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Unexpected inhibition of bradycardia pacing due to oversensing in ICD lead fracture associated with spurious tachyarrhythmia detection and discharges

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ABSTRACT

In a 76-year old man with a dual-chamber ICD implanted five years ago, dizzy spells and significant bradycardia on Holter were not initially recognized as inhibition of bradycardia pacing, due to oversensing. Hospital admission was deemed necessary only after repetitive ICD shocks attributed to right ventricular pace-sense lead fracture. The need to ensure adequate ICD antibradycardia backup pacing in pacing-dependent patients when deleterious sensing errors occur, cannot be overemphasized.

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1. Introduction

Despite substantial improvements in implantable cardioverter defibrillator (ICD) lead technology and performance, there have been continued frustrating problems with lead reliability with a reported incidence of lead failure rate as high as 40% in 8 years [1]. Any ICD component failure manifesting as lead disruption, insulation defect, or connection problem, may cause electrical non-physiological artifacts (noise), which could result in sensing errors [2–7]. Oversensing of noise signals originating from a defective pace-sense RV lead includes either delivery of antitachyarrhythmia therapy and/or inhibition of bradycardia pacing in pacing-dependent patients resulting in severe bradycardia, with the latter malfunction given rather less attention to its clinical consequences.

2. Case report

A 76-year old man with a history of non-ischemic cardiomyopathy, presented to his physician complaining of marked dizziness, often accompanied by audible beeping tones coming from his

dual-chamber ICD device starting about 2 weeks ago. The patient had undergone the device implantation for secondary prevention of sudden cardiac death in 2015, and was doing well clinically ever since (model Maximo II DR D284DRG, Medtronic, Inc.; Minneapolis, MN, USA). Medtronic active fixation leads were placed by left subclavian vein puncture in the right atrium (CapSureFix Novus 5076) and in the right ventricle (RV; dual-coil Sprint Quattro 6947) with IS₁/DF₁ connectors. Because the patient resided in rural area on the mainland, far from the ICD implantation centre, the consulting cardiologist ordered ambulatory 24-h electrocardiogram (ECG) Holter monitoring which revealed atrioventricular-paced base rhythm and numerous episodes of severe bradycardia around 35 bpm unrelated to said particular activities (Fig. 1). It should be noted that remote ICD monitoring is not available in our clinical practice, and is largely underdeveloped in Greece. Finally, he was referred to the hospital after experiencing multiple ICD shocks the next day. At presentation, the ECG showed after cessation of pacing underlying escape rhythm of less than 40 bpm. Reviewing hospital records and patient's ICD identity card, we figured out that the initial ECG at the time of device implantation showed preserved atrioventricular conduction and incomplete right bundle branch block. However, the last three years follow-up notes informed about pacemaker-dependancy, despite programmed algorithms to promote intrinsic conduction. Overall, the patient had unchanged NYHA functional class II symptoms and no

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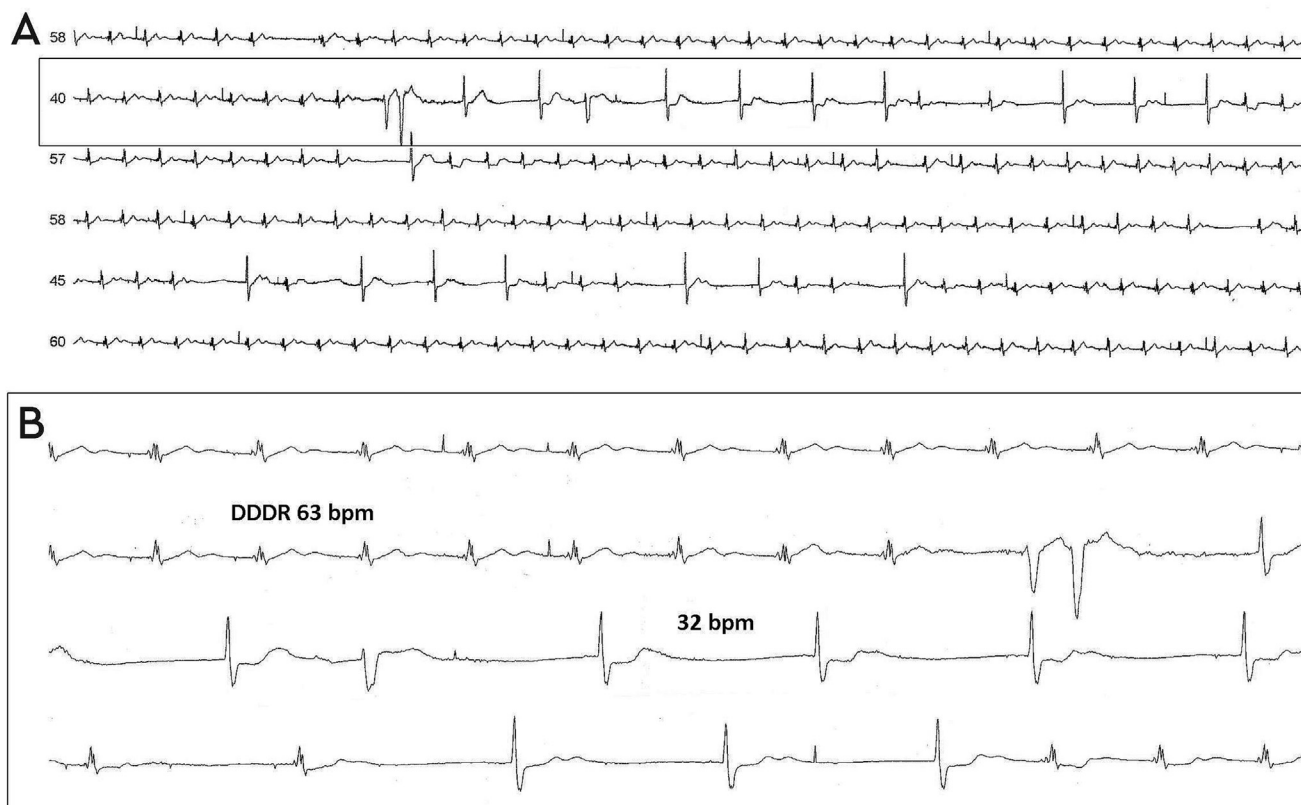


Fig. 1. Holter electrocardiographic recording (A) with a magnified fragment (B) showing transient ventricular escape rhythm at a rate of about 32 bpm during dual-chamber pacing at 63 bpm.

change to his medication regimen that included long-term amiodarone therapy. Standard features of sensing, detection and therapy of ventricular tachycardia (VT) and ventricular fibrillation (VF) related to device function were programmed, with standard alerts for out-of-range impedance values. The ICD identification card contained also information about appropriate function and adequate lead integrity of the system, stable impedance trends and threshold values, and no arrhythmia detection or defibrillation discharges during regular device check-ups.

Interrogation of the ICD revealed an abrupt rise in pace-sense RV lead impedance greater than 3000 Ω two weeks ago, coinciding with patient's complains of dizziness (Fig. 2B). The remainder of the interrogation showed always normal shocking impedances, and satisfactory lead capture thresholds. Other information retrieved from the device memory documented numerous ventricular tachyarrhythmia events with the intracardiac electrograms (EGM) showing intermittent high frequency, non-physiological noise signals of variable amplitude on the pace-sense RV lead, triggering shock delivery or aborted tachyarrhythmia therapy, or inhibition of bradycardia pacing. There were no stored EGMs displaying such sensed events with noise signals treated with antitachycardia pacing (ATP). The need of backup pacing was always real during prolonged false tachyarrhythmia detection time resulting in significant bradycardia despite having the ICD programmed DDD with a heart rate of 60 bpm (Fig. 2A). Obviously, the erroneous ventricular detections on the pace-sense RV_{tip}-RV_{ring} EGM caused inhibition of atrial pacing as well. False signals could be reproduced in real-time leadless ECG, as well as by manipulation of the ICD generator in the pocket, causing failure to capture the myocardium (Fig. 2C). Due to the above findings, the patient was diagnosed as

having pace-sense RV lead fracture. The ICD lead inspected on the chest radiograph did not reveal migration, discontinuities, or inadequate connections to the pulse generator header. A new screw-in RV lead was placed and connected to the old ICD without removing the fractured lead through subclavian puncture [5].

3. Discussion

There are a number of ways by which the ICD device assures optimal sensing. These include utilization of various features of blanking period, refractory period windows and noise reversion algorithms, whether they need to be programmed or controlled by the device. Nevertheless, inappropriate device behavior related to lead failure has been, and still is, an ongoing concern. Even though the final diagnosis of lead failure is obtained by careful interrogation of the device in follow-up visits, the automated device-based assessment of lead's structural integrity and electrical performance by serial measurements of impedance was a pivotal engineering achievement in detecting lead problems earlier and warning the patient sooner. A sudden large increase in lead impedance beyond the post-implant period is able to help discriminate lead fractures from connection problems, while abrupt decreases are indicative of insulation breach. Typical pace-sense RV conductor fracture-related signals have characteristics as illustrated in Fig. 2A, and are not recorded on the shock channel in dedicated bipolar leads [6]. Other notable technological advances allowed manufacturers to incorporate elaborated self-diagnostic functions into newer ICD models that can be used to identify and minimize lead-related oversensing due to noise as such before clinical presentation [e.g. the RV Lead Integrity Alert feature (LIA,

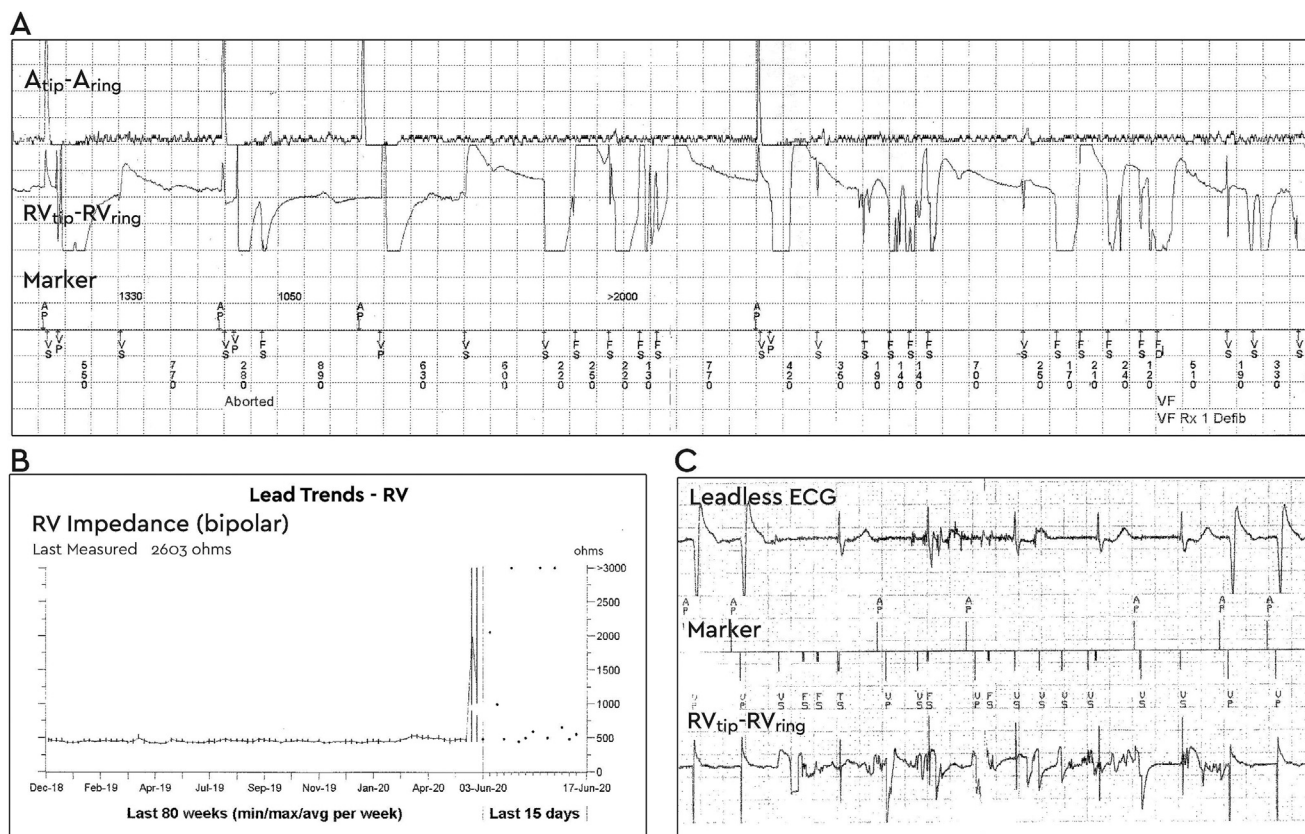


Fig. 2. Stored and real-time recordings of ICD diagnostics and therapy. A: From top to bottom are shown atrial EGM (A_{tip}-A_{ring}), near-field ventricular EGM (RV_{tip}-RV_{ring}), and marker annotations. Noise signals of high-frequency and of changing amplitude, spuriously detected in the RV lead as ventricular tachycardia (VT) and ventricular fibrillation (VF), resulted in prolonged detection times with aborted and triggered antiarrhythmic therapy. Oversensing affected both ventricular and atrial pacing, uncovering the patient’s pacemaker dependency and ventricular escape rhythm. Note the annotated atrial and ventricular events on marker channel that the first, second and fourth AP beat is followed by a VS and then immediately by a VP event, representing ventricular safety pacing (VSP) triggered by non-physiological ventricular impulse within 110 ms of the AP event. Also, the thickening of the baseline on the A_{tip}-A_{ring} EGM should not be mistaken for noise, as it is due to manual signal gain amplification for better viewing. B: RV pacing impedance trend showing a stable pattern of measurements over time with sudden rise occurring at the time of adverse clinical events. C: From top to bottom are shown real-time leadless ECG waveform trace (approximation of surface ECG signal through the Can to SVC EGM), marker channel, and near-field ventricular (RV_{tip}-RV_{ring}) EGM. Provocation of lead noise by manipulation of the pulse generator in the pocket, caused oversensing with failure to capture the myocardium, allowing in that instance the appearance of preserved intrinsic rhythm. AP = atrial pace; FS = fibrillation sense; FD = fibrillation detection; TS = tachycardia sense; VP = ventricular pace; VS = ventricular sense; VS, FS = ventricular intervals in fibrillation rate zone.

Medtronic]). LIA is designed to identify a potential lead issue if at least two of the following three criteria are satisfied, namely abnormal RV lead impedance, rapid non-sustained ventricular tachyarrhythmia episodes <220 ms, and counts of very short ventricular intervals ≤130 ms [5,7]. Remote-monitoring notification in devices with wireless telemetry, initiates an audible patient alert and extends the detection duration of VF to reduce inappropriate shocks. Noise signals are identified as such, by a “mismatch” intracardiac electrogram (EGM) comparison between the far-field signal to the near-field sensing after signal processing (Medtronic’s Lead Noise Discrimination, LND, and Abbott’s Secure-sense Algorithm) [3–6]. Additionally, if identification of noise does occur, the device is typically designed to revert to a safe set of bradycardia pacing (i.e. asynchronous noise reversion mode) to prevent inappropriate pacing inhibition, which, however, involves disabling all antiarrhythmic functions. Yet the main issue still at stake, is complete rejecting sensing errors. Even with any abovementioned software features, lead failure remains a relative common cause of adverse ICD operation, such as failure or inappropriate defibrillation, proarrhythmia, or loss of pacing [4–6]. In particular, in case of suspected inappropriate shocks, emergent measures should be focused on disabling ICD detection by applying a magnet until reprogramming can be performed, whereas long-term management around the decision to add or extract the dysfunctional lead. If

loss of capture occurs, immediate hospitalization is required for interrogation and possible insertion of a temporary pacing system until the underlying issue can be resolved [5,7].

In our patient, the characteristics of abrupt pace-sense RV pacing impedance rise and abrupt change in impedance trend late after implantation, coupled with noise oversensing, clearly indicated conductor fracture. Even if patient’s ICD model included the diagnostic LIA and LND features, these would not have been able to avert symptomatic bradycardia; they might have, at the most, prevented delivery of inappropriate shocks. Since the audible impedance warnings had already been heard by the patient, these alerts should have been sufficient to justify immediate specialized device testing and programming. As the electrical noise generated by lead fracture is intermittent, shocks will generally be aborted, often at the expense of prolonged detection times, whereby pacing-dependent patients require backup pacing. Overall, although oversensing is an expected occurrence, relatively minor attention has been so far devoted to the necessity of antibradycardia pacing. By the same token, patients perceive differently the clinical consequences of sensing errors. Usually, the frightening experiences of a shock far outweigh the perils of temporary illness due to bradycardia. To some degree, the same holds true for the general medical community. In fact, as exemplified by this report, the severity of patient’s initial symptoms was not fully appreciated, as the inability

of the device to provide antibradycardia pacing was inadvertently overlooked. Still, if remote monitoring with testing electrical integrity had been available, the earlier recognition of the problem would have prompted a faster therapeutic response. Since the body of evidence regarding the positive impact of remote monitoring on ICD patient outcomes is growing, its routine use is strongly recommended by professional societies [5,8]. However, in this case, clinic visit and device evaluation was considered necessary only once repetitive ICD discharges occurred. The lesson is instructive and suggests the necessity of the device to incorporate reliable backup antibradycardia surveillance pacing capabilities, particularly in pacing-dependent patients with atrioventricular conduction disturbances. In this context it is worth mentioning that the development of pacemaker dependency in up to 13.4% of patients with intrinsic rhythm at the time of ICD implantation, was found to be associated with decreased survival [9].

ICD oversensing in pacing-dependent patients may result in dangerous bradyarrhythmia. Constraints of ICD proper antibradycardia backup pacing behavior include inherent complexities of combining codependent bradycardia and tachycardia sensing and therapy schemes into the same operation. When sensing errors occur, the capability of reliable antibradycardia therapy in pacing-dependent patients is actually required rather than desired. This is a major challenge for ICD engineers and should be given high priority in the “wish lists” of features for future ICD technology.

CRediT authorship contribution statement

Fani Zagkli: Conceptualization, Investigation, Writing – original draft. **Panagiotis Chronopoulos:** Investigation, Validation, Writing – original draft. **John Chiladakis:** Supervision, Investigation,

Writing – review & editing.

Declaration of competing interest

There are no financial associations that might pose a conflict of interest.

References

- [1] Kleemann T, Backer T, Doenges K, Vater M, Senges J, Schneider S, et al. Annual rate of transvenous defibrillation lead defects in implantable cardioverter-defibrillators over a period of >10 years. *Circulation* 2007;115:2474–80.
- [2] Bera D, Saggi DK, Chandra Murthy GSC, Yalagudri S, Sridevi C, Narasimhan C. Inappropriate defibrillator shock due to oversensing. What is the mechanism? *Indian Pacing Electrophysiol J* 2021;21:54–8.
- [3] Gunderson BD, Patel AS, Bounds CA, Ellenbogen KA. Automatic identification of clinical lead dysfunctions. *Pacing Clin Electrophysiol* 2005;28:63–7.
- [4] Swerdlow CD, Sachanandani H, Gunderson BD, Ousdigian KT, Hjelle M, Ellenbogen KA. Preventing overdiagnosis of implantable cardioverter-defibrillator lead fractures using device diagnostics. *J Am Coll Cardiol* 2011;57:2330–9.
- [5] Kusumoto FM, Schoenfeld MH, Wilkoff BL, Berul CI, Birgersdotter-Green UM, Carrillo R, et al. HRS expert consensus statement on cardiovascular implantable electronic device lead management and extraction. *Heart Rhythm* 2017;14:e503–51.
- [6] Swerdlow CD, Asirvatham SJ, Ellenbogen KA, Friedman PA. Troubleshooting implanted cardioverter defibrillator sensing problems I. *Circ Arrhythm Electrophysiol* 2014;7:1237–61.
- [7] Swerdlow CD, Kalahasty G, Ellenbogen KA. Implantable cardiac defibrillator lead failure and management. *J Am Coll Cardiol* 2016;67:1358–68.
- [8] Slotwiner D, Varma N, Akar JG, Annas G, Beardsall M, Fogel R, et al. HRS expert consensus statement on remote interrogation and monitoring for cardiovascular implantable electronic devices. *Heart Rhythm* 2015;12:e69–100.
- [9] Sood N, Crespo E, Friedman M, Guertin D, Zweibel S, Kluger J, et al. Predictors of pacemaker dependence and pacemaker dependence as a predictor of mortality in patients with implantable cardioverter defibrillator. *Pacing Clin Electrophysiol* 2013;36: 945–945.