Implantable Defibrillator Timing Windows
When Coincidence Can Be Confusing

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We present the case of a 68-year-old man with dilated cardiomyopathy who had an implantable cardioverter defibrillator implanted for primary prevention (Unify Assura with a Durata 7122Q ventricular lead, St. Jude Medical). The device was programmed DDDR 60–110 beats per minute and Table shows more specific programming parameters.

Six months after implantation, routine device interrogation revealed many asymptomatic episodes logged as non-sustained lead noise (NSLN). The electrograms from one of these episodes are shown in Figure 1A. What is the differential diagnosis?

A rhythm strip showing sinus rhythm is shown for comparison in Figure 1B and similar episodes of tachycardia are shown in Figure 1C and 1D from subsequent interrogation. These subsequent figures assist in clarifying the rhythm diagnosis; however, further questions arise as to the behavior of the device itself. Why is there frequent and varied interaction between atrial and ventricular events in Figure 1A? Why does the device classify this rhythm as NSLN and what programming changes should be made if any?

Discussion

In Figure 1A, we see a regular ventricular rhythm at 130 beats per minute (460 ms) on the ventricular near field channel, whereas on the atrial near field channel, we see large atrial electrograms that seem to be in phase with every second ventricular near field electrogram. These atrial events are not seen by the device because of falling in the postventricular atrial blanking period. Because no intrinsic activity is seen on the atrial channel, the device paces the atrium at 65 beats per minute (accelerometer rate), which happens to be half the ventricular rate. The differential diagnosis for this tracing then includes ventricular tachycardia (VT) with the ventricular rate greater than the atrial rate and 2:1 retrograde conduction or atrioventricular nodal re-entry tachycardia. The onset of atrioventricular nodal re-entry tachycardia was never captured by the device but premature atrial beats or brief runs of atrial tachycardia such that seen in Figure 1C might serve as initiators.

Subtle variations in the relative timing of ventricular and atrial events affect how the device behaves. On the left hand side of the rhythm strip (Figure 1A), the second ventricular event (arrow 1) falls within the cross-talk detection window after the atrial-paced event and this triggers a ventricular safety pace (arrow 2). This pattern is repeated until the sixth ventricular event (arrow 3) falls outside the cross-talk detection window. The cross-talk sensing window is designed to prevent the device from inhibiting ventricular output because of the possibility that a ventricular-sensed event occurring soon after an atrial event is actually far-field sensing of the atrial event. Delivering a safety pace here (ventricular safety pace) would prevent failure of ventricular output in the event of far-field sensing. A schematic representation showing the relevant pacemaker timing cycles for this rhythm strip is shown in Figure 2.

In the center of the rhythm strip, a ventricular event falls within the postatrial ventricular blanking window of the atrial-paced beat and is not seen by the device (arrow 4). A ventricular paced beat is subsequently delivered (arrow 5) which does not capture, as the myocardium is still refractory (arrow 5). On the right hand side of the strip, a ventricular sense (VS) is followed rapidly by an AP (arrow 6). At first glance, it is unclear why this VS does not reset the VA interval and delay the AP, however, the preceding AV interval had expired and the device was committed to deliver an AP during which
The timing of these 2 events was so similar (<10 ms difference) that it was not possible to cancel the scheduled AP and initiate a new VA interval. The next VS event is marked by an F (arrow 7), as it falls within the ventricular fibrillation zone (it is coupling interval with the preceding ventricular pace is <280 ms [ventricular fibrillation zone]). This shows how St. Jude defibrillators include ventricular pace events when calculating intervals for tachycardia zones and lead alerts. If ventricular pace events that fuse with intrinsic events are ignored or if pacing occurs during lead noise from a fracture then blanking these events could lead to delayed tachycardia or lead noise detection.

At this point, the device declares the rhythm to be NSLN. Two of 3 fast ventricular intervals (within a VT zone) on the near field channel (boxed intervals) without any fast ventricular intervals on the far-field channel initiate the SecureSense algorithm (shown by VS2). When the counter for fast intervals on the near field channel reaches 5 (now 10 in the current version) without being reset by 2 fast intervals on the far-field channel then an episode of NSLN is declared (or right ventricular oversensing as it is now referred to). Ventricular intervals on the discrimination (far-field) channel are not displayed by the device, however, potentially making clarification of SecureSense algorithm

A Sense Amp (atrial near field) 
V Sense Amp (ventricular near field) 
Discrimination (far field, can-RV coil)

Markers

Table. Programming Parameters for Bradycardia and Tachycardia Therapies From the Patient’s Defibrillator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode/Lower Rate Limit</td>
<td>DDDR 60</td>
</tr>
<tr>
<td>Max track/Max sensor rate</td>
<td>110/110</td>
</tr>
<tr>
<td>Paced/Sensed atrioventricular delay</td>
<td>160 ms/150 ms</td>
</tr>
<tr>
<td>PVARP (rate responsive)</td>
<td>275–225 ms</td>
</tr>
<tr>
<td>PVAB</td>
<td>70 ms</td>
</tr>
<tr>
<td>Ventricular blanking</td>
<td>52 ms</td>
</tr>
<tr>
<td>Mode switch</td>
<td>DDDR at 180 beats per minute (initially)</td>
</tr>
<tr>
<td>VT zone</td>
<td>171 beats per minute (350 ms), 24 intervals</td>
</tr>
<tr>
<td>VF zone</td>
<td>214 beats per minute (280 ms), 12 intervals</td>
</tr>
</tbody>
</table>

PVAB indicates postventricular atrial blanking period; PVARP, postventricular atrial refractory period; VF, ventricular fibrillation; and VT, ventricular tachycardia.

Figure 1. A, A stored electrogram from the patients implantable cardioverter defibrillator that was classified as nonsustained right ventricular lead noise. Respective electrograms and marker channels are labeled and are consistent for each panel. Numbered arrows indicate key points in the tracing for discussion. Intervals annotated with a (−) on the ventricular marker channel indicate that the current interval is within the tachycardia zone, however, the interval average (average of the current interval and the previous 3 intervals) is not. These beats do not count toward tachycardia detection. B, Electrograms in sinus rhythm for comparison. C and D, Tachycardias recorded on different occasions. AP indicates atrial pace; F, beat in the ventricular fibrillation zone; NSLN, nonsustained lead noise; SIR, sensor-indicated rate; VP, ventricular pace; VS, ventricular sense; and VSP, ventricular safety pace.
behavior difficult. Fortuitously, this algorithm brought our attention to a sustained tachycardia that was occurring below the VT zone in this patient, however, this also demonstrates how dual chamber timing windows and coincidental ventricular and atrial events can confuse the SecureSense algorithm.

What is the best strategy to correct device function? Stopping the device from pacing the atrium during tachycardia would seem to prevent AP events leading to safety pacing or absolute blanking of some ventricular events. One way to do this would be to turn off the accelerometer so that atrial pacing rates would not be driven up to approximate a multiple of the ventricular rate, however, this may lead to chronotropic incompetence. In this instance, we introduced a mode switch to VVIR at a rate of $\geq 125$ beats per minute to prevent the device from pacing the atrium or tracking atrial events during tachycardia. Had the arrhythmia shown in Figure 1A been VT then lowering the VT monitor zone to $\geq 125$ beats per minute would also cause the device to switch to VVI pacing mode and similarly ignore any atrial events until return to sinus rhythm occurred. We also increased the patients’ $\beta$-blockade and no further tachycardia episodes have been logged as NSLN during 8 months of follow-up. Should further events occur then an electrophysiology study+catheter ablation of the slow pathway may be indicated.

Disclosures

None.

References


Key Words: implantable defibrillators $\blacklozenge$ primary prevention $\blacklozenge$ tachycardia
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