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## Case Report

# A case of inappropriate implantable cardioverter defibrillator therapy induced by T-wave oversensing due to hyperkalemia



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## ABSTRACT

There have been reports of hyperkalemia-induced T-wave oversensing in patients with implantable cardioverter defibrillators (ICDs). However, a comparison of T-wave amplitudes and morphologies between the surface 12-lead electrocardiogram (ECG) and ICD electrogram has not been reported. We present the case of a 70-year-old man who received inappropriate ICD shocks due to hyperkalemia-induced T-wave oversensing. The T-wave amplitudes on both the ICD electrogram and 12-lead ECG corresponded and normalized after normalization of the potassium level.

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## 1. Case

The patient was a 70-year-old man with a history of coronary artery bypass grafting and mitral annuloplasty due to ischemic heart disease, functional mitral regurgitation, type 2 diabetes mellitus, and chronic kidney disease (CKD). He received an implantable cardioverter defibrillator (ICD) (Medtronic Inc., Gem DR, dual chamber pulse generator, VT zone: 150–188 bpm, VF zone: > 188 bpm) for the primary prevention of sudden cardiac death and was admitted to our center for the incidence of ICD shocks. His admission surface 12-lead electrocardiogram (ECG) revealed an increase of the T-wave amplitude compared to his previously recorded surface 12-lead ECG (Fig. 1A and B). His serum potassium and creatinine levels were 7.4 mEq/L and 1.9 mg/dl, respectively. Interrogation of the ICD revealed 8 ICD shock therapies for 4 ventricular fibrillation (VF) episodes that occurred during sinus rhythm (SR) on the visit day. Ventricular intracardiac electrograms showed that the large amplitude of the T-waves during SR resulted in oversensing of the T-waves as R-waves (Fig. 2A). The patient was treated with calcium gluconate, and spironolactone was discontinued immediately after admission. He experienced no inappropriate ICD therapies during hospitalization. The patient's serum potassium level normalized to 4.4 mEq/L in 5 days. The increased T-wave amplitude recorded by both the surface 12-lead ECG and ICD electrograms resolved simultaneously along with the normalization of the plasma potassium level (Figs. 1C and 2B).

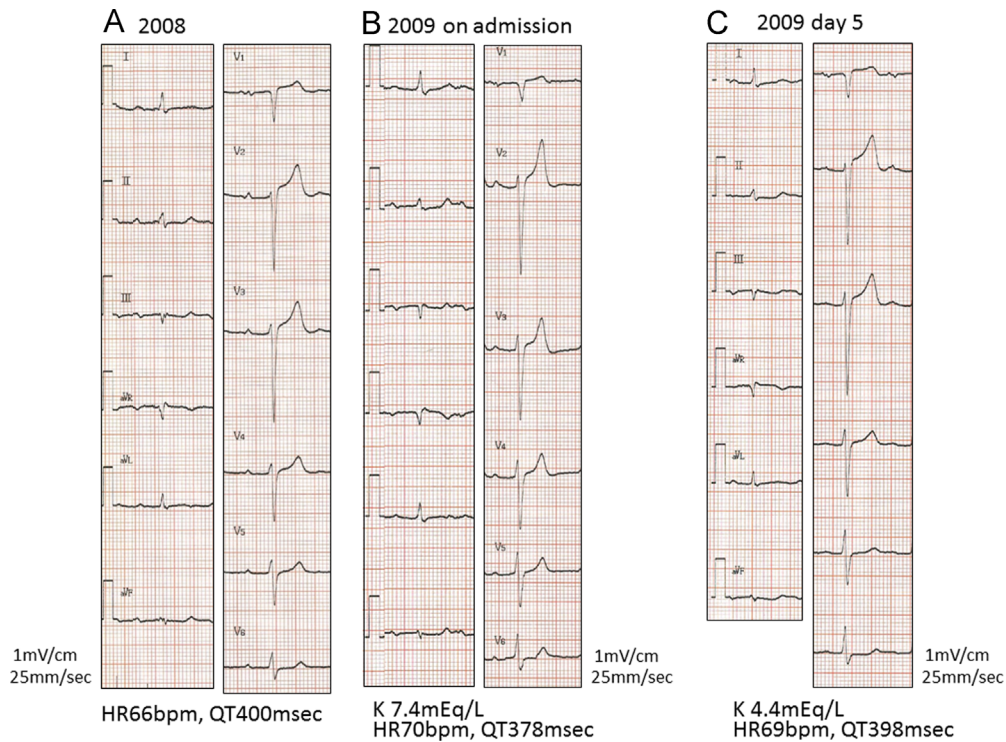
The patient was discharged with prescriptions of furosemide, temocapril, and calcium resonium, and no further inappropriate ICD therapies were observed over a period of 66 months.

## 2. Discussion

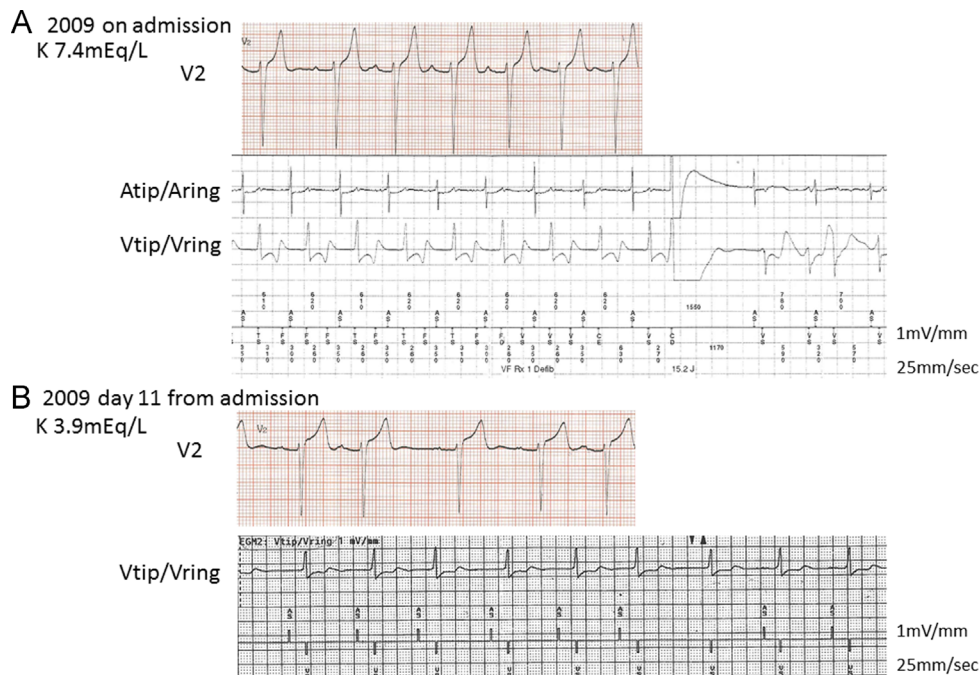
T-wave oversensing is caused by alternations or variations in intracardiac electrograms for reasons such as hyperglycemia, drugs, sympathetic tones, ventricular pacing, and hyperkalemia. Several similar cases of hyperkalemia-induced T-wave oversensing with inappropriate ICD therapies have been reported [1,2]. However, the relationship between 12-lead surface electrograms and internal ICD electrograms during hyperkalemia was not fully elucidated. A previous study reported that T-wave oversensing is more commonly observed after paced beats than spontaneous beats and this was attributed to the polarization voltage [3]. In the present case, T-wave oversensing originated from normal atrio-ventricular conduction, resulting in an inappropriate ICD shock. The amplitudes of the intracardiac R-waves and T-waves were measured as approximately 7–8 mV and 3 mV, respectively. Thus, the oversensing of T-waves with large amplitudes could not be prevented by a simple algorithm in this model. However, device programming may allow for the discrimination of T-wave oversensing. Possible approaches include prolongation of the number of intervals for tachycardia detection, adjustment of the VT and VF zone ranges, elevation of the sensing threshold, change of sensing vector, and use of all-time V pacing to mask T-waves in the blanking period. However, these strategies run

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**Fig. 1.** A 12-lead surface ECG. (A) ECG obtained in 2008 showing a normal T-wave amplitude. (B) ECG obtained in 2009 showing abnormal T-waves with a large amplitude. (C) The T-wave normalized to baseline by the fifth day after admission.



**Fig. 2.** (A) Internal cardioverter defibrillator (ICD) electrograms on admission. The amplitude of the T-waves measured 3 mV and both the R-waves and T-waves were counted in the VF zone, which resulted in the inappropriate ICD shock. (B) ICD electrograms 11 days after admission. The amplitude of the T-waves normalized.

the risk of ignoring true ventricular tachyarrhythmias and exhausting the battery. If these strategies are ineffective, ventricular lead repositioning/replacement may also be considered in order to obtain a greater R-wave amplitude, making oversensing less likely. In recently published reports, patients with ICDs including the latest T-wave oversensing discriminator program have experienced a dramatically lower rate of inappropriate ICD shocks compared to previous studies. Furthermore, the incidence of T-wave oversensing causing inappropriate ICD shocks in this study was much smaller than previously

reported [4]. Therefore, device replacement should be considered if needed. Interestingly, the T-wave amplitude on ICD electrograms corresponded with that on 12-lead surface electrograms, and the amplitude on ICD electrograms was dramatically changed compared to that on 12-lead surface electrograms. Differences between the action potential characteristics of ventricular endocardial and epicardial tissues were reported previously [5,6]. Of note, the  $I_{K1}$  channel is distributed in the endocardial tissue, and is strongly associated with the repolarization process and extracellular potassium concentration.

Furthermore, the differential characteristics of  $I_{K1}$  may contribute to the differences in action potential configuration between endocardial and epicardial myocytes [5,6]. Thus, we speculated that the change in the repolarization process during hyperkalemia was evident on the ICD electrogram as compared to the surface 12-lead ECG. This speculation was consistent with a previous case report [7]. Hyperkalemia should be carefully monitored in ICD recipients, especially those with CKD, to prevent inappropriate ICD shocks due to T-wave oversensing.

#### Conflict of interest

None.

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