

A case of withheld defibrillator treatment for 9 minutes of ventricular tachycardia



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Introduction

Implantable cardioverter-defibrillators (ICDs) reduce mortality in high-risk populations by sensing and appropriately treating ventricular tachyarrhythmias with either antitachycardia pacing or high-voltage shock.¹ An adverse effect of ICD implantation is inappropriate therapy for supraventricular tachycardia (SVT). ICD shocks for those non-life-threatening arrhythmias may increase mortality and cause psychological harm.^{2,3} At the most basic level, ventricular tachyarrhythmia detection is based on sensing consecutive R-R intervals of a preset cycle length for a prespecified duration. In addition, algorithms have been developed to better differentiate between ventricular and supraventricular arrhythmias. These algorithms can decrease the delivery of inappropriate therapy for SVT but may result in withholding of appropriate therapy for life-threatening ventricular tachyarrhythmias. We describe a case of withheld, appropriate ICD therapy due to an SVT discriminator algorithm.

Case report

A 79-year-old man with a recently implanted left ventricular assist device was admitted to hospital with *Staphylococcus aureus* bacteremia. He had a history of ischemic cardiomyopathy and ventricular tachycardia (VT) with 3 prior VT ablations. He had a Medtronic Viva XT biventricular ICD and recently received appropriate shocks for VT and inappropriate shocks for atrial fibrillation with rapid ventricular response. Medical treatment for his arrhythmias comprised metoprolol and mexiletine. During his hospitalization, telemetry captured 9 minutes of sustained VT without hemodynamic compromise. Interrogation of his ICD revealed a single episode (Figure 1) composed of 2 distinct VTs with unique morphologies on the far-field electrogram (Can to RV coil) and different cycle lengths. One VT comprised an

KEY TEACHING POINTS

- The Stability supraventricular tachycardia (SVT) discriminator works by preventing detection of ventricular tachycardia (VT). Other SVT discriminators work only after detection of VT.
- Stability may prevent detection of a VT episode if multiple VTs or cycle length wobble is present.
- Antiarrhythmic medication may increase the risk for failure to detect VT if Stability is activated.

rsR' with a cycle length of 380 ms; the other VT morphology had a monophasic R wave with a shorter cycle length of 310 ms. Both VTs fell within the programmed VT zone. VT was finally detected and treated by the fourth round of antitachycardia pacing at the conclusion of the 9-minute episode (Figure 2). Yet, therapy was withheld for prolonged stretches throughout the episode, including a period of 6 minutes and 30 seconds without any therapy. This was owing to reset of detection by Stability. The Stability discriminator had been turned on with a setting of 30 ms, significantly shorter than the 70 ms difference in VT cycle lengths. The other SVT discriminators, PR Logic and Wavelet, were enabled while Onset was disabled. During the tachycardia, atrioventricular dissociation was present with a faster ventricular rate than atrial rate; PR Logic would have correctly identified VT but was inhibited. Likewise, Wavelet found a match to template of 25% or less, also consistent with VT. Yet, because the tachycardia cycle length frequently alternated by more than 30 ms throughout the episode, detection was continuously being reset, thus withholding appropriate therapy. This represents normal ICD detection, resulting in a potentially catastrophic withholding of therapy. Fortunately, the patient's left ventricular assist device protected him from adverse clinical effects of the VT. Stability was thereafter disabled.

Discussion

A case of withheld ICD therapy owing to continuously alternating VTs of distinct cycle lengths and morphologies

KEYWORDS Defibrillator; PR logic; Stability; SVT discrimination; Ventricular tachycardia; Wavelet
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Treated VT/VF Episode #727

Device: Viva XT CRT-D DTBA1D4 Serial Number: Date of Visit:
 Patient: ID: Episode #727 - VT Chart speed: 25.0 mm/sec

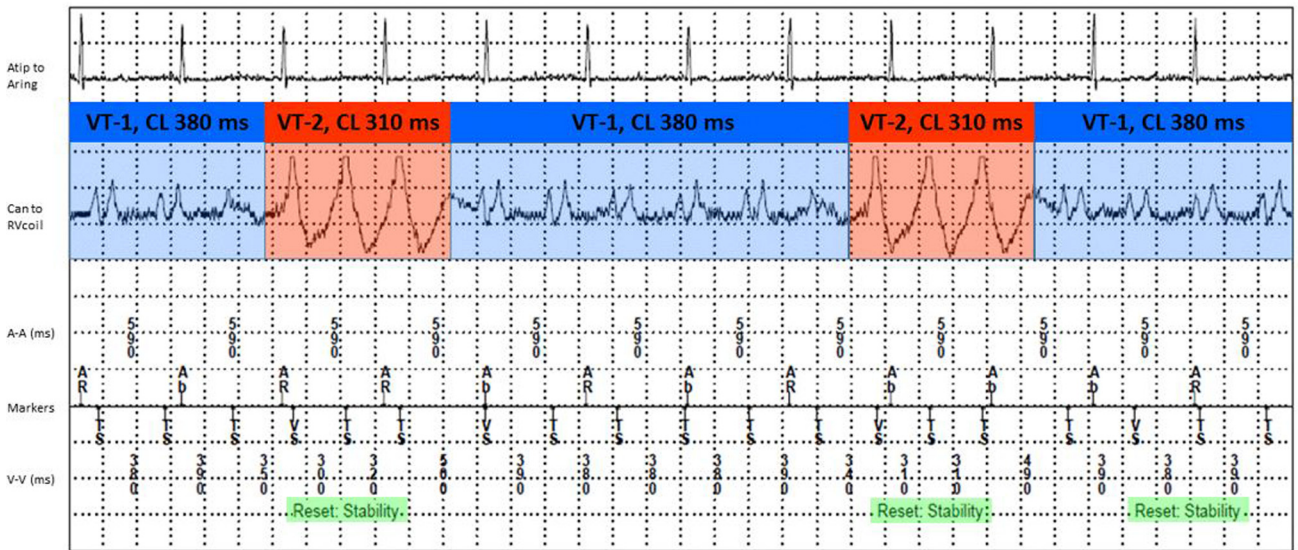


Figure 1 Two ventricular tachycardias of unique morphologies that alternate for 9 minutes, stored as a single ventricular tachycardia / ventricular fibrillation (VT/VF) episode. The cycle lengths vary by 70 ms, causing recurrent reset of VT detection by the Stability supraventricular tachycardia discriminator, set at 30 ms. AB = atrial blanked event; AR = atrial refractory sensed event; TS = sensed event in the VT zone; VS = ventricular sensed event; VT-1 = ventricular tachycardia, first morphology; VT-2 = ventricular tachycardia, second morphology.

has not been previously described. Manolis and colleagues⁴ described a case of briefly withheld ICD therapy due to 2 successive VTs of varying cycle lengths and stability. Polymorphic VT and ventricular fibrillation (VF) with unstable, sensed R-R intervals as well as VT of a single morphology

and unstable R-R intervals have also been implicated in withholding of appropriate ICD therapy.⁵

SVT discriminators function in an ICD to differentiate supraventricular tachyarrhythmias from VT / ventricular fibrillation in order to avoid inappropriate therapy. In

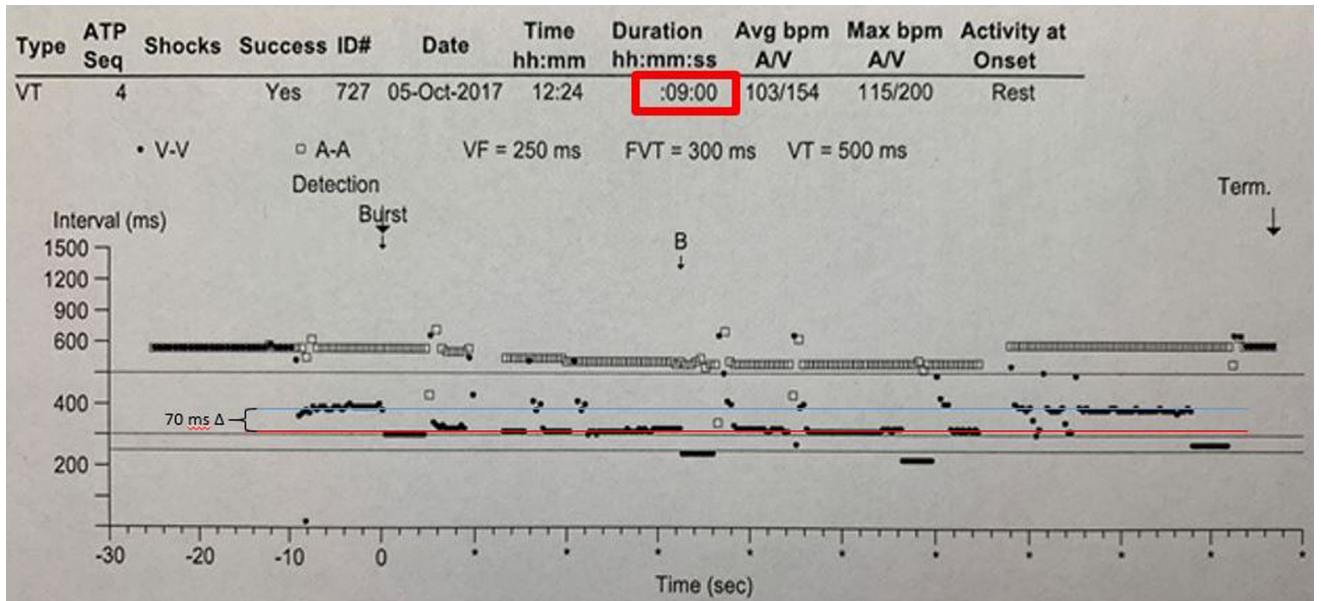


Figure 2 Interval plot shows the 9-minute episode of 2 ventricular tachycardias, varying by 70 ms in cycle length, finally terminated by a fourth round of antitachycardia pacing (ATP). Blue line indicates ventricular tachycardia of cycle length 380 ms. Red line indicates ventricular tachycardia of cycle length 310 ms. B = ATP burst; FVT = fast ventricular tachycardia detection zone; Term. = termination of event; VF = ventricular fibrillation detection zone; VT = ventricular tachycardia detection zone; Δ = difference.

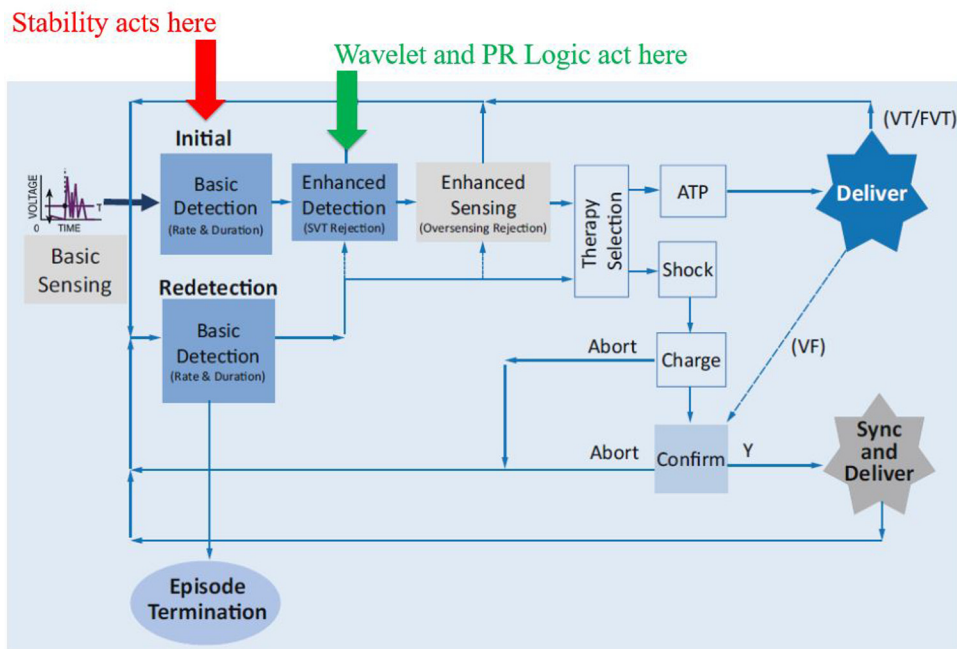


Figure 3 Block diagram depicting the sequence of basic detection, application of supraventricular tachycardia (SVT) discriminators, and enhanced detection in Medtronic implantable cardioverter-defibrillators. Basic detection and the number of intervals to detect (NID) must be satisfied before Enhanced detection (Wavelet, PR Logic) may be applied. Stability acts prior to the NID being satisfied, preventing the use of Enhanced detection algorithms. Reprinted and modified by permission from the author and Springer Nature: Brown ML, Swerdlow CD. Sensing and detection in Medtronic implantable cardioverter defibrillators. *Herzschrittmacherther Elektrophysiol* 2016;27:193–212.

Medtronic devices, these complement the basic tachycardia detection algorithm within the VT zone: consecutive R-R intervals shorter than the programmed VT detection cycle length are counted until that number reaches the programmed number of intervals to detect (NID), at which point VT is detected. In Medtronic ICDs, several discriminators are offered, including Onset, Stability, and Wavelet, as well as PR Logic in multichamber devices.⁶

Onset, which is nominally off, functions to prevent classification of gradually accelerating tachycardia, such as sinus tachycardia, from being detected as VT. Stability, like Onset, functions prior to the VT counter reaching the NID (Figure 3) and examines the tachycardia cycle length for variation. After an R-R interval short enough to fall within the VT zone is detected, the algorithm compares the fourth and subsequent R-R intervals with the immediately preceding 3 R-R intervals. If the cycle length varies by more than the programmed value in milliseconds, then the VT interval counter is reset to zero, inhibiting detection of the tachycardia as VT. Stability is nominally off but had been activated on our patient's device with the default setting of 30 ms. Stability had been activated for our patient owing to his history of inappropriate shocks for atrial fibrillation with rapid ventricular response. A cohort of 100 patients with ICDs, most of whom were not on antiarrhythmic medication, was studied to assess Stability's ability to reduce inappropriate shocks for atrial fibrillation. Set to allow for 40 ms in cycle length variation, Stability reduced inappropriate shocks for atrial fibrillation while still detecting 99.5% of all VT.⁷ However, when VT was induced in a second cohort of patients on Vaughan

Williams class Ic antiarrhythmics, the Stability algorithm with the identical setting of 40 ms caused significant delay in detection of VT 12.5% of the time.⁸ This finding may be relevant, as our patient was taking the class Ib antiarrhythmic mexiletine to prevent VT recurrence.

Two SVT discriminators function only once the NID has been satisfied (Figure 3). The Wavelet discriminator uses a wavelet mathematical transform to compare the ventricular electrogram during tachycardia to the ventricular electrogram in sinus rhythm. Wavelet discrimination to detect VT was precluded by the Stability function, as Stability prevented the consecutive VT zone NID from being met. PR Logic examines in multichamber ICDs the rate and regularity of both atrial and ventricular channels, as well as atrial and ventricular patterns and associations. Both of these discriminators would have correctly identified VT in this case but were precluded by Stability.⁶

Conclusion

Medtronic ICDs offer SVT discriminators that help prevent inappropriate ICD therapy. The Stability discriminator, when activated, works to prevent detection of VT and as a consequence may lead to inappropriate inhibition of therapy for patients with multiple concurrent VTs or wobble in VT cycle length. Antiarrhythmic medication increases the risk for this scenario. Stability therefore should remain nominally disabled in ICDs.⁹ If a patient experiences an inappropriate shock for atrial fibrillation, Stability may be considered but with a setting of greater than 40 ms, particularly in patients on antiarrhythmic medication. Given the above case and

presented data, a lengthening of the 30 ms default setting for the Stability discriminator should be considered in order to prevent failed detection of potentially fatal ventricular tachyarrhythmias.

References

1. Moss AJ, Zareba W, Hall WJ, et al. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. *N Engl J Med* 2002;346:877–883.
2. Schron EB, Exner DV, Yao Q, et al. Quality of life in the antiarrhythmics versus implantable defibrillators trial: impact of therapy and influence of adverse symptoms and defibrillator shocks. *Circulation* 2002;105:589–594.
3. Qian Z, Zhang Z, Guo J, et al. Association of implantable cardioverter defibrillator therapy with all-cause mortality—a systematic review and meta-analysis. *Pacing Clin Electrophysiol* 2016;39:81–88.
4. Manolis AG, Kourouklis S, Chatzis D, Kouvelas K, Kyriakides Z. Irregular ventricular tachycardia underdetected by implantable cardioverter defibrillator device. *Cardiol J* 2008;15:281–283.
5. Stroobandt RX, Duytschaever MF, Strisciuglio T, et al. Failure to detect life-threatening arrhythmias in ICDs using single-chamber detection criteria. *Pacing Clin Electrophysiol* 2019;42:583–594.
6. Brown ML, Swerdlow CD. Sensing and detection in Medtronic implantable cardioverter defibrillators. *Herzschrittmacherther Elektrophysiol* 2016;27:193–212.
7. Swerdlow CD, Chen PS, Kass RM, Allard JR, Peter CT. Discrimination of ventricular tachycardia from sinus tachycardia and atrial fibrillation in a tiered-therapy cardioverter-defibrillator. *J Am Coll Cardiol* 1994;23:1342–1355.
8. Le Franc P, Kuš T, Vinet A, Rocque P, Molin F, Costi P. Underdetection of ventricular tachycardia using a 40 ms stability criterion: effect of antiarrhythmic therapy. *Pacing Clin Electrophysiol* 1997;20:2882–2892.
9. Stiles MK, Fauchier L, Morillo CA, Wilkoff BL. 2019 HRS/EHRA/APHRS/LAHS focused update to 2015 expert consensus statement on optimal implantable cardioverter-defibrillator programming and testing. *J Arrhythm* 2019;35:485–493.