Local slow potential preceding the surface QRS complex detected at the subvalvular mitral annulus in patients with a left-sided concealed accessory pathway

Incidence, electrophysiological characteristics and the possible mechanism, with demonstration of anterograde concealed conduction through the pathway

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Aim We sought to evaluate the incidence and electrophysiological features of the local slow potential preceding the surface QRS complex (pre-QRS potential) which was detected more frequently at successful sites of catheter ablation of left parietal concealed accessory pathways, than at unsuccessful sites.

Methods and Results Thirty eight consecutive patients with a single left sided concealed accessory pathway underwent radiofrequency catheter ablation exclusively from the subvalvular mitral annulus. The local bipolar electrograms during sinus rhythm from the target sites were carefully analysed and the incidence of pre-QRS potentials was compared between successful and unsuccessful ablation sites. All ablation sessions attained a successful outcome with a total of 84 radiofrequency current applications (38 at successful sites, 46 at unsuccessful sites). The incidence of pre-QRS potentials (preceding by 10 ms or more) was 12/38 at successful sites (32%) and 1/46 at unsuccessful sites (2%) (P < 0.001). The QV interval, defined as the interval between the upstroke of the QRS complex and the ventricular electrogram, including the pre-QRS potential, was –5.6 ± 9.1 ms at successful sites, while it was 1.2 ± 6.1 ms at unsuccessful sites (P < 0.001). The pre-QRS potential disappeared during atrioventricular reciprocating tachycardia and right ventricular pacing, and was eliminated by successful ablation.

Conclusions Detection of the pre-QRS potential was clinically relevant and could be distinguished from artifact. This potential may be caused by anterograde concealed conduction through the accessory pathways.

Key Words: Pre-QRS potential, concealed accessory pathway, concealed anterograde conduction, radiofrequency catheter ablation, subvalvular mitral annulus, atrioventricular reciprocating tachycardia.

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Recently it has been demonstrated, through high resolution ECG recording using the signal averaging technique, that the low amplitude component preceding the initial upstroke of the body surface QRS complex, is detectable in about a half of concealed Wolff-Parkinson-White patients, whereas it was not detectable in either patients with atrioventricular nodal reentrant tachycardia or normal subjects. Similarly, we recently demonstrated, in the local bipolar electrogram during sinus rhythm, that a low-amplitude slow potential preceding the QRS complex (pre-QRS potential) is more frequently detected at successful sites of radiofrequency catheter ablation, than at unsuccessful sites in concealed Wolff-Parkinson-White patients. The presence of a pre-QRS potential at successful ablation sites has not been described in previous reports, and the electrophysiological mechanism underlying the pre-QRS potential is unknown. Thus, the aim of this study was to evaluate the incidence and electrophysiological characteristics of the pre-QRS potential, which is more frequently observed at the subvalvular mitral annulus adjacent to the accessory pathway-ventricular junction in the concealed Wolff-Parkinson-White syndrome.

Methods

Patient population
Thirty eight consecutive patients (28 males, 10 females, average 47 ± 14 years) with a single left-sided parietal concealed accessory pathway comprised this study. All patients had frequent episodes of atrioventricular reciprocating tachycardia and were admitted for radiofrequency catheter ablation.

Electrophysiological study

After written informed consent was obtained, an electrophysiological study was performed in the fasting and mildly sedated state. Administration of previous antiarrhythmic drugs was withheld for at least five half lives prior to the study. Three quadripolar catheters were inserted from the right femoral vein and advanced to the high right atrium, the His bundle region, and the right ventricular apex under fluoroscopic guidance. One decapolar catheter (Webster, 2-8-2 mm interelectrode spacing) was also inserted from the right subclavian vein and advanced into the coronary sinus as far anteriorly as possible. Intracardiac signals were amplified and filtered from 30 to 500 Hz (E for M, V600), and recorded on an optical disk using an EP Lab system (Quinton Instrument Co., Bothell, WA, U.S.A.). Programmed stimulation was delivered at twice the diastolic threshold with a 1 ms pulse width, and the intracardiac recordings were analysed using a paper speed of 400 ms.

Radiofrequency catheter ablation

In all patients, 7-8 French bi- or quadripolar catheters with a 4 mm large tip electrode (2 mm interelectrode spacing; Webster, EPT, Medtronic or Osypka) were used for the catheter ablation. The catheter was introduced from the femoral artery and advanced into the left ventricle. Mapping and radiofrequency current delivery for ablation of concealed accessory pathways were exclusively applied from the subvalvular mitral annulus in all patients. In the earlier 20 sessions, we used 500 kHz generators only capable of operating in the power control mode (Radionics: 3B and 3C, Osypka: Hut 200, Internova: Novaflame). With the power controlled generators, the radiofrequency current was delivered at 15–20 watts. In the remaining 10 sessions, a radiofrequency generator with a temperature control system (Osypka: Hut 200S) was used, and the target temperature was always set to 60 °C.

Definition of successful and unsuccessful radiofrequency applications

For comparison of the local electrogram at successful vs unsuccessful ablation sites, successful catheter ablation was defined in the present study as the elimination of retrograde conduction through the accessory pathway within 10 s of the onset of radiofrequency current delivery, assessed during ventricular pacing. Otherwise, the radiofrequency current delivery was considered unsuccessful.

Figure 1 Depiction of the distribution of the successful ablation sites in a total of 38 concealed Wolff-Parkinson-White patients with single left free-wall accessory pathways. The open circles indicate the sites with a QV interval ≤ −10 ms, open triangles, a QV interval ≤ −5 ms and > −10 ms, and open squares, a QV interval > −5 ms. It is noted that the successful ablation sites, with a local slow potential preceding the surface QRS complex, were equally distributed along the mitral annulus of the left free-wall.
Electrophysiological data are expressed as mean values ± 1 standard deviation. Comparisons of the interval parameters between successful and unsuccessful ablation sites were made using the unpaired t-test. Non-continuous variables were analysed using the chi-square test.

Results

The outcome of catheter ablation

In all 38 patients, conduction through the accessory pathway was successfully eliminated by the end of the ablation session. During the follow-up period, all but one patient in whom atrioventricular reciprocating tachycardia recurred 2 months after the ablation session, had been free from palpitation attacks. A mean of 2.2 ± 1.3 radiofrequency applications were delivered in each patient (a total of 84 radiofrequency applications at 84 different sites). The mean of the cumulative electrical energy was 3070 ± 2690 J. Out of the 84 ablation sites performed beneath the mitral annulus, 38 were assessed as successful, and the remaining 46 as unsuccessful. The anatomical distribution of all the ablation sites is depicted in Fig. 1. This shows that the ablation sites of the left accessory pathways were equally distributed along the entire circumferential area of the mitral annulus.

The low-amplitude potential preceding the surface QRS complex (pre-QRS potential) in the local electrogram at the ablation sites
at the successful sites. Such local potentials were less frequently observed at unsuccessful sites (5/46 sites: 11%) (P < 0.001). Similarly, a pre-QRS potential preceding the QRS complex by more than 10 ms was positive in 12/38 (32%) successful sites and in 1/46 (2%) unsuccessful sites (P < 0.001).

Twelve patients with positive pre-QRS potentials (QV interval ≤ 10 ms) at successful ablation sites were selected and are listed in Table 1. The pre-QRS potentials (QV interval ≤ 10 ms) were equally distributed along the circumference of the mitral annulus (Fig. 1 and Table 1). Three were located anteriorly, four laterally and three posteriorly. The QV intervals at the unsuccessful sites for each patient and the 3-D distance from the successful ablation sites are also shown in Table 1. The 3-D distance was estimated by using two different cine-flame projections (RAO 30°:A mm, LAO 60°:B mm) (equation: \( \sqrt{A^2+B^2} \)). These data suggest that pre-QRS potentials, which were appreciable at the successful ablation sites, could not be detected in areas 1 cm or more remote from the successful ablation sites in most cases.

The local electrograms with positive pre-QRS potentials are demonstrated in Fig. 4. The pre-QRS potential appeared to have several characteristics including (i) a low amplitude ranging from 0.1 to 0.2 mV, (ii) it was composed of one or more slow potentials, and (iii) the timing of the onset of the potential was variable (some of them arose immediately after the offset of the atrial potential while in others there was an isoelectric line intervening between the atrial potential and the pre-QRS potentials).

Representative recordings of the change in the pre-QRS potential during different electrophysiological conditions are demonstrated in Fig. 5. During sinus rhythm, the pre-QRS potential could be seen in the local electrogram at the successful ablation site (panel A). In contrast, this potential disappeared during orthodromic atrioventricular reciprocating tachycardia (panel B) when the impulse propagated through the accessory pathway exclusively in the retrograde direction. Similar findings were also observed in all three patients in whom the local recordings during both sinus rhythm and atrioventricular reciprocating tachycardia could be obtained. It was also confirmed in all patients that the pre-QRS potential was not seen during stable 1 to 1 retrograde conduction through the accessory pathway during pacing from the right ventricle (panel C).
Table 1 List of the patients with positive pre-QRS potential (QV interval \( \leq -10 \) ms)

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (years)</th>
<th>Gender</th>
<th>AP location</th>
<th>Successful site QV interval (ms)</th>
<th>Unsuccessful site 1</th>
<th>Unsuccessful site 2</th>
<th>Unsuccessful site 3</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>Male</td>
<td>anterior</td>
<td>-26</td>
<td>0 (8)</td>
<td>-</td>
<td>-</td>
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<tr>
<td>2</td>
<td>34</td>
<td>Male</td>
<td>anterior</td>
<td>-11</td>
<td>-2 (8)</td>
<td>0 (15)</td>
<td>-11 (11)</td>
</tr>
<tr>
<td>3</td>
<td>47</td>
<td>Male</td>
<td>anterior</td>
<td>-11</td>
<td>-2 (5)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>Female</td>
<td>anterior</td>
<td>-10</td>
<td>0 (10)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>34</td>
<td>Male</td>
<td>lateral</td>
<td>-21</td>
<td>14 (9)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>52</td>
<td>Female</td>
<td>lateral</td>
<td>-11</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>31</td>
<td>Male</td>
<td>lateral</td>
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<td>-1 (16)</td>
<td>-4 (20)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>8</td>
<td>49</td>
<td>Male</td>
<td>lateral</td>
<td>-31</td>
<td>0 (29)</td>
<td>-8 (24)</td>
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<tr>
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<td>posterior</td>
<td>-15</td>
<td>10 (16)</td>
<td>-</td>
<td>-</td>
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<td>Female</td>
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<td>-12</td>
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<td>-</td>
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<td>Male</td>
<td>posterior</td>
<td>-10</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>12</td>
<td>45</td>
<td>Male</td>
<td>posterior</td>
<td>-10</td>
<td>-4 (7)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The QV intervals at both successful and unsuccessful ablation sites are indicated in all patients with positive pre-QRS potential at the successful ablation sites (QV interval \( \leq -10 \) ms). The 3-D distances of each unsuccessful site from the successful site is also shown in parentheses. AP = accessory pathway.

Figure 4 Local electrograms during sinus rhythm of successful ablation sites with a pre-QRS potential (QV interval \( \leq -10 \) ms). Note that the pre-QRS potential was composed of a single deflection or multi-component slow electrical activity, regardless of the anatomical location of the accessory pathway.
Eventually the pre-QRS potential was eliminated after successful radiofrequency current delivery, as shown in panel D of Fig. 5. This phenomenon was consistently recognized in all patients with a pre-QRS potential before the catheter ablation.

Evidence for anterograde concealed conduction through the accessory pathways

It has been shown that the retrograde effective refractory period of concealed accessory pathways is shortened more by applying a single ventricular extrastimulus following atrioventricular simultaneous basic drives than when using conventional ventricular extrastimulus testing. This shortening of the refractory period was postulated to be caused by a leftward shift (so-called ‘peeling back’ phenomenon) of the refractory period in the accessory pathway distal to the collision level (from the ventricle) of the simultaneous atrial and ventricular impulses during the basic drives. Therefore such a phenomenon could be considered as evidence for concealed anterograde conduction through the accessory pathways, together with the direct recording of anterograde concealed excitation of accessory pathways previously shown by Kuck et al. We also observed similar findings in all patients in which this pacing technique was applied, irrespective of the presence of a pre-QRS potential as shown in Fig. 6. This implied that the anterograde impulse propagated into the accessory pathways in most of our patients. However, the level of the impulse penetration in the accessory pathways was uncertain.

Discussion

Possible mechanism of the pre-QRS potential

The major findings in the present study were as follows: (1) the local slow potential preceding the surface QRS complex was more frequently detected at successful subvalvular ablation sites of left parietal accessory pathways, than at unsuccessful sites; (2) such potentials were detectable only in a restricted region, within 1 cm of the successful ablation site, i.e. in the vicinity of the accessory pathway-ventricular junction; (3) the pre-QRS potential disappeared during orthodromic atrioventricular reciprocating tachycardia and ventricular pacing, and was eliminated after successful radiofrequency current delivery.

The observations in (1) and (3) above strongly suggest that the pre-QRS potential might be related to anterograde concealed conduction over the accessory pathway. Up to the present, direct recording of accessory pathway potentials has been used to elucidate the anatomical features of accessory pathways and to identify appropriate target sites for catheter ablation. In all previous reports, the accessory pathway potential has been
shown to have a discrete spiky configuration without exception. In the present study, possible accessory pathway potentials with a spiky configuration were similarly detected during retrograde conduction (see Fig. 5) in 15/38 (39%) successful ablation sites and 10/12 (83%) sites with positive pre-QRS potentials (QV interval $\leqslant 10$ ms). Therefore, it is unlikely that the pre-QRS potential reflects the anterograde excitation of the accessory pathway itself. A possible mechanism for the pre-QRS potential is that this slow potential might be a reflection of atypical electrical activation of the localized ventricular muscle adjacent to the accessory pathway-ventricular junction, such as that from the electrotonic effect and local graded response invoked by the excitation of the accessory pathway. In a previous experimental study utilizing the atrial isthmus model\(^1\), an appreciable rise in the resting membrane potential (electrotonic effect) was recorded at a site distal to the isthmus when the impulse from the proximal site was blocked at the isthmus. Furthermore, impulse propagation derived from incomplete depolarization (graded response) has been shown to decline in the adjacent cardiac tissue\(^{15}\). Such atypical excitation may form a small slow potential in the local electrogram.

**Figure 6** Comparison between the retrograde effective refractory period (ERP) of the accessory pathway determined with conventional right ventricular (RV) extrastimulus testing (left) and that with RV extrastimulus testing following atrioventricular (RV and CS) simultaneous basic drives (right) with a cycle length of 600 ms. Open symbols (circle: QV interval $\leqslant 10$ ms, triangle: $-10 < $QV interval $\leqslant -5$ ms, square: QV interval $> -5$ ms) indicate ERPs less than the plotted numbers ($> $ ERP), and closed symbols indicate ERPs equal to the plotted numbers ($\leqslant $ ERP). The ERPs were significantly shorter during the atrioventricular simultaneous method than that during the conventional method, irrespective of the presence of a pre-QRS potential.

Distinction of the pre-QRS potential from a far-field potential, injury current or artifact

The possibility that the pre-QRS potential reflects a far-field electrical excitation could be excluded, because the pre-QRS potential was diffusely recorded along the entire circumference of the left parietal subvalvular
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mitral annulus, remote from the specialized conduction tissue which excites at a corresponding period to the pre-QRS potential. The influence of prior radiofrequency current applications (injury current) could also be excluded, because some of the patients with positive pre-QRS potentials had only one successful burn and no unsuccessful ablation trials. Moreover, it is thought to be unreasonable that an injury current could constantly form a local potential only during the pre-QRS period. It is also unlikely that the pre-QRS potential could have been caused by artifact, because of the following observations: (i) the pre-QRS potential was present only after atrial potentials, and was not detected after either ventricular potentials or stimulus artifact; (ii) it was recorded in a restricted region (successful ablation sites) and was not found in the adjacent region (unsuccessful ablation sites); (iii) finally, we were able to consistently reproduce the findings in different patients at similar recording sites.

This is the first report demonstrating the presence of a local slow potential which might be caused by anterograde concealed conduction through the accessory pathway. Since electrophysiological evidence for the mechanistic hypothesis which we proposed is limited, further detailed experimental study is needed.

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References


