



Case Report

Pacing failure caused by automatic pacing threshold adjustment system

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ABSTRACT

Ventricular capture management is an automatic pacing threshold adjustment algorithm that automatically measures pacing threshold through detection of the evoked response after a pacing stimulus. Although it is principally designed to save device battery under the maintenance of the patient's safety, we experienced a rare case with serious pacing failure due to a weakness of this algorithm. This pacing failure might be explained by a large variation in the ventricular pacing threshold depending on the atrioventricular interval and daily variation of pacing threshold and concomitant steroid use in this patient.

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1. Introduction

Most permanent pacemakers recently have an automatic pacing threshold adjustment algorithm, e.g., ventricular capture management (Medtronic, Inc., Minneapolis, MN, USA), as a basic optional function to maximize device battery longevity. This algorithm measures the stimulation threshold and automatically updates the pacing output to optimal value. This function avoids unnecessary high-output pacing, and is considered to save the device battery and prolong battery longevity [1]. Although this algorithm has been widely implemented, we experienced a case with serious pacing failure due to the weakness of this system.

2. Case

A 63-year-old female underwent pacemaker implantation (Medtronic®, Minneapolis, MN, USA Advisa DR) due to complete atrioventricular (AV) block in 2010. She had a history of systemic lupus erythematosus and was prescribed 10 mg/day prednisolone for 20 years. No specific episodes occurred during the initial 4 years; however, she suddenly experienced syncopal attacks in 2014. The electrocardiogram showed irregular spontaneous heart beat at 30/min and uncaptured pacing spikes at 60/min. Ventricular lead dislodgement was ruled out by the chest X-ray.

Pacemaker investigation revealed unchanged lead impedance, and the ventricular pacing output was set at 3.0 V with 0.40 ms through the automatic threshold adjustment, because the most recent ventricular pacing threshold was 0.625 V with 0.4 ms. We performed manual threshold testing with various AV intervals of 80, 120, and 220 ms, and various atrial rates of 100 and 120 bpm. Interestingly, the ventricular pacing threshold was influenced by the AV interval, i.e., the shorter the AV interval, the lower the pacing threshold (Fig. 1). No differences in the pacing thresholds were found between the supine and sitting positions. Because the routine automatic pacing threshold algorithm uses a short AV interval (110 ms) to avoid fusion from native conduction, this algorithm resulted in an inappropriately lower pacing output in a programmed AV interval (160 ms). In addition, this patient showed large daily variation in pacing threshold ranging from 0.625 V with 0.40 ms to 1.625 V with 0.40 ms even in the same rate and AV interval (Fig. 2).

After reprogramming the ventricular output to provide an adequate safety margin (3.5 V with 0.40 ms), consistent ventricular capture was achieved with no pacing failure in further observation.

3. Discussion

In this case, the automatic pacing threshold adjustment algorithm sets the pacing output at “optimal” value in accordance with the result of its measurement of the pacing threshold, but pacing failure occurred as a result.

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Ventricular pacing threshold measured in 2014				
Pulse width : 0.40 ms		Atrial rate		
AV interval		100 bpm	120 bpm	
	80 ms	1.00 V	1.00 V	
	120 ms	1.25 V	1.00 V	
	220 ms	1.75 V	1.50 V	

↓ 2.5 years later ↓

Ventricular pacing threshold measured in 2017				
Pulse width : 0.40 ms		Atrial rate		
AV interval		80 bpm	100 bpm	120 bpm
	80 ms	1.50 V	1.50 V	1.25 V
	120 ms	2.00 V	1.50 V	1.50 V
	160 ms	2.25 V	2.00 V	1.75 V
	220 ms	2.75 V	2.25 V	2.20 V

Fig. 1. Manual threshold testing with various AV intervals and various atrial rates. The upper table shows the data of 2014. The ventricular pacing threshold is influenced by the AV interval, i.e., the shorter the AV interval, the lower the pacing threshold (e.g., 1.00 V with 0.40 ms at 80 ms AV interval, 1.25 V with 0.40 ms at 120 ms AV interval, 1.75 V with 0.40 ms at 220 ms AV interval at 100 bpm atrial rate, 1.00 V with 0.40 ms at 80 ms AV interval, 1.00 V with 0.40 ms at 120 ms AV interval, 1.50 V with 0.40 ms at 220 ms AV interval at 120 bpm atrial rate). The lower table shows manual threshold testing 2.5 years after the first observation with various AV intervals and various atrial rates. The ventricular pacing threshold is influenced by the AV interval also, i.e., the shorter the AV interval, the lower the pacing threshold. (e.g., 1.50 V with 0.40 ms at 80 ms AV interval, 2.00 V with 0.40 ms at 120 ms AV interval, 2.25 V with 0.40 ms at 160 ms AV interval, 2.75 V with 0.40 ms at 220 ms AV interval at 80 bpm atrial rate, 1.50 V with 0.40 ms at 80 ms AV interval, 1.50 V with 0.40 ms at 120 ms AV interval, 2.00 V with 0.40 ms at 160 ms AV interval, 2.25 V with 0.40 ms at 220 ms AV interval at 100 bpm atrial rate, 1.25 V with 0.40 ms at 80 ms AV interval, 1.50 V with 0.40 ms at 120 ms AV interval, 1.75 V with 0.40 ms at 160 ms AV interval, 2.00 V with 0.40 ms at 220 ms AV interval at 120 bpm atrial rate).

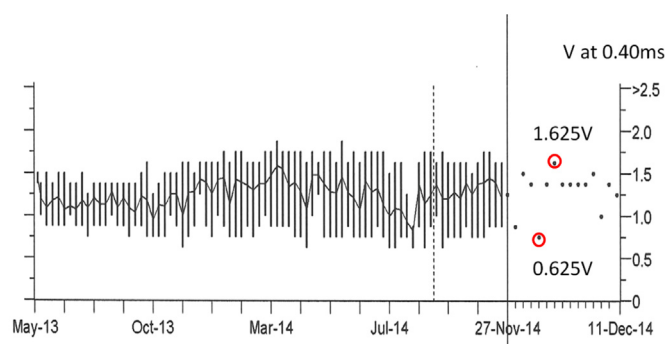


Fig. 2. Ventricular capture management trend report. Pacing threshold exhibited large daily variation ranging from 0.625 V with 0.40 ms to 1.625 V with 0.40 ms.

This algorithm uses a short AV interval (110 ms) to obtain accurate ventricular capture, and it is necessary to avoid confusing fusion beat with spontaneous ventricular beat. Although the stimulus with shorter coupling interval tends to result in lower threshold, the difference should be acceptable in ordinal cases for the setting of pacing output because sufficient safety margin is considered between the output and actual threshold. However, interestingly, the pacing threshold was significantly lower with shorter AV interval of 110 ms than that with longer AV interval of

160 ms in this case. This phenomenon was unusual and the difference was unexpectedly large. To the best of our knowledge, this is the first case that reported pacing failure using an active fixation lead by the automatic pacing threshold adjustment algorithm.

The mechanism of the differences between capture management threshold data and manual threshold data in this case is unclear; however, this may be explained as follows:

- The alternation of the right ventricular (RV) filling depending on the timing of the atrial systole may lead to a slight difference in the RV dimension, and it may result in variation of contact between the lead and ventricular tissue.
- Variations are found in pacing lead impedance originating in a small volume of tissue and fluids surrounding the lead tip. Danilovic et al. reported that the lead impedance was influenced by the pacing rate, i.e., the shorter the pacing rate, the higher the pacing impedance. It has been explained by changes in RV geometry and fluctuation in myocardial contact with the lead, depending on RV diastolic filling time [2]. Sauer et al. reported a similar case that used a passive fixation lead in the RV apex [3].

We repeated manual threshold testing 2.5 years after the first observation and realized that the ventricular pacing threshold was influenced by the AV interval in the same manner. However, the ventricular threshold was gradually increased from 0.625 with 0.40 ms to 2.375 V with 0.40 ms during these 2.5 years. In addition, this case showed a large daily variation in pacing threshold, ranging from 0.625 V to 1.625 V with 0.40 ms, with the same rate and AV interval. This phenomenon can be explained by the normal and circadian variation. Silvetti et al. has reported that the highest thresholds were registered between 2:00–4:00 a.m., which was likely due to alternation in cardiac size, differences in tissue–lead contact, changes in catecholamine concentration, and change in cardiac electrolyte level during sleep [4]. Ribeiro et al. reported > 1-V variability of the threshold in 7.5% patients by AutoCapture management in St. Jude Medical (Sylmar, CA, USA) pacemaker [5].

Although these variable factors might lead to pacing failure in this case, we could not document a prominent increase in the pacing threshold that exceeds the safety margin of actual pacing output setting; hence, the real mechanism of pacing failure is unclear. However, our manual measurement may also fail to document such changes because the threshold itself may vary during different times in the day. The automatic pacing threshold adjustment algorithms are different among the manufactures. For example, the Medtronic pacemaker was implanted in the patient in the present case, which measures capture threshold once daily at 1:00–2:00 a.m., so as not to inflict unnecessary distress on patients, which might lead to failure to measure the optimal threshold. Besides the automatic pacing threshold adjustment algorithms and the large daily variation in pacing threshold, the patient was prescribed 10 mg/day prednisolone for 20 years due to a history of systemic lupus erythematosus. The use of steroid induced cardiac fibrosis, which might lead the increased threshold during the 2.5-year observation. This might influence the misjudgment of the algorithm in this case.

4. Conclusion

We experienced a rare case of a patient with serious pacing failure caused by the automatic pacing threshold adjustment system. Although the automatic pacing threshold adjustment algorithm has been shown to be effective and may improve

battery longevity, it might improperly lead to low pacing output in specific cases.

Conflict of interest

All authors declare no conflict of interest related to this study.

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