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A devices' game of thrones: cardiac resynchronization therapy vs. pacemaker

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Aims Oversensing can interfere with biventricular pacing. Cardiac Resynchronization Therapy (CRT) output inhibition due to automatic brady mode change from a sensing to a pacing mode of a previously implanted pacemaker as it reached battery capacity depleted indicator has not been previously published in the medical literature.

Methods and results We report the first case of CRT output inhibition in a pacemaker dependent patient due to electrical stimuli from a previously right-sided implanted pacemaker, after unaware reversion of OVO mode (O = no chambers paced; V = ventricular sensing; O = no response to sensing) to backup VVI (V = ventricular pacing; V = ventricular sensing; I = inhibitory response to sensing) when it reached the elective replacement interval.

Conclusion This paper emphasizes the importance of knowing the distinct pacemaker brady mode behaviours after battery capacity depleted indicator has been reached, according to the pacemakers' manufacturer, including the possibility of automatic brady mode change from sensing to pacing mode. It also highlights the potential for severe bradycardia or asystole of this automatic brady mode change from a previously implanted pacemaker in pacemaker dependent patients submitted to CRT upgrade.

Keywords Troubleshooting • Cardiac pacing • Biventricular pacing • Cardiac resynchronization • Implantable cardioverter defibrillator

Introduction

Oversensing, defined as the failure of a pacemaker to deliver a programmed stimulus due to sensing of unwanted signals, can interfere with biventricular pacing. It is commonly caused by electrical noise, physiological cardiac electrical potentials (atrial depolarization or ventricular repolarization), electromagnetic interference or skeletal myopotentials.[1]

This is the first case report of CRT output inhibition in a pacemaker dependent patient due to electrical stimuli from a previously right-sided implanted pacemaker, after unaware automatic reversion of OVO mode (O = no chambers paced; V = ventricular sensing; O = no response to sensing) to backup VVI (V = ventricular pacing; V = ventricular sensing; I = inhibitory response to sensing), when it reached the elective replacement interval (ERI).

Case report

In 2006, a 67-year-old man with chronic kidney disease (creatinine clearance 44 mL/min/1.73 m^2), type 2 diabetes mellitus, hypertension, and dyslipidaemia underwent uncomplicated right-sided implantation of an Adapta D pacemaker (Medtronic) due to complete heart block, incorporating a passive fixation lead (5592, Medtronic) in the right atrial appendage and a passive fixation lead (5092, Medtronic) in the right ventricular (RV) apical position.

In September 2014, the patient was hospitalized due to symptomatic polymorphic ventricular tachycardia associated with refractory non-ischaemic heart failure [left ventricular (LV) ejection fraction = 34%, New York Heart Association class III]. He was up-graded to a Quadra Assura MP (St. Jude Medical) Cardiac Resynchronization Therapy-Defibrillator

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What's new?

- First case report of Cardiac Resynchronization Therapy (CRT) output inhibition due to automatic brady mode change, from a sensing to a pacing mode, of a previously implanted pacemaker as it reached the elective replacement interval (ERI).
- Potential for severe bradycardia or asystole of the automatic brady mode reversion from a sensing to pacing mode of a previously implanted pacemaker as it reaches ERI, in pacemaker dependent patients submitted to CRT upgrade procedure.
- Importance of understanding the various pacemaker's brady mode behaviours after ERI when deciding to leave in place a previously implanted pacemaker in pacemaker dependent patients with an increased risk for infectious complications undergoing a CRT upgrade procedure.

(CRT-D) device (left side implantation): a bipolar RV lead (7121Q-65, St. Jude Medical) was placed at the apex; a quadripolar LV lead (Quartet 1458Q, St. Jude Medical) was implanted in a lateral coronary vein and a bipolar atrial lead (1944-52, St. Jude Medical) was positioned in the RAA. The device was programmed in the bipolar DDDR mode. As it was a long CRT upgrade procedure in a patient with an increased risk for infectious complications, it was decided to leave in place the pacemaker device previously implanted, programming it in OVO mode.

Subsequent routine follow-up evaluation was unremarkable, with normalization of LV ejection fraction. In April 2016, the patient presented to the clinic with a 48-h history of severe dizziness and presyncope. CRT-D interrogation showed a recent marked loss of biventricular pacing, although the percentage of biventricular pacing was globally high (96%) and similar to previous follow-up evaluations (*Figure 1*). Further CRT-D interrogation revealed adequate right atrial, as well as right and left ventricular leads impedance, capture and sensing thresholds (*Table 1*). Provocative manoeuvres did not induce myopotential pacing inhibition and chest X-ray confirmed stable position of all leads.

Device telemetry demonstrated pacemaker output inhibition, with complete loss of biventricular pacing and evidence of atrioventricular dissociation (*Figure 2*). Monitoring of intracardiac electrograms showed pacemaker ventricular sensing of two electrical stimuli, both morphologically distinct from each other and from those recorded with biventricular pacing: the high-amplitude (>12 mV) potential was recorded in both ventricular leads and the low-amplitude (1.3 mV) was only recorded in the right ventricular lead. Both sensed stimuli had a right ventricular origin and had no relationship with the atrial potential, excluding atrial farfield oversensing as a source of biventricular pacing inhibition. Importantly, there was a striking regular interval between the two ventricular sensed electrical potentials, without beat to beat variation (average frequency of 65 bpm). This raised the possibility of CRT-D output inhibition due to electrical stimuli from the previously implanted pacemaker. Therefore, Adapta D pacemaker (Medtronic) was interrogated, confirming reversion of OVO mode to backup VVI at 65 bpm, as the device reached ERI, with intermittent ventricular capture of the pacing stimuli, causing severe symptomatic bradycardia (average ventricular frequency of 32 bpm). Importantly, after battery capacity depletion is indicated, Autocapture (algorithm for automatic adaptation of ventricular output to capture threshold) is immediately switched off, allowing persistent ventricular capture failure and therefore increasing the risk of severe bradycardia or asystole in pacemaker dependent patients under these circumstances. As switching off or programming the device back to OVO mode was not possible, pacemaker generator removal was decided on, ending CRT-D output inhibition.

Discussion

The authors present the first report of CRT-D output inhibition in a pacemaker dependent patient due to electrical stimuli from a previously right-sided implanted pacemaker, after unaware automatic reversion of OVO mode to backup VVI at 65 bpm, as it reached the ERI.

It is reasonable to keep a previously right-sided implanted pacemaker in place (by switching off the device or programming it in sensing mode) in patients undergoing a CRT upgrade procedure, mainly when the risk of infectious complications is significantly increased. When considering this hypothesis, it is fundamental to understand the pacemaker's brady mode behaviour after the battery capacity depleted indicator has been reached, as it is distinct according to the device's manufacturer (*Table 2*). This is especially important in

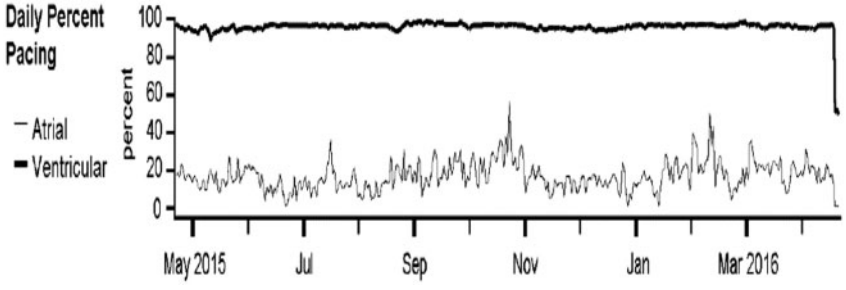


Figure 1 CRT-D interrogation showing a recent and abrupt marked loss of biventricular pacing.

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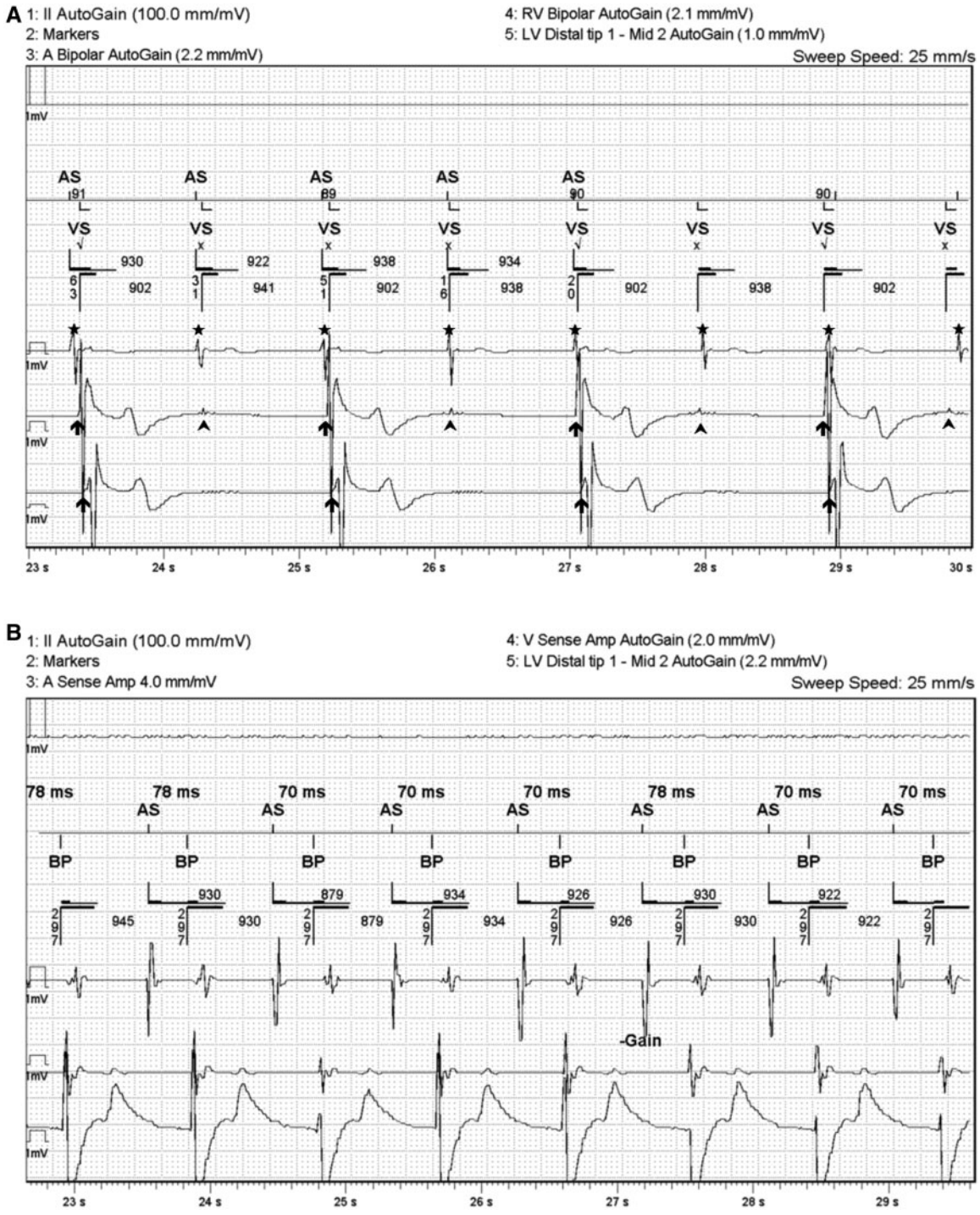


Figure 2 CRT-D intracardiac electrograms. (*A*) Two right-ventricular electrical stimuli, both morphologically distinct from each other and from those recorded with biventricular pacing: a high-amplitude potential recorded in both ventricular leads, corresponding to the capturing RV pacing stimulus (labelled as ↑) and a low-amplitude potential only recorded in the right ventricular lead, corresponding to the non-captured RV pacing stimulus (labelled as). There is a regular interval between these electrical potentials, with no beat to beat variation (average frequency of 65 bpm). As safety pacing was not active, there are no spikes from the CRT device after the sensed ventricular events. Atrioventricular dissociation is also noticeable, with lack of atrial sensing as the atrial signal (labelled as ★) falls further behind the sensed ventricular signal, presumably into the post-ventricular atrial blanking period (last three atrial signals). (*B*) Previous follow-up intracardiac electrogram, showing the morphology of the ventricular potential with biventricular pacing, distinct from the two ventricular electrical stimuli depicted in *A*.

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Table 1 Programmed and measured CRT-D lead parameters

Parameter	Value
Mode	DDD
Lower rate limit	65
Upper tracking rate	120
Atrial lead capture output	1.5 V (threshold 0.5 V at 0.5 ms)
Atrial lead sensing value	Auto (minimum 0.3 mV); P wave 3.7 mV
Atrial lead impedance	530 Ohms
Senseability settings	Auto (maximum 0.3 mV)
Right ventricular lead capture output	2 V (1.0 V threshold V at 0.4 ms)
Right ventricular lead impedance	360 Ohms
Left ventricular lead capture output	2.25 V (threshold 1.0 V at 0.4 ms
Left ventricular lead impedance	410 Ohms
Ventricular lead sensing value	1.3 – >12.0 mV
Paced atrioventricular delay	180 ms
Sensed atrioventricular delay	110 ms
Post-ventricular atrial refractory period	275 ms
Biventricular pacing	96%

pacemaker dependent patients. In fact, the possibility of automatic reversion of a previously implanted pacemaker from a non-pacing mode to VVI, as the battery capacity depleted indicator has been reached, can inadvertently inhibit the CRT if the VVI mode pacing frequency is equal or higher than that programmed for the CRT. Furthermore, the electrical potential provided by the previously implanted pacemaker device may not be adequate to sustainably stimulate the ventricles, putting a pacemaker dependent patient at an increased risk of severe bradycardia or asystole, as shown in this case report. In this way, when deciding to leave in place a previously implanted pacemaker in pacemaker dependent patients undergoing a CRT upgrade procedure, time remaining to battery depletion should always be considered and, in devices with automatic brady mode change from a sensing to a pacing mode, decision to proceed to pacemaker generator removal as ERI approaches should be taken, although an increased risk for infectious complications may exist.

Finally, the authors would like to pose an open question to device manufacturers about the divergent end-of-life behaviour of their pacemakers. In our opinion, it would make sense to standardize end-of life behaviour of pacemakers, not forcing removal of devices to avoid asynchronous pacing as they reach ERI. Alternatively, in similar situations, right-sided CRT implants could be considered, although they provide a less advantageous defibrillation vector and the implantation procedure is more challenging.

Table 2 Brady mode behaviour prior and after battery capacity depleted indicator

Brady mode prior to battery capacity depleted indicator	Brady mode after battery capacity depleted indicator
Medtronic	
Adapta DR[2], Adapta DR Large[2]; Adapta SR[2]; Ensura SR MRI[3], Ensura DR MRI[3]	
DDD(R), DDI(R), VDD(R), VVI(R)	VVI at 65 per minute, with output as previously programmed.
AAI(R)	
ODO, OVO, OAO	
DOO, VOO	
AOO	
Livanova	
Kora 250 SR MRI[4], Kora 250 DR MRI[5], Reply 200 SR[6], Reply 200 DR[7]	
DDD(R), DDI(R), VDD(R), VVI(R)	VVI at 70 per minute, with output as previously programmed.
AAI(R)	
ODO, OVO, OAO	
DOO, VOO	
AOO	
St. Jude Medical	
Assurity SR MRI, Assurity DR MRI, Endurity SR, Endurity DR[8]	
DDD(R), DDI(R), VDD(R), VVI(R)	No brady mode change; increase of the pacing interval by 100 ms over the Base Rate to reduce current drain.
AAI(R)	
Off	
DOO, VOO	
AOO	
Boston Scientific	

Continued

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Table 2 *Continued*

Brady mode prior to battery capacity depleted indicator	Brady mode after battery capacity depleted indicator
Advantio SR MRI, Advantio DR MRI, Ingenio SR MRI, Ingenio DR MRI, Proponent SR MRI, Proponent DR MRI, Essentio SR MRI, Essentio DR MRI[9]	
DDD(R), DDI(R), VDD(R), VVI(R)	VVI (Lower Rate Limit of 50 per minute)
AAI(R)	AAI (Lower Rate Limit of 50 per minute)
Off	Off
DOO, VOO	VOO (Lower Rate Limit of 50 per minute)
AOO	AOO (Lower Rate Limit of 50 per minute)

Conclusions

This is the first report of CRT-D output inhibition due to automatic brady mode change of a previously implanted pacemaker as it reached battery capacity depleted indicator from a sensing to a pacing mode, highlighting the potential for severe bradycardia or asystole in pacemaker dependent patients.

Conflict of interest: none declared.

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