Real-world use of a novel ventricular tachyarrhythmia detection algorithm: A case report

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Introduction

Currently, according to patient characteristics and treatment needs, cardiologists or electrophysiologists can define different implantable cardioverter-defibrillator (ICD) and cardiac resynchronization therapy defibrillator (CRT-D) device therapy parameters, including heart rate cutoffs of tachyarrhythmia rate zones and intervals to detect (ITD). When a certain number of R-R intervals equal to ITD programmed exceeds the heart rate cutoff of the tachyarrhythmia rate zone, the device discriminates arrhythmia as ventricular tachycardia or supraventricular tachycardia and delivers high-voltage therapy (HVT) (ie, antitachycardia pacing [ATP], high-voltage shock therapy) as appropriate. Based on recent studies that have demonstrated reduced morbidity and mortality with a reduction in avoidable or inappropriate HVT,[1–3] the 2015 HRS/EHRA/APHRS/SOLAECE expert consensus statement on optimal ICD programming and testing recommends a different way to program ICD and CRT-D therapy parameters, preferring a more conservative approach with faster detection rate cutoffs and longer detection times.[4,5] These changes in recommended programming can lead to delayed or undelivered therapy for polymorphic ventricular tachycardia and ventricular fibrillation (VF).[6,7]

A novel device-based algorithm, VF Therapy Assurance (VFTA; Abbott, Sylmar, CA), has been developed to mitigate the risk of overlooking low- and variable-amplitude ventricular arrhythmias. ICDs and CRT-Ds discriminate arrhythmias using near-field R-wave signals, detected by tip-to-ring sensing channel. Instead, VFTA, during a ventricular tachyarrhythmia episode, uses far-field R-wave signals, detected by coil-to-can sensing channel, to promptly identify and treat tachyarrhythmias for which HVT would otherwise be delayed or deferred. The functioning of the VFTA algorithm has been described in an earlier publication.[8] It bases discrimination on 2 undersensing criteria: (1) 2 consecutive low-amplitude R waves (<0.6 mV); and (2) long R-R intervals on the far-field sensing channel (>2 seconds). Individual counters are increased when a low-amplitude R wave or long R-R interval is detected and are fulfilled when they are greater than a threshold. The counters are verified at different checkpoints, including at first arrhythmia detection or redetection after an earlier ineffective HVT. When criteria are fulfilled at the checkpoint, 4 modifications of ICD or CRT-D therapy programming go into effect: (1) setting up a single zone with a slower rate cutoff (adding 100 ms to the slowest programmed therapy zone up to a maximum of 400 ms), which enables skipping less aggressive therapies in favor of prompt high-voltage shock therapy and makes the device more sensitive to low- and variable-amplitude ventricular arrhythmias that might be undersensed; (2) decreasing the number of ITD to 6 to anticipate arrhythmia detection; (3) increasing the number of sinus intervals required to terminate the episode from 5 to 7, thus extending redetection time before ending HVT; and (4) skipping further ATP in favor of high-voltage shock therapy. These adjusted parameters are not user-programmable but are based on the programmed detection and therapy parameter values, and they remain in

KEY TEACHING POINTS

- Undersensing of ventricular tachyarrhythmias in implantable cardioverter-defibrillators, even though rare, can be life-threatening.
- New device-based algorithms can help to identify and early treat low- and varying-amplitude ventricular tachyarrhythmias.
- VF Therapy Assurance (Abbott, Sylmar, CA) leverages the far-field discrimination channel to promptly identify and treat ventricular tachyarrhythmias for which high-voltage therapy would otherwise be delayed or deferred.

KEYWORDS High-voltage therapy; Ventricular tachyarrhythmias; Discriminators; Cardiac implantable electronic devices; Case report
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effect until the device determines that the ongoing episode has ended. In this way, although favoring an initial conservative programming, when dangerous conditions are verified the device applies a less conservative therapy programming, leading to direct effect on the patient's clinical outcome.

The VFTA algorithm has been evaluated retrospectively on 564,353 recorded ventricular tachycardia arrhythmia electrograms from 20,000 devices, and it would have led to a new or earlier HVT in 0.27% (53/20,000) of devices with an increase of inappropriate HVT in 0.07% (14/20,000) devices[8]; however, to our knowledge, VFTA has not yet been evaluated in prospective clinical trials. One case report[9] described VFTA activation leading to HVT in a monomorphic ventricular tachycardia episode that would has not been treated without VFTA because the arrhythmia rate was lower than the treatment zone cutoffs. The authors suggested the therapy in that case could be inappropriate, but some programming changes could also improve the algorithm's specificity. As reported by Wilkoff and colleagues,[8] VFTA activation involves a low risk of inappropriate HVT broadly compensated by the efficacy in treating life-threatening arrhythmias that could be delayed or withdrawn without VFTA activation. We report on 1 case of a patient implanted with an Abbott CRT-D, in which the VFTA algorithm leads to an earlier proper HVT.

Case report

A 77-year-old male patient affected by heart failure with reduced ejection fraction and broad QRS complex with left bundle branch block was treated with a CRT-D in October 2021 and returned to the hospital in November 2021 for a scheduled follow-up. The patient had had some episodes of polymorphic ventricular tachycardia and VF, amenable to a ventricular arrhythmic storm, recorded a few days postimplant and treated with multiple shocks. In 1 episode we found the activation of the VFTA algorithm that automatically adjusted the detection and therapy parameters of CRT-D, avoiding withdrawal of high-voltage shock.

According to our clinical practice, the therapy programming (Supplemental Figure 1) was based on 3 tachyarrhythmia rate zones: (1) monitor zone VT-1 from 141 min^{-1}/425 ms to 171 min^{-1}/350 ms, 50 ITD; (2) active zone VT-2 from 171 min^{-1}/350 ms to 200 min^{-1}/300 ms, 25 ITD; and (3) active zone VF from 200 min^{-1}/300 ms, 12 ITD. Each R-R interval, named current interval, is compared with the average of current interval and 3 previous R-R intervals; then the result of comparison is classified as sinus ventricular interval (VS), biventricular paced interval (BP), ventricular tachycardia 1 interval (VT1), ventricular tachycardia 2 interval (VT2), ventricular fibrillation interval (VF), reconfirmed interval (R) according to the binning rule. In the episode under consideration (Figure 1) the patient presented an atrial fibrillation rhythm and the ventricular arrhythmia arose suddenly with a cycle length <300 ms. The arrhythmia was detected and recognized by the device after 12 ITD classified as "VF"; at this first VFTA checkpoint the criteria were not fulfilled, and the algorithm was not triggered. As per normal behavior, the CRT-D delivered ATP during charging and a first shock at 36 joules, which proved to be ineffective in converting the ventricular arrhythmia. After the shock, a change on the right ventricle near-field channel was seen (Figure 2)—the myocardial signal had lower amplitude than before and more fragmented morphology, while on the right ventricle far-field channel, there were some low amplitude (<0.6 mV) and undersensed R-waves (<0.3 mV). Nevertheless, the CRT-D redetected the arrhythmia after 6 ITD, as expected by redetection parameters, and at that checkpoint the VFTA criteria were fulfilled. Consequently, VFTA readjusted CRT-D therapy programming: (1) single therapy zone with a slower rate cutoff at 400 ms; (2) decreased number of ITD to 6; (3) increased number of sinus intervals required to terminate the episode from 5 to 7; (4) no further ATP. After 10.1 seconds from redetection, the device delivered a shock at 40 joules (Figure 3) that was effective in converting the ventricular arrhythmia and restoring normal sinus rhythm. According to VFTA programming, the episode was concluded after 7 ITD below the therapy zone cutoff binned as "VS" or "BP." Without VTFA activation, the slower rate cutoff would have remained at 350 ms, and after 5 consistent intervals binned as "VS" or "BP" the device would have declared the "End of Episode," before delivering a new high-voltage therapy. In the episode the intervals 1–5 marked in red (Figure 2) would have been binned as "VS," based on the binning rule summarized in Table 1, leading to a mistaken "End of Episode" and a consequent delayed or undelivered therapy.

According to VFTA, the programming changes and the application of a single therapy zone with the cutoff at 400 ms results in a different classification of the intervals that are binned, as reported in Table 2. The algorithm was effective in solving a life-threatening condition for the patient, who had no consequences from the episode.

Conclusion

Following the suggestions of the 2015 HRS/EHRA/APHRS/SOLAECE expert consensus statement,[4-5] we can reduce avoidable or inappropriate high-voltage therapy; however, we need to consider every risk factor for the patient and correctly tailor high-voltage therapy parameters. A small but significant percentage of patients may experience episodes of ventricular arrhythmias with withheld or delayed therapy. The VFTA algorithm can help to reduce this risk, allowing prompt detection and therapy during dangerous low- and varying-amplitude ventricular tachycardia arrhythmia.

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Appendix

Supplementary Data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2023.10.002.

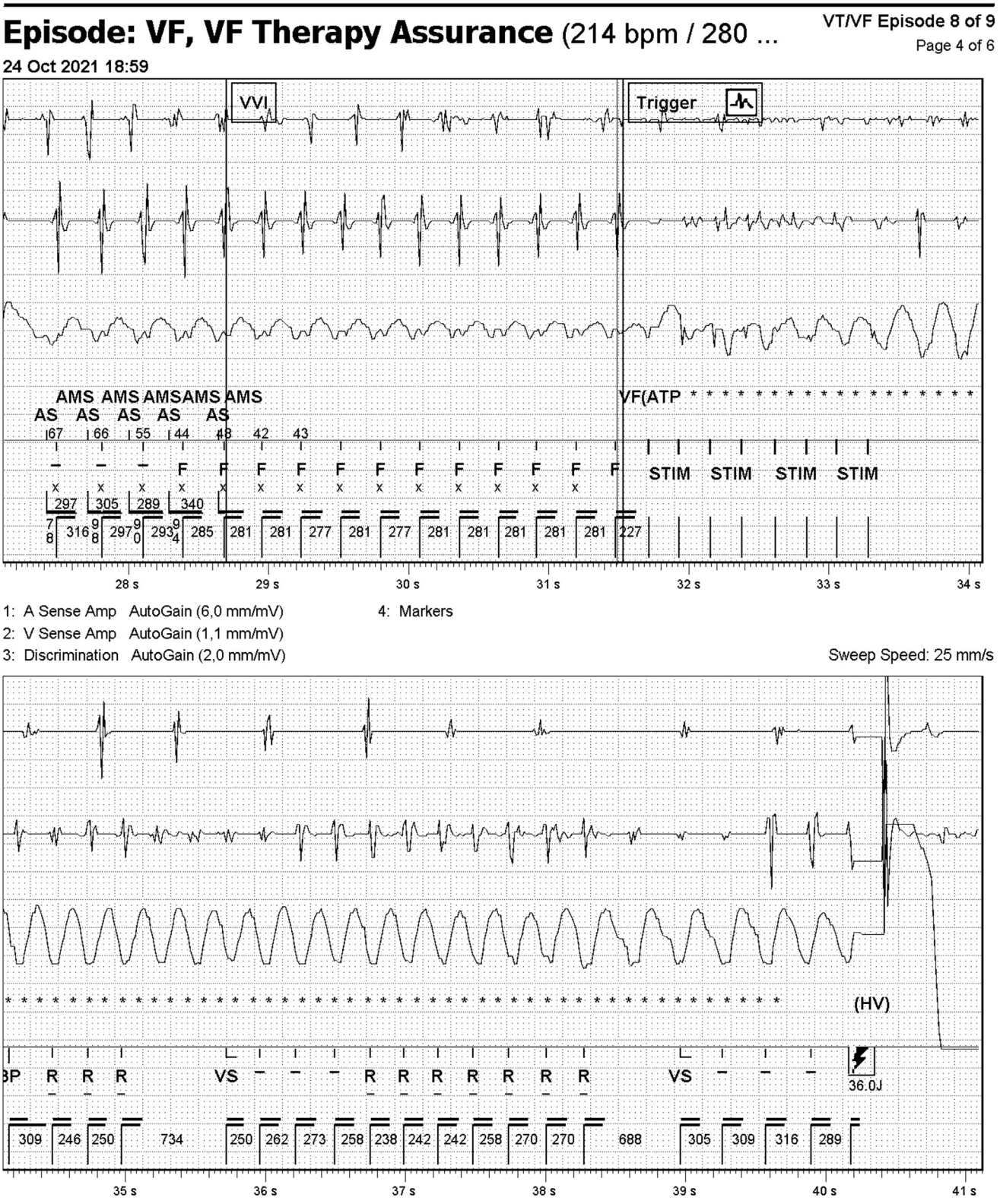

Figure 1 Onset of ventricular arrhythmia detected by the device and treated with antitachycardia pacing and high-voltage shock at 36 joules. R = reconfirmed interval; VF = ventricular fibrillation interval; VS = sinus ventricular interval.

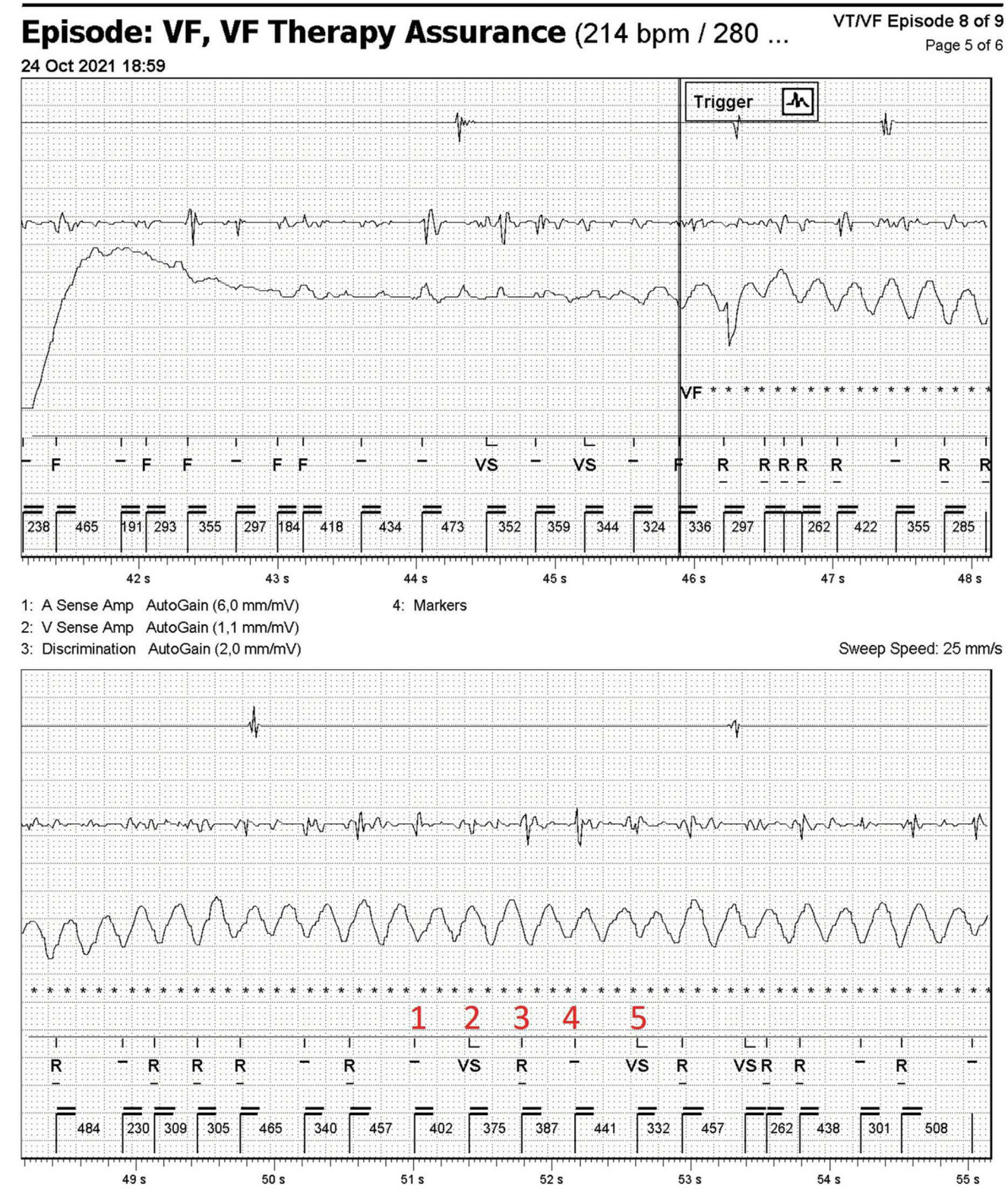

Figure 2 Redetection of ventricular arrhythmia and VF Therapy Assurance (VFTA; Abbott, Sylmar, CA) activation. Intervals 1–5, shown in red, would have been binned as sinus ventricular interval (VS) if VFTA was not activated, resulting in withdrawn therapy. R = reconfirmed interval.

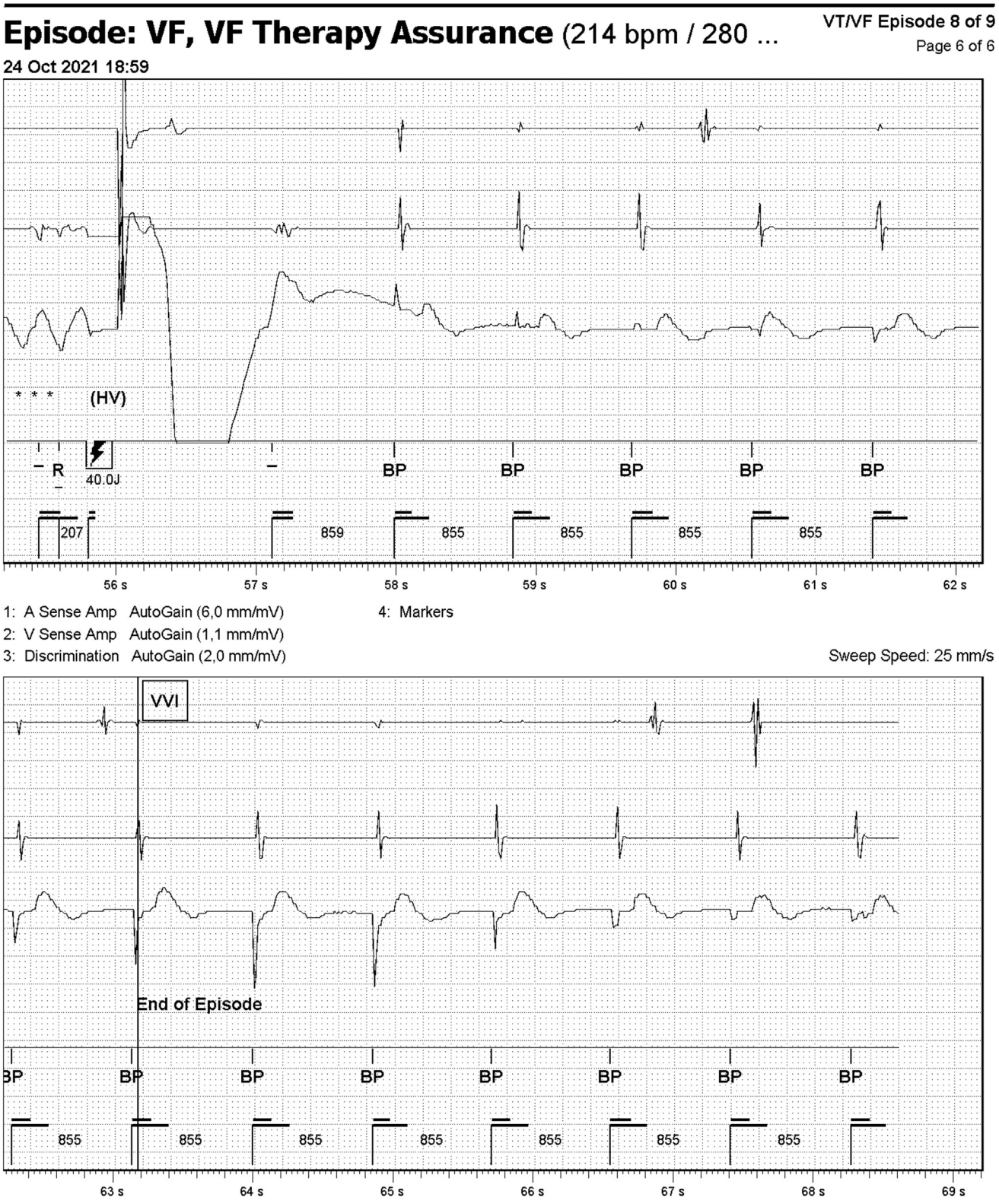

Figure 3 Effective therapy and end of episode. Effective 40 J high-voltage shock results in restoring normal sinus rhythm after 7 intervals to detect below the therapy zone cutoff binned as biventricular paced interval (BP).

Table 1 Device binning rule in redetection without VF Therapy Assurance activation

Current interval	Average interval	Binning without VFTA
457 ms - VS	392 ms - VS	VS
402 ms - VS	416 ms - VS	VS
375 ms - VS	394 ms - VS	VS
387 ms - VS	405 ms - VS	VS
441 ms - VS	401 ms - VS	VS
332 ms - VF	384 ms - VS	-

Every current interval is compared with the average interval (average of current and 3 previous intervals) and the interval is assigned following binning.

VF = ventricular fibrillation interval; VFTA = VF Therapy Assurance; VS = sinus ventricular interval.

Table 2 Device binning rule in redetection after the activation of VF Therapy Assurance algorithm

Current interval	Average interval	Binning with VFTA
457 ms - VS	392 ms - VF	-
402 ms - VS	416 ms - VS	VS
375 ms - VF	394 ms - VF	R
387 ms - VF	405 ms - VS	-
441 ms - VS	401 ms - VS	VS
332 ms - VF	384 ms - VF	R

R = reconfirmed interval; VF = ventricular fibrillation interval; VFTA = VF Therapy Assurance; VS = sinus ventricular interval.

When activating, the VFTA applies a single therapy zone with the cutoff at 400 ms, leading to a different classification of current and average intervals compared to binning without VFTA.

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