CASE REPORT

Incessant atrioventricular dissociation due to far-field QRS oversensing and recurrent mode switch in a dual chamber pacemaker

P. Maury, J. Schlaepfer, M. Arbane, G. Girod and L. Kappenberger

Division of Cardiology, University Hospital, Lausanne, Switzerland

We report the case of a repetitive and incessant activation of mode switch in a dual chamber pacemaker because of the inappropriate sensing by the atrial lead of far-fields signals from the ventricular evoked response. The incidence, consequences and prevention of the oversensing of far-field QRS complexes are discussed.

Case Report

A 65-year-old man was implanted with a dual chamber pacemaker (Inos® CLS/DR, Biotronik GmbH, Berlin, Germany) for permanent high grade atrio-ventricular block, using a bipolar screw-in lead (Medtronic 4068, Medtronic Inc., Minneapolis, MN, U.S.A.) in the right atrial appendage and a unipolar tined lead (Biotronik Px-60-UP) in the right ventricle apex. The atrial parameters were found acceptable post-implant (threshold 1 V/0·4 ms, P wave 3·5 mV, impedance 474 Ohms).

Four months later, the patient underwent a coronary artery by-pass. In the early postoperative stage, atrial sensitivity was increased to 0·5 mV because of intermittent loss of detection leading to haemodynamic problems. At discharge, the atrial pacing and sensing parameters were satisfactory (threshold 1·2 V/0·4 ms, P wave 2·5 mV, impedance 341 Ohms) and DDD mode, with automatic mode switching (threshold rate: 170 bpm=350 ms), using an atrial output of 3 V/0·5 ms and bipolar atrial sensing at 0·5 mV was programmed. Atrial oversensing was not observed during myopotential provocative tests.

During treadmill exercise at the first rehabilitation, the patient suffered symptomatic AV dissociation (sinus tachycardia 150 bpm together with ventricular pacing at the basic rate). Pacemaker parameters were found comparable with those measured at discharge. Spontaneous and incessant conversion from DDD to asynchronous ventricular pacing mode with rate smoothing were observed, followed by sudden accelerations of the ventricular rate due to conversion back to DDD mode (Fig. 1).

No displacement of the atrial lead was noted on X ray, and atrial undersensing was excluded by the absence of any atrial paced beat. An hypothesis was raised to explain multiple and recurrent episodes of mode switching[1] which was confirmed by telemetric interrogation of the Holter memory of the device. This showed a bimodal distribution of atrial rate histograms (90–100 bpm and >150 bpm) and incessant mode switches during the previous 24 h. As no precipitating arrhythmia was documented during these incessant mode switches, oversensing in the atrial channel was suspected. Electrical noise due to lead damage, electromagnetic interference, abnormal sensing of myopotentials or of T waves were excluded because of the absence of diastolic potentials on the intracardiac electrogram (EGM), and the lack of tracked ventricular paced beats before switching. Detection of retrograde P waves was ruled out on the surface ECG and was considered unlikely due to the short AV delay, the constant atrial capture and the correct P wave.
The definitive answer was given by analysis of the marker channel together with the atrial and ventricular EGMs and the surface ECG: the end of each evoked ventricular response was sensed by the atrial lead just outside the 100 ms post-ventricular atrial blanking period\[2\] (Fig. 2). This event, detected inside the post-ventricular atrial refractory period, did not induce pacemaker mediated tachycardia, but led to automatic switching to VDI mode when five of eight consecutive atrial sensed intervals were shorter than the 350 ms-programmed threshold interval\[2\] (interval from the sensed P wave to the sensed QRS far-field signal=260 ms and interval from the sensed far-field to the next sensed P wave=350 ms when the sinus rate was 98 bpm, Fig. 2).

Once rate smoothing reduced the ventricular paced rate to around 65 bpm, switch back to DDD mode occurred, as eight successive ‘atrial’ sensed intervals were longer than the 350 ms threshold interval\[2\]. Exact reasons for this switch back could not be clarified because of the automatic deactivation of mode switching during telemetry, so that only an hypothesis can be

Figure 1 Spontaneous conversion from desynchronized ventricular pacing to DDD mode immediately followed by switching back to ventricular pacing, as documented on a 3 leads-surface ECG strip printed by the Biotronik programmer. (A) ventricular paced rate is 65 bpm, sinus rate is 110 bpm. (B) DDD mode reoccurs suddenly. (C) the pacemaker switches again automatically to ventricular asynchronous mode (see text for explanation). P: distinguishable P waves.

Figure 2 Marker channel (upper tracing), surface ECG (second tracing), atrial and ventricular EGM (bottom tracings) on Biotronik-programmer print out. With an atrial sensitivity of 0.5 mV, the end of each ventricular evoked response is visible on the atrial EGM and is oversensed by the atrial channel around 100 ms after the ventricular stimulus (arrows), so that atrial tachyarrhythmia is diagnosed by the device (As: atrial sensed event; Ars: atrial refractory sensed event; Vp: ventricular paced event) (note that switching mode is automatically deactivated during telemetry).
proposed for this phenomenon: intermittent oversensing, decrease of the sinus rate, randomly appropriate AV dissociation (with some P waves covered by the 35 ms post-ventricular atrial blanking period during VDI mode[2]) or rate-dependent improvement in intraventricular conduction leading to appropriate modification of the timing or signal characteristics in the atrial channel.

After reprogramming the atrial sensitivity (1 mV) (Fig. 3), neither atrial oversensing nor mode switching were observed, AV association was preserved, and the patient became asymptomatic.

Discussion

Disorders of pacemaker function due to sensing of the QRS through atrial leads have long been recognized[3–6]. This phenomenon is classically described in atrial single chamber pacemakers, and leads to P wave undersensing, to inappropriate decrease in the pacing rate in AAI or AAIR mode or to pacemaker-mediated tachycardia in AAT mode[6,7]. These problems are more rarely encountered in modern dual chamber pacemakers, because of the atrial blanking and refractory periods automatically added after each ventricular spontaneous or paced event and because of the common use of bipolar atrial leads[6].

Anecdotal cases of pacemaker mediated tachycardias have been reported when the timing of inappropriate detection is sufficiently delayed[3,4,5,7].

Most DDD pacemakers actually detect intrinsic R waves in the atrium at the highest sensitivity[8]. Spontaneous or post-paced far-field ventricular signals from unipolar or bipolar atrial leads can be recorded during peroperative implant procedures in all patients[9]. Far-field QRS are oversensed in one third of patients implanted with DDD pacemakers using unipolar atrial leads and high atrial sensitivities (0·7 mV), but prevalence is decreased with reduced sensitivities (only 2% with 2 mV)[6,10]. Mean far-field QRS amplitudes of 0·9 to 1·6 mV and of 0·3 to 0·6 mV have been reported using unipolar and bipolar atrial leads respectively[6,9]. Evoked R waves can be detected in bipolar atrial leads outside the 100 ms-blanking period in half of Medtronic DDD pacemakers set at maximal sensitivity (<0·5 mV), but in only 4% with a setting of 1 mV or more[8].

In a recent study including patients implanted with Biotronik Actros and bipolar atrial leads in the right appendage, QRS sensing occurred in all patients programmed at maximum atrial sensitivity (0·1 mV) after paced, spontaneous or fusion complexes, but was virtually absent with a sensitivity ≥0·5 mV, the median sensing threshold being around 0·2–0·3 mV. The window of detection was centered around 120 ms after the ventricular stimulus and around 50 ms after normally conducted ventricular beats[6,11], conducted beats, sometimes, even being sensed by the atrial channel during the spontaneous AV delay[6,11], since ventricular activation begins closer to the base of the heart than to the apex in these cases. Far-field signals from intrinsic ventricular depolarization can be detected in only a minority of VDD pacemakers, but these are as susceptible as other dual chamber devices to ventricular paced beats[8].

Apart from pacemaker mediated tachycardias or apparent atrial undersensing[5,7], various potential consequences of far-field QRS oversensing may be encountered in dual chamber pacemakers.

First, atrial oversensing can lead to AV dissociation due to automatic mode switch[1,6] which is frequently programmed in modern dual chamber pacemakers, because of a 30 to 60% incidence of paroxysmal atrial...
fibrillation in implanted patients\textsuperscript{[2]}. Moreover, high sensitivities (<0.5 or 1 mV) are used for reliable and fast detection of atrial fibrillation\textsuperscript{[1,2,6]}. Inadequate activation of mode switching is usually due to far-field sensing of ventricular depolarization\textsuperscript{[1]}. Mode switch was shown to be inappropriate in 12 to 32\% of patients predominantly due to far-field or near-field (e.g. end of the spontaneous or paced P wave) oversensing\textsuperscript{[11]}. Such inappropriate mode switch is a rather common phenomenon when a high sensitivity is programmed (i.e. 0.5 mV)\textsuperscript{[1]}. If far-field QRS oversensing is present in every cycle, the pacemaker will inevitably and repetitively switch to non-tracking mode\textsuperscript{[2]} as in our case. Also in the Vitatron Saphir single-lead VDD, oversensing of ventricular far-fields potentials 150 to 200 ms after the ventricular stimulus is documented in half of the cases and result in inappropriate mode switch and AV asynchrony when high sensitivity settings (i.e. 0-1 mV) are used\textsuperscript{[12]}.

Second, because the newer generations of implantable pacemakers offer the possibility to study the occurrence of asymptomatic episodes of atrial tachyarrhythmias and the impact of drugs or electrical prevention\textsuperscript{[11]}, many studies have recently been published attempting to define the rate and characteristics of atrial oversensing and to quantify the risk of false detection. Detections of far-field or near-field signals have been reported to occur in 1 to 40\% of patients and could lead to inappropriate detection of high rate atrial episodes in 11\%\textsuperscript{[11]}. However, in a recent study with the Medtronic Thera DDD pacemaker, only 1-5\% of more than 1600 episodes were classified as far-field or near-field oversensing\textsuperscript{[11]}.

False detection, furthermore, carries the risk of induced atrial fibrillation if inappropriate atrial pacing is delivered\textsuperscript{[11]}.

Third, sensing of far-field QRS may also influence various algorithms used for automatic adjustment of atrial sensitivity, detection of retrograde conduction or reduction of induced pacemaker mediated tachycardia\textsuperscript{[9]}. Timing of retrograde P waves is usually delayed compared with the sensed far-field QRS, but may vary according to patients specific characteristics and to the autonomic nervous system\textsuperscript{[9]}, while far-field ventricular signals can also be delayed\textsuperscript{[12]}.

Appropriate manoeuvres to correct far-field QRS oversensing can be applied in many steps, if deactivation or changes in automatic switching mode or antitachycardia algorithm settings, or DDI programming are not desired.

1. During the implant procedure, the atrial lead should be better placed in a lateral position, rather than in the atrial septum, right appendage, low right atrium or coronary sinus\textsuperscript{[6,9]}. Furthermore, the possibility of oversensing should be checked. Amplitudes of far-field QRS signals are lower in the lateral position, while atrial leads overlap ventricular tissue in the right appendage\textsuperscript{[6,11]}, although atrial amplitudes and slew-rates are shown to be higher than far-field QRS in this location\textsuperscript{[9,14]}. On the other hand, intra-cardiac amplitude of the atrial signal is not indicative of the future occurrence of the phenomenon\textsuperscript{[10]}.

2. Use of bipolar atrial sensing lead and configuration is highly recommended because of lower far-field QRS amplitudes and slew-rates which decrease the risk of detection\textsuperscript{[2,6,9,13]}, as does a short interelectrode spacing\textsuperscript{[6]}.

3. Programming of atrial sensitivity should be selected with attention to P waves and to the potential for atrial arrhythmias (e.g. the highest atrial sensitivity level without evidence of myopotential oversensing during provocative tests and without cross-talk during transient high output ventricular pacing)\textsuperscript{[1,2,5,15]}. Since far-field signals are usually of smaller amplitude and of lower slew-rate than atrial deflections\textsuperscript{[9]}, adequate atrial sensitivity can eliminate the problem in the majority of cases, otherwise other programme adjustments may be needed\textsuperscript{[5,10]}.

4. Early oversensing occurring in the AV delay can be avoided by shortening the interval (so that ventricular pacing occurs before termination of atrial blanking) or by increasing the ventricular sensitivity (earlier sensing by the ventricular lead)\textsuperscript{[11]}.

5. Far-field QRS sensing is promoted by short atrial blanking periodic\textsuperscript{[11]}, which are usually non-programmable or depend on pacing output\textsuperscript{[5,11]}. Increasing the ventricular output in Medtronic Thera is therefore a means of triggering a longer blanking\textsuperscript{[11]}, and could be used for covering the longer far-field signal duration observed in case of a large amplitude QRS\textsuperscript{[9]}. 150 ms blanking values would eliminate most far-field QRS sensing in Biotronik Actros using 0.5 mV sensitivity setting, but this would decrease the sensitivity of arrhythmia detection\textsuperscript{[6]}.

In Biotronik Inos, programming short atrial blanking periods, used to avoid undersensing of some arrhythmias, are possible due to use of low polarization leads and to the high quality sensing amplifier\textsuperscript{[13]}, however this was not enough to avoid QRS oversensing in our case.

6. Slew-rates of atrially sensed QRS are lower than those of P waves in uni or bipolar configuration\textsuperscript{[6,9]} and could therefore be used in a more discriminant algorithm. However, whether this differentiation applies to atrial arrhythmias is unknown\textsuperscript{[9]}. Finally, differential bipolar sensing\textsuperscript{[6,10]}, analysis of spectral content\textsuperscript{[12]}, new morphology-based algorithms, waveform analysis and advanced signal processing techniques might allow better discrimination between P waves and far-field R waves\textsuperscript{[15]}.

**References**


