A 54-year-old male with ischemic cardiomyopathy and cardiac resynchronization therapy defibrillator implantation (St. Jude Medical, St. Paul, MN) 6 months prior to presentation and with a history of ventricular tachycardia (VT) storm suddenly received multiple implantable cardioverter-defibrillator (ICD) shocks. Device interrogation showed a normally functioning biventricular ICD. The initial supraventricular tachycardia appears to be a sinus tachycardia. A premature ventricular complex during tachycardia and the atrioventricular (AV) Interval Delta parameter value of 60 ms led to a diagnosis of VT resulting in inappropriate therapies. The AV Interval Delta is helpful for discrimination during dual tachycardia, but utilization of every discriminator algorithm in a particular patient should be adapted to the specific arrhythmic substrate of the patient.

**KEYWORDS.** AV Interval Delta, cardiac resynchronization therapy defibrillator, discriminator algorithm, post-shock electrograms (EGM) changes, Quadra Assura.

Case presentation

A 54-year-old man with ischemic cardiomyopathy was implanted with a cardiac resynchronization therapy defibrillator (CRT-D, Quadra Assura, St. Jude Medical, IESD – Implantable Electronic Systems Division, Sylmar, CA) for secondary prevention of sudden cardiac death. The patient had a history of ventricular tachycardia (VT) storm and acute amiodarone toxicity. He previously had three ablations of recurrent symptomatic monomorphic VT. The most recent ablation, 4 months prior to presentation, was effective with no recurrent VT when off antiarrhythmic medications. The patient dramatically improved and his device remained programmed in DDI pacing mode because of suspicion for proarhythmic VT. The most recent ablation, 4 months prior to presentation, was effective with no recurrent VT when off antiarrhythmic medications. The patient dramatically improved and his device remained programmed in DDI pacing mode because of suspicion for proarhythmic VT. The slowest VT zone was used due to the presence of slow VT prior to the last ablation. The underlying rhythm was sinus rhythm with first-degree atrioventricular (AV) block and no retrograde ventriculoatrial conduction (VA). Programmed SVT/VT discriminators and therapy settings are seen in Figure 1.

Review of the arrhythmia log showed episodes of tachycardia falling into the VT-1 zone at rates ranging from 127 to 136 bpm (Figure 2a). There was a 1:1 AV/VA relationship, and the tachyarrhythmia was diagnosed as SVT by the Rate Branch algorithm (V = A); Onset and
Morphology Criteria (before the first therapy) and therapy was withheld. Subsequently, because of programming of the AV Interval Delta, the patient received multiple VT therapies resulting in a change in EGM morphology (Figure 2a,b). The change in morphology led to further therapies because the Morphology Criteria diagnosed VT. Therapies did not affect the tachycardia, which eventually slowed down below the rate detection.

**Discussion**

The annual rate of inappropriate shocks has fallen from 37–50% for SVT alone in early studies to 1–5% for all causes in modern clinical trials. Most trial data concern the programming for primary prevention (e.g., PREPARE, MADIT-RIT). There are only a few trials (e.g., the subset of the ADVANCE III study) that have evaluated the programming approach in secondary prevention patients. According to the recent HRS Consensus Statement for secondary prevention patients, discrimination algorithms should be programmed to include rhythms with rates faster than 200 bpm and potentially up to 230 bpm (unless contraindicated). The ventricular rate alone is a mandatory discriminator, and all other discriminators can be considered individually. Each of SVT discriminators may have limitations that should be carefully understood when programming ICD therapies, especially for lower treatment zones.

Several interval-based discriminators focus on differences in sinus tachycardia. Sudden onset was one of the first single-chamber, interval-based discriminators. Onset discriminators classify the rhythm only once, and thus cannot correct misclassifications. Current devices provide algorithms based on the PR–RP interval relationship to avoid inappropriate therapy. Consistent PR patterns usually indicate SVT. Each manufacturer provides their own building blocks for discrimination of tachycardias with the atrial rate equal to ventricular rate. Medtronic

### Table 1: Programmed supraventricular tachycardia/ventricular tachycardia (SVT/VT) discriminators and therapy.

<table>
<thead>
<tr>
<th>Discriminator</th>
<th>Therapy</th>
<th>VT Therapy Timeout</th>
<th>SVT Discrimination</th>
<th>SVT Discrimination Timeout</th>
<th>SVT Upper Limit</th>
<th>Rate Branch</th>
<th>Additional Discriminators</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SVT</strong></td>
<td>ATP x3</td>
<td>Off</td>
<td>SVT Discrimination</td>
<td>Dual Chamber</td>
<td>Same as VF</td>
<td>A</td>
<td>Intervals</td>
<td>If Any of the criteria in this rate branch indicate VT, deliver therapy.</td>
</tr>
<tr>
<td><strong>VT</strong></td>
<td>ATP x3</td>
<td>Off</td>
<td>SVT Discrimination</td>
<td>Dual Chamber</td>
<td>Same as VF</td>
<td>A</td>
<td>Intervals</td>
<td>If All of the criteria in this rate branch indicate VT, deliver therapy.</td>
</tr>
<tr>
<td><strong>If All</strong></td>
<td>ATP x1</td>
<td>Off</td>
<td>Morphology</td>
<td>On</td>
<td>On</td>
<td>A</td>
<td>Intervals</td>
<td>If Ventricular Rate is greater than the Atrial Rate, deliver therapy.</td>
</tr>
</tbody>
</table>

- **Figure 1:** Programmed supraventricular tachycardia/ventricular tachycardia (SVT/VT) discriminators and therapy. Notably, in the V = A field, the "If All" criterion is on. If the rhythm is 1:1 or V = A, but the difference between the AV intervals is greater than the setting for the AV Interval Delta parameter (in this case 60 ms), then the rhythm is diagnosed as VT and additional discrimination using the Morphology and Sudden Onset/Chamber Onset criteria are not evaluated. If the difference is less than the AV Interval Delta setting, the rhythm is analyzed using these criteria further for differentiation of VT/SVT. If AV Interval Delta = OFF, then Morphology and Sudden Onset/Chamber Onset are always evaluated.
provides PR Logic (Medtronic Inc., St. Paul, MN), Biotronik provides SMART Detection® algorithm (Biotronik, Berlin, Germany), and St. Jude Medical provides AV Rate Branch + (St. Jude Medical, St. Paul, MN), etc. In the Medtronic and Guidant algorithms, incremental addition of discriminators increases specificity and decreases sensitivity of classification. In the St. Jude Medical ICDs, discriminators may be combined using either the “ANY” or “ALL” operators. Measurement of AV intervals is part of the AV Rate Branch building block in St. Jude Medical devices (AV Detection Enhance™, St. Paul, MN). This algorithm counts the AV intervals before detection (up to 16 AV intervals if in VT Detection) and calculates the difference between the second longest and second shortest AV interval. If the rhythm is 1:1 or V=Å, but the difference between the AV intervals is greater than the setting for the AV Interval Delta parameter (in this case 60 ms), then the rhythm is diagnosed as VT and additional discrimination using the Morphology and Sudden Onset/Chamber Onset criteria are not evaluated. If the difference is less than the AV Interval Delta setting, the rhythm is analyzed using these criteria further for differentiation of VT/SVT. If AV Interval Delta = OFF, then Morphology and Sudden Onset/Chamber Onset are always evaluated (Figure 3). In this case the initial VT appears to be sinus tachycardia. The AV Interval Delta parameter forced a VT diagnosis; therefore, inappropriate therapy was delivered. The AV Interval Delta is intended to facilitate identification of a dual tachycardia with isorhythmic AV dissociation by detecting subtle changes in the PR intervals. The Morphology Discrimination was not a party to this. In this case, a relatively late cycle premature ventricular contraction (PVC), occurring after the native P wave during the tachycardia caused PR interval irregularity, resulted in VT detection with subsequent therapy (Figure 4).

This case represents a situation where the programmed AV Interval Delta resulted in inappropriate ICD shocks after a PVC altered the AV interval. After resumption of β-blocker therapy along with deactivating the AV Interval Delta discrimination feature, and increasing
the lower detection rate of the VT-1 zone, no further arrhythmia or device therapies were noted during follow-up.

What can cause morphology changes in the situation in Figure 2b?
- Post-shock EGM changes have been previously described and are thought to be the result of local myocardial injury.3 In some patients with ICD, EGM morphology changes over time occur, but the precise reasons for these changes have not been elucidated.4 Owing to the constant rate and evidence for ongoing SVT (likely sinus tachycardia), shock may be the likely cause of morphology change in this case.
- It is not unusual to observe aberrancy during SVT.5 The rapidity of conduction during tachycardia can lead AV Interval Delta Algorithm to functional block in one of the bundles, most often the right bundle.8,9 In the case of rate dependent bundle branch block, morphology discrimination algorithms will not correctly differentiate SVT from VT with the tachycardia has a 1:1 AV/VA relationship.
- Dual tachycardias should be also excluded. It seems to be much less likely given no response of arrhythmia to ICD shocks and almost perfect AV relationship.
disturbed only by premature ventricular beat that do not affect the timing of subsequent atrial EGM (Figure 1). As reported by Stein et al., dual tachycardia is common in ICD recipients with a history of atrial tachycardia or atrial fibrillation and 20% of patients with VT/VF had at least one dual tachycardia episode.6,7,11

- In overall even after a short period of ventricular pacing (e.g. antitachycardia pacing), there may be a period of T wave abnormalities (myocardial memory).

Conclusions

No discriminator algorithm functions with 100% sensitivity and specify. The discriminator algorithms utilized in a particular patient should be adapted to the specific arrhythmic substrate of the patient. Each of the SVT discriminators have limitations that should be carefully understood when programming ICD therapies, especially for lower treatment zones. Detailed knowledge of the patient’s arrhythmia history along with the subtleties of specific ICD algorithms may help in individualization of the device programming. When tachycardias are recorded by the device and after therapies are delivered, careful review of stored episodes should be performed to further tailor programmed settings for discrimination of SVT and VT.1

REFERENCES