Inappropriate defibrillator shock due to oversensing. What is the mechanism?

Debabrata Bera a, Daljeet Kaur Saggub, Goddu Sreeram Chandra Murthy c, Sachin Yalagudrib, Chennapragada Sridevib, Calambur Narasimhanb, *

a Dept of Cardiology, RTIICS, Kolkata, India  
b Dept of Cardiology, AIG Hospitals, Hyderabad, India  
c Dept of Cardiology, CARE Hospital, Vishakhapatnam, India

A 55-year-old lady presented to emergency department with ventricular tachycardia (VT) of left bundle branch block (LBBB) morphology with superior axis (Appendix 1). Echocardiography revealed normal left ventricular (LV) systolic function with right ventricular (RV) systolic dysfunction and RV inflow dilatation. Her coronary angiogram was normal. Final diagnosis of RV cardiomyopathy was made based on cardiac magnetic resonance findings. A single coil DF1 active fixation (6935 Sprint Quattro Secure S, Medtronic Ltd, USA) lead was fixed at the RV lower apical septum. A single chamber ICD (Protecta VR D364VRG, Medtronic Ltd., USA) was implanted for secondary prevention of sudden cardiac death (SCD). She received two ICD shocks on the same day 3 hours after implantation. Device interrogation revealed ICD shock for an episode detected in VF zone. Stored electrograms (EGM) revealed irregular varying amplitude high frequency noise in the FF signal whereas NF signals showed normal electrogram during a device recorded VF (Fig. 1). This noise was reproducible with the left-hand abduction. Generally, sensing of an event in the ICD is based on EGM from NF (true bipolar, RV tip to ring in a dedicated bipolar lead). However, NF did not record any overt noise in our case. Then, what could be the mechanism for the inappropriate shock?

Commentary

These were certainly inappropriate shocks due to noise, as NF (tip to ring) bipolar signals did not reveal any arrhythmia (Fig. 1). The FF artifact was confirmed by: (i) The tachycardia cycle length (TCL) having wide fluctuations with non-physiological rates (Fig. 1, and Appendix 1) (ii). Numerous non-sustained self-terminating VF episodes (even less than 1 sec) in a short span of time (Appendix 1). (iii) Typical ‘make and break’ pattern in the recorded FF channel (Fig. 1). Moreover, the patient was asymptomatic before the shock. All this favored noise rather than true VT/VF [1].

Device interrogation via telemetry revealed normal pacing lead impedance and thresholds. Trends of pacing impedance and
Fig. 1. The channels recorded from top to below were RV tip to ring (near-field EGM), Can to coil (Far-field EGM) and Marker channel. The stored EGMs reveal multiple short episodes of recorded ‘VF’ in marker channel which correlated with far field EGM. However, the near field EGM was clean with normal ventricular sensing happening at regular interval confirming diagnosis noise-related oversensing. The fine noise apparent in near field is due to autogain amplification of that channel. An inappropriate ICD shock was delivered (marked as CD, red asterix) in VF zone due to noise, as evident by classical make-and-break signals.
sensing from RV pace-sense electrode were also normal. However, impedance trend of shocking HV coil was found to be widely varying (Appendix 1).

Default factory setting for sensing in these devices vector is RV tip to ring. It was retrospectively found that, patient’s bipolar R wave amplitude during initial implant was low (<2mV), the sensing polarity was changed to RV tip to RV coil (extended bipolar). The best possible R wave amplitude achieved with extended bipolar sensing was 4.5 mV. However, the device was not programmed to store the EGM of this channel and was left with default setting (tip to ring). Thus, the sensing NF channel was not set to store EGM during any arrhythmia. Nevertheless, when noise took place, the NF got translated into the marker channel and lead to misdiagnosis of VF and subsequent shock. The summary page of ICD programmer did not issue any alert of abnormal parameters despite wide fluctuations in measured impedances (67Ω and 170 Ω) within 3 hours as they were still within the normal reference range (Appendix 1). As the coil was common in both near and far field signals, problem was narrowed down to the shocking port. Electromechanical interference (EMI) was ruled out as it results in noise in all/multiple channels. In our case, NF signal (EGM1) recorded discrete electrical undulation of baseline was possible due to higher amplification of gain.

Fluoroscopy was normal. Both the lead ports were well across the header but we could not comment on appropriate screwing (appendix 2). The indicative finding was noise in tip-coil EGM with left arm movement which disappeared after changing sensing polarity back to default ‘tip-to-ring’ (although the measured R wave was only 1.5 mV). Hence it could be inferred that either there is an issue with shocking HV lead or the set screw was loose. Although this change was able to resolve the oversensing, she had to be finally subjected for pocket re-exploration after discussion with relatives. The rationale for re-exploration was: (i) Very low R wave amplitude in RV tip to ring configuration during sinus rhythm might lead to undersensing during a true VF, (ii) ICD might deliver an appropriate but ineffective shock which can be fatal during a true VF.

On the next day the pocket was re-explored. Before unscrewing the leads, a gentle traction on the shocking port could release it easily. The pace-sense port was however adequately fixed and needed unscrewing to pull it out. Both the ports were checked on operative table through the programmer and were found to have stable sensing, impedance and pacing values. Finally, the lead ports were connected to the pulse generator (Can) and properly screwed while the assistant held them tightly. The polarity for sensing was changed to RV ‘tip to coil’ again (achieving a better R wave amplitude) and the same was set to store EGM for any future arrhythmia.

The patient was discharged next day and is doing well over 2.5 year follow up. To summarise, this was a case of inappropriate shock due to loose set screw of shocking port. Similar cases have been reported previously but diagnosis was generally made with fluoroscopy [2,3]. It is always preferable to hold the port into the device header while the assistant does the screwing. Moreover, in ICDs/CRT-Ds (specially with DF-1 devices) ensuring repeated measurement of normal and stable HV impedance via RF wireless testing is recommended before the pocket is closed. In DF-4 devices the possibility of improper screwing is less and diagnosis is more easily evident if ever encountered.

The learning points from this case are:

1. DF1-ICD leads can have isolated shocking/ pacing port issues without affecting true bipolar sensing.
2. Medtronic dedicated bipolar leads can be programmed to sense and record VT/VF from the tip-to coil (in contrast to default tip-to-ring, true bipolar setting) [1]. When such a vector is chosen, the channel for storing EGMs shall be programmed accordingly. This can prevent NF vs. marker channel disparity and make the interpretation easier, although it cannot prevent oversensing per se.
3. Fluoroscopy is helpful for lead related (e.g. lead fracture) or screw related issues, but normal fluoroscopy does not rule out possibility of set screw issues [4].

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Declaration of competing interest

This is to declare that all of us are authors of the following manuscript titled ‘inappropriate defibrillator shock due to oversensing. What is the mechanism?’ and we have no conflict of interest.

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Appendix 1

Upper panel shows the VT and baseline ECG respectively. Middle panel shows the apparently alright ICD parameters and therapy zones on left. On right side the multiple short even in non-physiological zones recorded.

Lower panel shows highly variable VV intervals suggestive of noise on left. On right side the wide variation in RV shocking impedance was noted over a span of few hours.
Appendix 2

The fluoroscopy still image of the lead and header. The leads were seen across the header screw apparently.
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