

Unsuccessful antitachycardia pacing: What is the mechanism?

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1 | CASE PRESENTATION

A 67-year-old man was implanted in 1996 with a single-chamber implantable cardioverter-defibrillator (ICD) for secondary prevention since he experienced ventricular fibrillation (VF) late after inferior myocardial infarction. Nearing battery depletion, his ICD was replaced in 2015 (Evera XT VR, Medtronic, Dublin, Ireland). He had not experienced any sustained ventricular tachyarrhythmias since his first episode of VF. One night, while brushing his teeth and washing his face, he suddenly experienced the familiar feeling of a faint headache, which reminded him of the moments prior to the onset of VF in 1996. Immediately after, he felt an ICD shock during full consciousness. He presented to our hospital where we performed ICD interrogation. Figure 1 shows the near-field electrogram (EGM) derived from right ventricular (RV)-tip to RV-ring (top electrograms), far-field EGM derived from can to RV-coil (bottom electrograms), and markers with V-V intervals (ms) during onset and termination of a ventricular tachycardia (VT) in the VF zone. The ventricular tachyarrhythmia (onset in top panel) is diagnosed as VF after 30 FS/TF markers detected in the VF zone (in a sliding window of 40 events) and treated by unsuccessful antitachycardia pacing (ATP) during charging of the capacitors (middle panel), followed by a 36-J shock, which successfully converts the rhythm to sinus (bottom panel). What is the mechanism of the failed ATP?

2 | COMMENTARY

For the ICD treatment of ventricular tachyarrhythmias in the VF zone, the 2015 HRS/EHRA/APHR/SOLAECE Expert Consensus Statement on Optimal ICD Programming and Testing recommends to program ATP in the form of a single burst before or during charging of the capacitors.¹ The underlying rationale is that many arrhythmias in the VF zone are in

fact VT, which are often treatable by ATP. A single ATP is advised since programming more than one ATP in the VF zone may delay therapy of true VF, which could lower success rate of subsequent ICD shocks. For ATP to be successful, the timing of ventricular pacing is essential. The induced activation wave front by the RV electrode is required to depolarize the VT re-entry circuit in the *window of opportunity*; after refractoriness of the previous VT wave front and *before* depolarization by the next VT wave front. Therefore, the recommendations suggest the burst to be delivered at 85-88% (according to manufacturer) of the coupling interval of the detected ventricular tachyarrhythmia. The most common causes of the failed ATP are lack of capture or inability of the pacing-induced wave front to interrupt the VT re-entry circuit. In the presented tracing, the ATP is delivered by burst pacing at 280 ms, substantially longer than the detected VV-intervals of the VT, which have an average interval of 240 ms. Since the interval at which burst pacing was performed was too long, the ATP is too slow to be effective. In case of extremely fast VT (>300 bpm), ATP will also be too slow even during proper sensing as ATP burst cycle length is capped at a minimum of 200 ms. The burst coupling interval is calculated as 88% of the average of four VV-intervals prior to detection, which is marked by FD, *fibrillation detected*, on the tracing. When ventricular events are not sensed (undersensed), such as in this case, the average cycle length will be overestimated and exceed the VV-interval of the ventricular tachyarrhythmia, with high failure rate of ATP. When we redo the calculation (see Figure 2) by taking 88% of the average of 260, 250, 510 ms (which comprises two VV-intervals, misclassified as one VV-interval due to undersensing) and 260 ms, a burst interval of 280 ms (rounded from 281.6 ms) is acquired which was indeed delivered in this case. While earlier during the day, the R-wave during sinus rhythm was measured 12.9 mV, the R-waves during the VT showed variable amplitudes including R-waves of very low amplitude, which were undersensed prior to detection, but also during charging

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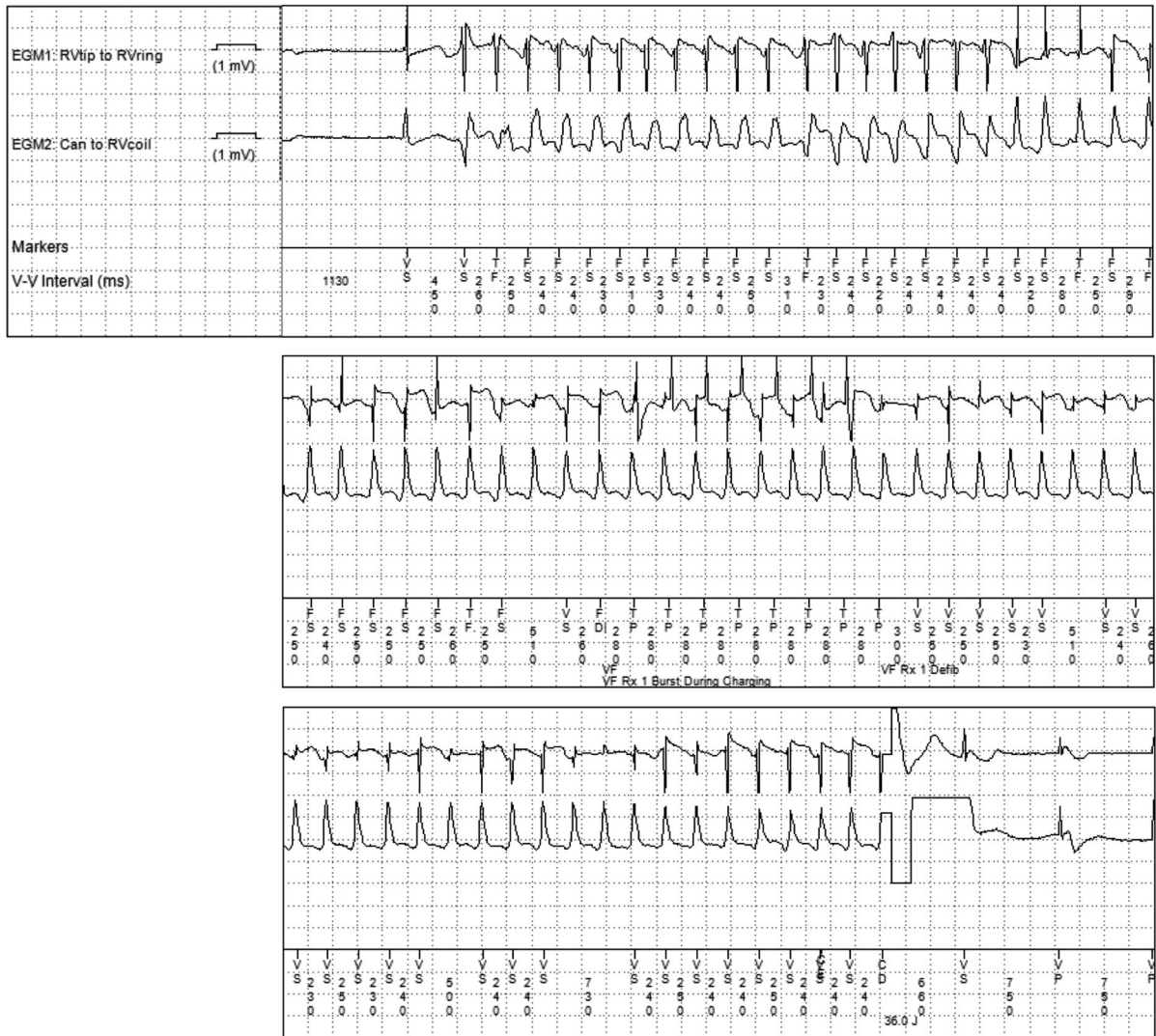


FIGURE 1 What is the mechanism of the failed ATP? Onset (top panel), detection with failed ATP during charging (middle panel) and termination of the ventricular tachyarrhythmia by 36-J shock (bottom panel). ATP = antitachycardia pacing

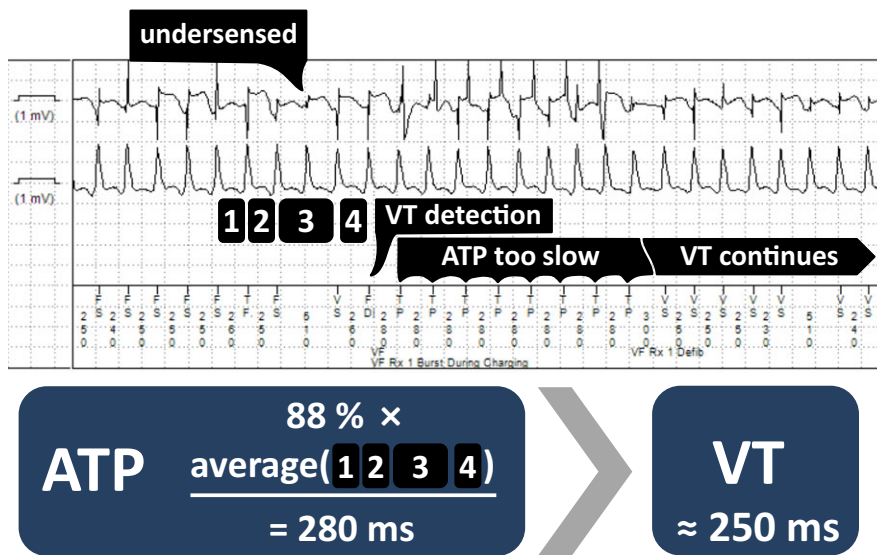


FIGURE 2 This extract from Figure 1 shows how the undersensed ventricular event causes burst pacing coupling intervals to be longer than the VT coupling intervals. Since the ATP is too slow, it fails to terminate the VT. ATP = antitachycardia pacing; VT = ventricular tachycardia [Color figure can be viewed at wileyonlinelibrary.com]

four ventricular events were missed (note: any ventricular events during charging are marked VS in Medtronic ICDs). Since calculation of burst cycle length is the same for all major manufacturers, other ICD types would have handled similarly in case of intermittent ventricular undersensing. Further interrogation revealed that the programmed sensitivity was set at 0.6 mV, instead of the default 0.3 mV (out-of-the-box setting). It was discovered that this was changed in the past due to periods of T-wave oversensing in his old ICD. Sensitivity was changed back to the nominal value of 0.3 mV and we intensified remote and outpatient monitoring in this patient. In ICD troubleshooting, it is generally not advised to change the sensitivity threshold as all algorithms are built with this threshold as a reference. This case confirms that even limited alterations in ICD sensitivity can significantly compromise arrhythmia detection and its treatment. Interestingly, in new Medtronic devices, changing sensing from true bipolar to integrated bipolar can sometimes lead to an increase of the R-wave amplitude and an increase in the ratio R/T.

3 | CONCLUSIONS

The case demonstrates the importance of comprehension of ICD functioning and algorithms. Many ventricular tachyarrhythmias occurring

in the VF zone are in fact VTs, which rely heavily on one-hit ATP to terminate the arrhythmia. Ventricular undersensing may render ATP much less effective due to too slow burst pacing.

CONFLICTS OF INTERESTS

The authors report no conflicts of interest.

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