Repetitive Non-reentrant VA Synchrony and Pacemaker-Mediated Tachycardia Induced by the AF Suppression Algorithm

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Case Summary
A 76-year-old man underwent implantation of a model 5386 Identity® ADx XL DR pacemaker (St. Jude Medical, Sylmar, CA, USA) for intermittent, high-degree atrioventricular (AV) block. A model 4480 passive bipolar lead (St. Jude) was placed in the right atrial appendage, and a model 1688T active fixation lead (St. Jude) was placed on the right ventricular midseptum. The device was programmed in DDD mode, with a backup rate set at 50 bpm, maximum tracking rate and maximum sensor rate limit at 110 bpm, and AV/PV delays at 250/250 ms. The postventricular atrial refractory period (PVARP) and postventricular atrial blanking periods were set at 250 and 165 ms, respectively. The rate-responsive AV/PV delay and PVARP were set at MEDIUM level. The atrial fibrillation (AF) suppression algorithm was programmed ON. Since ventriculoatrial (VA) conduction during ventricular pacing at 70 ppm was observed neither at the time of device implantation nor at any of the follow-up visits, the pacemaker-mediated tachycardia (PMT) option was programmed OFF. The atrial high rate episodes (AHRE) function was activated for detection of rates >190 bpm. Far-field R-wave oversensing was excluded by setting of the postventricular atrial blanking. Since the bipolar atrial electrogram measured 2.3 mV and the capture threshold was 0.75 V/0.4 ms, the atrial sensitivity was set at 0.5 mV and atrial pulse amplitude at 2.5 V/0.4 ms.

At the 1-year follow-up visit, the intracardiac electrograms (iEGM) of recorded AHRE were reviewed (Fig. 1). AF suppression, initiated by atrial premature complexes, increased the atrial pacing rate to the maximum tracking rate. Retrograde conduction was observed, with approximately 200-ms VA intervals, causing the retrograde P wave to fall within the PVARP. Overdrive atrial pacing was initiated by the AF suppression algorithm immediately after the retrograde P wave within the PVARP, increasing the atrial sensed and paced rate to >190 bpm. This was detected as an AHRE. As the VA conduction time gradually increased, the 8th retrograde P wave was sensed beyond the PVARP, triggering PMT (Fig. 1).

Discussion
In the present case, repetitive nonreentrant VA synchrony (RNRVAS) was due to the AF suppression function, which sensed retrograde P waves within the PVARP, spontaneously evolving toward PMT, after a gradual lengthening of VA conduction, until the retrograde P wave fell beyond the PVARP. In the presence of retrograde VA conduction, a short VA conduction time was associated with an atrial event that fell within the PVARP, causing RNRVAS, while a longer VA conduction time was associated with an atrial event that fell beyond the PVARP, triggering PMT in the same patient. Both PMT and RNRVAS episodes were stored as a single AHRE. In Figure 1, the iEGM shows RNRVAS up to the 8th ventricular paced event associated with approximately 200-ms VA intervals. The retrograde P wave after ventricular pacing fell within the PVARP, at an interval that increased gradually to 211 ms. Overdrive atrial pacing by the AF suppression algorithm was triggered by the sensed retrograde P wave. However, since the interval between that sensed P wave and the next paced atrial event was 160 ms, the stimulus fell in the atrial refractory period and failed to capture the atrium. Ventricular pacing after a relatively long AV interval allowed repetitive VA conduction and sustained RNRVAS. Since AV/PV delay and PVARP were rate-responsive, their initial value of 211 ms was shorter than the programmed 250-ms intervals. The VA conduction time increased thereafter gradually to 220 ms, at which point the retrograde P wave fell beyond the PVARP. Following the 9th ventricular paced
event, the 8th sensed retrograde P wave initiated PMT, spontaneously converting RNRVAS to PMT (Fig. 1).

Most of the previously described mechanisms of RNRVAS, which accelerate the pacing rate, have been associated with sensor-driven DDDR pacing. The relationship between RNRVAS and PMT has been reviewed by Barold.1 Both forms of VA synchrony are associated with long AV intervals and relatively high atrial rates in the setting of DDD or DDDR pacing modes. In our patient, the AF suppression function, intended to prevent the onset of AF, induced RNRVAS.

The initiation of RNRVAS and conversion to PMT were due to (1) VA conduction and retrograde P waves sensed within the PVARP, which triggered the AF suppression function, and (2) the AV delay programmed at 250 ms, a relatively long interval chosen because of the presence of intrinsic AV conduction in this patient who had a history of paroxysmal AV block.2 Overdrive atrial pacing by AF suppression was ineffective, since the atrial stimuli were delivered during the atrial refractory period. However, the next retrograde P wave following the retrograde P wave that depolarized the atria, because of a long enough programmed AV interval (atrial refractory sense to the next ventricular pacing stimuli) allowing the recovery of atrial myocardium.

The rate-responsive AV/PV delay and PVARP were automatically activated to MEDIUM by the AF suppression function. In the presence of retrograde VA conduction, shortening of the PVARP triggers PMT. In this patient, the shortening of PVARP was calculated as

\[ 250 - (109.5 - 90) \times 2 = 211 \text{ ms} \]

where 250 = AV delay, 109.5 = ongoing mean heart rate, 90 = rate that triggers the shortening of PVARP, and 2 = rate of PVARP shortening at MEDIUM setting. In addition, the AV interval during RNRVAS lengthened beyond 211 ms, causing the retrograde P wave to fall outside the PVARP, at which time RNRVAS ended spontaneously and PMT was triggered. Had the rate-responsive PVARP been programmed OFF, in this patient, PMT would have been prevented. On the other hand, had the rate-responsive AV/PV delay been programmed HIGH, the AV delay would have shortened to 250 - (109.5 - 90) \times 3 = 192 \text{ ms} \] (where 3 is a HIGH rate of shortening), shorter than the 211 ms calculated with the MEDIUM setting. In general, a short AV interval is likely to prevent RNRVAS. In this patient, retrograde VA conduction tests had disclosed the presence of VA conduction neither at the time of pacemaker implantation nor during any of the follow-up visits. However, since the detection of retrograde VA conduction is known to be unpredictable,3 the PMT option should be systematically programmed “ON.”

In conclusion, a meticulous scrutiny of the EGM is recommended when analyzing AHRE stored in the devices of paced patients, when the AF prevention functions have been activated.
References


