

Low room temperature can trigger ventricular fibrillation in J wave syndromes



Masaru Yamaki, MD,* Nobuyuki Sato, MD, PhD,[†] Rina Imanishi, MD,*
Hirotaka Sakai, MD, PhD,* Yuichiro Kawamura, MD, PhD,[†] Naoyuki Hasebe, MD, PhD[†]

From the *Department of Cardiology, Nayoro City General Hospital, Hokkaido, Japan, and [†]Department of Cardiology, Asahikawa Medical University, Asahikawa, Japan.

Introduction

Recently, much attention has been focused on early repolarization and what has been called the “J wave syndrome,”^{1,2} based on the association between the early repolarization patterns observed in electrocardiograms (ECGs) and the risk of idiopathic ventricular fibrillation (VF), as reported by several researchers.² The triggering mechanisms underlying J wave syndromes have not been fully elucidated. As for the causative genes for J wave syndromes, various genetic mutations related to sodium, calcium, and potassium channels have been reported to date.^{1,2} Also, triggering factors for VF, such as certain autonomic nervous system activity, hypokalemia, ischemia, febrile illnesses, use of certain drugs, and hypothermia, have been reported.¹

Osborn J waves were initially described in experimental hypothermia.³ Although J waves are frequently observed in hypothermic therapy, few reports have discussed the lethal ventricular arrhythmias associated with J waves. Current guidelines recommend mild therapeutic hypothermia to prevent neurologic damage following cardiac arrest.⁴ However, several recent case reports have described J-wave augmentation and subsequent VF episodes induced by hypothermic therapy or hypothermia in early repolarization syndrome.^{5–7}

To date, the mechanisms underlying hypothermia-induced J waves and arrhythmogenesis remain unclear. By using a canine arterially perfused right ventricular wedge preparation, which mimics Brugada syndrome, Fish and Antzelevitch⁸ demonstrated that hypothermia results in an enhanced action potential spike-and-dome morphology and the loss of the epicardial action potential dome. Similarly, using a canine left ventricular wedge preparation mimicking early repolarization syndrome, Gurabi et al⁹ demonstrated that hypothermia causes accentuation of the epicardial action potential notch, leading to loss of the action potential dome at some sites,

creating the substrate for the development of phase 2 reentry. They also demonstrated that quinidine, cilostazol, and milrinone suppress hypothermia-induced ventricular arrhythmias by reversing the repolarization abnormalities.

We encountered a patient with J wave syndrome in whom frequent implantable cardioverter-defibrillator (ICD) shocks were induced by low room temperature; the combination of quinidine and a long-acting β_2 agonist was effective in preventing these shocks. We herein discuss the possible link between low room temperature and VF episodes and the underlying mechanisms in J wave syndrome based on this case.

Case report

A 28-year-old man presented with his first VF episode at the age of 20 years. Cardiopulmonary resuscitation and defibrillation were successfully performed, and he was then transferred to his local hospital. Since the clinical examination revealed no particular abnormalities except for J waves in the ECG, the patient was diagnosed with idiopathic VF with early repolarization. The patient subsequently underwent an ICD implantation procedure. Thereafter, VF storms occasionally occurred, so radiofrequency catheter ablation of the VF-triggering premature ventricular complex was attempted twice. However, in both procedures, the VF-triggering premature ventricular complex could not be induced, and a pace map-guided ablation was performed, first at the right ventricular inferior aspect and then in the left ventricular posterolateral region. VF recurred after both ablation procedures, and adjuvant therapy with bepridil 150 mg/day was started. The patient was free from any VF episodes for 6 months. However, in November 2015, the patient presented with another VF episode, so he was referred to our hospital for adjustment of his medical therapy. His ECG on admission showed J waves in the inferolateral leads (Figure 1).

After admission, we changed his medication from bepridil (150 mg/day) to disopyramide (300 mg/day) along with cilostazol (300 mg/day); however, this therapy was likewise ineffective. An accidental event occurred; because of a problem with the heating system, room temperature decreased to an estimated 15°C, and the patient’s core body temperature decreased from 36.5°C to 35.8°C. This event

KEYWORDS Low room temperature; Hypothermia; J wave syndrome; Ventricular fibrillation; Quinidine
(Heart Rhythm Case Reports 2016;2:347–350)

Address reprints and correspondence: Dr Nobuyuki Sato, Department of Cardiology, Asahikawa Medical University, Midorigaoka Higashi 2-1-1, Asahikawa 078-8510, Japan. E-mail address: nsato@asahikawa-med.ac.jp.

KEY TEACHING POINTS

- In this case report, we demonstrated that not only core body hypothermia but also low room temperature could induce ventricular fibrillation in J wave syndrome.
- Quinidine and a β_2 agonist were effective in preventing low room temperature–induced ventricular fibrillation episodes in our J wave syndrome case.
- Patients with early repolarization syndrome and hypothermia or those under low-room-temperature conditions should be carefully monitored.

exacerbated the VF episodes; the patient had 6 VF episodes within 48 hours. During these VF episodes, the ECG showed J-wave augmentation in leads II, III, and aVF (Figure 2). Later, with maintenance of room temperature above 26°C and after starting the long-acting β_2 agonist tulobuterol (4 mg/day) and quinidine (600 mg/day), no more VF episodes occurred. The ECG after the disappearance of the VF episodes also showed a regression of the J waves in the inferolateral leads. The time course of the ECG change is shown in Figure 3. Note that the J wave occurrence was markedly reduced with quinidine therapy. The patient has since been free from VF episodes under medication with quinidine and the β_2 agonist.

Discussion

Here, we present a report of a J wave syndrome patient with VF episodes possibly induced by low room temperature. The combination of quinidine and a β_2 agonist was effective in

preventing the frequent excessive ICD shocks. To the best of our knowledge, this is the first report describing an exacerbation of ventricular arrhythmias as a result of a low room temperature, not core body hypothermia, in J wave syndrome. Bastiaenen et al⁵ presented a report of a patient with idiopathic VF in whom therapeutic hypothermia (body temperature, 32°C) increased J-point elevation and exacerbated ventricular arrhythmias. The patient's ECG showed J-wave elevation in the inferolateral leads at a body temperature of 36°C. The authors suggested that hyperthermia seems proarrhythmic in Brugada syndrome, whereas hypothermia could be proarrhythmic in patients with idiopathic VF and early repolarization syndromes, despite the fact that hypothermia-induced Brugada-type ECGs have also been reported.¹⁰

Indeed, it has been shown that the seasonality of Brugada syndrome and early repolarization syndrome might differ; the former is prevalent in hot seasons, whereas the latter is prevalent in cold seasons.¹¹

Similarly, Federman et al⁶ reported a case of cardiac arrest in the context of spontaneous thermal dysfunction after an intracranial hemorrhage. The patient, whose ECG showed early repolarization in the inferolateral leads, presented with multiple episodes of VF both on admission to hospital (32°C) and during a hypothermic protocol for neurologic protection (32°C). The authors concluded that patients with early repolarization syndrome undergoing hypothermia should be carefully monitored.

An Osborn wave (J wave) is a deflection at the R-ST junction of the ECG, and is considered to be the result of a transient outward current in the ventricular epicardium, but not the endocardium, creating a transmural voltage gradient during early repolarization.³ It is usually characteristic of hypothermia but also has nonhypothermic causes. Although hypothermic therapy is usually performed for patients with

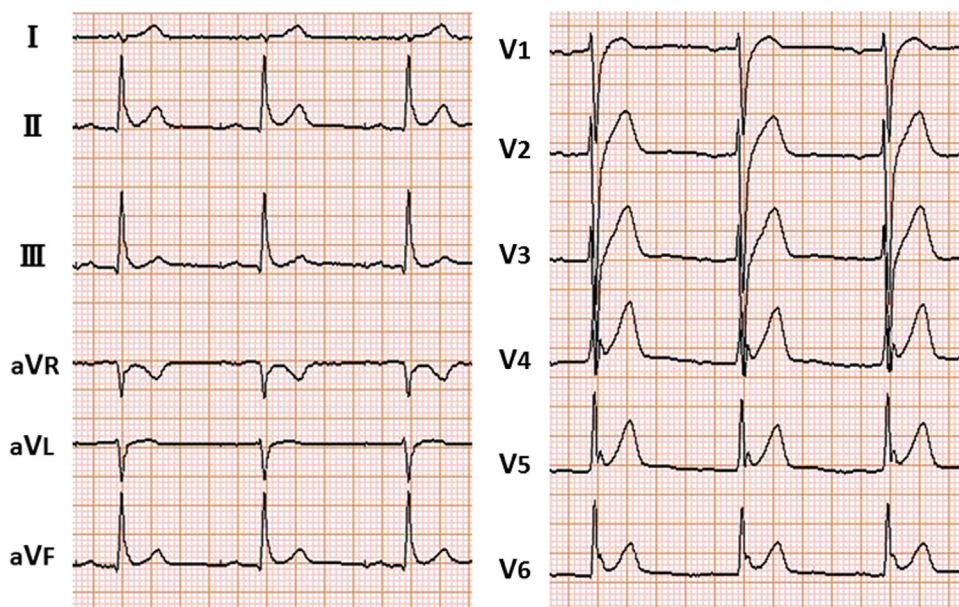


Figure 1 Electrocardiogram on admission. Note the J-wave augmentation in leads II, III, and aVF, and V4–V6.



Figure 2 Electrocardiogram tracing during a ventricular fibrillation storm. The ventricular fibrillation was initiated by a short coupled premature ventricular complex, and prominent J-wave augmentation is also noted.

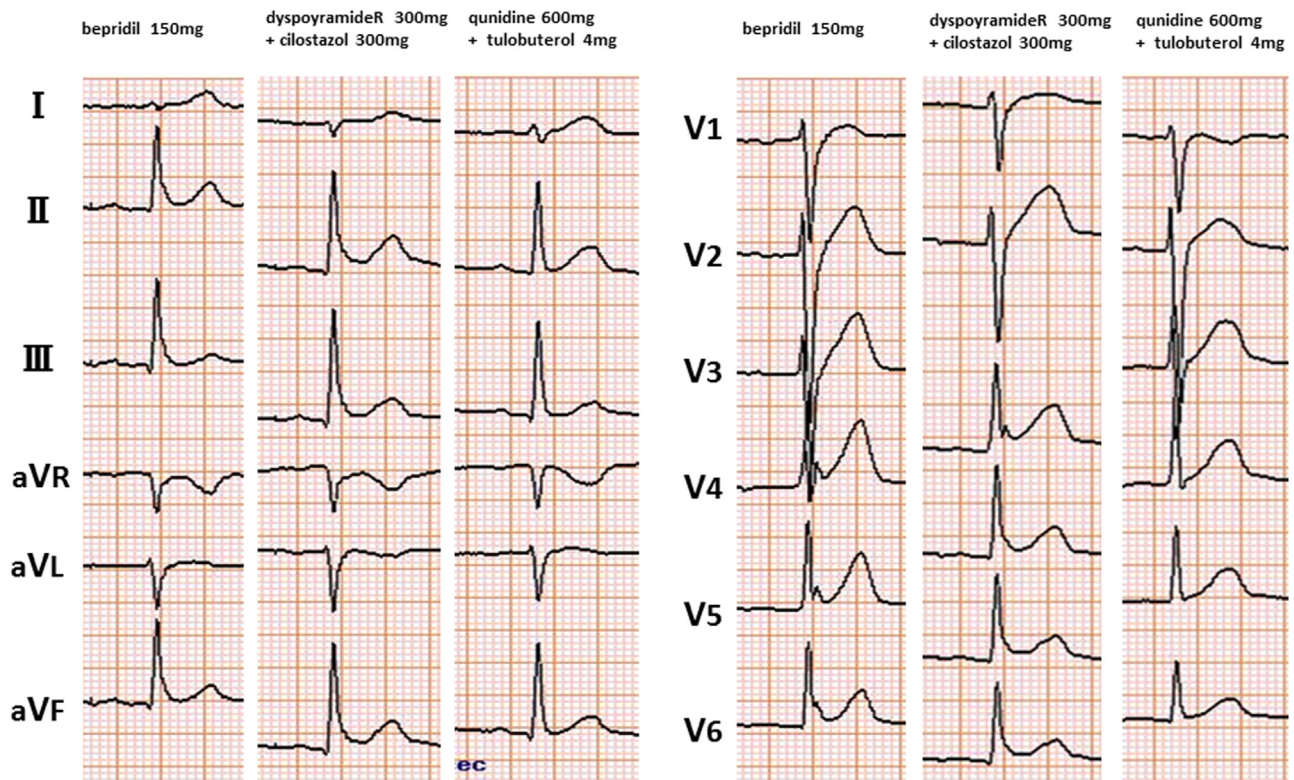


Figure 3 Electrocardiogram tracing during the administration of different drugs. Note the regression of the J waves with the administration of quinidine and the β_2 agonist.

cardiac arrest, including early repolarization syndrome and Brugada syndrome, to prevent neurologic damage, few reports have described a direct hypothermia-induced exacerbation of ventricular arrhythmias, even though J-wave augmentation is frequently seen.⁵

In their study using canine left ventricular wedge preparations, Gurabi et al⁹ reported that hypothermia leads to ventricular tachycardia or VF in the setting of early repolarization by exaggerating repolarization abnormalities. They also showed that quinidine, by virtue of its I_{to} inhibition, and cilostazol, by virtue of its effect of augmenting the I_{Ca} channels, are effective in reversing the hypothermia-induced repolarization abnormalities.

On the other hand, there is an interesting report regarding the possible association of the different mechanisms of J waves in hypothermia. Higuchi et al¹² reported the prevalence of J waves and the relationship between the body temperature and J-wave amplitude in 61 patients with accidental hypothermia. They also examined the augmentation of J waves following variable RR intervals in such patients with atrial fibrillation, and found that J waves are augmented after a relatively short RR interval. Their findings suggest that there is a conduction delay induced by suppression of the sodium channels or I_{to} suppression during very low temperatures, as demonstrated by the experimental work by Li et al.¹³ A similar J-wave augmentation with short RR intervals has also been reported in the case of a severe accidental hypothermia (27.5°C)-induced electrical storm successfully treated with isoproterenol.⁷

In the present case, although the patient did not have any prominent hypothermia, low room temperature exacerbated the VF episodes, suggesting that low room temperature itself can be a trigger in J wave syndrome. Furthermore, a β_2 agonist and quinidine, with appropriate room temperature management, were effective in preventing frequent VF episodes, suggesting that suitable medical control using I_{to} blockers and enhancing the I_{Ca} channel current, as well as management of room temperature, are critically important in patients with J wave syndrome, which is in agreement with the findings of experimental studies by Gurabi et al.⁹

The precise mechanism by which low room temperature induced VF episodes in the present case is unclear. The low room temperature may have had an indirect effect by modulating autonomic tone, because lower temperature and cold exposure are associated with an increased risk of ventricular arrhythmias, probably as a consequence of parasympathetic and sympathetic stimulation.^{14,15}

It is well known that J waves are augmented by hypothermia and usually by bradycardia. However, as described above, Higuchi et al¹² and Takahiro et al⁷ have demonstrated J-wave augmentation during short RR intervals in some hypothermic states, suggesting a difference in the Q10 for the activation of the I_{to} , I_{Ca} , and I_{Na} channel currents, and that a balance might be responsible for, and also critical for, the rate dependency of the J waves.

In the recent report by Takahiro et al,⁷ isoproterenol was effective for the treatment of accidental hypothermia-

induced electrical storms. We also demonstrated the effectiveness of quinidine combined with a β_2 agonist in preventing low temperature-induced VF in J wave syndrome. These observations suggest that an I_{to} blockade and enhanced I_{Ca} channel current resulting in an increased heart rate are critical for the management of electrical storms in hypothermia-induced J wave syndrome. Further studies are needed to elucidate the exact mechanisms underlying hypothermic exacerbations of ventricular arrhythmias in J wave syndrome.

Conclusions

A low room temperature can trigger J wave syndromes; I_{to} blockers and management of room temperature are critically important to prevent such exacerbations of ventricular arrhythmias.

Acknowledgments

We express special thanks to Dr Hisashi Yokoshiki for providing detailed information on the patient's previous therapy.

References

1. Antzelevitch C, Yan GX. J-wave syndromes: Brugada and early repolarization syndromes. *Heart Rhythm* 2015;12:1852–1866.
2. Haïssaguerre M, Derval N, Sacher F, et al. Sudden cardiac arrest associated with early repolarization. *N Engl J Med* 2008;19:2016–2023.
3. Osborn JJ. Experimental hypothermia: respiratory and blood pH changes in relation to cardiac function. *Am J Physiol* 1953;175:389–398.
4. Castrén M, Silfvast T, Rubertsson S, et al; Task Force on Scandinavian Therapeutic Hypothermia Guidelines, Clinical Practice Committee Scandinavian Society of Anaesthesiology and Intensive Care Medicine. Scandinavian clinical practice guidelines for therapeutic hypothermia and post-resuscitation care after cardiac arrest. *Acta Anaesthesiol Scand* 2009;53:280–288.
5. Bastiaenen R, Hedley PL, Christiansen M, Behr ER. Therapeutic hypothermia and ventricular fibrillation storm in early repolarization syndrome. *Heart Rhythm* 2010;7:832–834.
6. Federman NJ, Mechulan A, Klein GJ, Krahn AD. Ventricular fibrillation induced by spontaneous hypothermia in a patient with early repolarization syndrome. *J Cardiovasc Electrophysiol* 2013;24:586–588.
7. Takahiro T, Kou S, Toshinobu Y, Yuichi H. Accidental hypothermia-induced electrical storm successfully treated with isoproterenol. *Heart Rhythm* 2015;12:644–647.
8. Fish JM, Antzelevitch C. Link between hypothermia and the Brugada syndrome. *J Cardiovasc Electrophysiol* 2004;15:942–944.
9. Gurabi Z, Koncz I, Patocskaï B, Nesterenko VV, Antzelevitch C. Cellular mechanism underlying hypothermia-induced ventricular tachycardia/ventricular fibrillation in the setting of early repolarization and the protective effect of quinidine, cilostazol, and milrinone. *Circ Arrhythm Electrophysiol* 2014;7:134–142.
10. Bonnemeier H, Mäuser W, Schunkert H. Images in cardiovascular medicine. Brugada-like ECG pattern in severe hypothermia. *Circulation* 2008;26(118):977–978.
11. Maeda S, Takahashi Y, Nogami A, et al. Seasonal, weekly, and circadian distribution of ventricular fibrillation in patients with J-wave syndrome from the J-PREVENT registry. *J Arrhythm* 2015;31:268–273.
12. Higuchi S, Takahashi T, Kabeya Y, Hasegawa T, Nakagawa S, Mitamura H. J waves in accidental hypothermia. *Circ J* 2014;78:128–134.
13. Li GR, Feng J, Yue L, Carrier M. Transmural heterogeneity of action potentials and I_{to1} in myocytes isolated from the human right ventricle. *Am J Physiol* 1988;275:H369–377.
14. Nguyen JL, Laden F, Link MS, Schwartz J, Luttmann-Gibson H, Dockery DW. Weather and triggering of ventricular arrhythmias in patients with implantable cardioverter-defibrillators. *J Expo Sci Environ Epidemiol* 2015;25:175–181.
15. Hintsala H, Kenttä TV, Tulppo M, et al. Cardiac repolarization and autonomic regulation during short-term cold exposure in hypertensive men: an experimental study. *PLoS One* 2014;9:e99973.