodal reentrant tachycardia (AVNRT), 36; fast/slow or slow/slow form, 4; both the slow/fast and fast/slow form, 1).

Electrophysiological Study

The electrophysiological study was performed when the patients were in a fasting state under sedation with fentanyl and midazolam. Four multipolar electrode catheters were inserted percutaneously into the right and left femoral veins and positioned in the right atrial appendage, right ventricular apex, region of the His bundle, and posteriorseptal right atrium between the coronary sinus ostium and tricuspid annulus. A 5-French octopolar deflectable catheter was inserted into the right internal jugular vein and positioned in the coronary sinus (CS). In 12 patients with WPW syndrome, a 7F 20-polar deflectable catheter was positioned along the tricuspid annulus with the distal electrode placed in the proximal CS. The presence of retrograde AP conduction was confirmed or excluded by the standard techniques, including late extrastimuli during supraventricular tachycardia and programmed ventricular stimulation. The electrograms, including the surface ECG, were recorded using an EP Lab computer system (Quinton Electrophysiology Co, Toronto, Canada) with digital amplifiers. The heart was stimulated at twice the diastolic threshold current level with a pulse duration of 2 ms.

Technique for Para-Hisian Pacing

In all of the patients, PHP was performed by the previ-
Table 1 Response Patterns to Para-Hisian Pacing in Patients With Retrograde AP Conduction

<table>
<thead>
<tr>
<th>Site of AP</th>
<th>n</th>
<th>AVN only</th>
<th>AP only</th>
<th>Both AVN and AP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AVN/AVN</td>
<td>AP/AP</td>
<td>AVN/Fusion (or AP)</td>
</tr>
<tr>
<td>Anterosetal</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Midseptal</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Posteroseptal</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Right free wall</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Left free wall</td>
<td>41</td>
<td>4</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>PJRT</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>4</td>
<td>15</td>
<td>19</td>
</tr>
</tbody>
</table>

APs, retrograde conduction over an AP with lengthening of the S-A interval due to delay in ventricular activation close to the AP with loss of HB-RB capture; AVN/Fusion (or AP), either the AVN/Fusion pattern or AVN/AP pattern; Fusion/Fusion (or AP), either the Fusion/Fusion pattern or Fusion/AP pattern; PJRT, permanent junctional reciprocating tachycardia resulting from retrograde conduction over a concealed AP with a long conduction time and decremental properties.

Table 2 Morphological Change in the Atrial Electrogram During Para-Hisian Pacing

<table>
<thead>
<tr>
<th>Response Pattern</th>
<th>n</th>
<th>Morphological change (+)</th>
<th>Overlap with VE (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessory pathway (AP) patients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP/AP, or AP/AP</td>
<td>34</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>AVN/AVN</td>
<td>14</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>AVNRT</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>AVN/AVN</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>

Morphological change (+) indicates the presence of morphological change in the atrial electrogram between HB-RB capture and HB-RB non-capture; Overlapping with VE (+) indicates the atrial electrogram overlapped with the ventricular electrogram. AVN, atrioventricular node; AVNRT, AVN reentrant tachycardia.

Analysis of Para-Hisian Pacing

Para-Hisian pacing was retrospectively analyzed. Essential evaluation of PHP was based on the change in the following variables between that occurring with HB-RB capture and HB-RB non-capture: (1) atrial activation sequence; (2) stimulus-atrial (S-A) interval and local ventriculo-atrial (V-A) interval in each electrogram, including the electrograms recorded close to the site of the earliest retrograde atrial activation during tachycardia; and (3) His bundle-atrial (H-A) interval measured in the His bundle electrogram (HBE) if the HB electrogram was clearly recorded. To eliminate the possibility of atrial morphological change due to the instability of the electrode catheters, a comparison between 2 HB-RB captured beats and 2 HB-RB non-captured beats was performed. Classification of the various patterns of the response to PHP was essentially based on previous reports.1,2 and was performed by a comparison between the retrograde atrial activation sequence during HB-RB capture and that during loss of HB-RB capture. An identical atrial activation sequence indicates that retrograde conduction is occurring over the same pathway during PHP. During loss of HB-RB capture, a constant S-A interval indicates that retrograde conduction is occurring only over an AP (AP/AP pattern).

During loss of HB-RB capture, a constant local V-A interval with a longer S-A interval also indicates that retrograde conduction is occurring only over an AP (AP/AP pattern). Lengthening of the S-A interval (or local V-A interval) indicates that retrograde conduction is occurring only over the AV node (AVN/AVN pattern).

On the other hand, with loss of HB-RB capture, a change in the retrograde atrial activation sequence indicates that the retrograde conduction occurs over both an AP and the AVN, and the patients demonstrating this response have been classified into 4 patterns: Fusion/Fusion pattern; Fusion/Fusion pattern; AVN/AVN pattern; and AVN/Fusion pattern. The identification of the HB potential in the HB electrogram during PHP in this study was difficult in most of the patients, in whom the H-A interval was not used for differentiation of conduction over the AVN or an AP during loss of HB-RB capture. Instead, no change in the S-A or local V-A interval with loss of HB-RB capture was tentatively referred to as a Fusion/Fusion (or AP) pattern and an increase in the S-A or local V-A interval with loss of HB-RB capture was referred to as an AVN/Fusion (or AP) pattern in the present study.

Assessment of the Morphological Change in the Atrial Electrogram During Para-Hisian Pacing

The morphological change in the polarity, amplitude and width of the atrial electrogram was independently assessed at all recording sites between HB-RB captured beats and HB-RB non-captured beats by 2 of the authors (K.H. and T.H.). The changes were classified into 2 categories according to the relationship between the atrial electrogram and the ventricular electrogram. One was a morphological change in the atrial electrogram without overlapping with the ventricular electrogram, which was referred to as a 'real morphological change'. The other was a morphological change in

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the atrial electrogram with overlapping with the ventricular electrogram, in which the beginning part or total atrial electrogram fused with the ending part of the ventricular electrogram. After the loss of conduction over the AP by successful catheter ablation in the patients with orthodromic AV reentrant tachycardia, ventricular programmed pacing was performed to assess the presence or absence of retrograde conduction over the AVN.

Results
Para-Hisian pacing was successfully performed in all 96 patients. In 8 of 96 patients, the atrial electrogram recording was inadequate to assess the morphological change, because the amplitude of the atrial electrogram was too small or the atrial electrogram was not clear or unstable. Evaluation of PHP, therefore, was performed in the remaining 88 patients, consisting of 52 AP patients and 36 patients with AVNRT. In patients with an AP, the patterns of response to PHP were AP/AP in 15, AP/AP: in 19, Fusion/Fusion (or AP) in 14, and AVN/AVN in 4 patients, and none showed an AVN/Fusion (or AP) pattern (Table 1). In patients with AVNRT, PHP produced an AVN/AVN pattern in all 36 patients. A morphological change in the atrial electrogram was identified in 15 of 52 AP patients and in 26 of 36 patients with AVNRT (Table 2). While PHP in 9 of 15 AP patients and all 26 patients with AVNRT showed a morphological change in the atrial electrogram with an overlapping with the ventricular electrogram, 6 AP patients showed a real morphological change in the atrial electrogram.

Morphological Change With an Overlapping With the Ventricular Electrogram
In 26 AVNRT patients with a morphological change in the atrial electrogram, the morphological change in the atrial electrogram occurred in I-3 (1.9±0.8) sites of the total 5-10 (6.5±1.4) recording sites, and was observed mainly at the HBE recording site (0.9±0.6) and less frequently at the posteroseptal recording site (0.5±0.7) or CS (0.5±0.8) as demonstrated in Fig 1. This type of change was also observed at the other sites when the local ventricular electrogram occurred late or the conduction time from the ventricle to the atria via the AVN was short.

In 9 AP patients, who exhibited a morphological change...
in the atrial electrogram because of an overlapping with the ventricular electrogram, a morphological change in the atrial electrogram was observed in 1-2 (1.2±0.4) sites of the total 4-10 (7.7±1.8) recording sites. This change was identified at sites close to the AP (9 of 9 patients) and less frequently at the HBE (2 of 9 patients).

Real Morphologic Change Without an Overlapping With the Ventricular Electrogram

There were 6 AP patients demonstrating a 'real morphological change'. In Fig.2, recorded in a patient with a left anterolateral AP, the atrial electrogram at TA:3 (the proximal CS) during HB-RB capture exhibited an 'rsSr' pattern, but its morphology during HB-RB non-capture changed to a 'qRs' pattern. The ventricular electrogram at the same recording site showed a very small amplitude and was inscribed at a much earlier time than the atrial electrogram without overlapping with it.

Change not only in the polarity or amplitude, but also in the width of the atrial electrogram was observed in one of 6 patients as shown in Fig.3. In this patient, the width of the complex atrial electrogram in the CS3-4 electrogram, the distal recording site from the AP site (left lateral), became wider, resulting in a change in its morphology without the ventricular electrogram having any effect on it.

Fig.4 is a recording of a long RP tachycardia patient in whom PHP was useful to differentiate PJRT from the uncommon type of AVNRT. In this figure the retrograde atrial activation pattern appeared similar between that during HB-RB capture and that during non-capture. Besides, the atrial activation sequence was not eccentric and the local V-A interval was not short, suggesting that there was no V-A conduction over the AP in this patient. However, a morphological change in the atrial electrogram was identified at the PS sites in the figure. Therefore, the finding of the morphological change seemed to be another clue for diagnosing the presence of an AP with slow conduction in this patient.

It was notable that these 6 patients with a real morpho-
logical change exhibited a double retrograde conduction route pattern (a Fusion/Fusion (or AP) pattern) during PHP. After successful ablation of the AP, the presence of concomitant retrograde conduction over the AVN was confirmed in these 6 AP patients and the remaining 9 patients demonstrating a Fusion/Fusion (or AP) pattern before ablation. There was no significant discrepancy in the decision on whether or not there was a presence or absence of a morphological change in the atrial electrogram and its overlapping with the ventricular electrogram during PHP in each patient between the 2 observers.

Discussion

We focused on the morphological change in the atrial electrogram during PHP, which has not been reported or discussed prior to this present study except in our previous case reports. Morphological change was observed in 15 of 52 AP patients and in 26 of 36 patients with AVNRT, suggesting that this finding was common. In most of the patients with or without retrograde conduction over an AP, overlap of the atrial electrogram overlapping with the ventricular one appeared to cause a morphological change in the atrial electrogram. Morphological change without overlap of the ventricular electrogram, on the other hand, was identified only in patients who had retrograde conduction over both an AP and the AVN, and not in those who had V-A conduction only over an AP or the AVN.

Mechanism of the Change in the Morphology of the Atrial Electrogram

When the atrial electrogram is overlapped with the ventricular electrogram, the morphology of the atrial electrogram can be affected and will change variously according to the degree of overlapping as described above. If the morphological change occurs without any overlapping with the ventricular electrogram ("real change"), the change in the direction of the propagation within the atria due to a change in the manner of the atrial activation during PHP, seems to be the main reason for this. This might be fairly analogous to the phenomenon recognized in the fourth criterion of transient entrainment, in which a change in the morphology of the local electrogram is observed because a particular site is activated by the orthodromic wavefront at a slower pacing rate and by the antidromic wavefront at a faster pacing rate during tachycardia. Although the trigger inducing the morphological change in the atrial electrogram differed between that during the fourth criterion and that during PHP, the mechanism seems to be quite similar.

Therefore, a "real morphological change" in the atrial electrogram might result from a change in the propagation of atrial activation and can be interpreted as a change in the V-A conduction route or a change in the extent of activation of the different impulses originating from the 2 routes, the AP and the AVN, between HB-RB capture and non-capture: i.e., during HB-RB capture, a particular atrial site is activated by the impulse via the AVN, and is activated via the AP during HB-RB non-capture.

Study Limitations

Theoretically, in all of the patients who exhibited a Fusion/Fusion (AP) pattern during PHP, a morphological change in the atrial electrogram could be demonstrated at the appropriate recording site which was captured by the impulse via the AVN during HB-RB capture and captured by the impulse via an AP during HB-RB non-capture. However, the analysis in this study was performed retrospectively and all the mapping data for the atrial electrograms were obtained at fixed recording sites, thus catheter mapping for the appropriate site as mentioned above was not performed. Therefore, only 6 of 14 patients with a Fusion/Fusion (AP) pattern showed a real morphological change in the atrial electrogram in the present study.

Another limitation to this study is that a quantitative assessment was not adopted to determine whether there was a morphological change in the atrial electrogram during PHP. Instead, based on the change in the polarity, amplitude and width of the atrial electrogram, the morphological change was assessed by 2 of the authors. Since the assessment results were identical for the 2 observers, the qualitative assessment method adopted in the present study did not appear to be inappropriate.

Clinical Implications of the Morphological Change in the Atrial Electrogram

To interpret the response to PHP, it is critical to determine that the atrial activation sequence during HB-RB capture is identical to that during non-capture or to show the eccentricity of the atrial activation pattern. Clinically, in most cases there may not be a problem with interpreting the response to PHP by only using the previously reported method (comparison of the atrial activation sequences). However, if the degree of the difference in the activation sequence is small, possibly because of slow conduction over an AP or enhanced conduction over the AVN, interpretation of PHP would become difficult. Also, the posterior exit from the AVN can be recorded in a broad area extending from the right posteroseptum to the left posterolateral region; which might be mistakenly regarded as conduction over an AP. In such a case, as we reported in an earlier case report, the presence of a morphological change in the atrial electrogram would be useful in assessing the retrograde conduction route(s).

The presence of a morphological change in the atrial electrogram without overlap of the ventricular electrogram, therefore, would be a new diagnostic finding and another clue to support the presence of retrograde conduction over an AP as well as the AVN.

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References