Dynamicity of the J-Wave in Idiopathic Ventricular Fibrillation With a Special Reference to Pause-Dependent Augmentation of the J-Wave

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Objectives
This study evaluated the pause-dependency of the J-wave to characterize this phenomenon in idiopathic ventricular fibrillation (VF).

Background
The J-wave can be found in apparently healthy subjects and in patients at risk for sudden cardiac death, and risk stratification is therefore needed.

Methods
Forty patients with J-wave–associated idiopathic VF were studied for J waves with special reference concerning pause-dependent augmentation. J waves were defined as those ≥0.1 mV above the isoelectric line and were compared with 76 non-VF patients of comparable age and sex.

Results
The J-wave was larger in patients with idiopathic VF than in the controls: 0.360 ± 0.181 mV versus 0.192 ± 0.064 mV (p = 0.0011). J waves were augmented during storms of VF (n = 9 [22.5%]), which was controlled by isoproterenol; they disappeared within weeks in 5 patients. In addition, sudden prolongation of the R-R interval was observed in 27 patients induced by benign arrhythmia, and 15 patients (55.6%) demonstrated pause-dependent augmentation (from 0.391 ± 0.126 mV to 0.549 ± 0.220 mV; p < 0.0001). In the other 12 experimental subjects and in the 76 control subjects, J waves remained unchanged. Pause-dependent augmentation of J waves was detected in 55.6% (sensitivity) but was specific (100%) in the patients with idiopathic VF with high positive (100%) and negative (86.4%) predictive values.

Conclusions
Pause-dependent augmentation of J waves was confirmed in about one-half of the patients with idiopathic VF after sudden R-R prolongation. Such dynamicity of J waves was specific to idiopathic VF and may be used for risk stratification. (J Am Coll Cardiol 2012;59:1948–53) © 2012 by the American College of Cardiology Foundation

Early repolarization (ER) is defined as a slur or notch on the terminal part of the QRS complex with or without elevation of the ST-segment and is frequently observed in apparently healthy subjects (1–3). The prognosis of subjects with ER has been considered to be benign (4,5). However, J waves have been observed in association with idiopathic ventricular fibrillation (VF) (6,7), and recent studies have confirmed that ER is associated with idiopathic VF (8–10).

In population-based studies, Tikkanen et al. (11) and Haruta et al. (12) demonstrated that ER is a statistically significant risk for arrhythmic death, and a J-wave of a large amplitude (11) or a J-wave with a flat (horizontal or descending) ST-segment was shown to be a risk factor for sudden cardiac death (13). This risk was proven in cases of idiopathic VF (14). However, electrocardiogram (ECG) features that are able to distinguish “malignant” from “benign” J waves are still necessary for risk stratification.

Since our first reports of the association of the J-wave with idiopathic VF (6,7,15), we have studied pause-dependent augmentation of the J-wave and have been collecting case data regarding idiopathic VF. In this study,
we analyzed the pause-induced dynamicity of the J-wave in patients with J-wave–associated idiopathic VF and compared this with control subjects to propose another characteristic of J waves in idiopathic VF.

**Methods**

Since 1992, we have collected data on 40 patients with J-wave–associated VF from 9 institutions, mainly from the Niigata University Hospital (Niigata, Japan). All of the patients met the following inclusion criteria for idiopathic VF: 1) documented episode of VF at the time of cardiac arrest; 2) absence of structural heart disease with normal cardiac function; 3) negative serological test result for inflammatory diseases; and 4) absence of coronary artery disease and a negative provocative test result for coronary spasms.

Patients with bundle branch block, intraventricular conduction delay, long or short QT interval (16,17), Brugada syndrome (18), or Wolff-Parkinson-White syndrome (19) were excluded. Pilsicainide was given to exclude Brugada syndrome, and coronary spasms in patients were excluded by a provocation test using acetylcholine or ergonovine maleate.

**ECG analysis.** J waves were defined as: 1) notches or slurs at the terminal portion of the QRS complexes; and 2) amplitude \( \leq 0.1 \text{ mV} \) above the isoelectric line in at least 2 contiguous leads. The location was classified as inferior (II, III, or aVF), left precordial (V4 to V6), right precordial (V1 to V3), or high lateral (I or aVL) sites. The amplitudes of J waves were measured after 5-fold magnification in the leads to reveal maximal amplitude, by 2 cardiologists who were blinded to the clinical findings (19).

To investigate the instantaneous dynamicity of J waves, the amplitude of the J-wave was measured in the beat immediately after a pause and compared with the mean J-wave amplitude measured in the 2 to 3 beats preceding the pause (Fig. 1). A pause represented sudden prolongation of the R-R interval that was induced by benign arrhythmias such as sinus arrest, sinoatrial block, atrioventricular block, or atrial or ventricular premature beats. If possible, the J-wave amplitude was measured in the beat after the pause to identify temporary changes. Concomitant changes in the ST- and T-wave morphology with J-wave augmentation were analyzed.

J waves were observed after admission until discharge, and if VF developed in storms, isoproterenol was given.

As the control, the dynamicity of J waves was analyzed in 76 subjects who had J waves in the 12-lead ECG. They visited our hospitals for cardiac or noncardiac diseases but had no syncope or symptoms suggestive of serious arrhythmias such as ventricular tachycardia or VF. None had a family history of sudden cardiac death. Heart failure (New York Heart Association functional class >II) or organic heart diseases were excluded by ECG and echocardiography as well as clinical history. Other exclusion criteria were the same as in the experimental group. The dynamicity of J waves was analyzed on the standard ECGs or 12-lead Holter ECGs.

**Data analysis.** Patients were divided into 2 groups according to the presence of pauses. In the patients with pauses, the dynamicity of J waves and concomitant changes in the ST-segment were evaluated. The amplitudes of J waves were compared among the pre-, post-, and the beat next to the post-pause (Fig. 1). Temporary changes of the J waves were observed to the time of discharge. When VF recurred, the effects of isoproterenol were evaluated. Finally, the sensitivity, specificity, and predictive values of the pause-dependent J-wave augmentation were calculated.

**Statistical analyses.** Numerical values are presented as mean ± SD, and categorical variables are expressed as absolute numbers or percentages. The differences between groups were analyzed by using Wilcoxon or Mann-Whitney-Wilcoxon tests for continuous variables and the Pearson’s chi-square test for categorical variables. Statistical analyses were performed with SPSS version 12.0 (SPSS

![Figure 1 Measurements of the J-Wave Amplitude and ST-T](image-url)
Inc., Chicago, Illinois). A 2-sided p < 0.05 was considered statistically significant.

The study was approved by the ethics committee of Niigata University School of Medicine.

**Results**

**J-wave in idiopathic VF.** Forty patients displayed J waves: slurs or notches ≥0.1 mV in ≥2 contiguous leads. The mean age of the patients was 38 ± 14 years, and 37 (92.5%) were males. The QT and QTc intervals were all within normal ranges: 384 ± 25 ms and 401 ± 40 ms$^{1/2}$. The mean J-wave amplitude was 0.360 ± 0.181 mV. The J waves were located in the inferior region in 28 (70.0%), left precordial region in 19 (47.5%), right precordial region in 4 (10.0%), and high lateral region in 9 (22.5%) patients. Twenty (50.0%) patients exhibited J waves at ≥1 site (Table 1).

Pause-dependent changes in J waves could be analyzed in 27 (67.5%) of the 40 patients who experienced sudden prolongation of the R-R interval due to arrhythmias, and high lateral region in 9 (22.5%) patients. Twenty (50.0%) patients exhibited J waves at ≥1 site (Table 1).

**Pause-dependence of the J-wave.** Among these 27 patients with pauses by benign arrhythmias, 15 (55.6%) demonstrated significant augmentation of the J waves, as shown in Table 2 and Figures 3 and 4: from 0.391 ± 0.126 mV to 0.549 ± 0.220 mV (p < 0.0001); the R-R interval was prolonged suddenly from 802 ± 204 ms to 1,450 ± 572 ms (p < 0.0001). The changes in J-wave amplitude were 0.185 ± 0.129 mV and ranged from 0.05 to 0.43 mV (0.5 to 4.3 mm).

The amplitude of the J waves in the beat next to the post-pause beat was measureable in 6 of 15 patients and was smaller than those of the baseline J waves as well as the augmented J waves: 0.325 ± 0.092 mV (p = 0.0406 and p = 0.0065, respectively). When J waves were augmented, the ST-segment was depressed from 0.10 ± 0.39 mV at baseline to −0.24 ± 0.53 mV after pauses (p = 0.0015). VF was defibrillated. Amiodarone was noneffective, but isoproterenol given in drip suppressed the ventricular fibrillation (VF) (arrows). Lower panel: J waves became less distinct after administration of isoproterenol (arrows).

**Table 1** Clinical Characteristics of the Patient and Control Groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>J Waves (+) (n = 40)</th>
<th>Control (n = 76)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male patients</td>
<td>37 (92.5)</td>
<td>70 (92.1)</td>
<td>0.9398</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>38 ± 14</td>
<td>38 ± 14</td>
<td>0.8169</td>
</tr>
<tr>
<td>QT (ms)</td>
<td>384 ± 25</td>
<td>390 ± 30</td>
<td>0.0428</td>
</tr>
<tr>
<td>QTc (ms$^{1/2}$)</td>
<td>401 ± 40</td>
<td>404 ± 43</td>
<td>0.5128</td>
</tr>
<tr>
<td>R-R interval (ms)</td>
<td>855 ± 142</td>
<td>941 ± 138</td>
<td>0.0057</td>
</tr>
<tr>
<td>J-wave (mV)</td>
<td>0.360 ± 0.181</td>
<td>0.192 ± 0.064</td>
<td>0.0011</td>
</tr>
<tr>
<td>Location of J waves</td>
<td></td>
<td></td>
<td>0.5435</td>
</tr>
<tr>
<td>Inferior</td>
<td>28 (70.0)</td>
<td>65 (85.5)</td>
<td></td>
</tr>
<tr>
<td>Left precordial</td>
<td>19 (47.5)</td>
<td>25 (33.9)</td>
<td></td>
</tr>
<tr>
<td>Right precordial</td>
<td>4 (10.0)</td>
<td>10 (13.2)</td>
<td></td>
</tr>
<tr>
<td>High lateral</td>
<td>9 (22.5)</td>
<td>12 (15.8)</td>
<td></td>
</tr>
<tr>
<td>&gt;1 site</td>
<td>20 (50.0)</td>
<td>36 (47.4)</td>
<td></td>
</tr>
</tbody>
</table>

*Brugada syndrome was excluded from repeated electrocardiogram and/or drug testing.

Values are n (%) or mean ± SD.

**Table 2** Comparisons of Patients With and Without Pause-Dependent Changes in J-Wave Amplitude

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pause-Dependency (+)</th>
<th>Pause-Dependency (−)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male patients</td>
<td>15 (86.7)</td>
<td>12 (91.7)</td>
<td></td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>37 ± 15</td>
<td>36 ± 16</td>
<td>0.8009</td>
</tr>
<tr>
<td>Pre-R-R interval (ms)</td>
<td>802 ± 204</td>
<td>.809 ± 137</td>
<td>0.9783</td>
</tr>
<tr>
<td>Post-R-R interval (ms)</td>
<td>1,450 ± 572*</td>
<td>1,156 ± 175*</td>
<td>0.1570</td>
</tr>
<tr>
<td>Pre-J waves (mV)</td>
<td>0.391 ± 0.126</td>
<td>0.192 ± 0.079</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Post-J waves (mV)</td>
<td>0.549 ± 0.220*</td>
<td>0.196 ± 0.080†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Location of J waves (%)</td>
<td></td>
<td></td>
<td>0.8497</td>
</tr>
<tr>
<td>Inferior</td>
<td>10 (66.7)</td>
<td>9 (75.0)</td>
<td></td>
</tr>
<tr>
<td>Left precordial</td>
<td>9 (60.0)</td>
<td>7 (58.3)</td>
<td></td>
</tr>
<tr>
<td>Right precordial</td>
<td>1 (6.7)</td>
<td>2 (16.7)</td>
<td></td>
</tr>
<tr>
<td>High lateral</td>
<td>2 (13.3)</td>
<td>1 (8.3)</td>
<td></td>
</tr>
<tr>
<td>&gt;1 site</td>
<td>11 (73.3)</td>
<td>6 (50.0)</td>
<td></td>
</tr>
</tbody>
</table>

Values are n (%) or mean ± SD. *p < 0.0001, pre- versus post-pause; †p = 0.8377, pre- versus post-pause.
occurred in 5 (33.3%) of 15 patients in storms after a short-long sequence. Isoproterenol was effective in controlling VF (Fig. 2).

In the remaining 12 (44.4%) of 27 patients, the J-wave remained unchanged (<0.05 mV), as shown in Figure 3: 0.192 ± 0.079 mV versus 0.196 ± 0.080 mV (p = 0.8377) when the R-R interval was prolonged from 809 ± 137 ms to 1,156 ± 175 ms, as summarized in Table 2 (p < 0.0001).

In 4 (33.3%) patients, VF developed and was controlled by isoproterenol.

The patients with pause-dependent augmentation of the J-wave amplitude were similar in age, sex, and J-wave locations to those without (Table 2). The baseline R-R intervals and their changes were similar between the 2 groups, but the pre- and post-J-wave amplitudes were larger in the patients with pause-dependent augmentation of the J-wave compared with those without (p < 0.0001).

**Control group.** In the 76 control subjects, sex and age were comparable to the 40 patients (Table 1). The locations of J waves were as follows: 65 (85.5%) in the inferior region, 25 (33.9%) in the left precordial region, 10 (13.2%) in the right precordial region, 12 (15.8%) in the high lateral region, and 36 (47.4%) at 1 site. The distribution pattern did not differ between the 2 groups.

The baseline R-R interval and the J-wave amplitude were different from the patient group (Table 1). When the R-R interval was prolonged from 941 ± 138 ms to 1,352 ± 342 ms by arrhythmias (n = 17), there was no augmentation of the J-wave amplitude (Figs. 3 and 4).

**Sensitivity, specificity, and predictive values.** Pause-dependent augmentation of the J waves was observed in 15 of 27 VF patients with a sensitivity of 55.6%, or 37.5% of the original 40 patients with J waves. Pause-dependent augmentation of J waves was observed only in patients with idiopathic VF. Both the specificity and the positive predictive values were 100%: the negative predictive value was 86.4% of the 27 patients, or 75.2% of the original 40
patients. The presence of pause-dependent augmentation of J waves was highly diagnostic for idiopathic VF.

**Discussion**

Fifty-four patients with idiopathic VF were admitted to Niigata University Hospital, and J waves were observed in 24 (44.4%); another 16 similar patients were recruited from 8 other institutions.

Of the 40 patients, we were able to assess the instantaneous dynamics of J waves after pauses in 27 patients (67.5%), and pause-dependent augmentation of the J waves was observed in 15 (55.6%) of 27 patients but not in any of the control patients. Augmentation of J waves was associated with depression of the ST-segment or inversion of the T-wave, and the beats just after the post-pause beat revealed attenuated J waves. The pause-dependent augmentation of J waves was highly specific and had highly predictive value. Effects of isoproterenol were reconfirmed.

The age and sex of the patients with idiopathic VF were similar to those reported previously (8–10). Prevalence of the J-wave was also similar to that reported by earlier researchers varying from 31% to 65%. This prevalence was similar to those reported previously (8–10). Prevalence of the J-wave was highly specific and had highly predictive value. Effects of isoproterenol were reconfirmed.

The presence of early repolarization with a horizontal/descending ST-segment was found to be able to predict arrhythmic death in a large population study (13). The presence of J waves was associated with a history of idiopathic VF with an odds ratio of 4.0, but the combination of J waves and a horizontal/descending ST-segment yielded an odds ratio of 13.8 for patients with idiopathic VF (14). In the present study, the ST-segment or T waves became more negative when J waves were accentuated after a pause (Fig. 2). Regarding the discordant relationship between the J-wave amplitude and ST-segment, delayed epicardial repolarization causing the epicardium to repolarize after endocardium seems to be responsible (30,31).

To date, only a few such cases have been reported (22,25). Although rare, a striking pause-dependent augmentation of J waves in the inferolateral leads has been observed in a patient with Brugada syndrome (29). During the follow-up of 2 years, he developed electrical storms from VF.

Study limitations. This was a small case series, and our conclusions must be confirmed in a larger number of patients. However, this study represents 20 years of experience. A worldwide survey is needed for further elucidation.

The response of the J-wave associated with idiopathic VF as follows: 1) large amplitude (often >0.2 mV) (11); 2) recent appearance (7,8); 3) remarkable fluctuation without any apparent cause (8,10); 4) extensive distribution (8); 5) response to isoproterenol or quinidine (8,10,24–27); 6) a concomitant horizontal/descending ST-segment (13,14); and 7) pause-dependent augmentation (7).
Finally, genetic abnormalities have been noted in some patients with idiopathic VF (37–40), but the present study did not include genetic screening. A systematic survey is of great importance in this respect.

Conclusions

Regarding the dynamicity of the J-wave in idiopathic VF, the pause-dependent augmentation was highly specific with high predictive values. This simple phenomenon may be used for the risk stratification of J waves.

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23. Aizawa Y, Tamura M, Chinushi M, et al. J-wave in patients with idiopathic VF. (37–40), but the present study did not include genetic screening. A systematic survey is of great importance in this respect.

Key Words: idiopathic ventricular fibrillation • J-Wave • pause-dependency.