DEVICE THERAPY

COMPLEX CASE STUDY

Inappropriate Shock Delivery from a Biotronik CRT-D Due to Supraventricular Tachycardia

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ABSTRACT. In this case, a native atrial event was identified as an atrial sensed event in the refractory period; atrial pacing was delivered shortly after the event. An atrial refractory sensed event had occurred, because in Biotronik devices with atrial based timing an atrial event occurring within the refractory period does not affect the pacemaker timing when the device operates in non-atrial tracking (DDI) mode, including the first cycle after mode switching. The lower rate interval and the atrioventricular delay are not restarted. This means that the atrial channel remains refractory during the entire lower rate interval.

KEYWORDS. atrial arrhythmias, cardiac pacing, implantable defibrillation therapy, supraventricular tachycardias.

Case presentation

A 69-year-old male with a cardiac resynchronization therapy defibrillator (CRT-D) (Lumax 740, Biotronik, Berlin, Germany) implanted for New York Heart Association (NYHA) III functional class heart failure with left ventricular ejection fraction 30\% and primary prevention of sudden cardiac death was admitted to our clinic because of multiple defibrillator shocks. Device interrogation showed a properly functioning CRT-D programmed with a single ventricular fibrillation (VF) detection zone (detection cycle length 350 ms). The patient’s intrinsic rhythm was sinus with complete left bundle branch block (LBBB). Programmed pacing parameters are shown in Figure 1; atrial sensing and pacing thresholds were in their normal range. Atrial sensing was programmed to 0.3 mV.

The tracing on Figure 2 shows a brief automatic mode switch (AMS) episode caused by far-field R wave (FFRW) sensing in the atrial channel (Figure 2). A unique phenomenon was registered at the time of mode switch back to the DDD mode. The subsequent atrial event was marked as an atrial refractory sensed event (Ars, “A” on Figure 2), and an atrial pace (AP) was delivered at the programmed lower rate of 800 ms after the previous Ars (“B” on Figure 2). The Ars was conducted with normal PR interval, most likely over a fast pathway (“C” on Figure 2) and captured right ventricular (RV) myocardium (because of LBBB). The subsequent short-coupled atrial paced event (“B” on Figure 2) was conducted with a longer PR interval, initiating a short VA interval supraventricular tachycardia (SVT) (“D” on Figure 2). The VA interval less than 70 ms favored atrioventricular nodal re-entrant tachycardia, although an atrial tachycardia utilizing a slow atrioventricular pathway could not be ruled out. The ventricular activation following the Ars was detected first on the RV channel (“E” on Figure 2), whereafter a ventricular pace (“F” on Figure 2) was invoked by the AP. Ventricular pacing artifact on the RV channel (“F” on Figure 2) did not capture the myocardium because the myocardium was still refractory. The pacing artifact on the left ventricular (LV) channel coincided with the beginning of the conducted ventricular event, resulting in a pseudo fusion beat (“G” on Figure 2). Local LV capture by LV pacing spike, fused with delayed LV activation over the interventricular septum due to LBBB is also possible, as the morphology of evoked potential after this particular LV pacing artifact differs slightly from the preceding ones.
The tachycardia was detected in the VF zone. The initial inappropriate shock induced fast ventricular tachycardia, resulting in multiple appropriate shocks.

**Discussion**

This case demonstrated unique resolution of AMS, where the algorithm itself induced tachycardia. In this case, a native atrial event marked as an atrial sensed event in the refractory period; atrial pacing was delivered shortly after the event. An Ars occurred because in Biotronik devices with atrial based timing an atrial event occurring within the refractory period does not affect the pacemaker timing when the device operates in non-atrial tracking (DDI) mode, including the first cycle after mode switching. The lower rate interval and the atrioventricular delay are not restarted. This means that the atrial channel remains refractory during the entire lower rate interval.

The fact that FFRW sensing can induce inappropriate AMS is well known. Individual adjustment of post ventricular atrial blanking (VAB) significantly reduces the incidence of inappropriate AMS due to FFRW sensing compared with nominal post-VAB programming. Far-field blanking (FFB) can also be modified, but

![Figure 1: Programmed pacing parameters.](image1)

![Figure 2: The tracing shows inappropriate automatic mode switch (AMS) due to far-field R wave sensing.](image2)

At the beginning of the strip, the pacing mode is DDI. Right ventricular sensing and left ventricular (LV) pacing were recorded in ventricular channels (VV delay after right ventricular channels (RVs) were programmed to 0 ms, Figure 1). Then the DDI mode is switched back to DDD due to fulfillment of the AMS criteria. The subsequent atrial event was marked as an atrial refractory sensed event (Ars) (“A”) and an atrial pace (AP) was delivered at the programmed lower rate: 800 ms after the previous Ars (“B”). The Ars has been conducted (“C”). The subsequent short-coupled atrial paced event (“B’”) was conducted with a longer PR interval, initiating a short VA interval supraventricular tachycardia (“D”). The ventricular activation following the Ars was detected first on the right ventricular channel (“E”), whereafter a ventricular pace (“F”) was invoked by the AP. The pacing artifact on the LV channel coincided with the beginning of the conducted ventricular event, resulting in a pseudo fusion beat (“G”) or local LV capture.
it is advisable to increase it cautiously, just to eliminate the FFRW sensing on the intracardiac electrogram (EGM), as extended FFB may cause undersensing of actual atrial events.\(^3\) It is very important to program the post ventricular atrial refractory period (PVARP) less than 250 ms in CRT devices, to minimize the shift of the sinus P wave into the PVARP during sinus tachycardia.\(^4\) Also, the PVARP extension feature may result in a loss of biventricular capture.\(^4\) Biotronik offers a far-field protection algorithm. St. Jude devices have not only post-VAB for ventricular oversensing in the AS channel but also a pre-VAB period that provides extra protection from ventricular oversensing. This can happen due to atrial oversensing of the large ventricular evoked response before its detection on the ventricular channel as a ventricular paced event.\(^3\)

**Conclusion**

Inappropriate shock was delivered by a Biotronik CRT-D due to paroxysmal SVT triggered by automatic mode switching, which was caused by FFRW sensing during biventricular pacing.

Suggestions to prevent FFRW sensing are the following:

a. Extend the post-VAB interval (which can compromise detection of atrial events).

b. Decrease atrial sensitivity (but insure adequate intrinsic signal amplitude in sinus rhythm and that FFRW sensing is absent during LV pacing, biventricular pacing, and sensed ventricular (VS) events).

c. To avoid sensing of the ventricular stimulus artifact on the atrial channel, determine if it occurs during high-output pacing and program to the minimum required output, ideally with the auto-capture feature turned on.

d. Change the sensing polarity of the atrial lead.

e. Avoid positioning of the atrial lead in the anterior aspect of the right atrial appendage.

Suggestions to prevent inappropriate shocks due to detection of rapidly conducted SVT in the VF zone are the following:

a. Consider slow pathway or atrial focal ablation in cases similar to the presented one.

b. Narrow VF detection zone may be narrowed. Recent studies have shown that shock reduction by setting a higher VF detection rate improves both mortality and quality of life, especially for primary prevention patients. In this case, the VF detection zone was programmed to 350 ms (171 bpm) in a primary prevention patient, the nominal setting being 300 ms. Such a wide VF detection zone may be harmful and should be avoided, unless it is justified by individual circumstances.

c. Extend the tachycardia detection counter to allow more time for detection.

**References**


