CONTEMPORARY REVIEW

Repetitive nonreentrant ventriculoatrial synchrony: An underrecognized cause of pacemaker-related arrhythmia

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Similar to endless loop tachycardia (ELT), repetitive nonreentrant ventriculoatrial synchrony (RNRVAS) is a ventriculoatrial (VA) synchrony pacemaker-mediated arrhythmia. RNRVAS was first described in 1990 and can only occur in the presence of retrograde VA conduction and dual-chamber or cardiac resynchronization devices with tracking (P-synchronous ventricular pacing such as DDD, DDDR) or nontracking pacing modes that allow AV-sequential pacing (DDI, DDIR). RNRVAS is promoted by (1) high lower rate limit or any feature that allows rapid pacing, (2) long AV intervals, or (3) long postventricular atrial refractory period (PVARP). In contrast to ELT, RNRVAS is a less well-recognized form of pacemaker-mediated arrhythmia; thus, unlike ELT, there are no specific device algorithms to prevent, recognize, and terminate RNRVAS. However, RNRVAS has been recently shown to occur frequently. We present a series of cases, some of which were found fortuitously. Owing to its clinical implications, we propose that algorithms should be developed to prevent, identify, and terminate RNRVAS.

KEYWORDS Pacemaker-mediated arrhythmia; Dual-chamber pacemaker; Pacemaker syndrome; Retrograde VA conduction; Repetitive nonreentrant VA synchrony; Mode switching

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Introduction

Dual-chamber or biventricular cardiac implantable electronic devices are commonly programmed to pace in an atrial tracking mode (usually DDD or DDD-R) in order to preserve atrioventricular (AV) synchrony. In this programming mode, it is not uncommon to demonstrate ventriculoatrial (VA) synchrony and pacemaker-mediated tachycardia, which refers to an inappropriate faster pacing rate driven solely by persistent retrograde VA conduction. The 2 forms of pacemaker-mediated VA synchrony arrhythmias include (1) endless loop tachycardia (ELT), also referred to as pacemaker-mediated tachycardia; and (2) repetitive nonreentrant ventriculoatrial synchrony (RNRVAS). As both ELT and RNRVAS may cause symptoms or other adverse events, it is important to properly program the device to avoid them.

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RNRVAS is a repetitive process characterized by a functional atrial undersensing due to retrograde atrial activation falling within the postventricular atrial refractory period (PVARP) with subsequent functional atrial noncapture as the pacing stimulus occurs during the absolute refractory period of the atrium.[1,2] This repetitive pattern becomes established when the noncaptured atrial pacing (AP) is tracked by ventricular pacing (VP), which results in retrograde atrial conduction. During ELT a similar phenomenon occurs, except that the retrograde atrial activation is sensed outside PVARP, resulting in P-synchronous VP.

In this report, we present a collection of seminal cases of RNRVAS with examples from several device manufacturers and discuss the clinical implications of RNRVAS.

Case report

Case 1

A 60-year-old man with a history of hypertension, hyperlipidemia, recurrent vasovagal syncope, and intermittent prolonged AV block underwent dual-chamber pacemaker implant (Identity Adx XL DR; St Jude Medical, St Paul, MN) in 2007. His device was programmed DDDR 60–120 beats per minute (bpm), with both paced and sensed AV intervals of 200 ms and PVARP of 275 ms. Mode switch (automatic mode switch, AMS) was programmed to DDIR 60–120 and triggered at atrial rates of 170 bpm. To prevent

cardioinhibitory response during vasovagal events, hysteresis response was enabled to Intrinsic + 30 bpm. During a device follow-up visit, he complained of intermittent palpitations and shortness of breath. Device interrogation demonstrated 207 AMS episodes over the past 6 months. Figure 1A shows a representative stored electrogram episode.

VP events with retrograde VA conduction resulted in an atrial sensed (AS) event during PVARP (refractory event labeled AS with black background) without resetting the VA interval. Because of AV hysteresis (Intrinsic + 30 bpm), AP increased to 110–120 bpm. AP events (delivered approximately 100 ms after the retrograde AS event) resulted in functional atrial noncapture and lack of antegrade AV conduction. Thus, the VP event occurred after the AV interval expired, allowing repetitive retrograde VA conduction and AS event during PVARP. The perpetuating functional atrial noncapture and VP (AV sequential pacing) with retrograde VA conduction is consistent with RNRVAS. Given that any atrial events, including paced (AP) and refractory events, are counted in St Jude Medical devices, this resulted in an AMS episode.

VVI pacing during follow-up demonstrated retrograde VA conduction, which reproduced the patient's symptoms, confirming the diagnosis of pacemaker syndrome due to RNRVAS. To prevent these episodes, AV hysteresis was reprogrammed with a slower intervention heart rate of 90 bpm (extending VA interval). Thus, the subsequent AP event is delayed enough to allow atrial capture and prevent recurrence of RNRVAS. This reprogramming resolved the patient's symptoms.

Case 2

An 82-year-old man with a dual-chamber pacemaker (Assurity DR; St Jude Medical) implanted for high-degree AV block (DDD 80–120 bpm, PVARP 375 ms, paced and sensed AVinterval (AVI) 225 and 200 ms, respectively). The first 3 beats of his 12-lead electrocardiogram (Figure 1B) represent a sequential AV paced rhythm. This is followed by a premature ventricular complex (PVC) (black arrow) that results in retrograde P wave (VA interval of 240 ms) that falls within PVARP. The subsequent AP (after VA interval times out) results in functional noncapture (lack of inscribed P wave best seen in V_1). Thereafter, repetitive VP with VA conduction and functional atrial noncapture occurs for 5 cycles, consistent with RNRVAS. After 5 beats of RNRVAS (asterisk) the retrograde P wave falls outside the PVARP interval, likely owing to slight VA prolongation, resulting in P-synchronous pacing and ELT. Figure 1C represents the device electrograms from the same patient during a similar episode of RNRVAS (black arrow) transitioning to ELT.

Owing to a history of torsades de pointes, his lower rate limit (LRL) was kept at 80 bpm but the paced and sensed AV intervals were shortened (170 ms and 150 ms, respectively), thereby extending VA interval and preventing the development of RNRVAS.

Case 3

The third case involves a 68-year-old man with history of coronary artery disease, sinus node dysfunction, and ventricular tachycardia status post dual-chamber implantable cardioverter-defibrillator (Ventak Prizm 2DR, Guidant, Indianapolis, IN). He was admitted to the hospital with symptoms of nausea, palpitations, presyncope, and hypotension. The device was programmed DDDR 65–120 bpm (paced AV delay 280 ms). Dynamic AV delay, dynamic PVARP, and AV hysteresis were programmed on. A rhythm strip from telemetry (Figure 2A) demonstrates RNRVAS. The first 7 beats show atrial paced ventricular sensed complexes. This is followed by a PVC with retrograde atrial conduction (dashed arrows showing inverted P waves in lead II). The device does not track the retrograde P as it falls in the PVARP extended to 400 ms following a PVC. This results in a repetitive AV sequential pacing without atrial capture and subsequent retrograde atrial activation. In the present case, lowering sensor activity threshold and response factor and shortening paced AV delay should prevent RNRVAS by extending the VA interval.

Another 5 representative cases are shown in Figures 2–4. These cases illustrate the different clinical implications of RNRVAS as well as their presence in most device manufacturers. With the exception of RNRVAS in St Jude Medical devices, these events are only found fortuitously during clinical care and are likely significantly underreported. Owing to the specific nature of the St Jude mode switch algorithm, these events are stored as mode switch events. Table 1 provides a list of patient and device characteristics in all 8 RNRVAS cases.

Discussion

RNRVAS was described by Barold in 1990[1] where he compared ELT with RNRVAS. Subsequently, a few case reports of this phenomenon have been published.[2–5] In the present series, we report 8 cases of RNRVAS occurring in devices from different models/manufacturers. Six of the 8 patients had symptoms including pacemaker syndrome and atrial fibrillation (AF). In addition, we outline programming options to avoid or interrupt RNRVAS.

RNRVAS is initiated when VP or PVC results in retrograde VA conduction with retrograde atrial depolarization that falls within the PVARP. Subsequent AP results in functional noncapture because of atrial refractoriness following a retrograde P wave (Figure 5A). The noncaptured AP does not result in anterograde AV conduction, and thus a VP event would occur (AV sequential pacing) following expiration of the AV interval. Repetitive retrograde VA conduction and atrial depolarization perpetuates this cycle. The anterograde limb of the arrhythmia is thus provided by the pacemaker (AP followed by VP, AV sequential pacing) while the AV conduction system acts as the retrograde limb of the circuit back to the atrium. In contrast to ELT (Figure 5B), a true reentrant circuit does not exist in RNRVAS because the AS event occurs within the PVARP.