Devices for Resident Physicians

The tachycardia that outsmarted the SMART

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A 57-year-old man presented with palpitations and shock delivery from his implantable cardioverter-defibrillator (ICD). He had a history of ischemic cardiomyopathy with an ejection fraction of 20%. One month prior to this presentation, he received a DX ICD (Iforia 5 VR-T DX, Biotronik SE & Co. KG) for primary prevention of sudden cardiac death. Two ventricular tachycardia (VT) zones (VT1 162–188 bpm; VT2 188–222 bpm) were programmed in addition to a ventricular fibrillation (VF) zone (> 222 bpm). Upon device interrogation, intracardiac electrograms (EGM) during anti-tachycardia pacing (ATP) are shown in Fig. 1. What is the tachyarrhythmia and the reason for therapy delivery?

1. Discussion

The implanted ICD lead (Linox Smart ProMRI DX S 65/15; Biotronik SE & Co. KG) has a pentapolar design, which enables atrial sensing via the 2 floating atrial sensing rings. This DX system negates the need to implant a separate atrial lead for ventricular tachyarrhythmia discrimination. In addition, the DX ICD system is equipped with the SMART detection algorithm for ventricular tachyarrhythmia discrimination (Fig. 2).

In Fig. 1, the bottom panel shows the sequence of ATP in the ventricle upon fulfilling the requirements for VT2 detection. On close inspection, the atrial and ATP cycle lengths were found to be different. The atrial cycle length remained unchanged during ATP. The dissociation of A and V was consistent with the diagnosis of atrial tachycardia (AT), for which inappropriate device therapy was delivered [1]. In addition, all stored tachyarrhythmias terminated spontaneously with antegrade AV conduction. There were also episodes of paroxysmal atrial fibrillation (AF). The widened QRS morphologies in the far field (FF) channel were identical during AF and AT episodes (Fig. 1). These observations confirmed AT despite the presence of suspiciously broadened QRS complexes, which were likely due to rate-dependent bundle branch block.

The final question pertains to the inability of the SMART algorithm to correctly classify this tachyarrhythmia as a form of supraventricular tachycardia (SVT) and withhold therapy. The SMART algorithm in a DX device combines an atrial undersensing test (AUT) as shown in Fig. 2. An AUT is important as atrial undersensing may occur because the atrial signals are detected from the floating electrodes located in the right atrium and such signals could be temporarily small or even absent. The decisive question is whether intermittent and rare atrial undersensing or frequent undersensing occurs in the atrium. If atrial undersensing occurs frequently, SMART will revert to “ventricular only” discrimination, utilizing ventricular onset and stability as long as atrial sensing remains absent. AUT is confirmed if there are two consecutive RR intervals without a valid P wave. SMART will be reactivated when the first atrial sensed event is detected again. Repeated switching between SMART and “V-only” discrimination is therefore possible in an ongoing episode. As long as “V-only” discrimination is applied, “SVT” markers will be depicted correspondingly in the EGM tracings instead of “Sinust,” “Afib,” “Aflutter,” “Vf,” “Vf.”

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and “1:1” when SMART is used. SVT markers will also be displayed for up to 4 cycles directly upon cessation of ATPs (Fig. 1), until the sliding average algorithm allows the resumption for the comparison of the atrial and ventricular intervals. In our case, the SVT markers were not caused by the AUT but generated by repeated ATPs.

Nonetheless, we can observe occasional atrial undersensing due to a variation of atrial signal amplitudes during SVT, annotated by the three asterisks in Fig. 1. The Iforia VR-T DX utilizes Automatic Sensitivity Control (ASC) to automatically adjust both the atrial and ventricular sensing thresholds. In the standard setting of the atrial channel, each peak P wave resets an upper threshold (UT) and a lower threshold (LT). The atrial UT is set to 75% of the peak P wave amplitude by default. The duration of the UT is fixed at 350 ms. Thereafter, the sensitivity decreases to the lower threshold (LT), which is equal to 25% of the preceding measured P wave. The floating atrial rings are prone to FF QRS sensing because the sensing poles are mounted on a single lead body oriented perpendicularly to the ventricles. Therefore, atrial ASC requires an increased UT of 75% and a longer latent period of 350 ms to correct

Fig. 1. Top Panel: Tachycardia detected as ventricular tachycardia. Bottom Panel: Delivery of anti-tachycardia pacing. The asterisk indicates undetected atrial events. The bold numbers indicate the applied SMART branches according to Fig. 2. (0 = SVT marker caused by V-only discrimination; 1 = branch 1; 7 = branch 7).
for prolonged PR intervals. The amplitude of the undetected atrial signals is marginally smaller than 75% of the preceding atrial event. As a result of the use of the ASC, 3 atrial events were not sensed.

The flow chart of the SMART algorithm and the numbering of branches are shown in Fig. 2. In the absence of occasional atrial undersensing, SMART would have identified equal atrial and ventricular rates, and the algorithm tested for stability in both chambers. The existing paroxysmal AT with a stable antegrade 1:1 conduction used SMART branch 7, which is normally used for detecting VT with 1:1 retrograde conduction. VT markers (with annotations of branch 7) increased the VT counter stepwise. After every undetected atrial event, SMART changed four times to branch 1 because the doubled atrial cycle length was used four times into the sliding atrial average calculation. SMART believed now that the ventricular rate was faster than the atrial rate. Thus, the VT markers also increased the VT counter. In this case of a sudden and paroxysmal tachycardia, SMART could not distinguish between a 1:1 antegrade and retrograde conduction regardless of whether atrial signals were correctly sensed or occasionally undersensed. For correct atrial sensing, SMART branch 7 was applied. In the absence of the one or other of the atrial markers, SMART branch 1 was used. Both SMART branches would increase the VT and redetection counters resulting in several inappropriate therapies such as ATP and shocks.

Our patient had multiple episodes of AT that resulted in inappropriate therapies. Only limited troubleshooting measures are possible in this case. Reprogramming of the atrial UT from 75% to 50% might be helpful to prevent atrial undersensing. However, with correct atrial sensing, inappropriate therapies cannot be avoided because branch 7 is still used with this type of tachyarrhythmia. The new MorphMatch-criterion may be an appropriate recommendation and is available in the successive generation of DX ICDs. In our case, further management with antiarrhythmic medications or radiofrequency ablation can be considered. The patient was given oral amiodarone and the atrial UT was programmed to 50% instead of 75% of the preceding P wave to reduce the likelihood of atrial undersensing during AT. No further episodes of inappropriate therapies occurred after these corrective measures.

Conflict of Interest
All authors declare no conflict of interest related to this study.

Reference

[1] Ridley DP, Gula LJ, Krahn AD, et al. Atrial response to ventricular anti-tachycardia pacing discriminates mechanism of 1:1 atrioventricular tachycardia. J Cardiovasc Electrophysiol 2005 [16:601; 16:601-5].