The J-Wave as a Predictor of Life-Threatening Arrhythmia in ICD Patients

Naruya Ishizue, MD, Shinichi Niwano, MD, Hidehira Fukaya, MD, Hironori Nakamura, MD, Tazuru Igarashi, MD, Tamami Fujish, MD, Jun Oikawa, MD, Jun Kishihara, MD, Masami Murakami, MD, Hiroe Niwano, MD, and Junya Ako, MD

**Summary**

The J-wave has been reported to be associated with life-threatening ventricular arrhythmia. However, the clinical implication of the J-wave is still unclear in patients with an implantable cardioverter defibrillator (ICD).

The study population consisted of 170 ICD patients (age, 56 ± 16 years, 79.4% male) treated at Kitasato University Hospital between 2003 and 2014. Ventricular fibrillation (VF) and ventricular tachycardia (VT) events were documented via ICD interrogation, and the patients were divided into 3 groups: 1) VF event group, 2) VT event group, and 3) No-event group. To predict VT or VF events, univariate and multivariate analysis of clinical data including ECG findings were performed. A J-wave was defined as the presence of notching or slurring of the QRS complex (≥ 0.1 mV) in inferior/lateral leads. Among the 170 patients examined, 23 experienced VF and 38 experienced VT during 54 ± 39 months follow-up. In the multivariate Cox proportional hazards model, the J-wave was identified as an independent predictor for a VF event (HR: 3.886, 95% CI: 1.313-10.568, P = 0.012). In contrast, BNP (HR: 1.002, 95% CI: 1.000-1.003, P = 0.043) and left ventricular diastolic diameter (HR: 1.039, 95% CI: 1.002-1.081, P = 0.049) were independent predictors for a VT event.

The results suggest J-waves in the stable phase in an ECG may be a useful predictor for a VF event in ICD patients.

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**Key words:** J-wave syndrome, Sudden death

The J-wave, an elevation of the terminal part of the QRS complex and ST segment on surface ECG, has historically been considered as a normal variant. However, recent studies have reported a correlation between the J-wave and idiopathic ventricular fibrillation (VF), and the J-wave has been attracting attention as a clinical marker for life-threatening ventricular arrhythmias. The risk of VF in the general population is 3.4 in 100,000 individuals, and a J-wave in a young adult would increase the probability of idiopathic VF from 3.4:100,000 to 11:100,000. Recent studies identified a correlation between the J-wave and arrhythmic events in patients with myocardial infarction. Additionally, the importance of J-wave dynamicity, its circadian change, and the J-wave in a VF event group. To predict VT or VF events, univariate and multivariate analysis of clinical data including ECG findings were performed. A J-wave was defined as the presence of notching or slurring of the QRS complex (≥ 0.1 mV) in inferior/lateral leads. Among the 170 patients examined, 23 experienced VF and 38 experienced VT during 54 ± 39 months follow-up. In the multivariate Cox proportional hazards model, the J-wave was identified as an independent predictor for a VF event (HR: 3.886, 95% CI: 1.313-10.568, P = 0.012). In contrast, BNP (HR: 1.002, 95% CI: 1.000-1.003, P = 0.043) and left ventricular diastolic diameter (HR: 1.039, 95% CI: 1.002-1.081, P = 0.049) were independent predictors for a VT event.

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**Methods**

**Study population:** The study population consisted of 188 consecutive ICD patients at Kitasato University Hospital between 2003 and 2014. Eighteen patients with an observation period < 6 months were excluded from the evaluation. The remaining 170 patients were enrolled and their clinical characteristics including age, gender, serum examination data, and 12-lead ECGs were retrospectively analyzed (Figure 1). All studies were performed under approval from the Clinical Studies and Ethics Committee of Kitasato University Hospital.

**Recording and analysis of 12-lead ECGs:** Twelve-lead ECGs were recorded using a standard ECG recorder (cardio star FCP-7541, Fukuda Co Ltd, Tokyo) with standard positions for the recording leads. Data were digitally stored with a frequency of 500 Hz in the ECG data server of Kitasato University Hospital. All ECG data were retrieved for the analysis and electrocardiographic parameters, ie, heart rate (HR), PQ interval, QRS duration, and QT interval were obtained at a time resolution of 2 msec. The corrected QT (QTc) interval was calculated using Bazett’s formula (QTc = QT/RR^1/2). For the evaluation of QRS duration and QT interval, we measured these parameters during paced beats in patients with continu-
ECG recordings were performed after ICD implantation, and at each ICD interrogation. In patients with spontaneous clinical ventricular tachyarrhythmia (VT/VF) events, the time phases of ECG recordings were divided into two, i.e., acute and stable phases. Because Aizawa, et al have reported the J wave disappeared spontaneously within a few weeks, the acute phase was defined as the subsequent period after a VT/VF event within 1 month in the present study. The stable phase was defined as the time phase other than the acute phase. In patients without a spontaneous VT/VF event, all time phases were considered to be the stable phase. The stable phase ECG recording was always in the daytime (9:00 am - 5:00 pm). In the ECG analysis, a J-wave was defined as a junctional point elevation (≥ 0.1 mV), notching (A), or slurring (B) appearance of the terminal part of the QRS complex in inferior (II, III, aVF) or lateral leads (I, aVL, V6). Day-to-day variation of the J-wave was defined as a temporal increase or decrease in the amplitude of the J-wave (≥ 0.1 mV) at the stable phase during the daytime on 12-lead ECGs (C). See the text for details.
Device programming and interrogation: Device implantation was indicated in each patient for the purpose of the primary or secondary prevention of VT/VF events in accordance with the recommendations by the guidelines of the Japanese Cardiology Society. All defibrillator systems were implanted in the pectoral region, and all leads were successfully implanted via a transvenous approach without using thoracotomy lead systems. Patients were followed-up under the same 2-zone therapeutic approach without using thoracotomy lead systems. In each set of echocardiographic data, left ventricular diastolic and systolic dimensions were evaluated, and the left ventricular ejection fraction was calculated using the modified Simpson’s method.

Device interrogations were repeated every 4 months in the device outpatient clinic. The follow-up period was calculated as the time interval between the date of ICD implantation and that of the last device interrogation in patients without VT/VF events, and as the time interval between the date of ICD implantation and the date of the arrhythmic event in patients with VT/VF events. Each therapeutic episode was analyzed by an expert electrophysiologist in the outpatient clinic, and only appropriate therapies for true VT/VF were considered as VT/VF events in the present study.

Clinical data analysis: Serum laboratory data and transthoracic echocardiography were routinely evaluated one month after device implantation. In each set of echocardiographic data, left ventricular diastolic and systolic dimensions were evaluated, and the left ventricular ejection fraction was calculated using the modified Simpson’s method.

Device interrogations were performed by 2 investigators blinded to other clinical parameters.

Clinical data analysis: Serum laboratory data and transthoracic echocardiography were routinely evaluated one month after device implantation. In each set of echocardiographic data, left ventricular diastolic and systolic dimensions were evaluated, and the left ventricular ejection fraction was calculated using the modified Simpson’s method.

Grouping and statistical analysis: The study population was classified into 3 groups according to the guidelines of the Japanese Cardiology Society. All defibrillator systems were implanted in the pectoral region, and all leads were successfully implanted via a transvenous approach without using thoracotomy lead systems. Patients were followed-up under the same 2-zone therapeutic setting, ie, one VT zone and one VF zone. The tachycardia and fibrillation detection interval (TDI/FDI) employed default settings (TDI of 420-430 ms and FDI of 300 ms). In the VT zone, a nominal algorithm for supraventricular tachycardia discrimination was employed and antitachycardia pacing (ATP) was set at the first 1-3 steps of the sequence of VT therapy.

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Clinical data analysis: Serum laboratory data and transthoracic echocardiography were routinely evaluated one month after device implantation. In each set of echocardiographic data, left ventricular diastolic and systolic dimensions were evaluated, and the left ventricular ejection fraction was calculated using the modified Simpson’s method.

Grouping and statistical analysis: The study population was classified into 3 groups according to the first documented event. A statistical analysis was performed using the JMP 11.2 (SAS Institute, Cary, NC, USA) statistical software package. Continuous variables are presented as the mean ± standard deviation, and were compared using the Student’s t-test or Mann-Whitney U test. Discontinuous variables are presented as numbers and percentages and were compared using the chi-squared test. The primary endpoint was detected as VT/VF events. In patients who did not exhibit VT/VF events, observations were censored at the

Table I. Clinical Characteristics

| Total n = 170 | VF event n = 23 | VT event n = 38 | No-event n = 109 |
|--------------|----------------|----------------|---------------|
| Demographic data |                |                |               |
| Age (years) | 55 ± 15 | 50 ± 12 | 62 ± 14 | 55 ± 16 |
| Sex, males, n (%) | 135 (79) | 18 (78) | 28 (74) | 89 (82) |
| Underlying disease |            |                |               |
| Hypertension | 32 (19) | 5 (22) | 8 (21) | 19 (18) |
| Dyslipidemia | 52 (31) | 5 (22) | 17 (45) | 30 (28) |
| Diabetes mellitus | 41 (24) | 3 (13) | 12 (32) | 26 (24) |
| ECG parameter |            |                |               |
| Heart rate (bpm) | 66 ± 12 | 67 ± 16 | 65 ± 12 | 67 ± 12 |
| QRS duration (msec) | 112 ± 27 | 114 ± 5 | 118 ± 30 | 110 ± 26 |
| QTc (msec) | 436 ± 43 | 427 ± 40 | 447 ± 40 | 435 ± 44 |
| J-wave in the stable phase | 45 (26) | 12 (52) | 9 (24) | 24 (25) |
| J-wave in the acute phase | 19 (12) | 7 (30) | 8 (22) | 23 (21) |
| Day-to-day variation of J-wave | 19 (12) | 5 (22) | 7 (18) | 7 (6) |
| Laboratory data |            |                |               |
| Cr (mg/dL) | 1.2 ± 1.5 | 1.6 ± 1.9 | 1.2 ± 1.1 | 1.1 ± 1.5 |
| Na (mEq/L) | 137 ± 19 | 141 ± 1 | 140 ± 3 | 138 ± 19 |
| K (mEq/L) | 4.4 ± 0.8 | 4.3 ± 0.3 | 4.3 ± 0.4 | 4.4 ± 0.8 |
| BNP (pg/dL) | 136 ± 288 | 296 ± 68 | 173 ± 190 | 87 ± 32 |
| Echocardiogram parameters |            |                |               |
| EF (%) | 54 ± 15 | 55 ± 15 | 48 ± 15 | 56 ± 13 |
| LVDd (mm) | 53 ± 11 | 53 ± 12 | 58 ± 11 | 52 ± 9 |
| LVDs (mm) | 38 ± 13 | 36 ± 14 | 43 ± 14 | 36 ± 12 |
| Medication |            |                |               |
| Use of ACE/ARB | 89 (52) | 9 (39) | 22 (58) | 58 (53) |
| Use of β-blockers | 82 (49) | 13 (59) | 21 (55) | 48 (44) |
| Use of aldactone | 26 (15) | 1 (4) | 10 (26) | 15 (14) |

EF indicates ejection fraction; LVDd, left ventricular diastolic diameter; and LVDs, left ventricular systolic diameter.
time of the last follow-up. Kaplan-Meier curves were drawn to evaluate the time-course of event-free survival rates, and differences between with and without J-waves were evaluated by the log-rank test in the VF event group. To predict VT/VF events, univariate analysis of clinical data were performed. In multivariate analysis, Cox proportional hazards models were used to identify prognostic factors predicting VT/VF events. Variables were selected by the stepwise method from parameters with \( P \) values < 0.05 in the univariate analysis. A \( P \) value < 0.05 was considered to be significant.

## Results

### Clinical Characteristics:

The mean follow-up period was 54 ± 39 months. Among the 170 patients examined, 61 exhibited VT/VF events (38 and 23 exhibited VT and VF, respectively), while the remaining 109 did not (Figure 1). The clinical characteristics of the 170 patients are summarized in Table I. The mean age was 55 ± 15 years old and 135 (79%) were male. The study population contained some patients with ventricular pacing (5%) and bundle branch block (12%). In such patients, the evaluation of J-waves was practically impossible, so that such patients were judged as patients without a J-wave. The organic heart diseases or conditions for ICD implantation are summarized in Table II.

### Clinical VF Event and Its Predicting Factors:

Table III shows the results of the univariate analysis for predicting the clinical VF event with various clinical factors. During the follow-up period of 54 ± 39 months, the VF event was observed in 23 patients. In this analysis, a J-wave in the stable phase, day-to-day variation of the J-wave, and BNP were identified as predictors for a VF event. In the multivariate analysis, Cox proportional hazards models were used to identify predictors for a VF event. In this analysis, a J-wave in the stable phase, day-to-day variation of the J-wave, and BNP were identified as predictors for a VF event (Table IV). Figure 3 shows the Kaplan-Meier curves of freedom from the VF event. The risk of a VF event was markedly higher in patients with a J-wave in the stable phase than in patients without a J-wave (\( P = 0.0015 \)).

### Clinical VT Event and Its Predicting Factors:

Table V shows the results of the univariate analysis for predicting a clinical VT event with various clinical factors. During the follow-up period of 54 ± 39 months, a VT event was observed in 38 patients. In this univariate analysis, day-to-day variation of the J-wave, BNP, LVEF, LVDd, LVDs, age, and morbidity of hypertension were identified as predictors for a VT event, additionally, an organic heart disease such as Brugada syndrome and IVF were identified as negative predictors for a VT event. In the multivariate analysis, serum BNP levels (HR: 1.002, 95% CI: 1.000-1.001, \( P = 0.043 \)) and LVDd (HR: 1.039, 95% CI: 1.002-1.071, \( P = 0.049 \)) were identified as independent predictors for a VT event (Table VI).

## Discussion

Our study found that the incidence of J-wave recordings was higher in ICD patients than in the general population. A J-wave in the stable phase on ECG was identified as an independent predictor for a VF event, but not a VT event. BNP and LVDd were identified as independent predictors for a VT event.

### Clinical Importance of J-waves:

J-waves have been classified as a normal variant and are considered to be a benign ECG finding. However, several studies have emphasized the importance of a J-wave as a risk marker in association with life-threatening arrhythmias, in patients with idiopathic VF or
In contrast, a J-wave may be detected in 3.3-12.9% of health examination ECGs, even in those of normal subjects, 2-5,16 therefore, the specificity of a documented J-wave needs to be addressed, and thus, remains controversial. The mechanism underlying the appearance of a J-wave is unclear, however, its relationship to a transmural electrical voltage gradient or local ventricular conduction delay has been emphasized.7 Several experimental studies reported that delayed depolarization or early repolarization may reproduce J-wave-like ECG changes under specific conditions.7 Furthermore, the amplitude of a J-wave may be modulated by various factors including heart rate, autonomic nervous tone, and various types of cardio-active drugs.8,10 Transmural electrical current, which is associated with the J-wave, causes dispersion of repolarization and phase 2 reentry, leading to VF.7 As suggested in previous studies, the J-wave may reflect the presence of non-specific structural candidates for arrhythmogenic substrates.2,5 In the present study, patients who were selected as candidates for ICD implantation exhibited a higher incidence of J-wave recordings in the stable phase than that of normal subjects in previous reports,2,5,7 and this may indicate that they have structurally or electrophysiologically abnormal ventricles.

Predictors for VT/VF events in ICD patients: Choi, et al reported that the incidence of J-wave recordings was higher in patients with VT/VF episodes, especially during the peri-event phase within 1 week, than in control subjects.16 Naruse, et al also found that a J-wave was more frequently observed in ischemic heart disease patients with VT/VF events.7,15 Although the specificity of a J-wave as a risk marker in the general population is limited, it may be considered to be a risk marker in patients with some underlying heart diseases related to ventricular arrhythmias. Hayashi, et al recently showed that the incidence of J-waves in the stable phase was higher in ICD patients with VT/VF events than in those without.16 The results of the present study also revealed that the J-wave in the stable phase was an independent predictor of a VF event in ICD patients, which was consistent with previous findings.16 However, the J-wave was not considered to be a predictor for a VT event, whereas other parameters, such as serum BNP levels or LV dimensions, were independent predicting factors for a VT event in the same study population. Difficulties are al-

### Table IV. Multivariate Analysis for Predictors of a VF Event

| Predictor                      | HR    | P      | 95% CI          |
|-------------------------------|-------|--------|-----------------|
| J-wave in the stable phase    | 3.771 | 0.018  | 1.313-10.568    |
| Day-to-day variation of J-wave| 0.658 | 0.574  | 0.118-2.691     |
| BNP                           | 1.001 | 0.088  | 0.999-1.001     |

### Table V. Univariate Analysis of a VT Event

| Predictor                      | HR    | P      | 95% CI          |
|-------------------------------|-------|--------|-----------------|
| Use of β-blockers             | 1.208 | 0.615  | 0.555-2.418     |
| Sex, males                    | 1.208 | 0.615  | 0.555-2.418     |
| Underlying Diseases           |       |        |                 |
| Hypertension                  | 2.001 | 0.038  | 1.039-3.839     |
| Dyslipidemia                  | 1.613 | 0.188  | 0.781-3.149     |
| Diabetes mellitus             | 1.533 | 0.307  | 0.652-3.216     |
| Organic Heart Diseases        |       |        |                 |
| IHD                           | 1.954 | 0.055  | 0.268-1.016     |
| DCM                           | 1.966 | 0.163  | 0.736-4.429     |
| HCM                           | 2.915 | 0.126  | 0.695-8.273     |
| IVF                           | 0.126 | 0.035  | 0.071-0.583     |
| BrS                           | 0.117 | 0.028  | 0.060-0.555     |
| LQT                           | 1.948 | 0.114  | 0.559-1.606     |
| VSA                           | 0.793 | 0.693  | 0.190-2.218     |
| ECG parameters                |       |        |                 |
| Heart rate                    | 0.983 | 0.259  | 0.950-1.012     |
| QRS duration                  | 1.008 | 0.116  | 0.997-1.019     |
| QTc                           | 1.006 | 0.069  | 0.999-1.012     |
| J-wave in the stable phase    | 1.395 | 0.437  | 0.407-2.754     |
| J-wave in the acute phase     | 1.019 | 0.966  | 0.407-2.754     |
| Day-to-day variation of J-wave| 3.286 | 0.013  | 1.314-2.765     |
| Laboratory data               |       |        |                 |
| Cr                             | 0.979 | 0.331  | 1.009-1.023     |
| Na                             | 1.023 | 0.151  | 0.995-1.159     |
| K                              | 0.599 | 0.075  | 1.039-1.670     |
| BNP                            | 1.002 | 0.016  | 1.000-1.003     |
| Echocardiogram parameters     |       |        |                 |
| EF (%)                        | 0.972 | 0.016  | 0.949-0.994     |
| LVDd (mm)                     | 1.043 | 0.019  | 1.007-1.081     |
| LVDs (mm)                     | 1.032 | 0.029  | 1.003-1.061     |
| Medication                    |       |        |                 |
| Use of ACE/ARB                | 1.440 | 0.268  | 0.756-2.805     |
| Use of β-blockers             | 1.890 | 0.052  | 0.996-3.656     |
| Use of aldactone              | 1.781 | 0.138  | 0.820-3.565     |

![](https://example.com/image.png)

Figure 3. VF event-free rate in patients with and without J-wave in the stable phase. This figure shows Kaplan-Meier estimates of the probability of freedom from a VF event. The VF event rate was significantly higher in patients with a J-wave in the stable phase than in those without. See the text for details.

### Table VI. Multivariate Analysis for Predictors of a VT Event

| Predictor                      | HR    | P      | 95% CI          |
|-------------------------------|-------|--------|-----------------|
| Day-to-day variation of J-wave| 2.930 | 0.063  | 0.933-7.838     |
| BNP                           | 1.002 | 0.043  | 1.000-1.003     |
| LVDd                          | 1.039 | 0.049  | 1.000-1.081     |

*significance.
ways associated with distinguishing precise differences in the arrhythmogenic substrates of VT and VF; however, the stabilities of the substrates may be the key. By considering the relationship between VF and non-specific random micro reentries including transmural phase 2 reentry, the relationship between VF and the J-wave appears to be rational.\textsuperscript{17} On the other hand, stable arrhythmogenic substrates may be related to fixed anatomical abnormalities constructed under various heart diseases, such as ischemic heart disease, cardiomyopathies, and/or heart failure. From this point of view, it also appears reasonable that a VT event, which is presumably related to stable arrhythmogenic substrates, exhibited relationships with several clinical parameters representing the cardiac condition of heart failure. The results of the present study suggest that the high risks of VT events and VF events are identified by use of different clinical parameters in ICD patients.

**Importance of day-to-day variation of the J-wave:** Although day-to-day variation of the J-wave was not identified as an independent predictor for a VT/VF event in our study population, a significant difference was observed in the univariate analysis. This result indicates the potential role of day-to-day variation of the J-wave as a predictor for a VT/VF event in some populations. In the present study, we did not elucidate the reason for the relationship between day-to-day variation of the J-wave and a VT/VF event. Nam, \textit{et al} showed the temporal appearance or increase in the amplitude of the J-wave, especially in the peri-event phase.\textsuperscript{23} Previous studies investigated circadian variations of the J-wave in relation to VT/VF events.\textsuperscript{10,17,19,26} Day-to-day variation in the J-wave, like the autonomic nervous tone, may have a role as a modulator for arrhythmia. Since all of our ECGs were recorded in the outpatient clinic during the daytime, this methodology itself may have underestimated circadian variations of the J-wave. Due to this limitation in the methodology, the role of the J-wave needs to be evaluated in future studies with different study designs.

**Limitations:** The present study has several limitations. First, the number of patients was small. It is important to classify patient background when evaluating the role of the J-wave; however, this was not applied because of the small size of the study population. Furthermore, since this was a single center clinical study, the indication for ICD implantation poses a risk for selection bias. We could not evaluate the J-wave itself in cases that the J-wave incidence might be underestimated in this study. The relationship between wide QRS including continuous ventricular pacing. It is technically impossible to evaluate the J-wave in such cases, so that the J-wave incidence might be underestimated in this study. The relationship between wide QRS including continuous ventricular pacing and VT/VF event was unclear. In addition, because ECG recordings in the stable phase were only performed during the daytime in the outpatient clinic, day-to-day variation of the J-wave during the night time was not evaluated. These points need to be evaluated in future studies in a larger study population using a different study design.

**Conclusions:** The J-wave in the stable phase in an ECG may be a useful predictor for a VF event in ICD patients. Parameters related to left ventricular dysfunction may function as predictors for a VT event. J-wave dynamicity may also work as a predictor of a VT/VF event, which needs to be evaluated in a larger study population.

**Disclosure**

This study received no financial support from commercial sources, and the authors state that there were no conflicts of interest. No specific unapproved use of any compound or product occurred.

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