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A compound problem of sensing and pacing alternans

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1. Case presentation

A 66-year old male patient underwent implantation of a model Accent™ DR RF 2212 (St Jude Medical, CA, USA) dual chamber pacemaker for sinus-node dysfunction and paroxysmal atrial fibrillation (AF). The right atrial lead was placed in the right atrial appendage and the right ventricular lead in the outflow tract. He had no structural heart disease and was on oral-anticoagulation. Three years later, he presented with recurrent palpitations and dizziness with self-terminating episodes of ‘wide-QRS tachycardia’ (Fig. 1) prompting an emergency hospital admission. On pacemaker interrogation, the lead and battery parameters were in normal range. The device had recorded multiple mode-switch episodes concurrent with the patient’s symptoms. Do the detailed information on the programmed settings of the pacemaker (Table 1), and the distinctive cycle length (CL) alternans amongst 130bpm and 100bpm aid in the correct diagnosis of the tachycardia?

2. Discussion

An interaction between a multiple-programmable dual-chamber pacemaker and the prevailing intrinsic AV/VA conduction with premature ventricular complexes (PVC) can introduce complexities in the heart rhythm. As elucidated through a telemetered episode with the time-aligned surface ECG (Fig. 2), concealed penetration

of a blanked PVC (PVCb) into the conduction system creates AV block during the AF suppression (AFx™) pacing, enabling a ventricular paced beat (VP₁) and switching to ventricular based timing [1]. The lengthening in the VIP™ related paced AV delay (281 ms) facilitates retrograde VA conduction (AS; VA interval 227 ms) after VP₁ through the partially refractory AV node. Clearly, this atrial event falls past the post-ventricular atrial refractory period (PVARP), which has been rate modulated by –30 ms (250 ms → 220 ms) due to the foregoing AFx™ pacing at 100bpm that abbreviated PVARP by 3 ms per bpm rise in the atrial rate beyond 90bpm (Table 2) [1]. The resulting faster atrial rate (AP-AS 508 ms) halts successive VIP™ induced AV lengthening and enforces rate responsive AV interval shortening acceptable at AFx™ driven pacing rate of 100bpm. The paced and sensed AV delays therefore reduce by –20 ms (200 ms → 180 ms and 180 ms → 160 ms, respectively) as per the rule of 2 ms decrease in AV delay per bpm rise in the atrial rate beyond 90bpm (Table 2) [1]. However, the retrograde AS is tracked to the ventricle (VP₂) at the shortest sensed AV delay (230 ms) that does not breach the maximum track rate, setting-up the classical reentrant form of pacemaker mediated tachycardia (VP₁-AS-VP₂ @130bpm; cPMT) initially [2]. Due to slightly shorter VA interval after VP₂ due to recovery of the AV nodal refractoriness, the resulting retrograde A (AR; VA interval ~210 ms) falls within the PVARP that terminates the cPMT, but is hence followed by a functionally non-captured atrial paced beat (AP) mandated by AFx™ pacing. The slightly longer atrial escape interval (648 ms, instead of 600 ms) of this AP beat is derived through ventricular based timing anticipating linking to the ventricle (VP₃) following the short paced AV delay of 180 ms. This completes a non-reentrant VA synchrony (VP₂-AR-AP-

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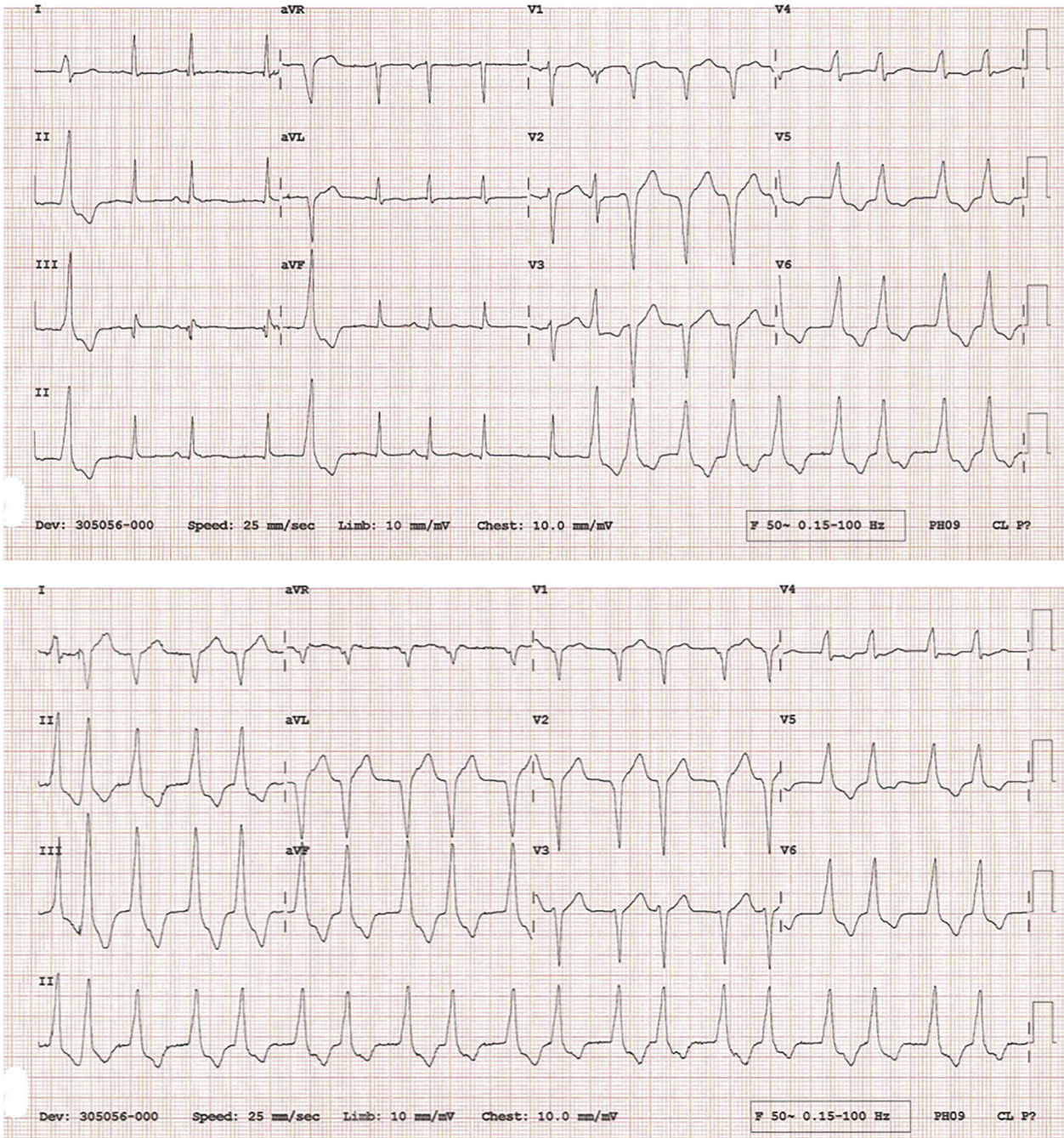


Fig. 1. Top: 12-lead surface ECG showing multiple broad QRS complexes, and initiation of a wide-QRS tachycardia with cycle length alternans; Bottom: 12-lead ECG during another incidence showing similar wide-QRS tachycardia initiated following a broad QRS complex.

Table 1
Programmed pacemaker settings.

Basic operation		Refractoriness and Blanking	
Mode	DDDR	PVARP	250 ms
Sensor	On	Post-Vent. Atrial Blanking	120 ms
Rates		Rate Responsive PVARP/ V Ref	High
Basic Rate	50bpm	Shortest PVARP/V Ref	175 ms
Hysteresis Rate	Off	A/V Pace Refractory	190/250 ms
Maximum Sensor Rate	130bpm	A/V Sense Refractory	93/125 ms
Maximum Track Rate	130bpm	Ventricular Blanking	Auto
2:1 block rate	216bpm	Ventricular Safety Standby	On
Delays		PVC Response	Atrial Pace
Paced AV Delay	200 ms	PMT Response	Atrial Pace
Sensed AV Delay	180 ms	PMT Detection Rate	125bpm
Rate Responsive AV Delay	Medium	AT/AF Detection and Response	
Shortest AV Delay	100 ms	Auto Mode Switch (AMS)	DDIR
Ventricular Intrinsic Preference (VIP™)	On	AT Detection Rate	180bpm
VIP™ Extension	150 ms	AMS Base Rate	80bpm
Search interval	30 sec	AF suppression (AFx™)	On
Search cycles	3	Overdrive Pacing Cycles	15
Capture & Sense		Maximum AFx™ Rate	100bpm
Autocapture™	On	Leads	A V
Pulse Amplitude	1.5V	Sense Configuration	Bipolar
Pulse width	0.4 ms	Sense Configuration	Bipolar
Autosense	On		Bipolar
Sensitivity	Auto		Bipolar

AF: Atrial fibrillation.
 AT: Atrial tachycardia.
 PMT: Pacemaker mediated tachycardia.
 PVARP: Post-ventricular atrial refractory period.
 PVC: Premature ventricular complex.

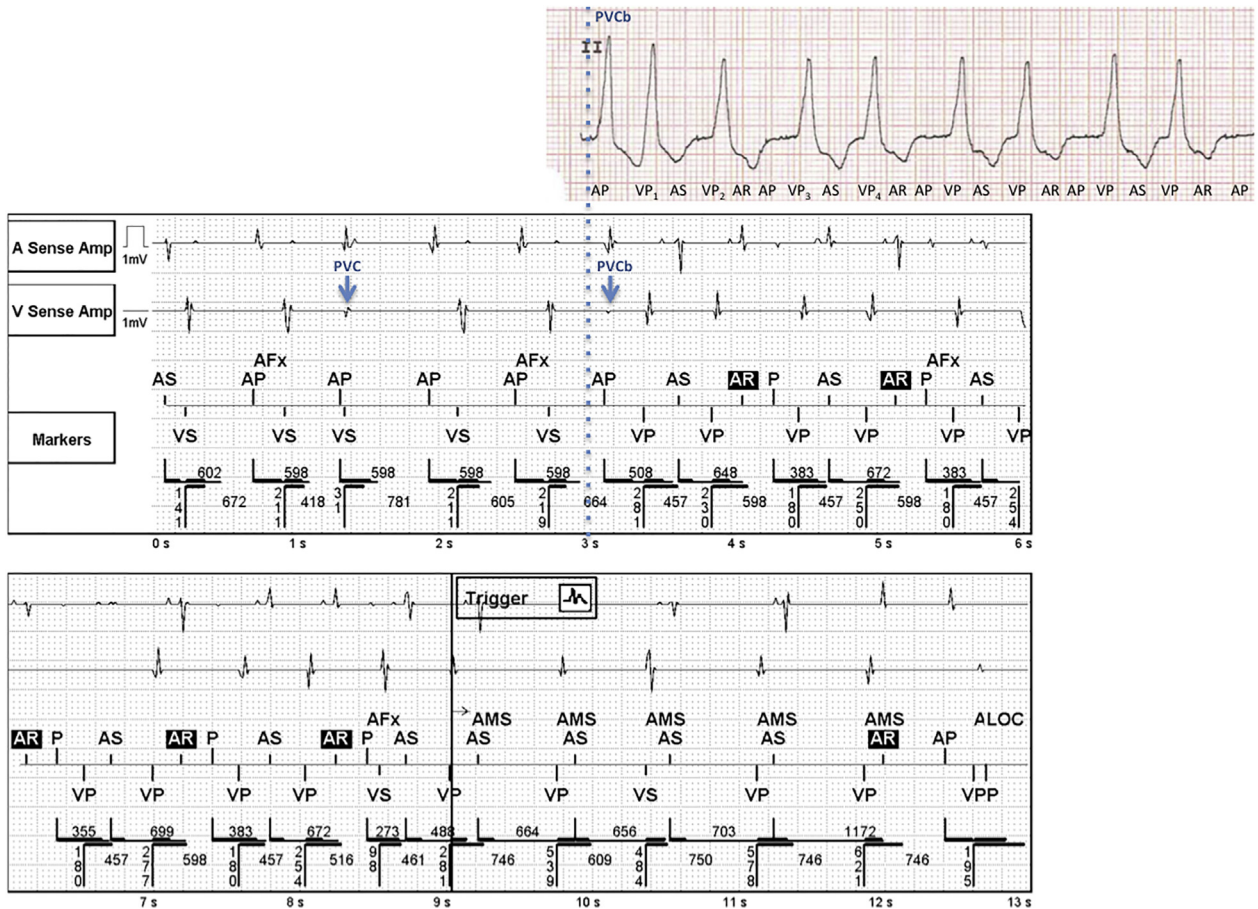


Fig. 2. Telemetered recording of a pacemaker mode-switch episode (13-s record). Channels presented from the top to bottom are: atrial, ventricular, marker labels, and interval duration in milliseconds. Premature ventricular complexes during the initial segment have been labeled. The inset shows the time-aligned strip of the surface ECG lead II commencing from the dashed vertical line at the 3-s mark. Refer to the discussion section for details. PVC = premature ventricular complex, PVCb = blanked PVC, AFx = atrial fibrillation suppression pacing, AP = atrial pace, AR = atrial refractory, AS = atrial sense, VP = ventricular pace, VS = ventricular sense, AMS = auto mode-switch.

Table 2
Details of pacemaker algorithms [1].

Algorithm	Application
Filtered Atrial Rate Interval (FARI)	A moving average atrial rate that shortens by 39 ms for each atrial interval shorter than the prevailing FARI, and lengthens by 25 ms for each atrial interval longer than the prevailing FARI. All atrial intervals, paced or sensed, including P-waves in PVARP are counted towards FARI. P-waves in the PVARP are not counted towards FARI if they are followed by an atrial pace.
Rate Responsive PVARP	Setting High PVARP shortens by 3 ms per bpm increase in FARI above 90bpm
	Medium PVARP shortens by 2 ms per bpm increase in FARI above 90bpm
	Low PVARP shortens by 1 ms per bpm increase in FARI above 90bpm
Rate Responsive AV Delay	Setting High AV delay shortens by 3 ms per bpm increase in AFx™ pacing driven rate or SIR above 90bpm
	Medium AV delay shortens by 2 ms per bpm increase in AFx™ pacing driven rate or SIR above 90bpm
	Low AV delay shortens by 1 ms per bpm increase in AFx™ pacing driven rate or SIR above 90bpm

AFx™: Atrial fibrillation suppression pacing.
 PVARP: Post-ventricular atrial refractory period.
 SIR: Sensor indicated rate.

VP₃ @100bpm; NRVAS) cycle [2]. The non-captured atrial beat introduces a long period of AV nodal quiescence, allowing a third return VA cycle after VP₃. This retrograde A (AS; VA interval 207 ms), however, falls outside the PVARP due to further regression in the PVARP to 199 ms led by the faster atrial rate, thus creating another cPMT cycle after a sensed AV delay (250 ms) permissible at the maximum track rate (VP₃-AS-VP₄ @130bpm) [1]. This consecutive switching of ventricular pacing between the maximum track (130bpm) and maximum AFx™ (100bpm) rates eventually becomes incessant due to alternating shorter and longer PVARP

effected, respectively, by the upstream shorter (AP-AS) and longer (AS-AP) atrial intervals, regularly changing the filtered atrial rate interval (FARI) values (Fig. 3). This tactical interlinking between FARI and rate responsive PVARP, further assisted through somewhat variable VA conduction times, presents as a ‘wide-QRS tachycardia’ with CL alternans. A false mode-switch is triggered when an atrial sensed alert window (273 ms), produced by an unrelated retrograde AS that followed a late coupled spontaneous PVC during the tachycardia, falls below the programmed atrial tachycardia detection interval (333 ms, or 180bpm) [1]. This

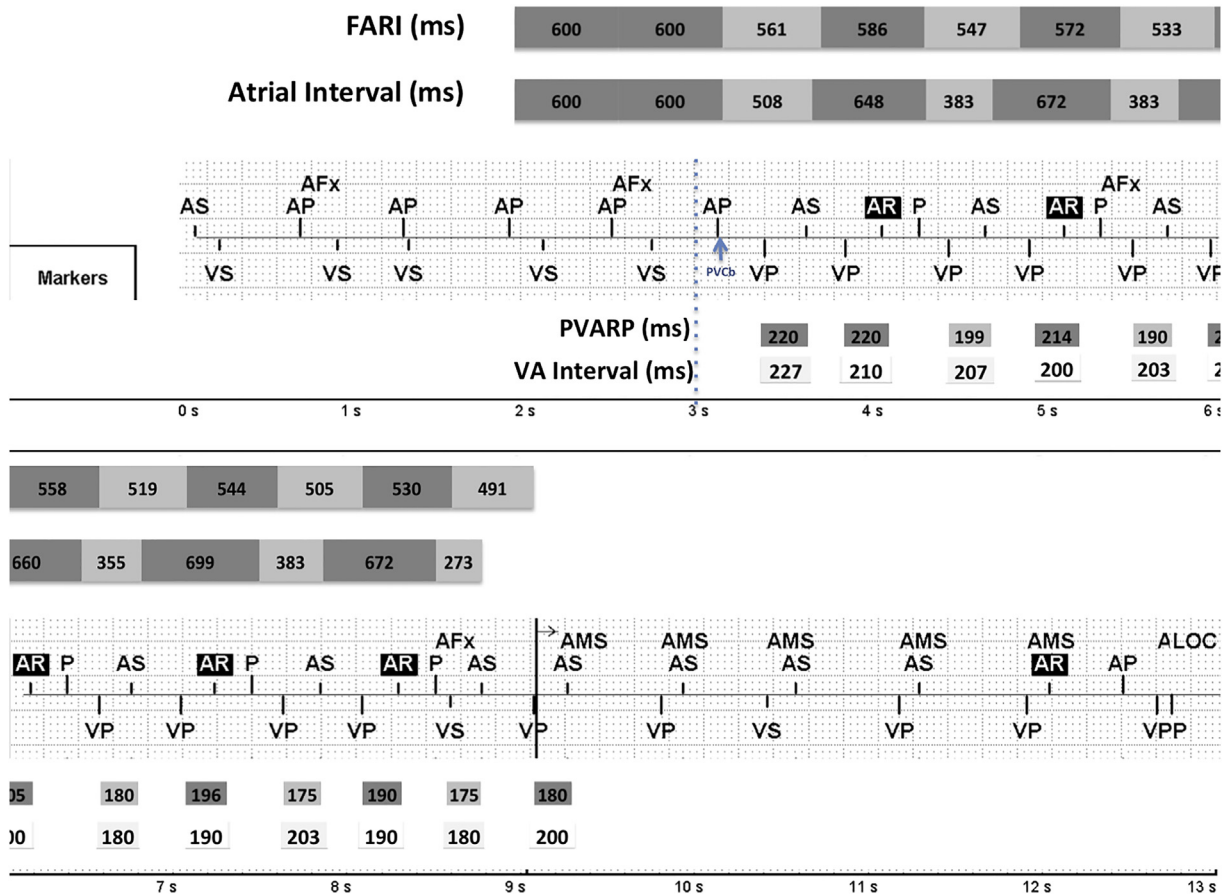


Fig. 3. Telemetry recording same as in Fig. 2 depicting changes in the filtered atrial rate interval (FARI), atrial (AP-AP, AP-AS, AS-AP) interval, post-ventricular atrial refractory period (PVARP), and VA interval during 3rd to 9th seconds of the episode. The moving FARI and rate responsive PVARP have been derived as per the information presented in Tables 1 and 2. The sensed refractory atrial (AR) events are not counted for the calculation of FARI as they are followed by paced atrial (AP) events. Alternating short (light-shaded boxes) and long (dark-shaded boxes) values of atrial intervals, and thus FARI, trigger corresponding changes in the PVARP in each succeeding cycle. The temporal variation in the beat-to-beat VA intervals does not have a distinctive pattern. PVCb = blanked premature ventricular complex.

concomitantly terminates the wide-QRS tachycardia.

A previous report has described a full transition from repetitive NRVAS to cPMT of another CL in the same episode [3], however, beat-to beat two alternating forms of PMT have never been described. We encountered this unfamiliar situation when a beat-to-beat oscillating series of cPMT and NRVAS was driven by PVARP alternans and AFx™ pacing, resulting in a tachycardia with CL alternans (100bpm ↔ 130bpm). The frequent PVC's with retrograde conduction repetitively initiated this fortuitous linking of reentrant and non-reentrant types of PMT, driven by multiple interacting rate responsive pacemaker algorithms. Besides, common forms of cPMT and repetitive NRVAS also occurred independently on other occasions. It required turning-off the AFx™ pacing

or the rate-responsive PVARP for the resolution of the anomalous pacemaker-mediated rhythms, averting any other unnecessary therapy.

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