PACEMAKER/ICD PROBLEM OF THE MONTH

# Erroneous automatic pacemaker arrhythmia diagnosis: Is it malfunction or a design limitation?

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**ABBREVIATIONS** **AF** = atrial fibrillation; **AMS** = automatic mode switching; **AP** = atrial stimulus; **(AS)** = atrial event detected in the atrial refractory period; **AT** = atrial tachycardia; **ATDI** = atrial tachycardia detection interval; **AV** = atrioventricular; **CI** = current interval; **MAI** = moving average interval; **PVARP** = postventricular atrial refractory period; **RNRVAS** = repetitive nonreentrant ventriculoatrial synchrony; **VP** = ventricular paced event; **VS** = ventricular sensed event (Heart Rhythm 2012;9:998–1001)

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A 76-year-old man received a St Jude Medical's Zephyr XL DR pacemaker 3 years ago for symptomatic second-degree atrioventricular (AV) block with bradycardia. The parameters when Figure 1 was recorded were as follows: mode DDDR, lower rate 55 ppm, upper tracking rate 130 ppm, paced AV delay 170 ms, sensed AV delay 120 ms (shortest AV delay 100 ms), postventricular atrial refractory period (PVARP) 275 ms, rate adaptive shortest duration 170 ms, postventricular atrial blanking period 100 ms, and atrial tachycardia detection rate (ATDI) 180 bpm (interval = 333 ms). By design, automatic mode switching (AMS) entry and high atrial trigger were automatically suspended by pro-

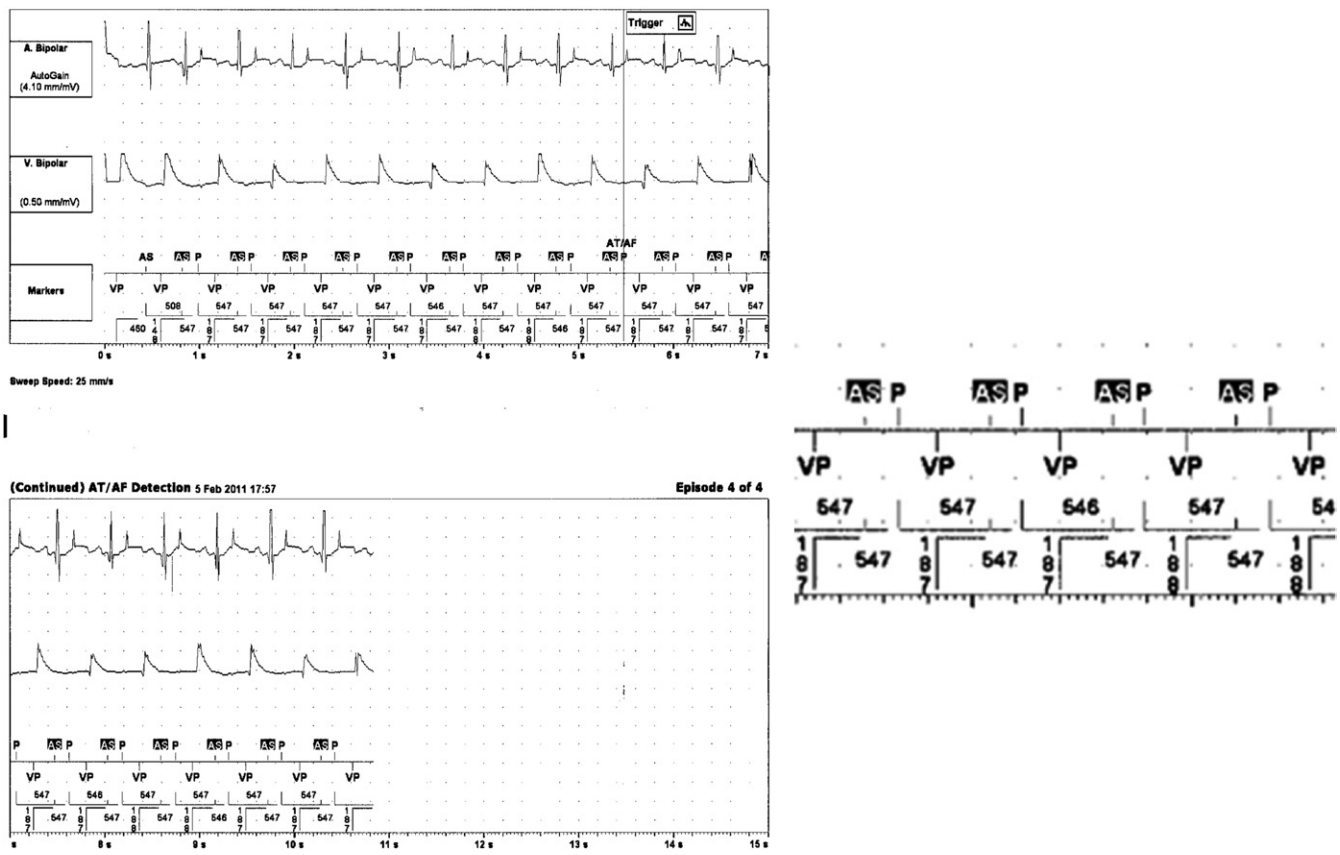


**Figure 1** Repetitive nonreentrant ventriculoatrial synchrony labeled "AT/AF" by the pacemaker. A magnified portion of the marker channel is shown on the right. See text for details. AF = atrial fibrillation; AT = atrial tachycardia; (AS) = atrial event detected in the atrial refractory period; VP = ventricular pacing.

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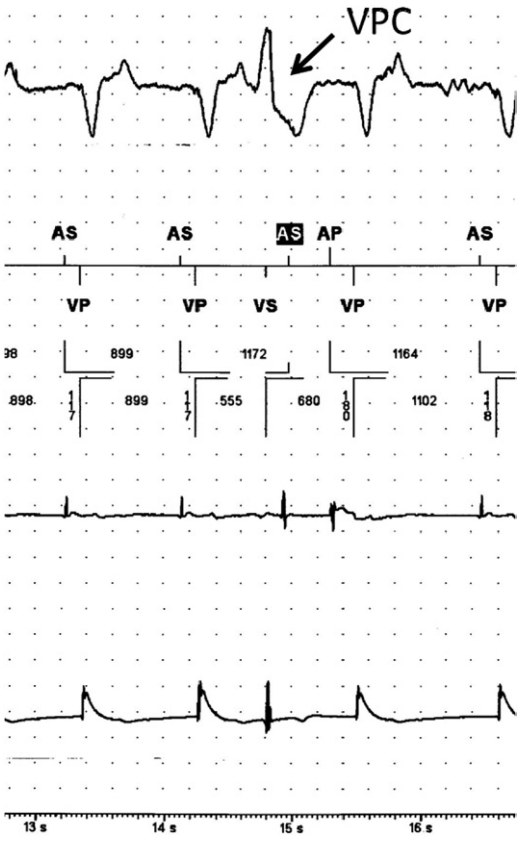


**Figure 2** DDD pacing with a ventricular premature complex associated with retrograde ventriculoatrial conduction detected in the postventricular atrial refractory period (PVARP). The marker depicting the PVARP shows that the PVARP terminates upon detection of a P wave within the PVARP. See text for details. AP = atrial stimulus; (AS) = atrial event detected in the atrial refractory period; VP = ventricular pacing; VS = Sensed ventricular premature beat.

gramming atrial tachycardia/atrial fibrillation (AT/AF) detection. At the time of follow-up, the device indicated that it had recorded 10 episodes of AT/AF over a period of 4 months. The AT/AF episodes lasted no longer than 6 minutes. The highest recorded rate of the AT/AF episodes was 284 bpm. No other important arrhythmias were recorded. Figure 1 is representative of all the recorded episodes labeled AT/AF by the pacemaker.

## What is the differential diagnosis?

The list includes repetitive nonreentrant ventriculoatrial synchrony (RNRVAS), marked first-degree AV block, and atrial sensing of far-field R wave. The diagnosis of marked first-degree AV block with a P wave in the PVARP is highly unlikely with the arrangement in Figure 1 because such a sequence has never been reported. The observations at the onset of the stored recording (see left side in Figure 1) and the response to a premature ventricular complex in Figure 2 strongly suggest RNRVAS[1]. The sharp and distinctive configuration of the atrial electrogram in the PVARP is consistent with atrial depolarization and not with the pattern of far-field R-wave sensing. The retrograde P waves generate an electrogram similar to that of the atrial premature beat at the start of the recording in Figure 1.

## What is the mechanism of RNRVAS?

A retrograde P wave is trapped in the PVARP and the subsequent atrial stimulus (AP) is ineffectual because it falls in the atrial myocardial refractory period.[1] The (AS)–AP interval measures about 140 ms. Therefore, the ventriculoatrial (VA) conduction time is 547 minus 187 minus 140 = 220 ms. The onset of RNRVAS was never recorded except for the start of Figure 1. There the pattern is consistent with an atrial premature beat with prolongation of the AS-VP interval to 148 ms because of upper rate limitation. The atrial premature beat initiates a cycle at the upper limit interval. This atrial premature beat seems to give rise to an atrial echo beat that then initiates RNRVAS.[1]

## How is RNRVAS possible because the patient had complete AV block?

Ventricular pacing during follow-up revealed intact 1:1 retrograde ventriculoatrial conduction that remained constant at 220 ms at a pacing rate of 115 ppm. Figure 2 shows P-synchronous pacing (cycle about 900 ms) and a sensed ventricular premature complex with retrograde ventriculoatrial conduction detected by the device in the PVARP. This is followed by an AP. Such a response typically initiates RNRVAS.[1]

## Why did the pacemaker interpret RNRVAS as AT/AF?

AT/AF is defined as an average atrial rate greater than the ATDI setting.[2] The AT/AF detection system classifies the rhythm intervals into 2 bins: sinus interval > ATDI and AT/AF interval < ATDI. To determine whether AT/AF has occurred, the device computes a moving average atrial rate or moving average interval (MAI). If both the MAI and the current interval (CI) are shorter than the ADTI setting, the device bins a single episode (interval) of AT/AF. It takes 5 intervals binned as AT/AF for the device to classify the rhythm as AT/AF (Table 1) (D. Davis, personal communication, 2011). The calculation does not distinguish between tachycardia and fibrillation. Return to sinus rhythm is more complex.

### Moving average interval

The device identifies AT/AF by using an MAI, which is a proportional average, meaning that the delta increases/decreases in proportion to the difference between consecutive beats. All atrial intervals are counted (Table 1) (D. Davis, personal communication, 2011).

If CI ≤ MAI, the following formula is used: MAI = (3/4)MAI + (1/4)CI. If CI > MAI, the following formula is used: MAI = (7/8)MAI + (1/8)CI.

### Timing cycles

The detected atrial event in the PVARP is labeled (AS). Assume that the (AS)–(AS) interval measures 550 ms (547 ms). The (AS)–AP interval measures 140 ms. Each long interval measures 410 ms, and the short interval measures 140 ms. The