Diastolic Potentials Observed in Idiopathic Left Ventricular Tachycardia

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Radiofrequency catheter ablation (RF-CA) has demonstrated a high success rate in eliminating idiopathic left ventricular tachycardia (ILVT), and the target site is determined by the score of pace mapping or the Purkinje potential (PP) preceding the onset of the ventricular activation, which is considered to indicate the exit site of the reentrant circuit. However, only a few reports have described the potential obtained from the slow conduction zone. RF-CA was successfully performed in 8 patients with ILVT. Careful mapping of the left ventricle during tachycardia was carried out to find the diastolic potential (DP). A DP was obtained in 4 patients (group 1), but not in 4 others (group 2). The local electrogram was recorded from the distal tip of the ablation catheter during the RF current application in order to investigate the pattern of termination of ILVT. A DP was recorded at the point where the catheter was slightly pulled back to a site proximal to the exit site of the reentrant circuit at the left interventricular basal septum. In group 1, conduction block between the DP and PP eliminated ILVT in 3 out of 4 cases, and 1 case showed conduction block between the DP and ventricular potential. In 2 out of 4 patients in group 2, the local electrogram showed conduction block between PP and the ventricular potential when VT terminated. The ablation site in group 1 was located relatively more basal than that in group 2 in anatomy. A DP was obtained in a half of the cases with ILVT and RF-CA at this site could eliminate ILVT. A DP was obtained at a site relatively basal to the exit of the reentrant circuit and it is considered that this is a useful marker in terms of the successful ablation of ILVT. (Jpn Circ J 1999; 63: 917–923)

Key Words: Catheter ablation; Diastolic potential; Idiopathic left ventricular tachycardia; Purkinje potential; Radiofrequency

Diastolic left ventricular tachycardia (ILVT) with right bundle branch block and left axis deviation is known to be verapamil sensitive, and is considered to originate close to or in the posterior fascicle of the Purkinje fiber network.1–3 Reentry has been postulated as the mechanism of this ventricular tachycardia (VT) on the basis that it can be induced and terminated by extrastimuli, and this hypothesis is supported by the fact that transient entrainment is seen in this VT.4 Thus it is considered that the VT has an excitable gap and slow conduction zone. Radiofrequency catheter ablation (RF-CA) has a high success rate in eliminating this VT. Both a perfect pace map and a Purkinje potential (PP) preceding the ventricular activation are recognized as good guides for RF-CA of this VT.5–9 However, only a few reports have described the origin of a diastolic potential (DP) in ILVT and RF-CA guided by that DP. We were able to record a DP in some cases with ILVT and the aim of the present study was to determine the significance of the DP recorded during the VT by examining the type of termination of the VT, and evaluating the efficacy of mapping for a DP as a guide for RF-CA.

Methods

Patient Characteristics

The study group consisted of 8 patients (all males, mean age 31 years, range 17–57 years) who were referred for RF-CA therapy of VT (Table 1). QRS morphology of the VT exhibited a right bundle branch block pattern and left axis deviation, and intravenous verapamil (2–10mg) was effective in terminating the VT in all patients. None of the 8 patients had evidence of structural heart disease.

Electrophysiologic Study

After written informed consent, an electrophysiologic study was performed in the postabsorptive state. All antiarhythmic drugs were stopped for at least 5 half-lives. Three quadripolar catheters with 2- or 5-mm interelectrode spacing were introduced via the right femoral vein, and positioned at the high right atrium, His bundle recording site, and right ventricular apex. The intracardiac electrograms were filtered at a band pass of 30–400 Hz, and recorded using EPLab (Quinton, Seattle, WA, USA). Each pacing stimulus was performed at twice the diastolic threshold with a programmable stimulator (NEC San-ei, Tokyo, Japan).

Radiofrequency Catheter Ablation

A 7Fr large-tip catheter was inserted through the left femoral artery. Meticulous mapping of the left ventricle was performed during VT. We determined the ablation site by the following criteria. First, we sought a DP, defined as a fragmented potential recorded in the diastolic phase and...
which continued for more than 25 ms during VT. It could be clearly distinguished from the spiky PP. A DP was never seen during sinus rhythm in the same phase. When a DP was not found, we sought the PP preceding the onset of the QRS complex by more than 30 ms. Radiofrequency current application was performed at either of these 2 sites at a power of 20 W for 10 s. If this RF delivery terminated the VT, RF-CA was continued for 120 s. The local electrogram was recorded from the distal tip of the ablation catheter during the RF application using a specially designed filtering system composed of 4 high-cut filters. The first high-cut filter attenuated the interference caused by the 520-kHz RF noise, and all the noise with frequencies of 1 kHz or higher entering the recorder was rejected through the other 3 (>1 kHz, >10 kHz, >100 kHz) high-cut filters. The low-cut filter, which was located on the RF current delivery side, blocked the inflow of current with frequencies of 1 kHz or lower coming from the endocardial electrograms to the generator. A previous study had shown that the local bipolar electrogram at the ablation site during RF application can be clearly recorded using this device.

Results

In all 8 patients the VT could be reproducably induced by single extrastimulus from the right ventricular apex, and transient entrainment could be confirmed by pacing from the right ventricular apex. In all cases, RF-CA eliminated the VT and made it noninducible without any adverse effects. We examined the local electrogram from the distal tip of the ablation catheter at the time the VT was terminated and the cases in this series were classified into 2 groups. In 4 cases (group 1), we obtained a DP and performed RF-CA at that site successfully. In another 4 cases (group 2), we could not find a DP and ablated the VT guided by the PP preceding QRS complex by more than 30 ms.

Successful Ablation Guided by a Diastolic Potential

In all group 1 patients, a DP was recorded at the successful ablation site. The DP was obtained at a site slightly basal from the site where the PP preceding QRS complex was at its maximum. The DP was recorded just before the ventricular potential. Note that this Purkinje potential preceded the onset of QRS configuration by only 3 ms. This site was not in the exit of this VT. V1, standard lead V1 of the 12-lead ECG; RVA, right ventricular apex; ABLp, proximal electrode of the ablation catheter; ABLd, distal electrode of the ablation catheter; PP, Purkinje potential; DP, diastolic potential.

Table 1 Patient Characteristics

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Symptom</th>
<th>QRS axis</th>
<th>TZ</th>
<th>VTCL (ms)</th>
<th>PP–QRS (ms)</th>
<th>DP–QRS (ms)</th>
<th>P/M score</th>
<th>Pattern of termination</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>57</td>
<td>Male</td>
<td>Syncope</td>
<td>−84°</td>
<td>V3–V4</td>
<td>245</td>
<td>11</td>
<td>47</td>
<td>12/12</td>
<td>DP–PP block</td>
</tr>
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<td>2</td>
<td>39</td>
<td>Male</td>
<td>Palpitation</td>
<td>−90°</td>
<td>V3–V4</td>
<td>410</td>
<td>ND</td>
<td>81</td>
<td>8/12</td>
<td>DP–VP block</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
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<td>Pulpsation</td>
<td>−94°</td>
<td>V3–V4</td>
<td>255</td>
<td>3</td>
<td>51</td>
<td>8/12</td>
<td>DP–PP block</td>
</tr>
<tr>
<td>4</td>
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<td>Male</td>
<td>Pulpsation</td>
<td>−85°</td>
<td>V3–V4</td>
<td>290</td>
<td>−8</td>
<td>45</td>
<td>9/12</td>
<td>DP–PP block</td>
</tr>
<tr>
<td>5</td>
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<td>Male</td>
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<td>−97°</td>
<td>V3–V4</td>
<td>295</td>
<td>41</td>
<td>ND</td>
<td>11/12</td>
<td>Sudden termination</td>
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<td>Pulpsation</td>
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<td>V3–V4</td>
<td>360</td>
<td>65</td>
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<td>V3–V4</td>
<td>250</td>
<td>30</td>
<td>ND</td>
<td>12/12</td>
<td>Sudden termination</td>
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<tr>
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<td>V3–V4</td>
<td>405</td>
<td>44</td>
<td>ND</td>
<td>11/12</td>
<td>PP–VP block</td>
</tr>
</tbody>
</table>

DP, diastolic potential; DP–QRS, interval between the DP and the onset of QRS configuration; ND, not detected; PP, purkinje potential; PP–QRS, interval between the PP and the onset of QRS configuration; P/M score, pace mapping score; TZ, transitional zone; VP, ventricular potential; VTCL, VT cycle length.

Fig 1. The local electrogram from the distal tip of the ablation catheter in case no.3 showing a discrete diastolic potential separated from a Purkinje potential by an isoelectric line. The Purkinje potential was recorded just before the ventricular potential. Note that this Purkinje potential preceded the onset of QRS configuration by only 3 ms. This site was not in the exit of this VT.
Fig 2. The local electrogram obtained from the distal tip of the ablation catheter showing a diastolic potential recorded continuous with a Purkinje potential in case no. 1. The diastolic potential precedes the QRS complex by 47 ms, and the Purkinje potential precedes the QRS by 11 ms. The proximal electrode of the ablation catheter shows only the Purkinje potential recorded slightly later than that of the distal tip. HBE, His bundle electrogram; HRA, high right atrium; P, Purkinje potential; DP, diastolic potential; V, ventricular potential. (Other abbreviations as in Fig 1.)

Fig 3. The local electrogram from the distal tip of the ablation catheter in case no. 2 showing a diastolic potential, but not a Purkinje potential. The diastolic potential precedes the QRS complex by 81 ms, and continues to the onset of the ventricular potential. II and V1, standard leads II and V1 of the 12-lead ECG. (Other abbreviations as in Fig 2.)
Fig 4. RF-CA terminated the VT in the same case as in Fig 2. During the radiofrequency delivery, conduction block between the diastolic potential and the Purkinje potential suddenly occurred. After this conduction block, the VT terminated and sinus rhythm was restored. Note that the sequence of the Purkinje potential became inverted from that during the VT, and the morphology of the Purkinje potential changed. Po, power of the radiofrequency current. (Other abbreviations as in Fig 2.)

Fig 5. Intracardiac recording during the radiofrequency application at the earliest Purkinje potential site during VT in case no. 6. Three seconds after the radiofrequency delivery was begun, the interval between the Purkinje potential and the ventricular activation was prolonged from 40 ms to 140 ms. The VT was terminated by a premature ventricular contraction originating from the myocardium near to the tip of ablation catheter (arrow). After this radiofrequency application, the VT was no longer inducible. (Abbreviations as in Fig 4.)
site exhibited only a DP (Fig 3). In 3 of the 4 patients (nos. 1,3,4), the local electrogram recorded from the distal tip of the ablation catheter during the RF energy application showed a conduction block between the DP and PP, coincided with termination of the VT (Fig 4). The electrogram after termination of the VT showed a PP preceding the ventricular potential (VP) with disappearance of the DP. In the remaining case (no.2), the DP was prolonged with the RF application. Finally, the VT was terminated with a conduction block between the DP and VP.

Successful Ablation Guided by a Purkinje Potential

In the 4 patients (nos.5–8) in group 2, we obtained a PP preceding the onset of the QRS complex by more than 30 ms, and performed RF-CA at that site. Two of these (nos. 5,7) showed sudden termination of the VT without any change in the relationship of the Purkinje and ventricular potentials. In the first ventricular activation after restoration of sinus rhythm, the PP was also observed, but the interval between the PP and ventricular activation shortened. Two other patients (nos.6,8) exhibited conduction block between the PP and VP. One case (no.6) exhibited prolongation of the interval between the PP and VP accompanied with prolongation of the VT cycle length (Fig 5). The interval between the VP and PP was constant at 320 ms. The VT was terminated by a premature ventricular contraction originating near the ablation site. After recovery of sinus rhythm, the intracardiac electrogram at the ablation site showed a discrete PP 320 ms after the ventricular activation. The morphology of the PP was the same during the VT and sinus rhythm; however, the amplitude during sinus rhythm was relatively low. This ‘delayed PP’ was also observed in another case (no.8). In both cases, the delayed PP was not observed during sinus rhythm prior to the RF current application. After the RF current application at the successful site, the amplitude of the delayed PP significantly decreased, and no delayed PPs could be clearly seen in either case.

Localization of the Ablation Site and the Pace Mapping Score

The RF-CA sites that terminated the VT in all patients are shown in Fig 6. The ablation sites in group 1 were located at a relatively more basal site and those in group 2 were located apically. As mentioned earlier, the DP was recorded at the point where the mapping catheter was pulled back to a basal site from the exit. A mean distance between the DP recording site and the presumed exit site was 19 (range, 12–25) mm measured by fluoroscopy in the right oblique projection. The pace mapping scores are shown in Table 1. The score in group 1 was relatively lower than that in group 2, but this difference was not statistically significant.

Characteristics of the QRS Morphology in the 12-Lead ECG

The characteristics of the QRS morphology in the 12-lead ECG are shown in Table 1. The transitional zone in the precordial leads occurred between leads V3 and V4 in all the cases in group 1, and in 1 case in group 2. The remaining 3 cases in group 2 exhibited a transitional zone between leads V2 and V3. There was no significant difference in the axis of the QRS complex and the transitional zone among groups 1 and 2.

Follow-up

The mean follow-up period was 22 months (range, 14–33). All 8 patients remained symptom-free without any antiarrhythmic drugs. Furthermore, 3–6 months after the ablation, all patients received a follow-up electrophysiologic study in which VT could not be induced.

Discussion

The mechanism of ILVT has been characterized as reentry on the basis that it can be induced and terminated by extrastimuli. Okumura et al confirmed this hypothesis by showing the properties of the slow conduction zone in an entrainment study. However, to the best of our knowledge, few reports have described the potential representing the slow conduction zone and the entire circuit of this VT has not yet been elucidated. In addition, whether this VT has a macro- or micro-reentrant circuit is still a controversy. The fact that anterograde His capture occurs without resetting the VT cycle length supports the micro-reentry hypothesis. However, the use of an entrainment study from the apex and outflow tract of the right ventricle revealed different intervals from the stimulus to exit site. In addition, recent studies showing successful RF-CA at a site distant from the exit predicted the mechanism of this VT to be macro-reentry.

Main Findings

Our main findings were that (1) a DP was recorded in 4 of 8 cases with ILVT, (2) RF-CA at the site of the DP could terminate the VT, (3) conduction block between the DP and PP was observed in the termination of the VT in 3 cases and between the DP and VP in 1 case in group 1, (4) when RF-CA was performed at the earliest recording site of the PP, conduction block occurred between the PP and VP with termination of the VT, and a ‘delayed PP’ appeared in 2 of 4 cases in group 2, and (5) the site of the DP was located relatively more basal compared with that of the PP sufficiently preceding the QRS complex.

Findings From the Diastolic Potential

To our knowledge, there have been few reports describing the fragmented potential observed in our cases. Kottkamp et al described the DPs as a continuously recorded potential, fragmented presystolic potential, and mid-diastolic potential. Our present findings resembled the fragmented presystolic potential observed in their study. However, the potentials we recorded exhibited a lower frequency than what
they described. The origin of the potential may differ between these 2 fragmented potentials. The exit site of the reentrant circuit was defined in previous studies as the site at which the pace map 12-lead ECG matched the recording taken during the tachycardia and where the local electrogram registered the earliest high-frequency Purkinje spike ≥25 ms before the onset of the QRS complex.\(^\text{5,6,13}\) In the present cases, the DP was recorded where the PP insufficiently preceded QRS complex, and the site where we obtained a DP had a relatively basal location. Thus we assumed that this site was not the exit of the reentrant circuit. Therefore, the PP recorded with a DP meant that the electrogram from the neighboring Purkinje fiber excited by the wave spread retrogradely from the exit.

When we performed RF-CA guided by a DP, conduction block was observed during the RF application between the DP and PP in 3 cases and between the DP and VP in 1 case. The VT became noninducible after those RF applications. Thus, we believe that the DP was in the circuit and might represent a potential from the critical slow conduction zone. Fragmented potentials recorded only during VT and not during sinus rhythm are thought to be potentials from the slow conduction zone in VT associated with myocardial infarction.\(^\text{15}\) The origin of fragmented electrograms in patients with a structurally normal heart is unresolved, but anisotropic conduction in Purkinje fibers has been shown to give rise to polyphasic, fragmented electrograms.\(^\text{16}\) We believe that this lower frequency, fragmented potential is characteristic of the slow conduction in ILVT, but we could not confirm it by the entrainment study.

**Findings From the Purkinje Potential** We observed different styles of termination of the VT in the cases in group 2. When we performed RF-CA guided by the PP preceding the QRS complex, conduction block between the PP and ventricular activation terminated the VT in 2 cases, and the VT was no longer inducible. The PP has been recognized as indicating the exit site of the reentrant circuit of ILVT in some previous studies.\(^\text{6,13}\) A delayed PP recorded after the termination of the VT indicates a wave running through the slow conduction zone, but one which cannot spread through the myocardium because of the RF delivery. This fact indicates that the RF-CA site was in the reentrant circuit and the reentrant circuit may have a slow conduction zone. However, it is still unknown where the entrance of the reentrant circuit is, as well as the path of the entire reentrant circuit of this VT. Recently Tada et al reported a retrograde PP obtained after RF-CA of ILVT (Purkinje potential 1),\(^\text{17}\) which they described as representing the activation in the distal portion of the specialized Purkinje tissue. Although we did not confirm the characteristics of the delayed PP, because it was not clearly seen when the RF current application was stopped, the delayed PP seen in the present study resembled their ‘Purkinje potential 1’. This finding strongly indicates the existence of a slow conduction zone in ILVT. We could not clearly record the ‘Purkinje potential 2’ shown by Tada et al and we assumed this was because it was hidden by the VP.

**Location of the Successful Ablation Site**

In group 1, a DP was recorded at the site at which we slightly pulled the catheter back from the exit site to the basal septum, and the successful ablation site was relatively basal compared with that in group 2. Therefore, in group 1 the slow conduction zone exhibiting a DP may be located at a basal site from the exit. However, pace mapping scores performed at the site where a DP was recorded were lower than those at the exit site. We might have been stimulating not only the slow conduction zone, but also the neighboring myocardium.

**Clinical Implications**

Although the PP preceding the QRS complex during VT is one of the reliable targets for ablating this VT, some reports have described other target sites for RF-CA.\(^\text{15–20}\) We believe that the DP is one of the feasible target sites for this VT with right bundle branch block and left axis deviation.

**Study Limitations**

We could not detect a DP in the early diastolic phase, and could not clarify the entire reentrant circuit. Meticulous mapping in the left ventricle during VT showed no electrical activity in the early diastolic phase. Part of the slow conduction zone may have been insulated, and therefore we could not elucidate the entrance of the reentrant circuit. Further, we could not clarify the properties of the slow conduction by using concealed entrainment. No pacing amplitude of any strength could exhibit concealed entrainment at the site where we detected a DP. The area in which we could obtain a DP was very small and therefore we might have stimulated not only the slow conduction zone, but also the neighboring myocardium. It may have been a similar reason for the worse pace mapping score in group 1 compared with group 2. We could not find a DP in the cases in group 2 in spite of meticulous mapping, which may indicate that ILVT contains a different reentrant circuit mechanism.

We examined only 8 cases and could not sufficiently estimate the feasibility of RF-CA guided by DP. Further study is required to confirm this.

**Conclusion**

In some cases of idiopathic ventricular tachycardia with right bundle branch block and left axis deviation, meticulous left ventricular (LV) mapping during VT exhibited DPs. Diastolic potentials may indicate the slow conduction zone of this VT and may be just as good a guide for RF-CA as PPs preceding the ventricular activation.

**References**

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