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An Abnormal Electrocardiogram Following Pacemaker Implantation: Red Flag or Red Herring?

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Abstract

An 88-year-old man underwent a dual chamber pacemaker implantation for complete heart block. Post procedure 12-lead electrocardiogram showed some abnormal findings. The reader is challenged to identify the abnormalities and then explain the mechanism of these findings. The discussion then guides the reader with the explanation.

Device Rounds

An Abnormal Electrocardiogram Following Pacemaker Implantation: Red Flag or Red Herring?

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Abstract

An 88-year-old man underwent a dual chamber pacemaker implantation for complete heart block. Post procedure 12-lead electrocardiogram showed some abnormal findings. The reader is challenged to identify

the abnormalities and then explain the mechanism of these findings. The discussion then guides the reader with the explanation.

Case presentation

An 88-year-old man came to the cardiology clinic with dizziness on exertion for two months. He had long standing hypertension and a baseline right bundle branch block (RBBB). Blood pressure was 140/70 mmHg and pulse rate was 40 beats/min at presentation. Systemic examination was unremarkable. Electrocardiogram (ECG) recorded in the clinic showed complete heart block. Subsequently, a dual chamber permanent pacemaker (Attesta^{TM}, Medtronic, Minneapolis, MN, USA) was implanted with the ventricular lead placed at the apex. The device was programmed to the DDDR mode, with a 60 bpm lower rate limit, 130 bpm upper tracking rate, mode switch ON, 140 and 120 ms paced and sensed AV intervals, 0.7 and 2.3 mV atrial and ventricular sensitivities, and atrial and ventricular pacing amplitude/pulse width of 1.0 V/0.4 ms and 1.0 V/0.4 ms, respectively. A 12-lead electrocardiogram recorded after pacemaker implantation is shown in Figure 1. What are the abnormalities in this electrocardiogram? What are the immediate concerns regarding pacemaker functionality?

Commentary

The ECG shows sinus tachycardia at a heart rate of 100 bpm. There are atrial sensed ventricular paced complexes with a sensed atrioventricular delay of 120 ms. There is no pacing spike or QRS complex after the 12th P wave in the rhythm strip lead II (arrow), raising the possibility of atrial undersensing. The following beat is a paced P wave at the lower rate of 60 bpm from the last tracked P wave, confirming that the preceding P wave was not sensed. There is subsequent resumption of atrial sensed ventricular paced complexes. Another point of concern is the RBBB morphology of paced QRS complexes. This contrasts with the expected LBBB morphology of paced QRS complexes when the lead is implanted inside the right ventricle. Although RBBB morphology of paced beats may point towards left ventricular pacing due to fallacious lead placement, it may still be seen in up to 8% of patients with uncomplicated RV pacing.[1] Right ventricular pacing can be identified in patients with RBBB pattern on pacing, by the presence of left superior axis deviation and precordial transition at V_3, with good sensitivity and specificity.[1] One hypothesis suggests that portions of interventricular septum that are anatomically RV may behave functionally and electrically as LV and thus activating LV first.[2]Another possible explanation is early penetration of the electrical impulse to LV and RV activation delay due to baseline disease of RV conduction system,[3] which may be the reason in our case. Appropriate lead positions were confirmed with fluoroscopy, echocardiography and a CT scan. Further, both the leads had normal sensing and pacing parameters.

Peculiarly, under sensing of the P wave was noticed on telemetry to be happening at regular intervals of around 90 seconds. The answer lied in understanding the pacemaker algorithms designed to detect atrial tachyarrhythmias. Multiple algorithms (Table 1) effect an appropriate pacemaker mode switch during episodes of atrial tachyarrhythmias to prevent tracking of high atrial rates. Atrial tachycardia with 2:1 atrioventricular conduction poses a special challenge for tachycardia detection and mode switch. Due to alternate tachycardia P waves lying in the post ventricular atrial blanking period (Figure 2A), the pacemaker is unable to distinguish this from 1:1 conduction of sinus tachycardia.

Blanked flutter search is an algorithm designed to unmask atrial tachyarrhythmia in such a situation. The algorithm is activated when (1) cycle lengths of eight consecutive tracked atrial sensed events are less than twice the sum of atrioventricular delay and post-ventricular atrial blanking period, and (2) twice the sensed atrial rate is higher than the programmed tachycardia detection rate.[4] The algorithm then prolongs the post-ventricular atrial refractory period for next cycle, so that the next atrial event lies in refractory period and is not tracked. During an episode of atrial tachyarrhythmia with 2:1 conduction, the formerly blanked atrial activation will now no longer coincide with a blanking period, thereby unmasking atrial arrhythmia and initiating mode switch. If no atrial tachyarrhythmia is detected by the pacemaker, normal pacing resumes (Figure 2B). The algorithm checks again for atrial tachyarrhythmia after a set interval. The algorithm however, may operate during sinus tachycardia, leading to undersensing of a P wave at regular intervals,

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as in the present case. Another disadvantage is that mode switch can be triggered erroneously if an atrial premature beat occurs by chance during this period.[4] Thus, for interpreting abnormal electrocardiograms after pacemaker implant, knowledge of various pacemaker algorithms is essential to avoid misinterpretation as pacemaker malfunction.

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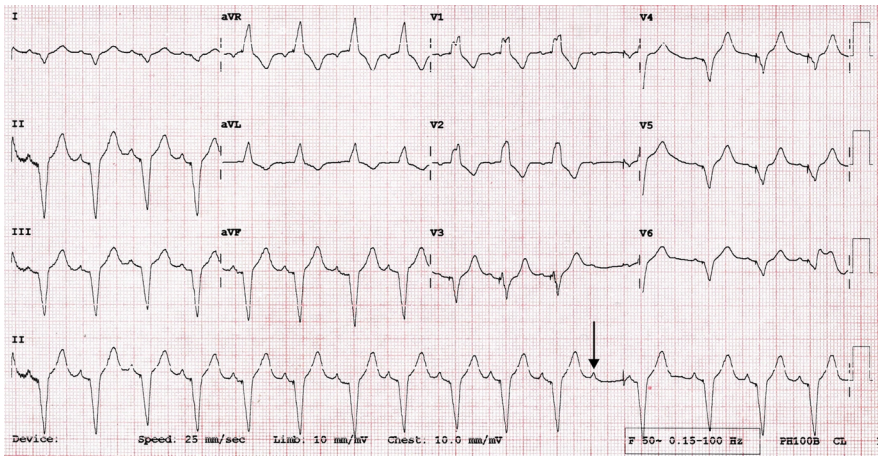
Figure 1. The 12-lead ECG recorded immediately after dual chamber permanent pacemaker implantation.



There is absence of a paced QRS complex after the 12^{th}P wave (arrow) in the rhythm strip lead II, followed by an atrial paced P wave and ventricular paced QRS complex.

Figure 2. A. Diagrammatic representation of 2:1 atrial tachycardia. B. Details of the electric circuit in a ladder diagram.

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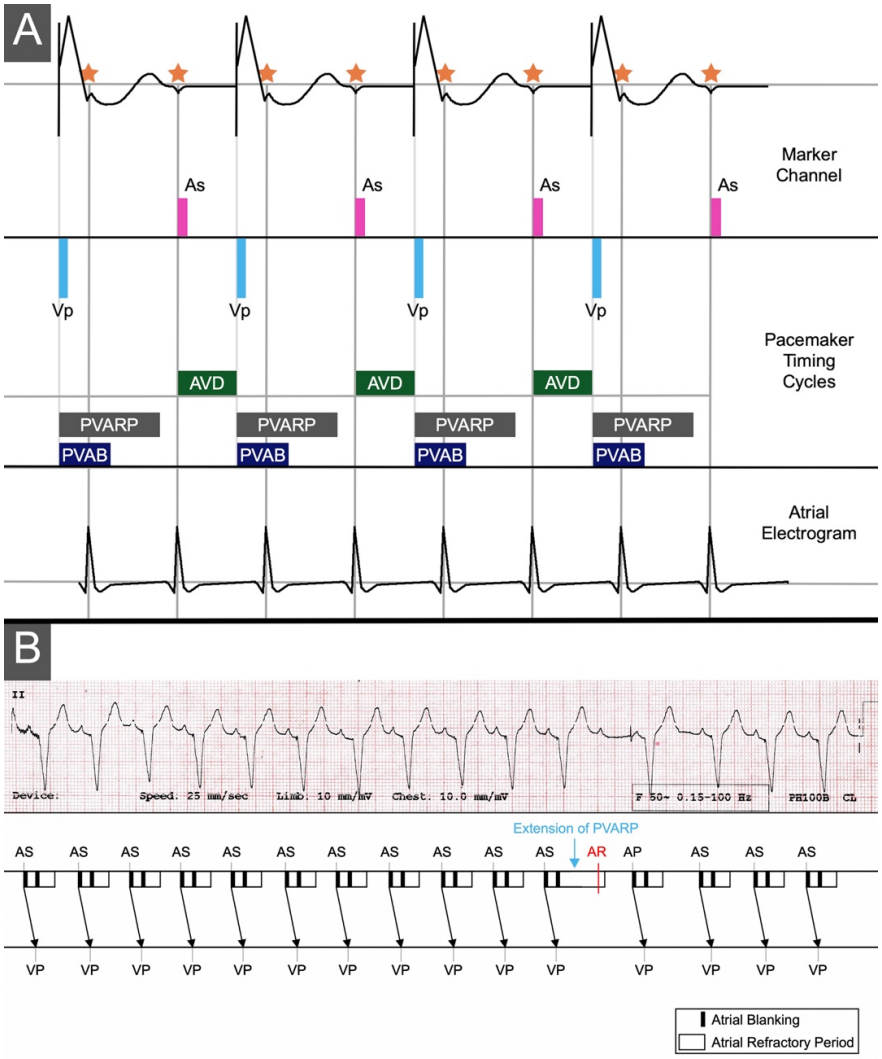

A. Every alternate P wave (orange star) falls in the blanking period. PVARP represents post ventricular atrial refractory period; PVAB, post ventricular atrial blanking; AVD, atrioventricular delay; Vp, ventricular paced; As, atrial sensed. **B.** Depiction of ECG lead II in our patient, where blanked flutter search algorithm increased the PVARP for one cycle leading to the dropped beat. AS indicates atrial sensed event; VP, ventricular paced; AR, atrial refractory; PVARP, post ventricular atrial refractory period.

Table 1. Supplemental algorithms (in addition to atrial rate cut-off) for detection of atrial flutter by different manufacturers to affect an appropriate automated mode switch.

Supplemental algorithms (in addition to atrial rate cut-off) for detection of atrial flutter by different manufacturers to affect an appropriate automated mode switch

Manufacturer	Algorithm

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Medtronic	**Blanked Flutter Search** When set criteria are fulfilled, it prolongs the PVARP for one cycle, so that the next atrial events lie in the refractory period and true atrial rate can be detected. It is useful in situations where every alternate beat falls in the blanking period
Boston Scientific	**Atrial Flutter Response** It is operational only when atrial events are detected in PVARP. The algorithm increases the refractory period by a programmable duration for every atrial event that is sensed in the refractory period, so that high rates are not tracked. If atrial events continue to be sensed with every extension of the refractory period, ventricular pacing occurs at the lower set rate, and mode switch is initiated. It is not useful when every alternate beat falls in the blanking period.
Biotronik	**2:1 Lock-in Protection** When the suspicion criteria are met, the atrioventricular delay is increased by the a programmed interval. If the event sensed in this window moves with the ventricular paced event, it is cross-talk. However, if it does not move with the ventricular paced event when the atrioventricular delay is extended, it is an intrinsic atrial event, and mode switch is initiated. It is useful in situations where every alternate beat falls in the blanking period.
Abbott	**Filtered Atrial Rate Interval** (No specific algorithm for flutter) The device measures the current PP interval for each beat and calculates a filtered atrial rate interval (FARI). P waves falling in the PVARP followed by atrial sensing are taken into account when calculating the FARI and mode switch occurs when FARI is less than the atrial tachycardia detection interval. It is not useful when every alternate beat falls in the blanking period.

PVARP indicates post ventricular atrial refractory period; FARI, filtered atrial rate interval.

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