Duelling pacemakers: Unexpected pacemaker interaction resulting from a proprietary rate smoothing algorithm

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Introduction

Advances in pacemaker technology have allowed devices to better approximate physiologic variations in heart rate. It is important to be aware of how these manufacturer-specific algorithms might influence pacemaker activity, especially when unexpected behavior occurs. Here, we present a case of unexpected pacemaker interaction resulting from a proprietary rate smoothing algorithm.

Case Report

An 89-year-old man had a left-sided dual-chamber pacemaker (Symphony DR; Sorin CRM, Clamart, France) implanted for syncope, second-degree Mobitz II heart block, and periodic third-degree heart block. He was found to have an abrupt increase in right ventricular lead impedance and high capture thresholds, consistent with an impending lead fracture. Owing to occlusion of the left innominate vein, the left-sided pacemaker was abandoned and a new dual-chamber pacemaker was implanted on the right side (Reply DR; Sorin CRM) and programmed to DDD 60–130 ppm. Paced and sensed atrioventricular (AV) delays were 220 msec and 165 msec, respectively. Given that the patient was dependent on ventricular pacing (VP), the original left-sided device was set with a backup rate of VVI at 40 ppm in case of early dislodgement of the new right-sided lead.

The patient was seen in follow-up 1 month later. The devices were interrogated and it was found that the original left-sided device was pacing approximately 75% of the time (Figures 1 and 2). Thus, despite the abandoned device’s being programmed at a backup rate slower than the lower rate limit of the new pacemaker, frequent unintended pacing from the former was still exhibited.

An intracardiac electrogram from the new right-sided pacemaker was obtained (Figure 3). This shows that while every fourth ventricular complex results from appropriate atrial tracking and subsequent VP by the new right-sided pacemaker, a competing, nontracking, regular rhythm at approximately 75 ppm is seen.

Although the left-sided device was set to VVI at a rate of 40 ppm, it was discharging at a rate closer to 75 ppm. Why might this be? Possibilities include rate response phenomenon, pacing behavior resulting from End of Life mode, interference or cross-talk from the other device, and a manufacturer-specific pacing algorithm, such as rate smoothing.

It was confirmed that rate response had already been deactivated and the battery was not close to expiring, so neither of these factors was contributing. While cross-talk from independent devices may give rise to unexpected pacing behavior, in a demand pacing mode such as VVI, suppression of pacing—instead of triggering—would be expected. It was noted that rate smoothing had been inadvertently programmed on and was set to a “slow” response. It was deduced that the pacing behavior observed here was the result of a proprietary rate smoothing algorithm. Rate smoothing was deactivated, which ultimately resolved the problem.

Discussion

Rate smoothing algorithms for pacemakers were introduced in the 1980s to reduce large cycle-to-cycle variations in rate and improve symptoms during exercise when upper rate behavior (pacemaker Wenckebach and 2:1 AV block) may occur. Rate smoothing has also been more recently employed to reduce the risk of certain arrhythmias in patients with long QT syndromes or pause-dependent ventricular arrhythmias after a “short-long-short” R-R sequence.

At a most basic level, a rate smoothing value is assigned, generally between 3% and 25% of preceding R-R intervals, and the subsequent R-R intervals are not allowed to increase more than the rate smoothing value. With early rate smoothing options, there were reports of

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ABBREVIATIONS AV = atrioventricular; PVARP = postventricular atrial refractory period; VP = ventricular pacing; VS = ventricular sensing; VT = ventricular tachycardia

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Problems such as irregular pacemaker-mediated tachycardia and AV dyssynchrony. There have also been reports of interactions between rate smoothing algorithms and ventricular tachycardia (VT) detection, causing VT to go untreated.4

This patient’s device employed a smoothing algorithm that calculated the average of the 8 previous R-R intervals and would not allow the following R-R interval to increase further than the set rate smoothing parameter. Gradual prolongation of the R-R interval to either the set lower rate limit or the patient’s own intrinsic rate would then occur to eliminate sudden fluctuations in the effective rate. We hypothesize that the patient’s heart rate, perhaps with exertion, increased above 75 bpm, at which point rate smoothing resulted in pacing close to this rate. Gradual return of the pacing rate to the lower rate limit was interrupted, though, by intermittent pacing of the ventricle by the new right-sided device, thus regularly shortening the preceding R-R interval and resetting the smoothing algorithm. This accounts for why the new right-sided device was pacing only 24% of the time.

Although the tracing in Figure 3 is truncated, a basic repeating pattern of 4 paced intervals is displayed. This is composed of 2 distinct R-R intervals, with 3 consecutive 800-msec intervals corresponding to VP from the original left-sided device (“ventricular sensing [VS] interval”), followed by 1 707-msec interval corresponding to VP from the new right-sided device (“VP interval”). This unexpected repetitive phenomenon can be explained as follows.

Despite the new right-sided pacemaker’s being set at DDD 60–130 ppm, competing pacing in the ventricle by the original left-sided device is treated as ventricular ectopy (VS events), with the majority of the sinus beats falling into the postventricular atrial refractory period (PVARP) (atrial refractory events). Given that the patient’s basic sinus rate is slower than the paced rate and there is no fixed VA association owing to heart block, there is gradual lengthening of the V-A interval such that every third atrial event falls out of PVARP and is tracked by the new right-sided pacemaker, resulting in VP. This resulting “VP interval” is shorter than the preceding “VS interval” at 707 msec.

The original left-sided pacemaker is set at VVI 40 but with rate smoothing set to “slow” setting. The smoothing algorithm responds to this change in heart rate by calculating the average R-R interval of the 8 previous cycles. Given the cyclical nature of this phenomenon, this consists of 3 “VP intervals” of 707 msec and 5 “VS intervals” of 800 msec. The average of these products is \( [(3 \times 707 \text{ msec}) + (5 \times 800 \text{ msec})] / 8 = 765 \text{ msec}. \) As the rate smoothing was set to “slow,” 31 msec is added to this, to roughly equal the 800-msec “VS interval” seen on the electrogram in Figure 3. This then sets up a repetitive loop of intermittent pacing from the new right-sided device that is counterchecked by the rate smoothing algorithm of the left-sided device.

The patient’s own sinus rate serves as the third unwitting accomplice perpetuating the phenomenon. Hypothetically, if the patient’s sinus rate were to increase such that the A-A interval shortens to less than 800 msec, appropriate tracking by the right-sided device would occur, thus overriding the rate smoothing algorithm. However, any subsequent reduction in the sinus rate would trigger the rate smoothing algorithm and could foreseeably reintiate a cyclical pattern of pacing between the 2 devices. The sinus rate would ultimately govern the “VP interval” and subsequently—via the rate smoothing algorithm—the “VS interval.” With disabling of the smoothing mode in the original left-sided
device, the patient’s new right-sided pacemaker was able to function as intended.

When troubleshooting unexpected pacing behavior, it is important to consider how manufacturer-specific algorithms such as rate smoothing might contribute. Our case describes a complex interaction between 2 devices that was propagated by a rate smoothing algorithm. Furthermore, it illustrates why having 2 simultaneously active pacemakers should be avoided unless absolutely necessary, and when it is, to consider all device algorithms in both devices and how they may interact.

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