A guide to the operation and programming of the EnTrust Implantable Cardioverter Defibrillator systems
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ATP During Charging, Active Can, Cardiac Compass, CareLink, ChargeSaver, Checklist, EnTrust, Flashback, InCheck, Intrinsic, MVP, Marker Channel, Medtronic, Medtronic CareLink, PR Logic, Patient Alert, Quick Look, QuickLink, Reactive ATP, Switchback, T-Shock
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<td>Solving atrial tachyarrhythmia detection problems</td>
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<td>13.4</td>
<td>Solving ventricular tachyarrhythmia detection problems</td>
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<td>13.5</td>
<td>Solving atrial tachyarrhythmia therapy problems</td>
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<td>13.6</td>
<td>Solving ventricular tachyarrhythmia therapy problems</td>
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<td>13.7</td>
<td>Solving bradycardia pacing problems</td>
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<td>Responding to device status indicators</td>
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<td>General</td>
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<td>Lead evaluation and lead connection</td>
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<td>Device operation</td>
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<td>Warnings, precautions, and guidance for clinicians performing medical procedures on cardiac device patients</td>
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Reference Manual
Introduction

About this manual

This manual describes the operation and intended use of the EnTrust Model D154ATG, D154DRG, and D154VRC systems.

EnTrust Model D154ATG devices, referred to as “AT” devices in this manual, provide atrial and ventricular tachyarrhythmia detection and therapy and a full range of dual chamber bradycardia pacing modes and associated features. Unless otherwise noted, all information in this manual applies to AT devices.

EnTrust Model D154DRG devices, referred to as “DR” devices in this manual, provide atrial tachyarrhythmia monitoring, dual chamber tachyarrhythmia detection, ventricular tachyarrhythmia therapy, and a full range of dual chamber bradycardia pacing modes and associated features. Information in this manual that describes atrial tachyarrhythmia detection features (other than atrial monitoring) and atrial tachyarrhythmia therapy features does not apply to DR devices.

EnTrust Model D154VRC devices, referred to as “VR” devices in this manual, provide ventricular tachyarrhythmia detection, ventricular tachyarrhythmia therapy, and single chamber bradycardia pacing. Information in this manual that describes atrial tachyarrhythmia detection, atrial tachyarrhythmia therapy, dual chamber detection, dual chamber pacing features, and atrial pacing modes does not apply to VR devices.

Programmer hardware and screen images

The screen image examples in this manual show the Medtronic CareLink Model 2090 programmer screen. Wherever possible, these screen images show the application for an AT device (EnTrust Model D154ATG).

The information provided in this manual about using the programmer assumes the Medtronic CareLink Model 2090 Programmer is used. For information about using the Model 9790C Programmer, see the 9790/9790C Programmer Instruction Manual.

Manual conventions

Throughout this document, the word “device” refers to the implanted EnTrust device.

The $\oplus$ symbol in parameter tables indicates the Medtronic nominal value for that parameter.

On-screen buttons are shown with the name of the button surrounded by brackets: [Button Name].
Additional literature
Before implanting the device, it is strongly recommended that you take the following actions:

- Refer to the product literature packaged with the device for information about prescribing the device.
- Thoroughly read the technical manuals for the leads used with the device.
- Discuss the procedure and the device with the patient and any other interested parties, and provide them with any patient information packaged with the device.

Technical support
Medtronic employs highly trained representatives and engineers located throughout the world to serve you and, upon request, to provide training to qualified hospital personnel in the use of Medtronic products.

In addition, Medtronic maintains a professional staff of consultants to provide technical consultation to product users.

For more information, contact your local Medtronic representative, or call or write Medtronic at the appropriate telephone number or address listed on the back cover.

Customer education
Medtronic invites physicians to attend an educational seminar on the device. The course describes indications for use, system functions, implant procedures, and patient management.

References

See these additional references for more background information:

Notice

The Patient Information screen of the programmer software application is provided as an informational tool for the end user. The user is responsible for accurate input of patient information into the software. Medtronic makes no representation as to the accuracy or completeness of the patient information that end users enter into the Patient Information screen. Medtronic SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES TO ANY THIRD PARTY WHICH RESULT FROM THE USE OF THE PATIENT INFORMATION SUPPLIED BY END USERS TO THE SOFTWARE.
Part I
Quick overview

1 Quick reference

1.1 Physical characteristics, AT and DR devices

Table 1. Device physical characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35 cm³</td>
</tr>
<tr>
<td>Mass</td>
<td>68 g</td>
</tr>
<tr>
<td>H x W x D&lt;sup&gt;b&lt;/sup&gt;</td>
<td>62 mm x 51 mm x 15 mm</td>
</tr>
<tr>
<td>Surface area of device can</td>
<td>60 cm²</td>
</tr>
<tr>
<td>Radiopaque ID</td>
<td>PNR</td>
</tr>
<tr>
<td>Materials in contact with human tissue&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Titanium, polyurethane, silicone rubber</td>
</tr>
<tr>
<td>Battery</td>
<td>Lithium silver vanadium oxide hybrid</td>
</tr>
</tbody>
</table>

<sup>a</sup> Volume with connector holes unplugged.
<sup>b</sup> Grommets may protrude slightly beyond the can surface.
<sup>c</sup> These materials have been successfully tested for the ability to avoid biological incompatibility. The device does not produce an injurious temperature in the surrounding tissue during normal operation.
Figure 1. Connector and suture holes

1. IS-1 connector port, V
2. IS-1 connector port, A
3. DF-1 connector port, SVC (HVX)
4. DF-1 connector port, RV (HVB)
5. Device Active Can electrode, Can (HVA)
6. Suture holes

1.2 Physical characteristics, VR devices

Table 2. Device physical characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>35 cm³</td>
</tr>
<tr>
<td>Mass</td>
<td>68 g</td>
</tr>
<tr>
<td>H x W x D</td>
<td>63 mm x 51 mm x 15 mm</td>
</tr>
<tr>
<td>Surface area of device can</td>
<td>60 cm²</td>
</tr>
<tr>
<td>Radiopaque ID</td>
<td>PNT</td>
</tr>
<tr>
<td>Materials in contact with human tissue</td>
<td>Titanium, polyurethane, silicone rubber</td>
</tr>
<tr>
<td>Battery</td>
<td>Lithium silver vanadium oxide hybrid</td>
</tr>
</tbody>
</table>

a Volume with connector holes unplugged.
b Grommets may protrude slightly beyond the can surface.
c These materials have been successfully tested for the ability to avoid biological incompatibility. The device does not produce an injurious temperature in the surrounding tissue during normal operation.
1.3 Replacement indicators

Battery voltage and messages about replacement status appear on the programmer display and on printed reports. Table 3 lists the Elective Replacement Indicator (ERI) and the End of Life (EOL) conditions.

<table>
<thead>
<tr>
<th>Table 3. Replacement indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Replacement Indicator (ERI)</td>
</tr>
<tr>
<td>End of Life (EOL)</td>
</tr>
</tbody>
</table>

ERI date – The Quick Look and Battery and Lead Measurements screens display the date when the battery reached ERI.

EOL indication – If the programmer indicates that the device is at EOL, replace the device immediately.

Post-ERI conditions – EOL device status is defined as three months following an ERI indication assuming the following post-ERI conditions: 100% DDD pacing (VVI in VR
devices) at 60 bpm, 2.5 V, 0.4 ms; 500 Ω pacing load; and six full-energy charges. EOL may be indicated before the end of three months if the device exceeds these conditions.

1.4 Longevity projections

Device longevity is affected by how certain features are programmed, such as Pre-arrhythmia EGM. See Section 4.12, “Optimizing device longevity”, page 55.

1.4.1 AT and DR device longevity projections

The following longevity estimates are based on accelerated battery discharge data and device modeling, as specified.

These models assume the default automatic capacitor formation setting. As a guideline, each full energy charge decreases device longevity by approximately 34 days.

Table 4. Projected longevity in years with 0.4 ms pulse width and 60 bpm pacing rate

<table>
<thead>
<tr>
<th>Pacing</th>
<th>Maximum energy charging frequency</th>
<th>Pre-arrhythmia EGM storage</th>
<th>500 Ω pacing impedance</th>
<th>900 Ω pacing impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 V 3.0 V</td>
<td>2.5 V 3.0 V</td>
</tr>
<tr>
<td>DDD, 0%</td>
<td>Semi-annual</td>
<td>Off</td>
<td>8.3 8.3</td>
<td>8.3 8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>8.1 8.1</td>
<td>8.1 8.1</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>7.1 7.1</td>
<td>7.1 7.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>6.9 6.9</td>
<td>6.9 6.9</td>
</tr>
<tr>
<td>DDD, 15%</td>
<td>Semi-annual</td>
<td>Off</td>
<td>8.0 7.9</td>
<td>8.2 8.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>7.8 7.7</td>
<td>8.0 7.9</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>6.9 6.8</td>
<td>7.0 6.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>6.7 6.6</td>
<td>6.8 6.8</td>
</tr>
<tr>
<td>DDD, 50%</td>
<td>Semi-annual</td>
<td>Off</td>
<td>7.4 7.1</td>
<td>7.8 7.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>7.2 6.9</td>
<td>7.6 7.4</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>6.4 6.2</td>
<td>6.7 6.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>6.2 6.0</td>
<td>6.6 6.4</td>
</tr>
<tr>
<td>AAI&lt;=&gt;DDD, (MVP mode) 50% atrial, 5% ventricular</td>
<td>Semi-annual</td>
<td>Off</td>
<td>7.9 7.7</td>
<td>8.2 8.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>7.7 7.5</td>
<td>8.0 7.9</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>6.8 6.7</td>
<td>7.0 6.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>6.6 6.5</td>
<td>6.8 6.7</td>
</tr>
</tbody>
</table>
Table 4. Projected longevity in years with 0.4 ms pulse width and 60 bpm pacing rate (continued)

<table>
<thead>
<tr>
<th>Pacing</th>
<th>Maximum energy charging frequency(^a)</th>
<th>Pre-arrhythmia EGM storage(^b)</th>
<th>500 Ω pacing impedance</th>
<th>900 Ω pacing impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 V</td>
<td>3.0 V</td>
</tr>
<tr>
<td>DDD, 100%</td>
<td>Semi-annual</td>
<td>Off</td>
<td>6.6</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>6.5</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>5.8</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>5.7</td>
<td>5.3</td>
</tr>
</tbody>
</table>

\(^a\) Maximum energy charging frequency may include full-energy therapy shocks or capacitor formations.
\(^b\) The data provided for programming Pre-arrhythmia EGM on is based on a 6 month period (two 3 month follow-up intervals) over the life of the device. Additional use of Pre-arrhythmia EGM reduces longevity by approximately 27% or 3.3 months per year.

1.4.2 VR device longevity projections

The following longevity estimates are based on accelerated battery discharge data and device modeling, as specified.

These models assume the default automatic capacitor formation setting. As a guideline, each full energy charge decreases device longevity by approximately 49 days.

Table 5. Projected longevity in years with VVI pacing mode, 0.4 ms pulse width, and 60 bpm pacing rate

<table>
<thead>
<tr>
<th>% Pacing</th>
<th>Maximum energy charging frequency(^a)</th>
<th>Pre-arrhythmia EGM storage(^b)</th>
<th>500 Ω pacing impedance</th>
<th>900 Ω pacing impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 V</td>
<td>3.0 V</td>
</tr>
<tr>
<td>0%</td>
<td>Semi-annual</td>
<td>Off</td>
<td>11.1</td>
<td>11.1</td>
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<tr>
<td></td>
<td></td>
<td>On</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>9.1</td>
<td>9.1</td>
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<td></td>
<td></td>
<td>On</td>
<td>8.8</td>
<td>8.8</td>
</tr>
<tr>
<td>15%</td>
<td>Semi-annual</td>
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<td>10.7</td>
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<td></td>
<td></td>
<td>On</td>
<td>10.6</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>8.9</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>8.7</td>
<td>8.6</td>
</tr>
<tr>
<td>50%</td>
<td>Semi-annual</td>
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<td>10.3</td>
<td>9.9</td>
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<tr>
<td></td>
<td></td>
<td>On</td>
<td>10.0</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td>Quarterly</td>
<td>Off</td>
<td>8.5</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On</td>
<td>8.3</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Table 5. Projected longevity in years with VVI pacing mode, 0.4 ms pulse width, and 60 bpm pacing rate (continued)

<table>
<thead>
<tr>
<th>% Pacing</th>
<th>Maximum energy charging frequency</th>
<th>Pre-arrhythmia EGM storage</th>
<th>500 Ω pacing impedance</th>
<th>900 Ω pacing impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 V</td>
<td>3.0 V</td>
</tr>
<tr>
<td>100%</td>
<td>Semi-annual</td>
<td>Off</td>
<td>9.5</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>On</td>
<td></td>
<td>9.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Quarterly</td>
<td>Off</td>
<td></td>
<td>8.0</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>On</td>
<td></td>
<td>7.8</td>
<td>7.4</td>
</tr>
</tbody>
</table>

a Maximum energy charging frequency may include full-energy therapy shocks or capacitor formations.
b The data provided for programming Pre-arrhythmia EGM on is based on a 6 month period (two 3 month follow-up intervals) over the life of the device. Additional use of Pre-arrhythmia EGM reduces longevity by approximately 33% or 4.0 months per year.

1.5 Magnet application

When a magnet is placed near the device, the device responds as shown in Table 6. When the magnet is removed, the device returns to its programmed operations.

Note: Before implant and for the first 6 hours after implant, the device will not sound audible tones when a magnet is placed over the device.

Table 6. Effects of magnet application on the device

<table>
<thead>
<tr>
<th>Pacing mode</th>
<th>As programmed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacing rate and interval</td>
<td>As programmeda</td>
</tr>
<tr>
<td>Tachyarrhythmia detection</td>
<td>Suspendedb</td>
</tr>
<tr>
<td>Patient Alert audible tones (20 s or less)</td>
<td>With programmable alerts enabled:</td>
</tr>
<tr>
<td></td>
<td>● Continuous tone (Test)c</td>
</tr>
<tr>
<td></td>
<td>● On/off intermittent tone (seek follow-up)</td>
</tr>
<tr>
<td></td>
<td>● High/low dual tone (urgent follow-up)</td>
</tr>
<tr>
<td></td>
<td>With programmable alerts disabled:</td>
</tr>
<tr>
<td></td>
<td>● No tone</td>
</tr>
<tr>
<td></td>
<td>● High/low dual tone (urgent follow-up)</td>
</tr>
</tbody>
</table>

a Rate Response adjustments are suspended while a Patient Alert tone sounds.
b Detection resumes if telemetry between the device and the programmer is established and the application software is running.
c The Test tone does not sound if “VF Detection OFF, 3+ VF or 3+ FVT Rx Off” is the only alert enabled.

1.6 Typical charge times

The most recent capacitor charge time appears on the programmer display and on printed reports. You can evaluate charge time using the Charge/Dump test (see Table 7).
Table 7. Typical full energy charge times with fully formed capacitors

<table>
<thead>
<tr>
<th></th>
<th>At Beginning of Life (BOL)</th>
<th></th>
<th>At Elective Replacement (ERI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.0 s</td>
<td></td>
<td>11.0 s (AT and DR devices)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11.8 s (VR devices)</td>
</tr>
</tbody>
</table>

1.7 High-voltage therapy energy

The stored energy of the device is derived from the peak capacitor voltage and is always greater than the energy delivered by the device. Table 8 compares the programmed energy levels delivered by the device to the energy levels stored in the capacitors before delivery.

Table 8. Delivered (programmed) and stored energy levels

<table>
<thead>
<tr>
<th>Delivered/Programmed(^a)</th>
<th>Stored(^a)</th>
<th>Charge Time(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 J</td>
<td>39 J</td>
<td>8.0 s</td>
</tr>
<tr>
<td>32 J</td>
<td>36 J</td>
<td>7.3 s</td>
</tr>
<tr>
<td>30 J</td>
<td>34 J</td>
<td>6.9 s</td>
</tr>
<tr>
<td>28 J</td>
<td>32 J</td>
<td>6.4 s</td>
</tr>
<tr>
<td>26 J</td>
<td>29 J</td>
<td>5.9 s</td>
</tr>
<tr>
<td>25 J</td>
<td>28 J</td>
<td>5.7 s</td>
</tr>
<tr>
<td>24 J</td>
<td>27 J</td>
<td>5.5 s</td>
</tr>
<tr>
<td>22 J</td>
<td>25 J</td>
<td>5.0 s</td>
</tr>
<tr>
<td>20 J</td>
<td>23 J</td>
<td>4.6 s</td>
</tr>
<tr>
<td>18 J</td>
<td>20 J</td>
<td>4.1 s</td>
</tr>
<tr>
<td>16 J</td>
<td>18 J</td>
<td>3.7 s</td>
</tr>
<tr>
<td>15 J</td>
<td>17 J</td>
<td>3.4 s</td>
</tr>
<tr>
<td>14 J</td>
<td>16 J</td>
<td>3.2 s</td>
</tr>
<tr>
<td>13 J</td>
<td>15 J</td>
<td>3.0 s</td>
</tr>
<tr>
<td>12 J</td>
<td>14 J</td>
<td>2.7 s</td>
</tr>
<tr>
<td>11 J</td>
<td>13 J</td>
<td>2.5 s</td>
</tr>
<tr>
<td>10 J</td>
<td>11 J</td>
<td>2.3 s</td>
</tr>
<tr>
<td>9 J</td>
<td>10 J</td>
<td>2.1 s</td>
</tr>
<tr>
<td>8 J</td>
<td>9.1 J</td>
<td>1.8 s</td>
</tr>
<tr>
<td>7 J</td>
<td>8.0 J</td>
<td>1.6 s</td>
</tr>
<tr>
<td>6 J</td>
<td>6.9 J</td>
<td>1.4 s</td>
</tr>
<tr>
<td>5 J</td>
<td>5.7 J</td>
<td>1.1 s</td>
</tr>
<tr>
<td>4 J</td>
<td>4.6 J</td>
<td>0.9 s</td>
</tr>
<tr>
<td>3 J</td>
<td>3.5 J</td>
<td>0.7 s</td>
</tr>
<tr>
<td>2 J</td>
<td>2.3 J</td>
<td>0.5 s</td>
</tr>
<tr>
<td>1.8 J</td>
<td>2.1 J</td>
<td>0.4 s</td>
</tr>
</tbody>
</table>

\(\text{a}\) Reference Manual
Table 8. Delivered (programmed) and stored energy levels\textsuperscript{a} (continued)

<table>
<thead>
<tr>
<th>Delivered/Programmed\textsuperscript{a}</th>
<th>Stored\textsuperscript{a}</th>
<th>Charge Time\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6 J</td>
<td>1.9 J</td>
<td>0.4 s</td>
</tr>
<tr>
<td>1.4 J</td>
<td>1.7 J</td>
<td>0.3 s</td>
</tr>
<tr>
<td>1.2 J</td>
<td>1.5 J</td>
<td>0.3 s</td>
</tr>
<tr>
<td>1.0 J</td>
<td>1.2 J</td>
<td>0.2 s</td>
</tr>
<tr>
<td>0.8 J</td>
<td>0.9 J</td>
<td>0.2 s</td>
</tr>
<tr>
<td>0.6 J</td>
<td>0.7 J</td>
<td>0.1 s</td>
</tr>
<tr>
<td>0.4 J</td>
<td>0.5 J</td>
<td>0.1 s</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Delivered energy values are based on measurements at the connector block during high-voltage therapies into a 75 \(\Omega\) load. Stored energy values indicate the energy on the capacitor at the end of charging.

\textsuperscript{b}Typical charge time at Beginning of Life (BOL) with fully formed capacitors, rounded to the nearest tenth of a second.

1.8 Stored data and diagnostics

Table 9. Arrhythmia episode data storage

<table>
<thead>
<tr>
<th>Episode data type</th>
<th>AT devices</th>
<th>DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated VT/VF episode log entries</td>
<td>100 entries</td>
<td>100 entries</td>
<td>100 entries</td>
</tr>
<tr>
<td>Treated VT/VF episode EGM, markers, and intervals</td>
<td>9.25 min</td>
<td>12.5 min</td>
<td>13.75 min</td>
</tr>
<tr>
<td>Monitored VT episode log entries</td>
<td>15 entries</td>
<td>15 entries</td>
<td>15 entries</td>
</tr>
<tr>
<td>Monitored VT episode EGM, markers, and intervals</td>
<td>45 s</td>
<td>45 s</td>
<td>51 s</td>
</tr>
<tr>
<td>Non-sustained VT episode log entries</td>
<td>15 entries</td>
<td>15 entries</td>
<td>15 entries</td>
</tr>
<tr>
<td>Non-sustained VT episode EGM, markers, and intervals</td>
<td>30 s</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Treated AT/AF episode log entries</td>
<td>100 entries</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Treated AT/AF episode EGM, markers, and intervals</td>
<td>3.75 min</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Monitored AT/AF episode log entries</td>
<td>50 entries</td>
<td>50 entries</td>
<td>—</td>
</tr>
<tr>
<td>Monitored AT/AF episode EGM, markers, and intervals</td>
<td>1.0 min</td>
<td>1.5 min</td>
<td>—</td>
</tr>
<tr>
<td>SVT episode log entries</td>
<td>25 entries</td>
<td>25 entries</td>
<td>25 entries</td>
</tr>
<tr>
<td>SVT episode EGM, markers, and intervals</td>
<td>1.25 min</td>
<td>1.25 min</td>
<td>1.4 min</td>
</tr>
<tr>
<td>Patient activated episode log entries</td>
<td>50 entries</td>
<td>50 entries</td>
<td>50 entries</td>
</tr>
</tbody>
</table>

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### Table 9. Arrhythmia episode data storage (continued)

<table>
<thead>
<tr>
<th>Episode data type</th>
<th>AT devices</th>
<th>DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashback memory interval data before each of the following events:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Interrogation</td>
<td>2000 events</td>
<td>2000 events</td>
<td>2000 events</td>
</tr>
<tr>
<td>● Latest VF episode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Latest VT episode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flashback memory interval data before the latest AT/AF episode</td>
<td>2000 events</td>
<td>2000 events</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(includes both A- and V-events)</td>
<td>(includes both A- and V-events)</td>
<td>(V-events only)</td>
</tr>
</tbody>
</table>

### Table 10. VT/VF episode counters

<table>
<thead>
<tr>
<th>Counter data type</th>
<th>AT and DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts of each VT/VF episode type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>● VF</td>
<td></td>
<td>● VF</td>
</tr>
<tr>
<td>● FVT</td>
<td></td>
<td>● FVT</td>
</tr>
<tr>
<td>● VT</td>
<td></td>
<td>● VT</td>
</tr>
<tr>
<td>● VT Monitor</td>
<td></td>
<td>● VT Monitor</td>
</tr>
<tr>
<td>● VT-NS</td>
<td></td>
<td>● VT-NS</td>
</tr>
<tr>
<td>● Runs of PVCs</td>
<td></td>
<td>● Runs of PVCs</td>
</tr>
<tr>
<td>● Single PVCs</td>
<td></td>
<td>● Single PVCs</td>
</tr>
<tr>
<td>● Runs of VRS paces</td>
<td></td>
<td>● Runs of VRS paces</td>
</tr>
<tr>
<td>● Single VRS paces</td>
<td></td>
<td>● Single VRS paces</td>
</tr>
<tr>
<td>Counts of each SVT episode type (VT/VF therapy withheld)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>● AF/Afl</td>
<td></td>
<td>● V. Stability</td>
</tr>
<tr>
<td>● Sinus Tach</td>
<td></td>
<td>● Onset</td>
</tr>
<tr>
<td>● Other 1:1 SVTs</td>
<td></td>
<td>● Wavelet</td>
</tr>
<tr>
<td>● V. Stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Onset</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 11. VT/VF therapy counters

<table>
<thead>
<tr>
<th>Counter data type</th>
<th>AT, DR and VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT/VF therapy summary counters</td>
<td></td>
</tr>
<tr>
<td>● ATP-terminated episodes</td>
<td></td>
</tr>
<tr>
<td>● Shock-terminated episodes</td>
<td></td>
</tr>
<tr>
<td>● Total VT/VF shocks</td>
<td></td>
</tr>
<tr>
<td>● Aborted charges</td>
<td></td>
</tr>
<tr>
<td>VT/VF therapy efficacy counters</td>
<td>For VF Rx1–Rx6 and ATP during/before charging:</td>
</tr>
<tr>
<td>● Delivered therapy counts</td>
<td>● Delivered therapy counts</td>
</tr>
<tr>
<td>● Successful therapy counts</td>
<td>● Successful therapy counts</td>
</tr>
<tr>
<td>For FVT Rx1–Rx6:</td>
<td>● Counts of episodes accelerated to VF</td>
</tr>
<tr>
<td>● Delivered therapy counts</td>
<td>For VT Rx1–Rx6:</td>
</tr>
<tr>
<td>● Successful therapy counts</td>
<td>● Delivered therapy counts</td>
</tr>
<tr>
<td>● Counts of episodes accelerated by 60 ms or to FVT or VF</td>
<td>● Successful therapy counts</td>
</tr>
</tbody>
</table>

---

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Table 12. AT/AF episode counters

<table>
<thead>
<tr>
<th>Counter data type</th>
<th>AT devices</th>
<th>DR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT/AF summary data</td>
<td>• Percent of time in AT/AF</td>
<td>• Percent of time in AT/AF</td>
</tr>
<tr>
<td></td>
<td>• Average time in AT/AF per day</td>
<td>• Average time in AT/AF per day</td>
</tr>
<tr>
<td></td>
<td>• Percentage of AT/AF episodes terminated by ATP</td>
<td></td>
</tr>
<tr>
<td>Average number per day of each AT/AF episode type</td>
<td>• Monitored AT/AF</td>
<td>• Monitored AT/AF</td>
</tr>
<tr>
<td></td>
<td>• Treated AT/AF</td>
<td>• Non-sustained AT</td>
</tr>
<tr>
<td></td>
<td>• Non-sustained AT</td>
<td></td>
</tr>
<tr>
<td>Percent of time in each kind of pacing</td>
<td>• Atrial pacing</td>
<td>• Atrial pacing</td>
</tr>
<tr>
<td></td>
<td>• Atrial intervention pacing</td>
<td></td>
</tr>
<tr>
<td>Number of AT/AF episodes, presented in different groupings</td>
<td>• Grouped by duration&lt;sup&gt;a&lt;/sup&gt;</td>
<td>• Grouped by duration&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>• Grouped by start time&lt;sup&gt;a&lt;/sup&gt;</td>
<td>• Grouped by start time&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>This counter includes any instance when the device identifies AT/AF Onset. Therefore, the total number of episodes in this counter may exceed the number of detected AT/AF episodes recorded by the device.

Table 13. AT/AF therapy counters

<table>
<thead>
<tr>
<th>Counter data type</th>
<th>AT devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of AT/AF episodes treated and the percentage terminated, presented in different groupings</td>
<td>• Grouped by detection zone and therapy</td>
</tr>
<tr>
<td></td>
<td>• Grouped by atrial cycle length</td>
</tr>
<tr>
<td>Counts of different AT/AF therapy types</td>
<td>• Delivered ATP sequences</td>
</tr>
<tr>
<td></td>
<td>• Aborted ATP sequences</td>
</tr>
<tr>
<td></td>
<td>• Delivered automatic atrial CV shocks</td>
</tr>
<tr>
<td></td>
<td>• Automatic atrial CV shocks that failed to terminate the episode</td>
</tr>
<tr>
<td></td>
<td>• Delivered patient-activated shocks</td>
</tr>
<tr>
<td></td>
<td>• Patient-activated shocks that failed to terminate the episode</td>
</tr>
</tbody>
</table>

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Table 14. Battery and lead measurement data

<table>
<thead>
<tr>
<th>AT devices</th>
<th>DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery voltage</td>
<td>Battery voltage</td>
<td>Battery voltage</td>
</tr>
<tr>
<td>Last capacitor formation</td>
<td>Last capacitor formation</td>
<td>Last capacitor formation</td>
</tr>
<tr>
<td>Last charge</td>
<td>Last charge</td>
<td>Last charge</td>
</tr>
<tr>
<td>Lead impedance:</td>
<td>Lead impedance:</td>
<td>Lead impedance:</td>
</tr>
<tr>
<td>– A. pacing</td>
<td>– A. pacing</td>
<td>– RV pacing</td>
</tr>
<tr>
<td>– RV pacing</td>
<td>– RV pacing</td>
<td>– RV defibrillation</td>
</tr>
<tr>
<td>– RV defibr</td>
<td>– RV defibr</td>
<td>– SVC defibr (if used)</td>
</tr>
<tr>
<td>R-wave amplitude</td>
<td>R-wave amplitude</td>
<td>R-wave amplitude</td>
</tr>
<tr>
<td>P-wave amplitude</td>
<td>P-wave amplitude</td>
<td>P-wave amplitude</td>
</tr>
<tr>
<td>Last high-voltage therapy</td>
<td>Last high-voltage therapy</td>
<td>Last high-voltage therapy</td>
</tr>
<tr>
<td>Sensing integrity counter</td>
<td>Sensing integrity counter</td>
<td>Sensing integrity counter</td>
</tr>
<tr>
<td>Atrial Lead Position Check results</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 15. Lead performance trend data

14 days of daily measurements, 80 weeks of weekly minimum and maximum measurements, highest value, lowest value, value at implant, and latest value.

<table>
<thead>
<tr>
<th>AT and DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead impedance measurements:</td>
<td></td>
</tr>
<tr>
<td>– A. Pacing</td>
<td>RV pacing</td>
</tr>
<tr>
<td>– RV pacing</td>
<td>RV defibrillation</td>
</tr>
<tr>
<td>– RV defibrillation</td>
<td>SVC defibrillation (if used)</td>
</tr>
<tr>
<td>Sensing amplitude measurements:</td>
<td></td>
</tr>
<tr>
<td>– P-wave</td>
<td>R-wave</td>
</tr>
<tr>
<td>– R-wave</td>
<td></td>
</tr>
</tbody>
</table>

Table 16. Cardiac Compass trend data

Printed report showing up to 14 months of measurement trends and summary data.

<table>
<thead>
<tr>
<th>AT and DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annotations of interrogations, programming, and remote sessions</td>
<td>Annotations of interrogations, programming, and remote sessions</td>
</tr>
<tr>
<td>VT and VF episodes per day</td>
<td>VT and VF episodes per day</td>
</tr>
<tr>
<td>High-voltage therapies delivered per day</td>
<td>High-voltage therapies delivered per day</td>
</tr>
<tr>
<td>Ventricular rate during VT or VF</td>
<td>Ventricular rate during VT or VF</td>
</tr>
<tr>
<td>Episodes of non-sustained tachycardia per day</td>
<td>Episodes of non-sustained tachycardia per day</td>
</tr>
<tr>
<td>Heart rate variability</td>
<td>Heart rate variability</td>
</tr>
<tr>
<td>Total daily time in AF or AT</td>
<td>Percent pacing per day</td>
</tr>
<tr>
<td>Ventricular rate during AF or AT</td>
<td>Patient activity</td>
</tr>
<tr>
<td>Percent pacing per day</td>
<td>Average day and night ventricular heart rate</td>
</tr>
<tr>
<td>Patient activity</td>
<td></td>
</tr>
<tr>
<td>Average day and night ventricular heart rate</td>
<td></td>
</tr>
</tbody>
</table>
### Table 17. Rate Histograms report

<table>
<thead>
<tr>
<th>Data type</th>
<th>AT devices</th>
<th>DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graphs displaying the percent of time in each rate range for the listed conditions:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Atrial pacing and atrial sensing&lt;sup&gt;a&lt;/sup&gt;</td>
<td>• Atrial pacing and atrial sensing&lt;sup&gt;a&lt;/sup&gt;</td>
<td>• Ventricular pacing and ventricular sensing</td>
</tr>
<tr>
<td></td>
<td>• Ventricular pacing and ventricular sensing</td>
<td>• Ventricular pacing and ventricular sensing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ventricular pacing and ventricular sensing during AT/AF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent of time for each event type:&lt;sup&gt;b&lt;/sup&gt;</td>
<td>• AS-VS events</td>
<td>• AS-VS events</td>
<td>• VP events</td>
</tr>
<tr>
<td></td>
<td>• AS-VP events</td>
<td>• AS-VP events</td>
<td>• VS events</td>
</tr>
<tr>
<td></td>
<td>• AP-VS events</td>
<td>• AP-VS events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• AP-VP events</td>
<td>• AP-VP events</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>If more than 2% of atrial sensed events are identified as far-field R-waves, the general percentage range (either “2% to 5%” or “> 5%”) is reported above the atrial rate histogram.

<sup>b</sup>In AT and DR devices, if the programmed pacing mode during the reporting period was a dual chamber mode, the report displays the AS-VS, AS-VP, AP-VS, and AP-VP event sequence data. If a single chamber mode was programmed, the report displays the percent of time spent pacing and sensing. MVP modes (AAIR<>DDDR and AAI<>DDD) are considered dual chamber modes for this purpose.

### Table 18. Patient Alert event data

Log of events that triggered Patient Alert notifications. Each log entry includes the following information:

- Date when the event first occurred (since the last interrogation)
- Description of event that triggered the Patient Alert
- Programmed threshold for the Patient Alert, if applicable

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Medtronic ENTRUST<sup>®</sup> D154ATG, D154DRG, D154VRC

Reference Manual 25
2 The EnTrust system

2.1 System overview

EnTrust Implantable Cardioverter Defibrillator (ICD) systems are implantable medical devices that automatically detect and treat episodes of ventricular fibrillation (VF), ventricular tachycardia (VT), fast ventricular tachycardia (FVT), and bradyarrhythmia. The EnTrust AT device also detects and treats atrial tachyarrhythmia episodes.

Each EnTrust ICD system includes three major components: the implanted device, the leads connecting the device to the patient’s heart, and the Medtronic programmer with EnTrust application software installed.

2.1.1 Implanted device

The device senses the electrical activity of the patient’s heart using the sensing electrodes of the implanted leads. It analyzes the heart rhythm based on selectable sensing and detection parameters. If the device detects a ventricular tachyarrhythmia, it can deliver defibrillation, cardioversion, or antitachycardia pacing therapy to the patient’s heart. If the device identifies a bradyarrhythmia, it delivers bradycardia pacing therapy.

2.1.2 Leads

The device can be used with transvenous or epicardial defibrillation leads. The lead system should consist of bipolar or paired unipolar\(^1\) leads for pacing and sensing and one or two high-voltage cardioversion/defibrillation electrodes. The pacing and sensing electrodes sense cardiac activity and deliver pacing stimuli. AT and DR devices require both atrial and ventricular leads to be implanted. VR devices require only ventricular leads. The device case may optionally be used as an Active Can high voltage electrode. You can enable or disable this option using the programmable Active Can parameter.

2.1.3 Programmer and software

The Medtronic programmer and EnTrust application software allow you to perform the following tasks:

- configure the detection, therapy, and bradycardia features for your patient
- perform electrophysiological studies and system tests
- monitor, display, or print patient cardiac activity information
- view patient and device diagnostic data

---

\(^1\) With an appropriate unipolar to bipolar adapter kit.
The EnTrust device and application software are compatible with the Medtronic CareLink Model 2090 programmer with a Model 2067 or 2067L programming head.

2.1.4 Patient assistant

Patients with implanted AT devices can use the Model 2696 InCheck Patient Assistant to perform the following functions:

- Verify whether the implanted device has detected a suspected atrial tachyarrhythmia.
- Initiate recording of cardiac event data in the device memory.
- Request delivery of atrial cardioversion therapy (if the device is programmed to allow patient-activated cardioversion).

**Note:** Patient-activated cardioversion is only delivered if the implanted device is currently detecting an AT/AF episode.

2.1.5 Detecting ventricular tachyarrhythmias

The device monitors the cardiac rhythm for short ventricular intervals that may indicate the presence of VF, VT, or FVT.

You can program the device to distinguish between true ventricular arrhythmias and rapidly conducted supraventricular tachycardia (SVT) and to withhold therapy for SVT.

AT and DR devices also have the ability to detect double tachycardias (unrelated ventricular arrhythmias occurring simultaneously with SVTs) so that therapy is not withheld for a ventricular arrhythmia in the presence of an SVT.

2.1.6 Treating ventricular tachyarrhythmias

The device treats detected VF episodes by delivering a biphasic defibrillation shock. If the VF episode persists, up to 5 more individually programmed defibrillation shocks can be delivered.

You also have the option of delivering 1 sequence of ATP therapy before or during charging for a VF therapy. This option can prevent delivery of painful shocks for episodes that are detected as VF but can be terminated by pacing therapy.

The device treats detected VT episodes by delivering either a Ramp, Ramp+, or Burst antitachycardia pacing therapy or a biphasic cardioversion shock synchronized to a ventricular depolarization. If the VT episode persists, up to 5 more individually programmed VT therapies can be delivered.
The device treats detected FVT episodes by delivering either a Ramp, Ramp+, or Burst antitachycardia pacing therapy or a biphasic cardioversion shock synchronized to a ventricular depolarization. If the FVT episode persists, up to 5 more individually programmed FVT therapies can be delivered.

2.1.7 Detecting atrial tachyarrhythmias
If there is no ventricular episode in progress, the device applies the AT/AF detection algorithm, which detects AT/AF episodes by examining the atrial rate and the relationship between atrial and ventricular events. Both AT and DR devices can detect AT/AF episodes, but only AT devices can respond to detected AT/AF episodes with programmed atrial tachyarrhythmia therapies. AT devices also provide an additional detection zone for Fast AT/AF episodes. This second zone allows the device to treat a second, faster atrial tachyarrhythmia with a separately programmable set of therapies.

2.1.8 Treating atrial tachyarrhythmias
The device treats detected AT/AF episodes by delivering Burst+, Ramp or 50 Hz Burst antitachycardia pacing therapy or by delivering an atrial cardioversion. Each sustained AT/AF episode can be treated with up to 5 automatic therapies per detection zone: 3 antitachycardia pacing therapies and 2 atrial cardioversion therapies. Patient-activated cardioversion is also available to treat AT/AF episodes.

2.1.9 Treating bradycardia
The device provides rate responsive pacing to treat bradycardia. An internal accelerometer senses the patient’s physical activity, allowing the device to increase and decrease the pacing rate in response to changes in the level of activity.

VR devices provide single chamber ventricular pacing modes. AT and DR devices provide dual chamber pacing, single chamber pacing, and MVP (Managed Ventricular Pacing) modes. The MVP modes switch between single chamber atrial pacing and dual chamber pacing to promote intrinsic conduction and manage unnecessary right ventricular pacing.
2.1.10 Monitoring for real-time and stored data

The device and programmer provide real-time information on detection and therapy parameters and status during a patient session. The device also provides accumulated data on device operation, including stored electrograms, detected and treated tachyarrhythmia episodes, bradycardia interventions, and the efficacy of therapy. The Cardiac Compass report provides up to 14 months of clinically significant data, including arrhythmia episodes, shocks delivered, physical activity, heart rate, and bradycardia pacing activities. The Rate Histograms report shows the percent of time that cardiac events occurred at different heart rates. In AT and DR devices, this report also shows the distribution of ventricular heart rates during AT/AF episodes.

All of this information can be printed and retained in the patient's file or saved in electronic format on a floppy diskette.

2.1.11 Conducting electrophysiologic tests

You can use the system to conduct non-invasive electrophysiologic studies, including manual delivery of therapies, to manage an induced or spontaneous tachyarrhythmia.

2.1.12 Alerting the patient to system events

You can use the programmable Patient Alert monitoring feature to notify the patient with audible tones if certain conditions occur that are related to the leads, battery, charge time, or therapies. The patient can then respond based on your prescribed instructions.

2.2 Indications and usage, AT devices

The device is indicated for use in ICD patients with atrial tachyarrhythmias, or who are at significant risk of developing atrial tachyarrhythmias. The device is intended to provide ventricular antitachycardia pacing and ventricular defibrillation for automated treatment of life-threatening ventricular arrhythmias.

In addition, the device is intended to provide pacing, cardioversion, and defibrillation for treatment of patients with

- symptomatic, drug-refractory atrial fibrillation and/or
- life-threatening ventricular tachyarrhythmias.
Notes:
- The use of the device has not been demonstrated to decrease the morbidity related to atrial tachyarrhythmias.
- The effectiveness of high-frequency burst pacing (atrial 50 Hz Burst therapy) in terminating device classified atrial tachycardia (AT) was found to be 17%, and in terminating device classified atrial fibrillation (AF) was found to be 16.8%, in the VT/AT patient population studied.
- The effectiveness of high-frequency burst pacing (atrial 50 Hz Burst therapy) in terminating device classified atrial tachycardia (AT) was found to be 11.7%, and in terminating device classified atrial fibrillation (AF) was found to be 18.2%, in the AF-only patient population studied.

2.3 Indications and usage, DR and VR devices

The implantable cardioverter defibrillator is intended to provide ventricular antitachycardia pacing and ventricular defibrillation for automated treatment of life-threatening ventricular arrhythmias.

2.4 Contraindications, AT devices

The device is contraindicated for patients experiencing any of the following conditions:
- tachyarrhythmias with transient or reversible causes including, but not limited to, the following: acute myocardial infarction, digitalis intoxication, drowning, electric shock, electrolyte imbalance, hypoxia, or sepsis
- incessant ventricular tachycardia or ventricular fibrillation
- primary disorder of chronic atrial tachyarrhythmia with no concomitant VT or VF
- present implant of a unipolar implantable pulse generator
- primary disorder of bradyarrhythmia

2.5 Contraindications, DR and VR devices

The device is contraindicated for patients experiencing any of the following conditions:
- tachyarrhythmias with transient or reversible causes including, but not limited to, the following: acute myocardial infarction, digitalis intoxication, drowning, electric shock, electrolyte imbalance, hypoxia, or sepsis
- incessant ventricular tachycardia or ventricular fibrillation
- present implant of a unipolar implantable pulse generator
- primary disorder of bradyarrhythmia or atrial arrhythmia
2.6 Patient screening

Other optional screening procedures may include exercise stress testing to determine the patient’s maximum sinus rate and cardiac catheterization to determine if there is a need for concomitant surgery or medical therapy.
3 Emergency therapy

3.1 Overview of emergency therapies

The device provides emergency defibrillation, cardioversion, fixed burst pacing, and VVI pacing therapy. You can gain access to emergency therapies by pressing the on-screen [Emergency] button, or by pressing the red mechanical button on the programmer display panel. To return to other programming functions from an Emergency screen, select [Exit Emergency].

**Effect on system operation** – The device suspends the automatic detection features when emergency defibrillation, cardioversion, or fixed burst pacing therapies are delivered. Detection is not suspended during emergency VVI pacing. Remove the programming head or press [Resume] to enable detection again.

**Aborting an emergency therapy** – You can immediately terminate an emergency defibrillation or emergency cardioversion therapy by selecting [ABORT]. To stop an emergency fixed burst therapy, remove the programmer stylus from the [BURST Press and Hold] button. To terminate emergency VVI pacing, reprogram the bradycardia pacing parameters from the Parameters screen.

**Mechanical Emergency buttons on the Model 9790C programmer** – If you press the red mechanical Emergency button on the programmer display panel, the programmer displays the Emergency screen. The mechanical yellow-on-blue deliver button activates the emergency therapy displayed on the programmer screen. This button functions only when the Emergency screen is displayed.

**Mechanical Emergency VVI button on the Medtronic CareLink Model 2090 programmer** – If you press the red Emergency VVI button on the programmer display panel, the device initiates Emergency VVI pacing and the programmer displays the Emergency screen.

**Temporary parameter values** – Emergency tachyarrhythmia therapies use temporary parameter values that do not change the programmed parameters of the device. After the tachyarrhythmia therapy is complete, the device reverts to its programmed values.

**Note:** When you enable emergency VVI pacing, the programmed bradycardia pacing parameters are changed to the emergency settings.
3.2 Delivering an emergency defibrillation therapy

The default emergency therapy is a full-energy defibrillation. When you select [Emergency] and [DELIVER], the device charges and delivers a biphasic full-energy shock. The programmer sets the emergency defibrillation energy to its maximum value each time you select [Emergency] or select the [Defibrillation] option from an Emergency screen.

3.2.1 Parameters

| Energy – Amount of energy delivered to the heart by the therapy. | 0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J |
| Pathway — Direction the electrical current flows through the heart. | B>AX (fixed) |

^If the Active Can feature is Off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.

3.2.2 How to deliver emergency defibrillation

1. Position the programming head over the device.
2. Select [Emergency].
3. Accept the defibrillation energy shown on the screen, or select a new Energy value.
4. Select [DELIVER].
   If delivery is not confirmed, verify that the programming head is properly positioned, and select [Retry] or [Cancel].

3.3 Delivering an emergency cardioversion therapy

When you initiate an emergency cardioversion therapy, the device charges its capacitors to the selected energy and attempts to deliver therapy synchronized with a sensed tachyarrhythmia event. If the cardioversion therapy cannot be synchronized, it is aborted. See Section 7.7.5.5, “Synchronizing cardioversion after charging”, page 188.

3.3.1 Parameters

| Energy – Amount of energy delivered to the heart by the therapy. | 0.4; 0.6 … 1.8; 2; 3 … 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J |
| Pathway\(^a\) – Direction the electrical current flows through the heart. | B>AX (fixed) |

\(^a\)If the Active Can feature is off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.
3.3.2 How to deliver emergency cardioversion

1. Position the programming head over the device.
2. Select [Emergency].
3. Select [Cardioversion].
4. Accept the cardioversion energy shown on the screen, or select a new Energy value.
5. Select [DELIVER].
   If delivery is not confirmed, verify that the programming head is properly positioned, and select [Retry] or [Cancel].

3.4 Delivering emergency fixed burst pacing

Emergency fixed burst pacing delivers maximum output pacing pulses to the ventricle at a selectable interval. The therapy continues for as long as you keep the programmer stylus on the [BURST Press and Hold] button.
### 3.4.1 Parameters

**Interval** – Time interval between pacing pulses delivered during the fixed burst therapy.  
100; 110 ... 350 ... 600 ms

**RV Amplitude** – Voltage of the ventricular pacing pulses delivered during the fixed burst therapy.  
8 V (fixed)

**RV Pulse Width** – Duration of the ventricular pacing pulses delivered during the fixed burst therapy.  
1.5 ms (fixed)

### 3.4.2 How to deliver emergency fixed burst pacing

1. Position the programming head over the device.
2. Select [Emergency].
3. Select [Fixed Burst].
4. Accept the pacing interval shown on the screen, or a new Interval value.
5. Select [BURST Press and Hold].

If delivery is not confirmed, the programmer displays an error window. Verify that the programming head is properly positioned. Select [OK] from the window, and reselect [BURST Press and Hold].
3.5 Enabling emergency VVI pacing

Emergency VVI pacing programs the device to deliver high-output ventricular pacing. You can initiate emergency VVI pacing from the Emergency screen or by pressing the red mechanical button on the Medtronic CareLink Model 2090 Programmer display panel. To disable emergency VVI pacing, reprogram the bradycardia pacing parameters from the Parameters screen.

3.5.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pacing Mode</strong></td>
<td>NBG Code(^a) for the pacing mode provided during emergency VVI pacing.</td>
<td>VVI</td>
</tr>
<tr>
<td><strong>Lower Rate</strong></td>
<td>Minimum pacing rate to maintain adequate heart rate during periods of inactivity.</td>
<td>70 bpm</td>
</tr>
<tr>
<td><strong>RV Amplitude</strong></td>
<td>Voltage of the ventricular pacing pulses delivered during emergency VVI pacing.</td>
<td>6 V</td>
</tr>
<tr>
<td><strong>RV Pulse Width</strong></td>
<td>Duration of the ventricular pacing pulses delivered during emergency VVI pacing.</td>
<td>1.5 ms</td>
</tr>
<tr>
<td><strong>V. Blank Post VP</strong></td>
<td>Time interval during which sensing is disabled after a pacing pulse.</td>
<td>240 ms</td>
</tr>
<tr>
<td><strong>Rate Hysteresis</strong></td>
<td>Enables tracking of intrinsic heart rate below programmed Lower Rate to prevent pacing during extended periods of inactivity, such as when a patient is sleeping.</td>
<td>Off</td>
</tr>
<tr>
<td><strong>V. Rate Stabilization</strong></td>
<td>Modifies the pacing rate to eliminate the long pause that typically follows a premature ventricular contraction.</td>
<td>Off</td>
</tr>
</tbody>
</table>

\(^a\)N–North American Society of Pacing and Electrophysiology (NASPE), B–British Pacing and Electrophysiology Group (BPEG), G–Generic Pacemaker Code
3.5.2 How to enable emergency VVI pacing

1. Position the programming head over the device.
2. Select [Emergency].
3. Select [VVI Pacing].
4. Select [PROGRAM] to change the pacing parameters to the emergency VVI settings. If programming is not confirmed, verify that the programming head is properly positioned, and select [Retry] or [Cancel].
Part II
Device implant and patient follow-up procedures

4 Implanting the device

4.1 Overview
Proper surgical procedures and sterile techniques are the responsibility of the physician. The following procedures are provided for information only. Each physician must apply the information in these procedures according to professional medical training and experience.

The implant procedure includes the following steps:
- Section 4.3, “Preparing for an implant”, page 40
- Section 4.4, “Verify lead and connector compatibility”, page 41
- Section 4.5, “Position the leads”, page 42
- Section 4.6, “Test the lead system”, page 43
- Section 4.7, “Connect the leads to the device”, page 44
- Section 4.8, “Testing ventricular defibrillation operation and effectiveness”, page 47
- Section 4.9, “Position and secure the device”, page 51
- Section 4.10, “Completing the implant procedure”, page 53

For information about replacing a previously implanted device, see Section 4.11, “Replacing a device”, page 54.

4.2 Considerations
Review the following information before implanting the device:

**Electrical isolation during implant** – Do not allow the patient to have contact with grounded equipment that might produce electrical current leakage during implant. Electrical current leakage may induce arrhythmias that may result in the patient’s death.
External defibrillation equipment – Keep external defibrillation equipment nearby for immediate use whenever arrhythmias are possible or intentionally induced during device testing, implant procedures, or post-implant testing.

Lead coils and Active Can electrodes – Lead coils and Active Can electrodes in contact during a high-voltage therapy may cause electrical current to bypass the heart, possibly damaging the device and leads. While the device is connected to the leads, verify that therapeutic electrodes, stylets, or guide wires are not touching or connected by an accessory low impedance conductive pathway. Move objects made from conductive materials (for example, an implanted guide wire) well away from all electrodes before delivering a high-voltage shock.

Use by date – Do not implant the device after the “Use by” date on the package label. Battery longevity may be reduced.

4.3 Preparing for an implant

4.3.1 Equipment and sterile supplies for an implant

The following is the necessary equipment for an implant:

- Medtronic CareLink Model 2090 programmer with a Model 2067 or 2067L programming head
- EnTrust Model 9987 software application
- Model 2290 or 8090 Analyzer or equivalent pacing system analyzer
- external defibrillator

The following are the necessary sterile supplies for an implant:

- implantable device and lead system components
- programming head sleeve
  
  Note: If a sterilized programming head is used during an implant, a sterile programming head sleeve is not necessary.

- analyzer cables
- lead introducers appropriate for the lead system
- extra stylets of appropriate length and shape

4.3.2 How to set up the programmer and start the application

1. Set up the programmer as described in the instructions provided with the programmer.
2. Install the EnTrust Model 9987 software on the programmer if it is not already installed.
3. Place the programming head over the device, and start the application. Select the device model, or select [Find Patient…].

Note: The programmer automatically interrogates the device when the application starts.
4.3.3 How to prepare the device for implant

Before opening the sterile package, prepare the device for implant:

1. Interrogate the device. Print an initial interrogation report.

   **Note:** If the programmer reports that an electrical reset occurred, do not implant the device. Contact a Medtronic representative.

2. Check the initial interrogation report or the Quick Look screen to confirm that the battery voltage is at least 3.0 V at room temperature.
   If the device has recently delivered a high-voltage charge or if the device has been exposed to low temperatures, the battery voltage will be temporarily lower and capacitor charge time may increase. Allow the device to warm to room temperature and check the battery voltage again. If an acceptable battery voltage cannot be obtained, contact a Medtronic representative.

3. Set the internal clock of the device (see Section 10.2.3).

4. Perform a manual capacitor formation (see Section 11.7.2, for additional information).

   a. Dump any charge on the capacitors.
   b. Perform a test charge to full energy.
   c. Retrieve the charge data.
   d. Do not dump the stored charge. Allow the stored charge to dissipate for at least 10 min; the dissipation forms the capacitors.
   e. If the reported charge time is unacceptable, contact a Medtronic representative.

5. Program the therapy and pacing parameters to values appropriate for the patient (see Chapter 8 and Chapter 7). Ensure that tachyarrhythmia detection is programmed to Off or Monitor (see Section 6.1).

   **Note:** Do not enable the Atrial Preference Pacing feature or a rate responsive pacing mode before implanting the device. Doing so may result in a pacing rate that is faster than expected.

4.4 Verify lead and connector compatibility

Select a compatible lead. Refer to the following table.

<table>
<thead>
<tr>
<th>Port</th>
<th>Primary lead</th>
<th>Lead adaptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV, SVC</td>
<td>DF-1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6707 for 6.5 mm cardioversion/defibrillation lead</td>
</tr>
<tr>
<td>A, V</td>
<td>IS-1&lt;sup&gt;a&lt;/sup&gt; bipolar</td>
<td>5866-24M for 5 mm paired unipolar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5866-24M for 5 mm bifurcated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5866-38M for IS-1 unipolar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5866-40M for Medtronic 3.2 mm low-profile</td>
</tr>
</tbody>
</table>

4.5 Position the leads

Implant transvenous leads according to the supplied instructions unless suitable chronic leads are already in place. Do not use any lead with this device without first verifying connector compatibility. Transvenous or epicardial leads may be used. For AT and DR devices, a bipolar atrial lead with closely spaced pacing and sensing electrodes is recommended.

4.5.1 Using transvenous leads

Use standard transvenous implant techniques to position the ventricular lead tip in the right ventricular apex. For DR and AT devices, use standard transvenous implant techniques to position the atrial pacing lead tip high on the right atrial appendage.

Follow the general guidelines below for initial positioning of other transvenous leads (the final positions are determined by defibrillation efficacy tests):

- SVC (HVX) lead: Place the lead tip high in the innominate vein, approximately 5 cm proximal to the right atrium (RA) and SVC junction.
- SQ patch: Place the patch along the left mid-axillary, centered over the fourth-to-fifth intercostal space.

**Note:** An SQ patch is not implanted transvenously, but it is used with transvenous lead systems.

- CS lead: Advance the lead tip to a position just under the left atrial appendage, if possible.

If using a subclavian approach, position the lead using a more lateral approach to avoid pinching the lead body between the clavicle and the first rib.

**Warning:** Pinching the lead can damage the lead conductor or insulation, which may cause unwanted high-voltage therapies or result in the loss of sensing or pacing therapy.

4.5.2 Using epicardial leads

A variety of surgical approaches can be used to implant epicardial leads, including a limited left thoracotomy or median sternotomy. A typical placement may use an anterior right ventricular patch as the RV (HVB) and a posterolateral left ventricular patch as the SVC (HVX).

Follow these general guidelines for positioning epicardial leads:

- If unipolar epicardial pacing leads are used, position the electrodes about 1 to 2 cm apart to reduce electromagnetic interference, and route the leads together with several loose twists.
• Place the patches so that they encompass the maximum amount of cardiac mass and they have approximately equal amounts of mass between them.
• Ensure that the patches do not overlap and that the electrode portions do not touch.
• Avoid placing extra-pericardial patches over the phrenic nerve.
• Suture the smooth face of each patch lead against the epicardium or pericardium in locations that produce optimal defibrillation.

4.5.3 Surgical incisions
A single-incision submuscular or subcutaneous approach is recommended when the device is implanted in the pectoral region. Make the implant pocket about 1.5 times the size of the device.

Submuscular implant – An incision extending over the deltoid-pectoral groove typically provides access to the cephalic and subclavian veins as well as to the implant pocket. Place the device sufficiently medial to the humeral head to avoid interference with shoulder motion.

Subcutaneous implant – A transverse incision typically permits isolation of the cephalic vein. Place the device in a far medial position to keep the leads away from the axilla. Make sure that the upper edge of the device remains inferior to the incision.

4.6 Test the lead system
Sensing and pacing tests include the following measurements:
• P-wave amplitudes (AT and DR devices only)
• R-wave amplitudes
• slew rate
• pacing threshold
• pacing lead impedance

Medtronic recommends that you use a Model 2290 or 8090 Analyzer to perform sensing and pacing measurements. If you use a Pacing System Analyzer (PSA), such as the Model 5311 or 5311B, perform both atrial and ventricular measurements using the ventricular channel of the PSA.

Refer to the technical manual supplied with the PSA for details about performing sensing and pacing measurements.
4.6.1 Parameters

See Table 20 for information about acceptable measured sensing and pacing values at implant.

Table 20. Acceptable implant values\textsuperscript{a}

<table>
<thead>
<tr>
<th>Measurements required</th>
<th>Acute transvenous leads</th>
<th>Chronic leads\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-wave amplitude</td>
<td>(\geq 5 \text{ mV})</td>
<td>(\geq 3 \text{ mV})</td>
</tr>
<tr>
<td>P-wave amplitude</td>
<td>(\geq 2 \text{ mV})</td>
<td>(\geq 1 \text{ mV})</td>
</tr>
<tr>
<td>Slew rate</td>
<td>(\geq 0.5 \text{ V/s (atrial)})</td>
<td>(\geq 0.3 \text{ V/s (atrial)})</td>
</tr>
<tr>
<td></td>
<td>(\geq 0.75 \text{ V/s (ventricular)})</td>
<td>(\geq 0.5 \text{ V/s (ventricular)})</td>
</tr>
<tr>
<td>Capture threshold (0.5 ms pulse width)</td>
<td>(\leq 1.5 \text{ V (atrial)})</td>
<td>(\leq 3.0 \text{ V (atrial)})</td>
</tr>
<tr>
<td></td>
<td>(\leq 1.0 \text{ V (ventricular)})</td>
<td>(\leq 3.0 \text{ V (ventricular)})</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The measured pacing lead impedance is a reflection of measuring equipment and lead technology. Refer to the lead technical manual for acceptable impedance values.

\textsuperscript{b}Chronic leads are leads implanted for 30 days or more.

4.6.2 Considerations

\textbf{Note:} Do not measure the intracardiac EGM telemetered from the device to assess sensing.

When measuring sensing and pacing values, measure between the tip (cathode) and ring or coil (anode) of each bipolar pacing/sensing lead.

For paired unipolar epicardial pacing leads, either electrode can be the cathode; use the configuration that yields the lower pacing threshold.

4.7 Connect the leads to the device

\textbf{Warning:} Verify that the lead connections are secure. Loose lead connections may result in inappropriate sensing and failure to deliver arrhythmia therapy.

\textbf{Caution:} Use only the wrench supplied with the device. The wrench is designed to prevent damage to the device from overtightening a setscrew.

See the following figures for information about lead connections. Figure 3 shows the AT and DR device ports for lead connections. Figure 4 shows the VR device ports for lead connections.
Figure 3. AT and DR device ports for lead connections

1 IS-1 connector port, V
2 IS-1 connector port, A
3 DF-1 connector port, SVC (HVX)
4 DF-1 connector port, RV (HVB)
5 Device can electrode, Can (HVA)

Note: For easier lead insertion, insert the ventricular IS-1 connector leg first.

Figure 4. VR device ports for lead connections

1 IS-1 connector port, V
2 DF-1 connector port, SVC (HVX)
3 DF-1 connector port, RV (HVB)
4 Device can electrode, Can (HVA)
4.7.1 How to connect the lead to the device

1. Insert the wrench into a grommet on the connector port.
   a. Check that the setscrew is retracted from the connector port. If the connector port is obstructed, retract the setscrew to clear it. Do not disengage the setscrew from the connector block.
   b. Leave the wrench in the setscrew until the lead is secure. This allows a pathway for venting trapped air when the lead is inserted.

2. Push the lead or plug into the connector port until the lead pin is clearly visible in the pin viewing area. No sealant is required, but sterile water may be used as a lubricant.

3. Tighten the setscrew by turning the wrench to the right until the wrench clicks.
4. Repeat these steps for each connector port.
5. Gently pull on the lead to confirm the connection.

4.8 Testing ventricular defibrillation operation and effectiveness

**Warning:** Ensure that an external defibrillator is charged for a rescue shock before delivering a test shock.

Demonstrate reliable defibrillation effectiveness with the implanted lead system by using your preferred method to establish that a 10 J (minimum) safety margin exists.

4.8.1 High-voltage implant values

See Table 21 for information about measured high-voltage therapy values recommended at implant.

**Table 21. High-voltage therapy values recommended at implant**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Acute or chronic leads</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV Defib impedance</td>
<td>20–200 Ω</td>
</tr>
<tr>
<td>SVC Defib impedance (if applicable)</td>
<td>20–200 Ω</td>
</tr>
<tr>
<td>Defibrillation threshold</td>
<td>≤ 25 J</td>
</tr>
</tbody>
</table>

4.8.2 How to prepare for defibrillation threshold testing

1. Place the programming head over the device and start a patient session. Interrogate the device if this has not already been completed.
2. Observe the Marker Channel annotations to verify that the device is sensing properly.
3. Conduct a manual Lead Impedance Test to verify defibrillation lead connections. Perform this test with the device in the surgical pocket. Keep the surgical pocket very moist. If the lead impedance is out of range, perform one or more of the following tasks:
   - Recheck the lead connections and lead electrode placement.
   - Repeat the lead impedance measurements.
   - Inspect the EGM for abnormalities.
   - Measure the defibrillation impedance with a manual test shock.
4. Program the device to detect VF with an adequate safety margin. An adequate safety margin is typically 1.2 mV sensitivity.
4.8.3 How to perform defibrillation threshold testing using T-Shock

2. Select T-Shock from the Inductions/Therapies box.
3. Select [Resume at DELIVER] to resume arrhythmia detection after induction delivery.
4. Select [Adjust Permanent…].
5. Set the VF detection, RV Sensitivity, and VF therapy parameters. VF Enable should be On, and the Energy parameter for VF Therapies 2–6 should be set to the maximum value.
6. Select [Program].
7. Select [Close].
8. Select Enable.
9. Select [DELIVER T-Shock]. If necessary, you can abort an induction or therapy in progress by selecting [ABORT].
10. Observe the live rhythm monitor for proper post-shock sensing.
11. Use the [Adjust Permanent…] button to program a new energy level, if desired.
12. Wait until the on-screen timer reaches 5 minutes, then repeat Step 8 through Step 12 as needed.
13. Select the Params icon and disable VF, FVT, and VT detection before closing the pocket.
14. Interrogate the device, and print an episode summary report.
4.8.4 How to perform defibrillation threshold testing using 50 Hz Burst

2. Select 50 Hz Burst from the Inductions/Therapies box.
3. Select [RV] as the chamber for induction/therapy.
4. Select [Resume at BURST] to resume arrhythmia detection after induction delivery.
5. Select [Adjust Permanent…].
6. Set the VF detection, RV Sensitivity, and VF therapy parameters. VF Enable should be On, and the Energy parameter for VF Therapies 2–6 should be set to the maximum value.
7. Select [Program].
8. Select [Close].
9. Press and hold [50 Hz BURST Press and Hold]. If necessary, you can abort an induction or therapy in progress by selecting [ABORT].
10. Observe the live rhythm monitor for proper post-shock sensing.
11. Use the [Adjust Permanent...] button to program a new energy level, if desired.
12. Wait until the on-screen timer reaches 5 minutes, then repeat Step 9 through Step 12 as needed
13. Select the Params icon and disable VF, FVT, and VT detection before closing the pocket.
14. Interrogate the device, and print an episode summary report.

4.9 Position and secure the device

Cautions:
- If no SVC electrode is implanted, the pin plug provided with the device must be secured in the SVC port to avoid damage to the device.
- Program tachyarrhythmia detection to Off or Monitor before closing the pocket to avoid inappropriate detection and shock while closing the pocket.

Note: Implant the device within 5 cm (2 in) of the surface of the skin to optimize post-implant ambulatory monitoring. The side of the device engraved with the Medtronic logo should face toward the skin to optimize the Patient Alert feature.
4.9.1 How to position and secure the device

1. Verify that each lead connector pin or plug is fully inserted into the connector port and that all setscrews are tight.
2. To prevent twisting of the lead body, rotate the device to loosely wrap the excess lead length. Do not kink the lead body.
3. Place the device and leads into the surgical pocket.
4. Suture the device securely within the pocket. Use non-absorbable sutures. Secure the device to minimize post-implant rotation and migration. Use a surgical needle to penetrate the suture holes on the device (indicated by arrows in the drawing).
5. Suture the pocket incision closed.
4.10 Completing the implant procedure

**Warning:** For AT and DR devices, do not enable the Other 1:1 SVTs PR Logic detection criterion until the atrial lead has matured, approximately one month after implant. This criterion may inappropriately withhold therapy if atrial sensing is compromised by an unstable or dislodged atrial lead.

After implanting the device, obtain an x-ray of the patient to verify device and lead placement. To complete programming the device, select parameters that are appropriate for the patient.

**Note:** The high-voltage capacitors should be formed (or conditioned) periodically to maintain quick charging for high-voltage therapy. You can use the Automatic Capacitor Formation feature to ensure that they are formed regularly. See Section 5.3, “Optimizing charge time”, page 58, for details.

4.10.1 How to complete programming the device

1. Enable tachyarrhythmia detection and the desired tachyarrhythmia therapies.
2. Perform a final VF induction, and allow the implanted system to detect and treat the arrhythmia.
3. Program defibrillation and sensitivity parameters to values appropriate for the patient after defibrillation threshold testing is complete.
4. Monitor the patient after the implant, and take x-rays as soon as possible to document and assess the location of the leads.
5. Program patient information (see Section 10.12.1).
6. Configure the Patient Alert feature (see Section 10.4.3).
7. Set up data collection parameters (see Section 10.2.3).

Before the patient is discharged from the hospital, assess the performance of the implanted device and leads.

4.10.2 How to assess the performance of the device and leads

1. If any tachyarrhythmia therapies are enabled while the patient is in the hospital, interrogate the device after any spontaneous episodes to evaluate the detection and therapy parameter settings.
2. If the patient has not experienced spontaneous episodes, you may induce the clinical tachyarrhythmias using the non-invasive EP Study features to further assess the performance of the system. See Chapter 12, “Conducting electrophysiologic studies”, page 404.
3. Recheck pacing and sensing values, and adjust if necessary.
4. Interrogate the device, and print a Final Report to document the postoperative programmed device status.

4.11 Replacing a device

If you are replacing a previously implanted device, disable detection before explanting.

When implanting the device with a chronic lead system, perform the following evaluations to ensure appropriate detection and therapy:

- Check the integrity of the chronic high-voltage leads with a test shock, chest x-ray, and inspection.
- Inspect the chronic lead connector pins for signs of pitting or corrosion.
- Perform chronic pacing and sensing measurements.
- Measure lead impedances.
- Test defibrillation efficacy.
- Confirm adequate sensing during VF.
- Ensure proper fit of the lead connectors in the device connector block.

Notes:

- To meet the implant requirements, it may be necessary to reposition or replace the chronic leads or to add a third high-voltage electrode.
- Any unused leads that remain implanted must be capped.

4.11.1 How to explant and replace a device

1. Program tachyarrhythmia detection to Off or Monitor to avoid potential inappropriate shocks to the patient or implanter while handling the device (see Chapter 6).
2. Program the device to a non-rate responsive mode to avoid potential rate increases while handling the device (see Section 8.1.4).
3. For AT devices, disable Atrial Preference Pacing (see Section 8.14.4).
4. Dissect the lead and the device free from the surgical pocket. Do not nick or breach the lead insulation.
5. Use a wrench to loosen the setscrews in the connector port.
6. Gently pull the lead out of the connector port.
7. Evaluate the condition of the lead. Replace the lead if the electrical integrity is not acceptable or if the lead connector pin is pitted or corroded. Return the explanted lead to Medtronic for analysis and disposal.
8. Connect the lead to the replacement device.

Note: A lead adaptor may be needed to connect the lead to the replacement device. Contact a Medtronic representative for questions about lead adaptor compatibility.
9. Evaluate sensing, pacing, and defibrillation efficacy. Use the replacement device.
10. After confirming acceptable electrical measurements, suture the pocket incision closed.
11. Return the explanted device to Medtronic for analysis and disposal.

4.12 Optimizing device longevity
The following factors may affect the longevity of the device:

- a greater number of high-voltage charges, either for therapy or for capacitor formation
- higher programmed cardioversion or defibrillation therapy energies
- a greater number of bradycardia paced events, for example, an increase in the pacing rate
- use of Atrial Preference Pacing (AT devices only), which increases the number of bradycardia paced events
- higher programmed pacing amplitude or pulse width
- pacing outputs or high-voltage therapy energy increased to compensate for a decrease in pacing and high-voltage lead impedance
- use of the Pre-arrhythmia EGM storage or Holter telemetry features

For device longevity estimates, see Section 1.4.

4.12.1 Considerations

**Shock energy** – If the defibrillation threshold of the patient allows for an appropriate safety margin (at least 10 J, after the acute implant period), consider programming the first ventricular shock energy below the maximum value. Always program all subsequent shocks to the full available energy.

**Note:** If VF Detection is enabled, consider programming the Energy parameter for the first VF therapy to at least 20 J if you enable ATP During Charging. The charge times for therapies with energies less than 20 J may be too brief for the device to detect when ATP During Charging has terminated an arrhythmia.

**Pacing outputs** – If the patient’s pacing threshold allows for an appropriate safety margin (at least a factor of 2 after the acute implant period), consider decreasing the pacing outputs. Always consider the patient’s access to regular follow-up care in selecting a safety margin for chronic pacing.

**Pacing mode** – If the patient’s intrinsic rhythm allows for appropriate rate support, you can decrease the pacing burden by programming the Mode, Rate Response, and AV Interval parameters to promote intrinsic activation or conduction.
Pre-arrhythmia EGM storage – When Pre-arrhythmia EGM storage is enabled, the device collects up to 10 s of EGM information before the onset or detection of the tachyarrhythmia. However, using Pre-arrhythmia EGM storage reduces longevity by approximately 27% or by 3.3 months per year in AT and DR devices\(^2\), and by approximately 33% or 4.0 months per year in VR devices\(^3\). In a patient who uniformly repeats the same onset mechanisms, the greatest clinical benefit of Pre-arrhythmia EGM storage is achieved after a few episodes are captured.

To maximize the effectiveness of the Pre-arrhythmia EGM feature and optimize device longevity, consider these programming options:

- Enable Pre-arrhythmia EGM to capture possible changes in the onset mechanism following significant clinical adjustments, for example, device implant, medication changes, and surgical procedures.
- Disable Pre-arrhythmia EGM once you have successfully captured the information of interest.

Note: When Pre-arrhythmia EGM is disabled, the device starts storing EGM information after the third tachyarrhythmia event occurs. However, the device still records up to 20 s of information before the onset or detection of the tachyarrhythmia, including interval measurements and Marker Channel annotations. In addition, the most recent tachyarrhythmia episodes also provide Flashback interval data.

\(^2\) Based on device modeling with 50% atrial pacing, 5% ventricular pacing.

\(^3\) Based on device modeling with 15% ventricular pacing.
5 Conducting a patient follow-up session

5.1 Patient follow-up guidelines

During the first few months after receiving a new device, the patient may require close monitoring. Schedule office visits at least every 3 months to monitor the condition of the device and leads and to verify that the device is configured appropriately for the patient.

The Quick Look screen, which is displayed when you start the application, provides a good beginning for the follow-up. The Quick Look screen allows you to perform these functions:

- Verify that the device is functioning correctly.
- Review the clinical performance and device trends.
- Print appropriate reports to compare the results to the patient’s history and to retain for future reference.

**Note:** To print an Initial Interrogation Report, you may need to change Initial Report preferences and restart the session. See Section 9.12.4, “How to set Initial Reports preferences”, page 317.

**Note:** The Checklist feature provides a standard list of tasks to perform at a complete follow-up visit. You can also customize your own checklists. See Section 9.3, “Streamlining follow-up and implant sessions with Checklist”, page 282.

5.2 Verifying the status of the implanted system

To verify that the device and leads are functioning correctly, review the following information from the Quick Look screen, and perform follow-up tests as indicated:

- Review the displayed battery voltage for comparison to the Elective Replacement Indicator (ERI) value (see Section 1.3). If the displayed battery voltage is at or below the displayed ERI value or if the ERI indicator is displayed, schedule an appointment to replace the device.

  **Note:** Battery voltage may be low if high-voltage charging has occurred within 24 hours.

- If the programmer displays the EOL indicator for low battery voltage or excessive charge time, the device should be replaced immediately.

- Review the last full energy charge. For information about adjusting the capacitor formation interval, see Section 5.3, “Optimizing charge time”, page 58.

- Review the lead impedance values for inappropriate values or significant changes since the last follow-up. See Section 11.5, “Measuring lead impedance”, page 396.
• Perform P-wave and R-wave amplitude tests for comparison to previous P-wave and R-wave amplitude measurements. See Section 11.6, “Performing a Sensing Test”, page 398.
• To review trends in sensing and impedance measurements, select the [>>] button from the lead status area of the Quick Look screen. The programmer displays a detailed history of automatic sensing and impedance measurements. See Section 10.11, “Viewing Lead Performance Trends data”, page 377.

5.3 Optimizing charge time
The high-voltage capacitors should be formed (or conditioned) periodically to maintain quick charging for high-voltage therapy. You can use the Automatic Capacitor Formation feature to ensure that they are formed regularly.

The device can be programmed to automatically adjust the capacitor formation interval for interactive management of charge time and device longevity.

**Note:** The device capacitors have not been fully formed since manufacture. Capacitors should be manually formed before programming the Automatic Capacitor Formation Interval to reduce the device charge time. See Section 11.7.2, “How to perform a Charge/Dump test”, page 402.

5.3.1 Parameters

<table>
<thead>
<tr>
<th>Minimum Auto Cap Formation Interval</th>
<th>Auto; 1; 2 … 6 months</th>
</tr>
</thead>
</table>

5.3.2 Considerations

**Formation interval and longevity** – A shorter formation interval provides faster charge times by optimizing the efficiency of the capacitors. However, each capacitor formation includes a full energy charge, reducing the longevity of the device.

Assess the patient’s requirements for faster therapy delivery relative to the effect on device longevity. Each full energy charge decreases the longevity of AT and DR devices by approximately 34 days and decreases the longevity of VR devices by approximately 49 days.

**Programming a new formation interval** – When you program a new automatic formation interval, always confirm that the charge time is adequate at present. Either perform a manual capacitor formation or evaluate a recent full energy charge time recorded in the Battery and Lead Measurements display.

**Capacitor formation and Patient Alert** – You can use the Patient Alert monitoring feature to receive prompt notice if a long charge time has occurred.
5.3.3 How to evaluate charging performance

1. Perform a Charge/Dump test, and review the charge time (see Section 11.7, “Testing the device capacitors”, page 400).
2. Allow the charge to dissipate for 10 min.
3. Select [DUMP Capacitors].
4. Perform another Charge Time test, and review the second charge time.
   - If the second charge time is clinically acceptable, consider reducing the Automatic Capacitor Formation Interval (see Section 5.3.4, “How to program the Automatic Capacitor Formation Interval”, page 60).
   - If the second charge time is not clinically acceptable, contact your Medtronic representative.
5.3.4 How to program the Automatic Capacitor Formation Interval

1. Select the Params icon.
2. Select the Therapies... field for VF, FVT, or VT.
3. Select Auto Cap Formation....
4. Select the Minimum Auto Cap Formation Interval.
5. Return to the Parameters screen and select [Program].
5.3.5 Details about managing charge time

The device provides the fastest charging and most prompt therapy delivery just following a capacitor formation. During the time between formations, the capacitors gradually lose their efficiency. This results in longer charge times until the next formation.

The charge time also gradually increases over the life of the device as the battery is depleted. This occurs independently of capacitor formation.

Capacitor formation consists of 2 steps: First, the capacitors are charged to their full energy. Then the charge is allowed to dissipate for at least 10 min.

The device records the time and date when a full-energy charge dissipates for 10 min without interruption, and reports it on the programmer as a capacitor formation.

5.3.5.1 Smart Auto Cap

Therapeutic charging can also contribute to the efficiency of the capacitors. This occurs because the capacitors are partially conditioned each time they are charged (for example, during a full energy defibrillation). In these situations, there is less need for the next scheduled capacitor formation. Automatic capacitor formation is not enabled until the device is implanted.

More frequent formations decrease the device longevity, with little benefit to the charge time. To optimize the effectiveness of the automatic capacitor formations, the device postpones the schedule when full energy charging has occurred:

- Whenever the capacitor formation interval is reprogrammed, the device resets the automatic capacitor formation interval clock.
- After a manual capacitor formation, the device resets the automatic capacitor formation interval clock.
- After an incidental capacitor formation (a full energy charge that dissipates for 10 min), the device resets the automatic capacitor formation interval clock.
- After a full energy charge is delivered or dumped, the device extends the automatic capacitor formation interval clock by up to 2 months. The total of these extensions will not exceed the programmed automatic capacitor formation interval.

Parameter set to “Auto” – When the capacitor formation interval parameter is programmed to Auto, the device maintains a 6-month schedule for capacitor formation until the battery is close to end of life.

If a charging period for therapy or capacitor formation exceeds 16 s, the device changes to a 1-month schedule for capacitor formation. If a second charging period exceeds 16 s, the device sets the EOL status message, indicating that the device should be replaced immediately.
The rules for postponing the scheduled automatic formation after a full energy charge remain in effect if the device changes to a 1-month schedule.

5.4 Verifying accurate detection and appropriate therapy

To verify that the device is providing effective tachyarrhythmia detection and therapy, review the following information from the Quick Look screen, and investigate as indicated:

- Review Quick Look Observations that relate to patient history and device operation. To display more detailed information about an observation (when available), select the observation and then select the [>>] button.
- Review any Patient Alerts listed in the Observations of the Quick Look screen. For the most detailed information about Patient Alerts, select Patient Alert Events from the Data icon.
- Check stored episode records for appropriate sensing and detection of arrhythmias (see Section 10.5, “Viewing Arrhythmia Episode data”, page 342).
- Check stored SVT episode records for appropriate identification of SVTs.

5.4.1 Considerations

Review the following information before verifying detection and therapy.

**Caution:** Do not program the device to decrease oversensing without ensuring that appropriate sensing is maintained (see Section 6.2, “Setting up sensing”, page 70).

**Flashback memory** – In addition to the episode records and stored electrograms, use Flashback memory and interval plots to investigate the accuracy and specificity of atrial and ventricular detection.

**Episode misidentification** – If the episode records indicate that false detections have occurred, the Sensing Integrity Counter may help in determining the prevalence of oversensing. For more information, see Section 10.10.2.2, “Sensing integrity counter”, page 377.

If the device is oversensing, consider these options:

- Assess the lead integrity and lead connections.
- Assess the sensitivity threshold.
If the episode records reveal that a stable monomorphic VT has been identified and treated as VF, consider these options to improve the detection accuracy, which may also improve the therapy accuracy:

- Review the Interval Plot for the episode, and adjust the VF Interval if necessary. Use caution when reprogramming the VF Interval because changes to this value can adversely affect VF detection.
- Program the ATP parameter for VF therapies to ATP During Charging (see Section 7.5.4, “How to program VF therapies”, page 166).
- Enable FVT via VF detection (see Section 6.6.4, “How to program FVT Detection”, page 94).

If the SVT episode records include episodes of true VT, review the SVT episode records to identify the SVT detection criterion that withheld detection. Adjust the SVT detection criteria parameters as necessary.

5.5 Verifying effective bradycardia pacing

To verify that the device is sensing and pacing appropriately, review the following information from the Quick Look screen, and investigate as indicated:

- Confirm that the patient is receiving adequate cardiac support for daily living activities.
- Review the pacing conduction history for comparison to the patient history. A sharp increase in the paced beats percentage may indicate a need for investigation and analysis.
- Review the Cardiac Compass report for comparison to patient history (see Section 10.7, “Using Cardiac Compass to view long-term clinical trends”, page 356).
- Conduct pacing threshold tests (see Section 11.3, “Measuring pacing thresholds”, page 388) to verify that the programmed pacing outputs provide a sufficient safety margin.

5.5.1 Considerations

Review the following information for AT and DR devices before verifying bradycardia pacing.

Ventricular Pacing – If the ventricle is predominantly paced and the patient exhibits adequate ventricular response, consider these options:

- Program the device to an MVP mode (AAIR\Rightarrow-DDDR or AAI\Rightarrow-DDD). These modes are designed to manage unnecessary right ventricular pacing.
- Decrease the Lower Rate.
- Increase the Sensed AV interval.
- Increase the Paced AV interval.
Atrial Pacing – If the conduction history shows a predominance of atrial pacing despite a healthy sinus response, consider these options to decrease the atrial pacing burden:

- Decrease the Lower Rate.
- Decrease the Rate Response or increase the Activity Threshold.
- Decrease Paced AV and enable Rate Adaptive AV.

Conduction history – The reported percentages in the conduction history may not add up to 100 because of rounding.

Note: Rate histograms may also be used to assess pacing and sensing history. The pacing and sensing history on the Quick Look screen may not match the data in the histograms because of premature atrial contractions (PACs) and A:V dissociation.
Part III
Configuring the device for the patient

6 Detecting tachyarrhythmias

6.1 Detection overview

EnTrust devices provide several different atrial and ventricular tachyarrhythmia detection capabilities.

- AT devices provide AT/AF detection, AT/AF monitoring, VF/FVT/VT detection, and VT monitoring.
- DR devices provide AT/AF monitoring, VF/FVT/VT detection, and VT monitoring.
- VR devices provide VF/FVT/VT detection and VT monitoring.

The device detects atrial tachyarrhythmias (AT/AF) by examining the atrial rate and the relationship between atrial and ventricular events. If the atrial rate is fast enough and if enough evidence of an atrial tachyarrhythmia is accumulated, the device detects an AT/AF episode.

AT/AF detection can be programmed to Monitor or On. If AT/AF detection is programmed to Monitor, the device collects data about the incidence and duration of atrial arrhythmias, but it does not treat episodes with atrial therapies. If AT/AF detection is programmed to On, detected AT/AF episodes can be treated with atrial therapies (see Chapter 7, “Treating tachyarrhythmia episodes”, page 133). The AT/AF Detection Interval, whether programmed to Monitor or On, also triggers mode-switching in the device.

The device detects ventricular tachyarrhythmias (VF, VT, and FVT) by comparing the time intervals between sensed ventricular events to a set of programmed detection intervals. If enough intervals are shorter than the programmed intervals, the device detects a tachyarrhythmia.
In addition to VF, VT, and FVT detection zones, the device provides a VT monitoring zone, which functions as an independent VT zone. When the device detects a VT episode in the VT monitoring zone, it records the episode but does not deliver VT therapy.

To discriminate between rapidly conducted SVTs (for example, sinus tachycardia or atrial fibrillation) and ventricular tachyarrhythmias, the device provides several detection enhancements such as the following detection criteria:

- PR Logic with enhanced Sinus Tach criterion in AT and DR devices
- Wavelet Dynamic Discrimination in VR devices
- Stability
- Onset

Figure 5 shows how the ventricular tachyarrhythmia detection features interact in AT and DR devices during initial detection. Figure 6 shows how the ventricular tachyarrhythmia detection features interact in VR devices during initial detection. During redetection of ventricular tachyarrhythmias, devices do not apply Onset, PR Logic, or Wavelet detection criteria.

**Note:** Detection functions can be disabled by programming the VF, FVT, VT, and VT Monitor detection parameters to Off. For an example, see Section 6.4.4. AT/AF detection can only be programmed to On or Monitor.
Figure 5. How ventricular tachyarrhythmia detection features in AT and DR devices interact during initial detection.
Figure 6. How ventricular tachyarrhythmia detection features in VR devices interact during initial detection

- Is the interval in the VF, FVT, or VT detection zone?
- Has High Rate Timeout suspended detection enhancements?
- Does Stability reset the VT event count? (VT and FVT via VT detection only)
- Is the Onset criterion allowing VT event counting? (VT and FVT via VT detection only)
- Has a tachyarrhythmia event count reached an Initial Beats to Detect criterion?
- Is Wavelet enabled?
- Is the median ventricular interval less than the SVT V. Limit?
- Is Wavelet withholding detection?
6.1.1 Suspending tachyarrhythmia detection

When detection is suspended, the device temporarily stops classifying and counting tachyarrhythmia intervals. Sensing and bradycardia pacing remain active, and the programmed detection settings are not modified.

Note: Suspending detection during a VT Monitor episode terminates the data storage. If the ventricular episode continues following suspension, a new episode is detected.

Note: If detection is suspended during an AT/AF episode, a new episode is not recorded when detection resumes. Redetection of the episode begins when detection resumes.

Detection is suspended during the following occurrences:

- The device senses the presence of a strong magnet. The programmer head contains a magnet which suspends detection. Once telemetry between the device and programmer is established, detection resumes.
- The device is performing any of the manual system tests. Detection automatically resumes once the test is complete.
- The device is performing an EP Studies induction. You can choose to have the device automatically resume detection after delivering the induction.
- The device is delivering a manual therapy or emergency therapy. You can resume detection by selecting the [Resume] button or by removing the programming head from the device.
- You have selected the on-screen [Suspend] button. You can resume detection by selecting the [Resume] button or by removing the programming head from the device.
- The device is performing automatic daily lead impedance measurements. Detection resumes when the measurements are complete.

Note: The automatic daily lead impedance measurements are not performed during detected VT/VF episodes. These measurements are, however, performed during VT Monitor episodes.

- The device is delivering an automatic tachyarrhythmia therapy (including capacitor charging for defibrillation and cardioversion). However, the device does continue to confirm detected ventricular episodes during charging. Detection resumes when the therapy is complete.

Note: The device suspends VT detection (and Combined Count detection, see Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101) for 17 events following a defibrillation therapy delivered in response to a detected VF.\(^4\)

\(^4\) If the defibrillation therapy is delivered as a result of either a High Rate Timeout Therapy operation or Progressive Episode Therapies operation, VT detection is not suspended (see Section 6.15.4, “Details about High Rate Timeout”, page 132).
The device is charging for Automatic Capacitor Formation. Detection resumes when charging is complete.

6.2 Setting up sensing

The device provides bipolar sensing in both the atrium and ventricle using the sensing electrodes of the implanted atrial and ventricular leads. You can adjust the sensitivity to intracardiac signals using independent atrial and ventricular sensitivity settings. These settings define the minimum electrical amplitude recognized by the device as an atrial or ventricular sensed event.

Dual chamber atrial and ventricular sensing is available only in AT and DR devices. Only ventricular sensing is available in VR devices.

Proper sensing is essential for the safe and effective use of the device. To provide appropriate sensing, the device uses the following features:

- short (30 ms) cross-chamber blanking after paced events
- auto-adjusting atrial and ventricular sensing thresholds
- programmable options for PVAB

See Section 6.2.4, “Details about sensing”, page 72.

6.2.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV Sensitivity</td>
<td>Minimum amplitude of electrical signal that registers as a sensed ventricular event.</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
</tr>
<tr>
<td>A. Sensitivity</td>
<td>Minimum amplitude of electrical signal that registers as a sensed atrial event.</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2; 1.5; 2.1 mV</td>
</tr>
</tbody>
</table>

6.2.2 Considerations

Review the following information before programming sensing parameters.

Sensitivity thresholds – The programmed sensitivity thresholds apply to all features related to sensing, including detection, bradycardia pacing, and the Sensing Test.

Bradycardia pacing and sensing – A combination of high pacing pulse width or high amplitude with a low sensitivity threshold may cause inappropriate sensing across chambers or in the same chamber. Programming a lower pulse width, lower amplitude, longer pace blanking, or a higher sensitivity threshold may eliminate this inappropriate sensing.

Dual chamber sensing and bradycardia pacing modes (AT and DR devices) – The device senses in both the atrium and the ventricle at all times, except when the programmed
bradycardia pacing mode is DOO, VOO, or AOO. When the pacing mode is programmed to DOO or VOO, there is no sensing in the ventricle. When the pacing mode is programmed to DOO or AOO, there is no sensing in the atrium.

**Recommended ventricular sensitivity threshold** – A ventricular sensitivity threshold of 0.3 mV is recommended to maximize the probability of detecting VF and to limit the possibility of oversensing and cross-chamber sensing.

**High ventricular sensitivity threshold** – Setting RV Sensitivity to a value greater than 0.6 mV is not recommended except for testing purposes. Doing this may cause undersensing, which may cause any of the following situations:
- delayed or aborted cardioversion therapy
- delayed defibrillation therapy (when VF confirmation is active)
- asynchronous pacing
- underdetection of tachyarrhythmias

**Testing sensitivity after reprogramming** – If you change the ventricular sensitivity threshold, test for proper sensing. If appropriate, test for proper detection by inducing VF and allowing the device to automatically detect and treat the arrhythmia.

**Sensing during VF** – Always verify that the device senses properly during VF. If the device is not sensing or detecting properly, disable detection and therapies, and evaluate the system (making sure to monitor the patient for life-threatening arrhythmias until you enable detection and therapies again). You may need to reposition or replace the ventricular sensing lead to achieve proper sensing.

**Low sensitivity threshold** – If you set a sensitivity parameter to its most sensitive value of 0.15 mV, the device will be more susceptible to EMI, cross-chamber sensing, and oversensing.

**Recommended atrial sensitivity threshold** – An atrial sensitivity threshold of 0.3 mV is recommended to optimize the effectiveness of atrial detection and pacing operations while limiting the possibility of oversensing and cross-chamber sensing.

**High atrial sensitivity threshold** – If you set the A. Sensitivity value too high, the device may not provide reliable sensing of P-waves during AT/AF episodes and sinus rhythm.

**Atrial pacing and ventricular sensing** – If you program the device to an atrial pacing mode, make sure that it does not sense atrial pacing pulses as ventricular events.

**Atrial lead selection** – Atrial leads with minimal (10 mm) tip-to-ring spacing may reduce far-field R-wave sensing.

**Repositioning the atrial lead** – If reprogramming the atrial sensitivity threshold does not provide reliable atrial sensing during AT/AF episodes and sinus rhythm, you may need to reposition or replace the atrial sensing lead.
6.2.3 How to program sensitivity

1. Select the Params icon.
2. Select the desired A. Sensitivity and RV Sensitivity parameters.
3. Select [PROGRAM].

6.2.4 Details about sensing

6.2.4.1 Blanking periods

Blanking periods inhibit sensing after paced and sensed events. These periods help prevent the sensing of device pacing, cardioversion and defibrillation pulses, post-pacing depolarization, T-waves, and multiple sensing of the same event. The blanking periods after paced events are longer than or equal to those after sensed events to avoid sensing the atrial and ventricular depolarizations.

Table 22 shows the duration of the fixed blanking periods. See Section 8.1, “Providing basic pacing therapy”, page 198, for more information about programmable pace blanking periods.
Table 22. Duration of fixed blanking periods

<table>
<thead>
<tr>
<th>blanking period</th>
<th>duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-chamber blanking after atrial or ventricular pacing pulse</td>
<td>30 ms</td>
</tr>
<tr>
<td>Atrial and ventricular blanking after delivered cardioversion or defibrillation therapy</td>
<td>520 ms</td>
</tr>
</tbody>
</table>

The device does not sense electrical signals during blanking periods, except during the post-ventricular atrial blanking (PVAB) period. See Section 6.2.4.3, “Post-ventricular atrial blanking and far-field R-waves”, page 75, for details about PVAB.

6.2.4.2 Auto-adjusting sensitivity thresholds

The device automatically adjusts sensitivity thresholds after certain paced and sensed events to help reduce oversensing from T-waves, cross-chamber events, and pacing.

In Figure 7, sensitivity thresholds are adjusted after different types of events when the nominal PVAB method is programmed.

Note: The way the device adjusts the atrial sensitivity threshold depends upon the programmed method of PVAB. See Section 6.2.4.4 for details about the different PVAB methods.
Figure 7. Auto-adjusting sensitivity thresholds

1. After an atrial sensed event, the atrial sensitivity threshold increases to 75% of the EGM peak (maximum: 8x the programmed value).
2. After a ventricular sensed event, the ventricular sensitivity threshold increases to 75% of the EGM peak (maximum: 10x the programmed value).
3. After an atrial paced event, the device does not adjust the atrial sensitivity threshold. The ventricular sensitivity threshold increases to 0.45 mV.
4. After a ventricular paced event, the atrial sensitivity threshold increases to 4x the programmed value (maximum: 2.0 mV).
5. After the ventricular pace blanking period is finished, the ventricular threshold increases to 4.5x the programmed value (maximum: 1.8 mV).

---

5. If the programmed ventricular sensitivity threshold exceeds 0.3 mV, the threshold is adjusted to 1.25x the programmed value.
6. If the programmed atrial sensitivity threshold exceeds 1.2 mV, the threshold is adjusted to 1.25x the programmed value.
6.2.4.3 Post-ventricular atrial blanking and far-field R-waves

Nominally, atrial sensing is active during the post-ventricular atrial blanking (PVAB) interval. When the device senses an atrial event in the PVAB interval, the event is ignored by bradycardia pacing features. However, this event is detected by arrhythmia detection features. See Section 6.3, “Detecting atrial tachyarrhythmias”, page 78, for details about far-field R-wave sensing.

Note: Atrial events in the PVAB interval are not used by NCAP, PVC Response, Atrial Rate Stabilization, Rate Adaptive AV, and PMT Intervention features. See Chapter 8 for details.

The PVAB interval can be programmed to 3 different methods of operation. The 3 programmable PVAB methods are Partial (the nominal method), Partial+, and Absolute. The programmed method of PVAB affects how the atrial auto-adjusting sensitivity threshold operates.

6.2.4.4 Post-ventricular atrial blanking methods

The auto-adjusting sensitivity threshold operates in the same way if either the Partial method (the nominal method) or the Absolute method is programmed (see Figure 7). However, the auto-adjusting sensitivity threshold operates in a different way if the Partial+ method is programmed (see Figure 8). When the Partial+ method is programmed, the atrial sensitivity threshold is increased (less sensitive) following ventricular events to provide amplitude-based discrimination between far-field R-waves and intrinsic atrial events.

The following are details about the 3 PVAB methods:

Partial PVAB (nominal) – When the Partial PVAB method is programmed, atrial sensed events in the PVAB interval are ignored by bradycardia pacing features but are used by arrhythmia detection features.

See Section 8.2.6.4, “Post Ventricular Atrial Blanking interval (dual chamber)”, page 210, for details about the Partial PVAB method.

Absolute PVAB – When the Absolute PVAB method is programmed, atrial sensed events in the PVAB interval are not used by either arrhythmia detection features or bradycardia pacing features. This method is recommended only for addressing complications not addressed by the other PVAB methods.

See Section 8.2.6.4, “Post Ventricular Atrial Blanking interval (dual chamber)”, page 210, for details about programming the Absolute PVAB method.

Partial+ PVAB – When the Partial+ PVAB method is programmed, atrial sensed events in the PVAB interval are ignored by bradycardia pacing features but are used by arrhythmia detection features. The atrial sensitivity threshold is increased during the PVAB interval.

PVAB does not affect Mode Switch unless Absolute is the programmed PVAB method.
following a ventricular paced or sensed event for a period of time. This period of time, called
the desensitization period, reduces the chances of sensing far-field R-waves. Extending
the PVAB interval may affect intrinsic and far-field R-wave sensing.

Following a ventricular sensed or paced event, the length of the desensitization period is
similar to the length of the programmed PVAB interval. The length of the desensitization
period is 40, 60, 80, or 100 ms. The length of the desensitization period is determined by
the longest of these 4 lengths that does not exceed the length of the PVAB interval. The
desensitization period following a ventricular paced or sensed event reverts to the atrial
sensing threshold.

See Section 8.2.6.4, “Post Ventricular Atrial Blanking interval (dual chamber)”, page 210,
for details about the Partial+ PVAB method.

In Figure 8, sensitivity thresholds are adjusted after different types of events when the
Partial+ PVAB method is programmed.
Figure 8. Auto-adjusting sensitivity thresholds with Partial+ PVAB

1. After an atrial sensed event, the atrial sensitivity threshold increases to 75% of the EGM peak (maximum: 8x the programmed value; minimum: see Table 23).
2. After a ventricular event, the atrial sensitivity threshold is adjusted to the level to which it was adjusted for the previous atrial event. If no atrial event occurred during the most recent V-V interval, the atrial sensitivity is adjusted according to the minimum adjusted atrial threshold (see Table 23).
3. After an atrial paced event, the device adjusts the atrial sensitivity threshold to the minimum adjusted value (see Table 23).

Table 23. Minimum adjusted atrial threshold

<table>
<thead>
<tr>
<th>If the programmed atrial sensitivity is</th>
<th>Then the minimum adjusted threshold is</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15 mV</td>
<td>0.45 mV</td>
</tr>
<tr>
<td>0.3 mV</td>
<td>0.6 mV</td>
</tr>
<tr>
<td>0.45 mV</td>
<td>0.9 mV</td>
</tr>
</tbody>
</table>
Table 23. Minimum adjusted atrial threshold (continued)

<table>
<thead>
<tr>
<th>If the programmed atrial sensitivity is</th>
<th>Then the minimum adjusted threshold is</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 mV</td>
<td>1.2 mV</td>
</tr>
<tr>
<td>0.9–1.5 mV</td>
<td>1.8 mV</td>
</tr>
<tr>
<td>2.1 mV</td>
<td>2.1 mV</td>
</tr>
</tbody>
</table>

See “Partial+ PVAB”, page 211, for details about programming the Partial+ PVAB method.

6.2.4.5 Refractory periods

During a refractory period, the device senses normally but classifies sensed events as refractory and limits its response to these events. Pacing refractory periods prevent inappropriately sensed signals, such as far-field R-waves (ventricular events sensed in the atrium) or electrical noise from triggering certain pacing timing intervals.

Synchronization refractory periods help prevent the device from delivering cardioversion and defibrillation therapies at inappropriate times. See Section 7.5.5.7, “Synchronizing subsequent defibrillation therapies”, page 172 and Section 7.7.5.5, “Synchronizing cardioversion after charging”, page 188.

Note: Refractory periods do not affect tachyarrhythmia detection.

6.3 Detecting atrial tachyarrhythmias

The device detects atrial tachyarrhythmias (AT/AF) by examining the atrial rate and the relationship between atrial and ventricular events. If the atrial rate is fast enough and if enough evidence of an atrial tachyarrhythmia is accumulated, the device detects an AT/AF episode.

AT/AF detection is available in AT and DR devices. In DR devices, AT/AF detection can only be programmed to Monitor. If AT/AF detection is programmed to Monitor, the device collects data about the incidence and duration of atrial arrhythmias, but it does not treat episodes with atrial therapies.

If AT/AF Detection is programmed to On, detected AT/AF episodes can be treated with atrial therapies (see Chapter 7, “Treating tachyarrhythmia episodes”, page 133). The AT/AF Detection Interval, whether programmed to Monitor or On, also triggers mode-switching in the device.
6.3.1 Parameters

<table>
<thead>
<tr>
<th>AT/AF Detection</th>
<th>On; Monitor (AT devices) Monitor (DR devices)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of detection zones</td>
<td>1; 2 (AT devices)</td>
</tr>
<tr>
<td>AT/AF Interval (Rate)</td>
<td>150; 160 … 350; … 450 ms</td>
</tr>
<tr>
<td>Fast AT/AF A. Interval (Rate)</td>
<td>150; 160 … 200; … 250 ms (AT devices)</td>
</tr>
</tbody>
</table>

6.3.2 Considerations

Review the following information before programming AT/AF Detection.

**Two-zone AT/AF Detection** – If the patient exhibits two distinct atrial tachyarrhythmias, you can program the device to detect each separately. This allows you to deliver a separate therapy set for each tachyarrhythmia. Set the number of detection zones to 2, and program the AT/AF A. Interval (Rate) and Fast AT/AF A. Interval (Rate) parameters to values appropriate for each arrhythmia.

**Atrial therapies and AT/AF Detection** – If all atrial therapies are programmed Off and you change the AT/AF Detection parameter value from Monitor to On, the programmer automatically sets the first 2 AT/AF therapies to nominal or previously programmed settings.

6.3.3 Restrictions

Review the following information before programming AT/AF detection.

**VF detection backup during AT/AF** – To ensure VF detection backup during AT/AF episodes, AT/AF Detection cannot be On unless VF Detection is also On.

**Asynchronous pacing mode** – Atrial detection must be programmed to Monitor when the programmed pacing mode is DOO, VOO, or AOO.
6.3.4 How to program AT/AF Detection

1. Select the Params icon.
2. Select a value for AT/AF Detection.
3. Select a value for the AT/AF Interval (Rate).
4. To program Fast AT/AF Detection (only if AT/AF Detection is programmed to On), select the Therapies… field for AT/AF to open the AT/AF Detection and Therapies window.
   a. Set Zones to 2.
   b. Select a value for Fast AT/AF A. Interval (Rate).

5. Return to the Parameters screen and select [PROGRAM].

6.3.5 Details about AT/AF detection

Atrial tachyarrhythmia (AT/AF) detection has 4 phases:
- AT/AF onset
- initial AT/AF detection
- sustained AT/AF detection
- AT/AF episode termination

The device begins storing AT/AF data when the AT/AF onset criteria are met. After the AT/AF onset criteria are met, the rhythm is monitored for initial AT/AF detection criteria and then sustained AT/AF detection criteria. Once the rhythm is sustained, it is monitored until it meets AT/AF termination criteria if AT/AF Detection is programmed to Monitor. If AT/AF Detection is programmed to On and the device delivers an atrial therapy, the rhythm is monitored for redetection and termination criteria.

The device uses several detection criteria throughout the phases of AT/AF detection. For more information about AT/AF detection criteria, see Section 6.3.5.2, “AT/AF detection criteria”, page 83.

**Note:** AT/AF detection can occur only if the device has not detected a ventricular tachyarrhythmia. If an AT/AF episode is in progress and VF, VT, or FVT detection occurs, AT/AF detection is suspended, and AT/AF therapies are disabled until the ventricular episode terminates.

6.3.5.1 AT/AF detection phases

The 4 phases of AT/AF detection are discussed in detail as follows.

**AT/AF onset** – AT/AF onset occurs when the median atrial interval is less than the AT/AF detection interval and the AT/AF evidence counter has counted at least 3 ventricular events in which the A:V pattern shows evidence of an atrial tachyarrhythmia. The device begins storing episode data after AT/AF onset occurs.
Notes:

- AT/AF onset data is used to calculate the percentage of time that the patient was experiencing AT/AF.
- If Mode Switch is enabled, the device starts mode switch operations when AT/AF onset is detected. See Section 8.8, “Mode Switch”, page 240.

Initial AT/AF detection – Initial AT/AF detection occurs when the median atrial interval is less than the AT/AF detection interval and the AT/AF evidence counter has counted at least 32 ventricular events in which the A:V pattern shows evidence of an atrial tachyarrhythmia. If the device is programmed for two-zone AT/AF detection, the device identifies the episode in the episode log as a Fast AT/AF episode if the median atrial interval is less than the programmed Fast AT/AF detection interval.

Once initial AT/AF detection occurs, the AT/AF episode continues until episode termination.

Sustained AT/AF detection – Sustained AT/AF detection begins after initial detection. During sustained detection, the device monitors the cardiac rhythm for changes or episode termination. Sustained detection continues until the AT/AF episode termination criteria are met.

When AT/AF Detection is programmed to On, the device can respond to detected episodes with tachyarrhythmia therapies. For more information about the conditions required to deliver atrial therapies, see Section 7.1, “Controlling atrial therapy sequencing”, page 133. If AT/AF Detection is programmed to Monitor, the device delivers no atrial therapy, but monitors the episode until the AT/AF episode ends.

If the device delivers an atrial therapy, the AT/AF evidence counter is reset to zero and redetection begins. The AT/AF episode is redetected if the median atrial interval is less than the AT/AF detection interval and the AT/AF evidence counter reaches 32.

If the device detects a ventricular tachyarrhythmia episode during an AT/AF episode, it suspends AT/AF detection until the ventricular episode terminates. When AT/AF detection resumes, the AT/AF evidence counter is reset to zero and must reach 32 before the atrial episode is redetected.

AT/AF episode termination – Once the device detects an atrial tachyarrhythmia, the episode is considered ongoing until episode termination. The device classifies an AT/AF episode as terminated when one of the following conditions occurs:

- The device identifies sinus rhythm using the sinus rhythm criterion.
- The rhythm remains unclassified for 3 min because the median atrial interval is greater than the AT/AF detection interval or the AT/AF evidence counter is less than 27.

If AT/AF episode termination is detected, the AT/AF evidence counter is reset to zero.
6.3.5.2 AT/AF detection criteria

The device applies several criteria during AT/AF detection to help identify the presence of an atrial tachyarrhythmia. These criteria include the median atrial interval, the AT/AF evidence counter, the far-field R-wave criterion, and the sinus rhythm criterion.

**Median atrial interval** – The device continually updates the median atrial interval. This interval is calculated by finding the median of the 12 most recent atrial intervals. The last 12 atrial intervals are sorted in numerical order, and the median atrial interval is the larger of the middle 2 values in the set. The median atrial interval must be less than the programmed AT/AF detection interval for AT/AF detection to occur.

**AT/AF evidence counter** – The AT/AF evidence counter accumulates evidence of an atrial arrhythmia based on the number and location of atrial events during ventricular intervals. On each ventricular event, the device updates the counter as follows:

- If A:V pattern information indicates the presence of an atrial arrhythmia (that is, greater than 1:1 conduction in the absence of far-field R-wave sensing), the device increments the counter by one.
- If the counter was incremented on the previous ventricular interval because of A:V pattern information, the device increments the counter by one.
- If the AT/AF episode terminates or the device delivers an atrial therapy, the counter resets to zero.
- If none of the previous conditions is true, the device subtracts one from the counter.

**Far-field R-wave criterion** – If there are 2 atrial events in a ventricular interval, the device analyzes A:V pattern information to determine if one of the atrial events is actually a far-field R-wave. The device identifies a sensed far-field R-wave if it detects both of the following:

- a short-long pattern of A-A intervals
- a short AV interval (< 60 ms) or a short VA interval (< 160 ms)

**Sinus rhythm criterion** – The Sinus rhythm criterion identifies normal sinus rhythm (or a paced rhythm) if 5 consecutive beats exhibit the A:V pattern of sinus rhythm. If this criterion is satisfied after initial AT/AF detection, the device identifies episode termination, and the AT/AF evidence counter resets to zero.

**Note:** The device also applies the far-field R-wave criterion to identify normal sinus rhythm in the presence of far-field R-wave sensing.
6.4 Detecting VF episodes
The device detects VF episodes by examining the cardiac rhythm for short ventricular intervals. If a predetermined number of intervals occur that are short enough to be considered VF events, the device detects VF and delivers the first programmed VF therapy. After therapy delivery, the device continues to evaluate the ventricular rhythm to determine if the episode is ongoing.

6.4.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF Detection</td>
<td>Turns VF Detection on or off.</td>
<td>On; OFF</td>
</tr>
<tr>
<td>VF Initial Beats to Detect</td>
<td>Number of beats to detect: number of VF events the device must count to detect a VF episode.</td>
<td>12/16; 18/24; 24/32; 30/40; 45/60; 60/80; 75/100; 90/120; 105/140; 120/160</td>
</tr>
<tr>
<td>VF Beats to Redetect</td>
<td>Number of beats to redetect: number of VF events the device must count to redetect a continuing VF after a therapy.</td>
<td>6/8; 9/12; 12/16; 18/24; 21/28; 24/32; 27/36; 30/40</td>
</tr>
<tr>
<td>VF V. Interval (Rate)</td>
<td>V-V intervals shorter than this value are counted as VF events.</td>
<td>240; 250 ... 320 ... 400 ms</td>
</tr>
</tbody>
</table>

6.4.2 Considerations
Review the following information before programming VF detection parameters.

**VF Interval minimum setting** – To ensure proper VF Detection, do not program the VF Interval less than 300 ms.

**VF Interval maximum setting** – Programming the VF Interval to a value greater than 350 ms may cause inappropriate detection of rapidly conducted atrial fibrillation as VF or FVT via VF. Intervals shorter than the VF Interval are counted using the VF event counter, which is more sensitive than the consecutive VT event counter.

**VF, FVT, and VT Intervals** – To allow for normal variations in the patient’s tachycardia interval, you should program the VF, FVT, and VT Intervals at least 40 ms apart.

**Episode redetection** – You can expedite redetection by programming the VF and VT Beats to Redetect lower than the VF and VT Initial Beats to Detect.

**Enabling VF Detection** – When VF Detection enabled, the device initiates these functions:
- enables Automatic Capacitor Formation
- starts recording Cardiac Compass data
- starts recording lead performance trends (starting at 2:15 AM, by the device clock)
- clears all bradycardia pacing counters
VF detection and PR Logic criteria – You can program the device to distinguish between SVT and VF Detection by enabling the PR Logic detection criteria. Note that the SVT Limit must be programmed shorter than the VF Interval in order for the PR Logic criteria to affect VF detection. See Section 6.10, “Enhancing detection with PR Logic criteria”, page 107.

Double tachycardia detection – When any PR Logic detection criterion is enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT). See Section 6.14, “Detecting double tachycardias”, page 129.

6.4.3 Restrictions

Review the following information before programming VF detection parameters.

AT/AF detection – If AT/AF Detection is On, the VF Initial Beats to Detect must be programmed to a value less than or equal to the AT/AF evidence counter threshold, which is 32. The VF Initial Beats to Detect must be programmed to a value less than or equal to 24/32 when AT/AF Detection is On. See Section 6.3, “Detecting atrial tachyarrhythmias”, page 78.

Tachyarrhythmia detection and bradycardia pacing – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for bradycardia pacing and tachyarrhythmia detection.

Paced AV and temporary Lower Rate interval automatic adjustment – When VF or VT detection is enabled, the device automatically adjusts the temporary Lower Rate interval and PAV interval when needed. This adjustment maintains a ventricular event to atrial pace interval that is at least 30 ms greater than the ventricular detection interval.

Asynchronous pacing mode – All ventricular detection must be programmed Off and AT/AF Detection must be programmed to Monitor when the programmed pacing mode is DOO, VOO, or AOO.

VF detection backup – To ensure VF detection backup during VT and FVT episodes, VT and FVT detection cannot be enabled unless VF detection is also enabled.
6.4.4 How to program VF Detection

1. Select the Params icon.
2. Select Detection (V.).… from the Parameters screen.
3. Select the desired values for enabling or disabling VF Detection, VF Initial Beats to Detect, VF Beats to Redect, and VF V. Interval (Rate).
4. Return to the Parameters screen and select [PROGRAM].
6.4.5 Details about VF detection

The device detects VF by counting the number of VF events, which are V-V intervals shorter than the programmed VF V. Interval (Rate). On each event, the device counts the number of recent VF events. The number of recent events examined is called the VF Detection window. The size of the VF Detection window is the second number in the programmed VF Initial Beats to Detect (for example, 24 events if the VF Initial Beats to Detect is 18/24).

The threshold for detecting VF is the first number in the programmed VF Initial Beats to Detect (for example, 18 events if the VF Initial Beats to Detect is 18/24). This threshold is always 75% of the VF Detection window. That is, if 75% of the events in the VF Detection window are VF events, the device detects a VF episode (see Figure 9).

After the device detects VF, it delivers the first programmed VF therapy. Following the therapy, if the number of VF events reaches the programmed VF Beats to Redetect, the device redetects VF and delivers the next programmed VF therapy.

**Note:** The device can also detect VF episodes using the combined count detection criterion (see Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101).

**Figure 9.** Device detects VF episode

1. VF starts, and the device begins counting VF events (intervals shorter than the programmed VF Interval).
2. A ventricular interval occurs outside the VF Detection zone. The VF event count is not incremented.
3. The VF event count reaches the programmed VF Initial Beats to Detect value of 18 events out of 24, and the device detects VF.
6.5 Detecting VT episodes

The device detects VT episodes by examining the cardiac rhythm for short ventricular intervals. If enough intervals occur that are short enough to be considered VT events (but are not VF or FVT events), the device detects VT and delivers the first programmed VT therapy. After therapy delivery, the device continues to evaluate the ventricular rhythm to determine if the episode is ongoing.

You can program the device to detect and record VT episodes without treating them by using the VT Monitor zone. This zone is independent from other detection zones. It allows you to collect data without delivering therapy or affecting VF detection. See Section 6.7, “Monitoring VT episodes”, page 96 for details about the VT Monitor zone.

See Section 6.5.5, “Details about VT detection”, page 91.

6.5.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VT Detection</strong></td>
<td>Turns VT Detection on or off.</td>
</tr>
<tr>
<td><strong>VT Initial Beats to Detect</strong></td>
<td>Number of beats to detect: number of VT events the device must count to detect a VT episode.</td>
</tr>
<tr>
<td><strong>VT Beats to Redetect</strong></td>
<td>Number of beats to redetect: number of VT events the device must count to redetect a continuing VT after a therapy.</td>
</tr>
<tr>
<td><strong>VT V. Interval (Rate)</strong></td>
<td>V-V intervals shorter than this value are counted as VT events.</td>
</tr>
</tbody>
</table>

6.5.2 Considerations

Review the following information before programming VT detection parameters.

**VF, FVT, and VT Intervals** – To allow for normal variations in the patient’s tachycardia interval, program the VF, FVT, and VT V. Intervals (Rate) at least 40 ms apart.

**Episode redetection** – You can expedite redetection by programming the VF and VT Beats to Redetect lower than the VF and VT Initial Beats to Detect.

**VT detection, AF/Afl, and Sinus Tach in AT and DR devices** – When you program VT Detection to On in AT and DR devices, the AF/Afl and Sinus Tach parameters are also automatically set to On. See Section 6.10, “Enhancing detection with PR Logic criteria”, page 107 for details about AF/Afl and Sinus Tach parameters.

**VT detection and Wavelet in VR devices** – When you program VT Detection to On in VR devices, the Wavelet parameters are also automatically programmed to Monitor. See
Section 6.11, “Enhancing detection with Wavelet”, page 114 for details about Wavelet parameters.

**VT detection and combined count detection** – When VT Detection is On, the device applies the combined count detection criterion to help speed detection of rhythms that fluctuate between detection zones. Combined count detection is disabled if VT Detection is Off. See Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101.

**VT detection and rapidly conducted SVTs** – You can program the device to distinguish between SVT and VT detection by enabling the PR Logic (AT and DR devices only), Wavelet (VR devices only), Onset, or Stability detection criteria. See Section 6.10, “Enhancing detection with PR Logic criteria”, page 107, Section 6.11, “Enhancing detection with Wavelet”, page 114; Section 6.12, “Enhancing VT detection with the Onset criterion”, page 122; and Section 6.13, “Enhancing VT detection with the Stability criterion”, page 126 for details.

**Double tachycardia detection** – When any PR Logic detection criterion is enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT; see page Section 6.14, “Detecting double tachycardias”, page 129).

6.5.3 Restrictions

Review the following information before programming VT detection parameters.

**AT/AF detection** – If AT/AF Detection is On, the VT Initial Beats to Detect must be programmed to a value less than the AT/AF evidence counter threshold, which is 32. The VT Initial Beats to Detect must be programmed to a value less than or equal to 28 when AT/AF Detection is On. See Section 6.3, “Detecting atrial tachyarrhythmias”, page 78.

**Tachyarrhythmia detection and bradycardia pacing** – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for bradycardia pacing and tachyarrhythmia detection.

**Paced AV and temporary Lower Rate interval automatic adjustment** – If VF or VT detection is enabled, the device automatically adjusts the temporary Lower Rate interval and PAV interval when needed. This adjustment maintains a ventricular event to atrial pace interval that is at least 30 ms greater than the ventricular detection interval.

**Asynchronous pacing mode** – All ventricular detection must be programmed Off and AT/AF Detection must be programmed to Monitor when the programmed pacing mode is DOO, VOO, or AOO.

**VF detection backup** – To ensure VF detection backup during VT and FVT episodes, VT and FVT Detection cannot be enabled unless VF Detection is also enabled.
6.5.4 How to program VT Detection

1. Select the Params icon.
2. Select Detection (V.)... from the Parameters screen.
3. Select the desired values for enabling or disabling VT Detection, VT Initial Beats to Detect, VT Beats to Redect, and VT V. Interval (Rate).
4. Return to the Parameters screen and select [PROGRAM].
6.5.5 Details about VT detection

The device detects VT by counting the number of consecutive VT events. A VT event is a V-V interval shorter than the programmed VT Interval but greater than or equal to the VF Interval. If the number of consecutive VT events reaches the programmed VT Initial Beats to Detect, the device detects VT (see Figure 10).

The VT event count resets to zero whenever an interval occurs that is greater than or equal to the programmed VT Interval. The count remains at the current value if an interval is shorter than the programmed VF Interval.

After the device detects VT, it delivers the first programmed VT therapy. Following the therapy, if the VT event counter reaches the VT Beats to Redetect, the device redetects VT and delivers the next programmed therapy.

Note: The device can also detect VT episodes using the combined count detection criterion (see Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101).

Figure 10. Device detects VT episode

1 VT starts, and the device begins counting VT events (intervals less than the programmed VT Interval but greater than or equal to the VF Interval).
2 A ventricular interval occurs outside the VT detection zone. The VT event count resets to zero.
3 The VT event count reaches the programmed VT Initial Beats to Detect of 16 events, and the device detects VT.

### 6.6 Detecting FVT episodes

The device detects episodes of Fast Ventricular Tachycardia (FVT) by examining the cardiac rhythm for short ventricular intervals. If enough intervals occur in the programmed FVT Detection zone, the device detects FVT and delivers the first programmed FVT therapy. After therapy delivery, the device continues to evaluate the ventricular rhythm to determine if the episode is ongoing. To make sure it delivers sufficiently aggressive therapies, the device can merge the programmed detection zones during redetection to increase sensitivity.

### 6.6.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVT Detection</td>
<td>Enables FVT detection via the VF or the VT detection algorithm.</td>
<td>OFF; via VF; via VT</td>
</tr>
<tr>
<td>FVT V. Interval (Rate)</td>
<td>V-V intervals between this value and the programmed VF V. Interval (Rate) are marked as FVT events.</td>
<td>200; 210 ... 240 ... 600 ms</td>
</tr>
</tbody>
</table>

### 6.6.2 Considerations

Review the following information before programming FVT detection parameters.

**VF, FVT, and VT Intervals** – To allow for normal variations in the patient’s tachycardia interval, program the VF, FVT, and VT V. Intervals (Rate) at least 40 ms apart.

**Episode redetection** – You can expedite redetection by programming the VF and VT Beats to Redetect lower than the VF and VT Initial Beats to Detect.

**FVT Detection enabled** – Your choice for an appropriate setting for FVT Detection should depend on the patient’s VF and VT cycle lengths. After determining a reliably sensitive VF Interval, consider the following suggestions:

- If the patient presents with a clinical VT Interval that is in the VF zone, select via VF to ensure reliable detection of VF. (VT Detection need not be enabled at all.)
- If the patient presents with 2 clinical VT Intervals that are both outside the VF zone, select via VT to allow for correct classification of the faster VT and offer a separate therapy regimen for each VT.
- If the patient presents with only 1 clinical VT interval that is outside the VF zone, enable VF and VT Detection only, and set FVT Detection to Off.
FVT Detection and PR Logic criteria – You can program the device to distinguish between SVT and FVT detection by enabling the PR Logic criteria. Note that the SVT Limit must be programmed shorter than the VF Interval for the PR Logic criteria to affect FVT via VF Detection.

Double tachycardia detection – When any PR Logic criterion is enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT, see Section 6.14, “Detecting double tachycardias”, page 129).

6.6.3 Restrictions

Review the following information before programming FVT detection parameters.

Tachyarrhythmia detection and bradycardia pacing – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for bradycardia pacing and tachyarrhythmia detection.

VF detection backup – To ensure VF detection backup during VT and FVT episodes, VT and FVT detection cannot be enabled unless VF detection is also enabled.

Asynchronous pacing mode – All ventricular detection must be programmed Off and AT/AF Detection must be programmed to Monitor when the programmed pacing mode is DOO, VOO, or AOO.

FVT detection parameters – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for the FVT parameter as follows:

- If FVT Detection is set to via VT, VT Detection must be set to On.
- If FVT Detection is set to via VF, the FVT Interval must be programmed to a value shorter than the VF V. Interval (Rate).
- If FVT Detection is set to via VT, the FVT V. Interval (Rate) must be programmed to a value greater than the VF V. Interval (Rate) and less than the VT V. Interval (Rate).
6.6.4 How to program FVT Detection

1. Select the Params icon.
2. Select Detection (V.)... from the Parameters screen.
3. Select the desired values for enabling or disabling FVT Detection and FVT V. Interval (Rate).
4. Return to the Parameters screen and select [PROGRAM].
6.6.5 Details about FVT detection

You can program the device to detect FVT episodes using the VF or VT Detection zone and VF or VT Initial Beats to Detect.

When FVT Detection is set to via VF, a V-V interval within the FVT Detection zone is marked as an “FVT via VF” event. When the count is reached for the programmable VF Initial Beats to Detect, the device reviews the last 8 intervals:

- If any one of the last 8 intervals is in the VF Detection zone, the device detects the episode as VF.
- If all of the last 8 intervals are outside the VF Detection zone, the device detects the episode as FVT (see Figure 11).

When FVT Detection is set to via VT, a V-V interval within the FVT Detection zone is marked as an “FVT via VT” event. When the count is reached for the programmable VT Initial Beats to Detect, the device reviews the last 8 intervals:

- If any one of the last 8 intervals is in the VF or FVT Detection zones, the device detects the episode as FVT.
- If all of the last 8 intervals are outside the FVT and VF Detection zones, the device detects the episode as VT.

Note: The device can also detect FVT episodes using the combined count detection criterion (see Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101).

Figure 11. Device detects FVT via VF episodes

1. A fast ventricular tachycardia starts, and the first event falls into the FVT Detection zone.
2. The second event of the FVT episode has an interval that falls into the VT Detection zone. The VF event count is not incremented.
3. The device detects FVT after the VF event count reaches the VF Initial Beats to Detect.

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6.6.5.1 Zone merging after detection

To ensure the device delivers sufficiently aggressive therapies during an extended or highly variable tachyarrhythmia episode, the device merges detection zones during redetection in some instances, as shown in Figure 12. The merged zone configuration uses the event counting and therapies for the faster arrhythmia and remains in effect until episode termination.

**Figure 12. FVT zone merging**

<table>
<thead>
<tr>
<th>Before detection</th>
<th>FVT set to “via VF”</th>
<th>FVT set to “via VT”</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>VF</td>
<td>VF</td>
</tr>
<tr>
<td>FVT</td>
<td>FVT</td>
<td>FVT</td>
</tr>
<tr>
<td>VT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VF and FVT zones merge, leaving a larger VF zone. VT and FVT zones merge, leaving a larger FVT zone.

All zones remain unchanged. VT and FVT zones merge, leaving a larger FVT zone.

**Detection Intervals:**
- VF Interval: 320 ms
- FVT Interval: 280 ms / 360 ms
- VT Interval: 400 ms

6.7 Monitoring VT episodes

The VT Monitor zone provides a programmable, diagnostic zone used for monitoring tachyarrhythmias. This zone detects and records VT as VT Monitor episodes and does not deliver VT therapy.

The VT Monitor zone can provide additional data about a patient's condition by detecting arrhythmias that are not programmed for detection by the VF, FVT, and VT Detection zones.

See Section 6.7.5, “Details about VT Monitor detection”, page 99.
6.7.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT Monitor</td>
<td>Enables the VT Monitor.</td>
</tr>
<tr>
<td>VT Monitor Initial Beats to Detect</td>
<td>Number of beats to detect: number of VT Monitor events that the device must count to detect and classify a VT Monitor event.</td>
</tr>
<tr>
<td>VT Monitor V. Interval (Rate)</td>
<td>V-V intervals shorter than this value are counted as VT Monitor events.</td>
</tr>
</tbody>
</table>

6.7.2 Considerations

Review the following information before programming VT Monitor.

**VF Detection** – VF Detection must be enabled to have VT Monitor enabled.

**Combined count detection** – Combined count detection does not include VT Monitor events.

**Sustained rhythm type classification** – When a ventricular tachyarrhythmia occurs in the VT Monitor zone, monitoring classification stops until the ventricular arrhythmia termination criteria are met. See Section 6.7.5, “Details about VT Monitor detection”, page 99 for details about monitoring classification.

**SVT discrimination features** – The enabled SVT discrimination features are applied in the VT Monitor zone.

6.7.3 Restrictions

Review the following information before programming VT Monitor parameters.

**AT/AF detection** – If AT/AF Detection is On, the VT Monitor Initial Beats to Detect must be less than or equal to 32, which is the AT/AF evidence counter threshold. See Section 6.3, “Detecting atrial tachyarrhythmias”, page 78.

**VF detection backup** – To ensure VF detection backup during VT, FVT, and VT Monitor episodes, if VF Detection is disabled, VT Detection, FVT Detection, and VT Monitor must also be disabled.

**VT Monitor Initial Beats to Detect** – The VT Monitor Initial Beats to Detect must be greater than the VF and VT Initial Beats to Detect.

**Pacing rate** – The pacing (lower rate, upper tracking rate, and upper sensor rate) interval must be programmed 10 ms greater than the VT Monitor Interval (Rate).
6.7.4 How to program VT Monitor

1. Select the Params icon.
2. Select Detection (V.)... from the Parameters screen.
3. Select the desired values for enabling or disabling Monitor Detection, Monitor Initial Beats to Detect, and Monitor V. Interval (Rate).
4. Return to the Parameters screen and select [PROGRAM].
6.7.5 Details about VT Monitor detection

The VT Monitor zone functions as an independent VT zone, operating with a lower rate cutoff than any of the enabled detection zones. The enabled SVT discrimination features are applied to the VT Monitor zone.

VT Monitor detection features a programmable number of intervals to detect sustained arrhythmias. When the VT Monitor event count reaches the programmed number of intervals, the rhythm is considered sustained. For AT and DR devices, VT Monitor detection classifies sustained rhythms as either ventricular tachycardia (VTM) or double tachycardia (VTM+SVT). For VR devices, VT Monitor Detection classifies sustained rhythms as ventricular tachycardia (VTM).

Note: A double tachycardia (VTM+SVT) is a detected arrhythmia that comprises a ventricular tachyarrhythmia (VT) with a simultaneous SVT. Double tachycardia detection ensures that the PR Logic criteria do not compromise ventricular arrhythmia monitoring.

Once a ventricular tachycardia or double tachycardia is classified, further classification stops until that sustained rhythm ends or terminates (see Figure 13). Until a sustained rhythm is detected, a rhythm is classified as a rejected SVT rhythm, and VT Monitor continues to look for ventricular tachycardia and double tachycardia. The rejection is based on enabled features.

The device compares ventricular intervals to the VT Monitor Interval to identify when a VT Monitor episode has terminated. Any one of the following criteria terminates an episode:

- 8 consecutive intervals greater than or equal to the VT Monitor Interval.
- 20 s elapse without the median ventricular interval shorter than the programmed VT Monitor Interval.
- Detection of a VT, FVT, or VF rhythm. Detection of a VT, FVT, or VF rhythm (or a SVT rhythm in the VT, FVT, or VF Detection zones) terminates VT Monitor operation until the rhythm terminates.
Figure 13. Device detects and monitors VT

1 A VT starts in the VT Monitor zone, and the device begins counting VT events.
2 The VT Monitor event count reaches the programmed VT Monitor Initial Beats to Detect of 20 events, and the device detects a VT Monitor episode.
3 After detecting the VT Monitor episode, the device monitors the episode until termination or detection of VT, FVT, or VF rhythms.\(^8\)

6.7.5.1 Effects of enabling VT Monitor
Enabling VT Monitor causes the following detection operations to work differently:

**VF, VT, and FVT detection** – The VT Monitor zone is an independent zone, and it has no effect on the VF, VT, or FVT zones.

**PR Logic, Stability, and Onset criteria** – Before the device detects a VTM or a VTM+SVT episode, the PR Logic and Stability criteria, if enabled, are applied. If a VT Monitor episode accelerates into the VF, VT, or FVT detection zone, the device continues to apply PR Logic criteria as initial VF, VT, or FVT detection begins. Onset and Stability are independently tracked between the VT Monitor and VT Detection zones.

**Wavelet criterion** – If Wavelet is programmed to Monitor, and VT Monitor is enabled, SVTs are detected as VT Monitor events.

---

\(^8\) Detection of a VT, FVT, or VF rhythm (or SVT rhythm in the VT, FVT, or VF Detection zones) terminates monitoring operation until the rhythm terminates.
If Wavelet is programmed to On and VT Monitor is enabled, SVTs in the VT Monitor zone are detected as SVT-Wavelet stored episodes only. There will be no real-time decision channel annotations or any status line information.

6.8 Detecting tachyarrhythmia episodes with combined count

Because the device counts VF and VT events separately, rhythms with variable cycle lengths can cause both event counts to increment during an episode. To prevent these rhythms from delaying detection, the device automatically enables the combined count detection criterion if both VF Detection and VT Detection are programmed On.

The combined count criterion compares the sum of the VF and VT event counts to the combined beats to detect criterion, which the device calculates automatically from the programmed VF beats to detect values. If the combined count criterion is met, the device reviews the recent intervals to determine if the episode should be treated as a VF, FVT, or VT episode. The combined count criterion applies during both initial detection and redetection.

6.8.1 Details about combined count detection

The combined count detection algorithm expedites detection or redetection of ventricular tachyarrhythmias with ventricular intervals that fluctuate between the VF and VT detection zones. When VT detection is enabled, the device applies combined count detection, which tracks the combined number of VT and VF events counted. If this sum reaches the combined beats to detect criterion, the device detects VF, FVT, or VT. Combined count detection also applies to redetected episodes.

Note: Events in the VT Monitor zone are not included in the combined count detection.

If the VF event counter reaches 6, the device automatically applies the combined beats to detect criterion. The combined beats to detect criterion is calculated by multiplying the current VF beats to detect (initial or redetect) by 7/6 and rounding down. The combined beats to detect values that correspond to each VF beats to detect value appear in Table 24.

Table 24. Combined beats to detect values for each initial or redetect VF beats to detect value

<table>
<thead>
<tr>
<th>VF beats to detect</th>
<th>Combined beats to detect</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/8</td>
<td>7</td>
</tr>
<tr>
<td>9/12</td>
<td>10</td>
</tr>
<tr>
<td>12/16</td>
<td>14</td>
</tr>
</tbody>
</table>

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Table 24. Combined beats to detect values for each initial or redetect VF beats to detect value (continued)

<table>
<thead>
<tr>
<th>VF beats to detect</th>
<th>Combined beats to detect</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/24</td>
<td>21</td>
</tr>
<tr>
<td>21/28</td>
<td>24</td>
</tr>
<tr>
<td>24/32</td>
<td>28</td>
</tr>
<tr>
<td>27/36</td>
<td>31</td>
</tr>
<tr>
<td>30/40</td>
<td>35</td>
</tr>
</tbody>
</table>

Note: VT detection cannot be enabled when the VF beat to detect is greater than 30/40.

Combined count detection is fulfilled when the sum of the VF and VT event counts equals or exceeds the combined beats to detect. The device then reviews the last 8 intervals and classifies the episode as one of the following types:

- **VF**, if any of the last 8 intervals were in the VF zone (see Figure 14)
- **FVT**, if FVT detection is enabled and none of the last 8 intervals were in the VF zone, but one or more were in the FVT zone
- **VT**, if all 8 intervals were outside the VF zone and FVT zone

Figure 14. Device detects VF with the combined count criterion

1 A slow VF episode starts with a ventricular cycle length that varies between the VF and VT detection zones.
2 When a VT event occurs, the device increments the VT event count and the combined count.
3 The device detects VF even though the VF event count has not yet reached the VF Initial Beats to Detect (18/24 in this example). The combined count reaches the combined beats to detect value of 21 first, and there is a VF event in the last 8 intervals.

### 6.9 Determining episode termination or redetection

Once the device detects an arrhythmia, it considers the episode ongoing until it detects that the episode has ended. After delivering therapy, it monitors the ventricular rhythm using the programmed Redetect beats criteria. If one of these Redetect criteria is met, the device delivers the next programmed therapy for the detected arrhythmia.

See Section 6.9.4, “Details about episode termination and redetection”, page 105.

#### 6.9.1 Parameters

| VF Beats to Redetect – Number of beats to redetect: number of VF events the device must count to redetect a continuing VF after a therapy. | 6/8; 9/12; 12/16; 18/24; 21/28; 24/32; 27/36; 30/40 |
| VT Beats to Redetect – Number of beats to redetect: number of VT events the device must count to redetect a continuing VT after a therapy. | 4; 8; 12; … 52 |

#### 6.9.2 Considerations

Review the following information before programming redetection parameters.

**Initial and redetect beats** – You can expedite redetection by programming the VF and VT Beats to Redetect lower than the VF and VT Initial Beats to Detect.
6.9.3 How to program redetection parameters

1. Select the Params icon.
2. Select Detection (V.)… from the Parameters screen.
3. Select the desired values for VF Beats to Redetect and VT Beats to Redetect.
4. Return to the Parameters screen and select [PROGRAM].
6.9.4 Details about episode termination and redetection

After a therapy is delivered, the device evaluates the ventricular rhythm to determine if the episode has terminated, is continuing, or has changed to a different arrhythmia.

6.9.4.1 Episode termination

The device determines that the episode has terminated if one of the following conditions occurs:

- Eight consecutive ventricular intervals are longer than or equal to the programmed VT interval.\(^9\)
- 20 s elapse without the median ventricular interval shorter than the programmed VT interval.\(^9\)

**Note:** Detection of a VT, FVT, or VF rhythm terminates VT Monitor episodes and suspends the VT monitoring operation until the rhythm terminates. Detection of a SVT rhythm in the VT, FVT, or VF zones also suspends the VT monitoring operation until the rhythm terminates.

After antitachycardia pacing therapy, the device begins evaluating intervals for episode termination on the first ventricular cycle. After cardioversion or defibrillation, the device begins evaluating intervals for episode termination on the second ventricular event. (Due to the extended post shock blanking, this event may be the third event on the electrogram.)

**Note:** Any subsequent detection after the end of the episode marks the start of a new episode.

6.9.4.2 Episode redetection

After the device detects a tachyarrhythmia episode and delivers a therapy, the device redetects an arrhythmia if the VF or VT event count reaches the Beats to Redetect or if the combined VF and VT event count reaches the combined redetect beats (see Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101).

The device then delivers the next programmed therapy for the current arrhythmia and resumes monitoring for the outcome of that therapy. Figure 15 shows an example of redetection.

---

\(^9\) VF interval if VT Detection is set to Off, and the episode is a VF or an FVT via VF episode.
Figure 15. VT episode redetected after therapy

1 A VT episode is detected, and the device delivers a Burst ATP therapy.
2 After therapy, the device continues to detect events in the VT zone.
3 When the VT event count reaches the VT Beats to Redetect, the device redetects the VT.

Notes:
- The device suspends VT detection, including FVT via VT detection and combined count detection, for 17 ventricular events following a defibrillation therapy delivered in response to a detected VF. Suspending VT detection helps avoid detecting transient VTs that can follow high voltage therapies.
- The PR Logic, Wavelet, and Onset criteria are not applied during redetection. However, the Stability criterion may withhold detection or redetection of VT or FVT via VT throughout an episode.

6.9.4.3 VT acceleration

If the device redetects VT, it classifies the rhythm as accelerated if the average of the 4 intervals before redetection is at least 60 ms less than either the average of the 4 intervals before initial VT detection or the last accelerated VT detection. The most recent interval average is used to identify VT acceleration if VT is redetected again during the episode. The device also identifies VT acceleration if the initial VT episode is redetected as FVT or VF.

If the device redetects VF or an accelerated VT after an antitachycardia pacing sequence delivery, it skips the subsequent pacing therapy sequences for the duration of the episode and delivers the next therapy programmed for the current arrhythmia.

\(^{10}\) If the defibrillation therapy is delivered as a result of a High Rate Timeout Therapy operation, VT detection is not suspended (see Section 6.15.4.1, “High Rate Timeout Therapy”, page 132).
6.10 Enhancing detection with PR Logic criteria

The PR Logic criteria are designed to withhold inappropriate ventricular detection during episodes of rapidly conducted supraventricular tachycardia (SVT). The device analyzes the activation patterns and timing in both chambers using PR Logic pattern and rate analysis. This information helps identify evidence of atrial fibrillation, atrial flutter, sinus tachycardia, and other 1:1 SVTs. If this analysis indicates the presence of one or more of these rhythms, the device withholds detection.

PR Logic criteria are available only in AT and DR devices.

For more information, see
- Section 6.10.5, “Details about PR Logic pattern and rate analysis”, page 110
- Section 6.10.6, “Details about the PR Logic criteria”, page 113

6.10.1 Parameters

<table>
<thead>
<tr>
<th>AF/Afl</th>
<th>Identifies rapidly conducted atrial fibrillation, atrial flutter, or atrial tachycardia. On; Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus Tach</td>
<td>Identifies sinus tachycardia. On; Off</td>
</tr>
<tr>
<td>Other 1:1 SVTs</td>
<td>Identifies other one-to-one SVTs where the atrial and ventricular activation are roughly simultaneous. On; Off</td>
</tr>
<tr>
<td>SVT V. Limit</td>
<td>Defines the minimum ventricular interval at which the device applies the PR Logic criteria. 240; 250 … 320 … 650 ms</td>
</tr>
</tbody>
</table>

6.10.2 Considerations

Review the following information before programming PR Logic parameters.

Cautions:
- Before enabling the Other 1:1 SVTs criterion, ensure that the atrial lead has matured. This criterion may inappropriately withhold therapy if atrial sensing is compromised by an unstable or dislodged atrial lead.
- Use caution when programming the Other 1:1 SVTs criterion in patients who exhibit slow 1:1 retrograde conduction during VF or VT. This criterion could inappropriately withhold VT/VF therapy in such patients. See Section 6.10.5.1, “AV and VA interval patterns”, page 110.

Note: The device is able to discriminate sinus tachycardia with long PR intervals from VT/VF with no additional programming (see Section 6.10.5.2, “Expected range of V-V and AV intervals”, page 110)
PR Logic criteria and double tachycardia detection – If any of the PR Logic criteria are enabled, the device also enables double tachycardia detection (see Section 6.14, “Detecting double tachycardias”, page 129).

SVT Limit – To ensure that therapy is delivered for hemodynamically compromising rates of any origin, the device always delivers therapy when the median ventricular interval is shorter than the programmed SVT V. Limit (nominally 320 ms) if VT, VF, or FVT detection criteria are satisfied.

VF Interval and SVT Limit – If you program an SVT V. Limit longer than the VF V. Interval (Rate), you are effectively disabling the PR Logic criteria for VF detection.

PR Logic criteria and detecting VT – If VT Monitor or VT Detection is enabled, the device also enables the PR Logic criteria AF/AFL and Sinus Tach.

6.10.3 Restrictions

Review the following information before programming PR Logic parameters.

Detection intervals and SVT V. Limit – The SVT V. Limit must be less than the VT V. Interval (Rate). If VT Detection is disabled, the SVT V. Limit must be less than or equal to the VF V. Interval (Rate).
6.10.4 How to program the PR Logic criteria

1. Select the Params icon.
2. Select Detection (V.)… from the Parameters screen.
3. Select the desired values for AF/AFl, Sinus Tach, Other 1:1 SVTs, and SVT V. Limit.
4. Return to the Parameters screen and select [PROGRAM].
6.10.5 Details about PR Logic pattern and rate analysis

PR Logic pattern and rate analysis is based on the following aspects of atrial and ventricular activation:

- AV and VA interval patterns
- expected range of V-V and AV intervals
- AF evidence
- far-field R-wave sensing
- A:V dissociation
- V-V regularity

The information collected by PR Logic pattern and rate analysis is used by the PR Logic criteria to identify the presence of SVTs and withhold detection.

6.10.5.1 AV and VA interval patterns

The device uses pattern analysis to identify sinus tachycardia, atrial flutter, and other 1:1 SVTs. Within each V-V interval, the device categorizes the atrial rhythm according to the number of intervening atrial events and the zones in which those atrial events occur. From this information, the device assigns pattern codes to the intervals and interprets the pattern codes to identify SVTs.

6.10.5.2 Expected range of V-V and AV intervals

The device continuously analyzes the V-V and AV intervals and calculates an expected range of values for each type of interval. The expected range is constructed from the mean of recent interval values and the absolute differences of recent values from the mean intervals.

Intervals that fall within the expected range are included in subsequent expected range calculations. In this way, the expected range adapts to the patient’s current heart rate and variability. If an interval is outside the expected range, it is not included in the expected range calculation.

AV intervals that fall within the expected AV interval range are interpreted as normal conduction in pattern analysis. The expected V-V interval range helps the device recognize gradual rate increases associated with sinus tachycardia.

6.10.5.3 AF evidence

AF evidence is provided by a counter that accrues evidence to help identify atrial fibrillation or detect a double tachycardia (VF, VT, or FVT in the presence of an SVT; see Section 6.14, “Detecting double tachycardias”, page 129).
For each ventricular event, the device increments a running AF evidence count if it identifies all of the following conditions:

- AV pattern information for a high atrial rate
- timing consistent with an atrial tachyarrhythmia (see Section 6.10.5.1, “AV and VA interval patterns”, page 110)
- greater than 1:1 conduction

If the AV pattern is inconclusive, inconsistent, or if the device detects far-field R-wave sensing, the AF evidence count is unchanged. If no atrial event occurs within the current V-V interval or a consistent 1:1 pattern is present, the device subtracts one from the count.

The AF evidence criterion is satisfied when the AF evidence count is greater than or equal to 6. Once the criterion is met, it remains satisfied for as long as the AF evidence count is greater than or equal to 5.

### 6.10.5.4 Far-field R-wave sensing

The device identifies far-field R-wave oversensing in the atrium to exclude far-field R-waves from SVT classification.

If there are 2 atrial events within a ventricular interval, 1 atrial event may actually be a far-field R-wave (see Figure 16). The device identifies a sensed far-field R-wave if it detects both of the following conditions:

- a short-long pattern of A-A intervals
- a short AV interval (< 60 ms) or a short VA interval (< 160 ms)

The device uses far-field R-wave sensing for the Sinus Tach and AF/Afl criteria.

**Figure 16.** Intervals measured for far-field R-wave detection

![Diagram of intervals measured for far-field R-wave detection](image_url)
6.10.5.5 A:V dissociation

A:V dissociation provides cumulative evidence that there is no direct relationship between sensed atrial and ventricular events. The device identifies a rhythm as A:V dissociated if at least 4 of the most recent 8 ventricular intervals exhibit either of these characteristics:

- no atrial events in the ventricular interval
- an AV interval that differs from the average of the previous 8 AV intervals by more than 40 ms

The device uses this count to help identify a double tachycardia.

6.10.5.6 V-V regularity

The device uses the regularity and irregularity of the ventricular cycle length to evaluate atrial fibrillation, double tachycardia, and other 1:1 SVTs.

The device continuously measures the regularity of the ventricular intervals. The regularity count indicates how often the 2 most frequently occurring intervals (of at least 200 ms) occurred among the last 18 ventricular intervals.

For example, Figure 17 illustrates the 18 most recent intervals. The 2 most frequently occurring intervals are 330 ms (5 intervals) and 320 ms (3 intervals). Together these account for 8 of the 18 most recent intervals, for a regularity count of 44%.

Figure 17. Regularity of ventricular cycle length

- For a double tachycardia to be detected, the regularity count must be greater than or equal to 75%.
- To withhold detection under the atrial fibrillation rule of the AF/Afl criterion, the regularity count must be less than or equal to 50%. Atrial fibrillation that exhibits greater regularity (between 50% and 75%) may be identified by the atrial flutter rule, which does not require the regularity count.
- To withhold detection for Other 1:1 SVTs, the regularity count must be greater than or equal to 25%.
6.10.6 Details about the PR Logic criteria

The PR Logic criteria discriminate between SVT and VT if all of the following conditions are true:

- No detected VF, FVT, or VT episode is in progress.
- An Initial Beats to Detect is met (VT Monitor, VT, VF, or combined).
- One or more of the PR Logic criteria are met.
- The median ventricular interval equals or exceeds the SVT V. Limit.

6.10.6.1 AF/Afl criterion

The AF/Afl (atrial fibrillation and/or atrial flutter) criterion consists of 2 independent rules: the atrial fibrillation rule and the atrial flutter rule. If either rule is satisfied, the AF/Afl criterion is met, and the device withholds ventricular detection and therapy.

The atrial fibrillation rule requires that all the following conditions occur:

- The AF evidence counter indicates atrial fibrillation.
- Fewer than 10 of most recent 12 ventricular intervals include a far-field R-wave.
- The median atrial interval is less than or equal to 94% of the median ventricular interval.
- The ventricular cycle length is not regular (regularity of 50% or less).

The atrial flutter rule is satisfied if AV pattern information indicates atrial flutter without far-field R-wave sensing.

6.10.6.2 Sinus Tach criterion

Note: Sudden onset atrial tachycardia with 1:1 conduction may not be discriminated from VT/VF by the Sinus Tach criterion.

The Sinus Tach criterion is met if the AV and V-V intervals are within the expected range for the patient, and if AV pattern analysis identifies one of the following conditions:

- 1:1 sinus tachycardia
- 1:1 sinus tachycardia with far-field R-wave sensing (if at least 4 of the most recent 12 ventricular intervals contain a far-field R-wave)

6.10.6.3 Other 1:1 SVTs criterion

The Other 1:1 SVTs criterion is satisfied when AV pattern information indicates a 1:1 SVT in which the atria and ventricles are activated at approximately the same time, as in a junctional tachycardia (consistent atrial sensing in a junctional zone). The activation of these chambers is considered junctional if the activations produce AV intervals less than 80 ms or VA intervals less than 50 ms. Atrial events in a junctional zone indicate PAC, PVC, junctional rhythms, atrial fibrillation, or atrial flutter.
6.11 Enhancing detection with Wavelet

The Wavelet Dynamic Discrimination criterion is designed to withhold detection of rapidly conducted SVT episodes. It is based on the premise that rhythms of ventricular origin (such as VF and VT) generally have different QRS morphologies than rhythms of supraventricular origin.

When Wavelet is enabled, the QRS complexes that occur during fast ventricular rhythms are compared to a stored template. When Wavelet is programmed to On, the device withholds detection if enough QRS complexes that occur during the fast rate match the stored template.

You can use the Auto Collection option to collect and maintain the template automatically. You can also collect and assess the template manually using the Wavelet test (see Section 11.4, “Testing the Wavelet criterion”, page 391).

You can use the Monitor setting for Wavelet to evaluate its potential effectiveness for the patient. When Wavelet is set to Monitor, the device records Wavelet-related data but does not use the criterion to withhold detection.

Wavelet is available only in VR devices.

See Section 6.11.4, “Details about Wavelet”, page 118 and Section 6.11.5, “Details about Auto Collection”, page 120.

### 6.11.1 Parameters

- **Wavelet** – This enables the Wavelet dynamic discrimination criterion. When programmed to On, the criterion withholds detection if enough QRS complexes during an episode match the stored template.
  - Off; On; Monitor

- **Match Threshold** – Threshold percentage representing the degree to which a sensed event must match the stored template to be considered a “match.”
  - 40; 43 … 70 … 97%

- **Auto Collection** – Option to have the device automatically collect and maintain the stored template.
  - On; Off

- **SVT V. Limit** – Defines the minimum ventricular interval for which the Wavelet Dynamic Discrimination criterion will be applied.
  - 240; 250 … 320 … 650 ms
EGM 2 Source\textsuperscript{a} – Electrodes between which the device records the EGM signal for EGM channel 2. Wavelet operations are based on data from this EGM source.\textsuperscript{b}

<table>
<thead>
<tr>
<th>Source</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can to HVB\textsuperscript{c}; Can to Vring; Vtip to HVB; Vtip to Vring; Can to SVC\textsuperscript{c}; HVB to SVC\textsuperscript{c}</td>
<td>±2; 4; 8\textsuperscript{d}; 16 mV</td>
</tr>
</tbody>
</table>

EGM 2 Range\textsuperscript{a} – Amplifier signal range for EGM channel 2. Smaller settings result in higher-resolution telemetered and stored EGM waveforms.

\textsuperscript{a}See Section 10.2.3, “How to set up data collection”, page 326, for details about programming this parameter.

\textsuperscript{b}The nominal parameters for Wavelet are based on the Can to HVB EGM Source. This far-field source provides the most global information on EGM depolarization.

\textsuperscript{c}An SVC lead must be present for this configuration.

6.11.2 Considerations

Review the following information before programming Wavelet parameters.

Concurrent pacemaker – Use caution when programming Wavelet for patients who have a pacemaker concurrently implanted because the ICD cannot distinguish between intrinsic events and paced events from the pacemaker. Program Wavelet to Monitor, and evaluate its effectiveness before enabling it for detection. In addition, it is strongly recommended that you disable Auto Collection and collect a template manually with the Wavelet test, making sure the pacemaker is not pacing the heart during the collection process.

EGM 2 Source and Range – It may be necessary to adjust the EGM 2 Source and EGM 2 Range to optimize Wavelet performance.

Wavelet is less effective at identifying SVTs and withholding detection when one of following occurs:

- R-wave amplitudes on the EGM 2 signal are too small relative to myopotential interference.
- R-wave amplitudes on the EGM 2 signal are so large during intrinsic rhythm or SVT that they exceed the maximum EGM range and are clipped.

You can assess the EGM 2 signal using the programmer strip chart recorder (see Section 9.8, “Recording live waveform strips”, page 307). If the peak-to-peak R-wave amplitudes are less than 3 mV, consider selecting a different EGM 2 source.

If the R-wave amplitudes are too large (either clipped or within 1 mV of the EGM 2 Range), consider selecting a larger EGM 2 Range value. If R-wave amplitudes are too large at any EGM 2 Range, try a different EGM 2 Source and assess the R-wave amplitudes starting with an EGM 2 Range value of ±8 mV.

Note: The device clears the current template from memory when EGM 2 Source or EGM 2 Range is programmed to a different value.
**Leadless ECG** – Leadless ECG is designed to facilitate follow-up by eliminating the need for surface ECG connection. It is recommended that Leadless ECG is accessed using EGM 1. Can to SVC (Leadless ECG) EGM Source may not be an optimal EGM Source for Wavelet-based detection and should be considered carefully before choosing Can to SVC as an EGM 2 Source for Wavelet.

**Match Threshold** – Incorrect programming of the Match Threshold may result in inappropriate therapies or delayed detection of tachyarrhythmias. Figure 18 shows the general relationship among Match Threshold, tachyarrhythmia detection, and SVT identification.

Figure 18. Wavelet performance with varying Match Threshold values

1. With a decrease in the Match Threshold value, the device is more likely to appropriately withhold detection of rapidly conducted SVTs (increased specificity) but is less likely to detect true VT (decreased sensitivity).
2. With an increase in the Match Threshold value, the device is less likely to appropriately withhold detection of rapidly conducted SVTs (decreased specificity) but is more likely to detect true VT (increased sensitivity).

**Auto Collection** – When Auto Collection is enabled, the device updates and verifies the stored template if the patient’s QRS morphology changes over time (for example, due to lead maturation or changes in drug therapy). However, if you wish to preserve a manually collected template, disable Auto Collection.

**Missing template** – If Wavelet is enabled but no template is available, detection will occur as if Wavelet is disabled until a new template is stored.

**SVT V. Limit option** – You can use the SVT V. Limit parameter to define the minimum interval for which Wavelet will be applied.

**Monitor option** – Before using Wavelet, program the criterion to Monitor, and evaluate its potential effectiveness for the patient.
QRS Snapshot data – You can use the QRS Snapshot data stored with the Episode Records for SVT, VF, VT, and FVT episodes to evaluate Wavelet performance. Wavelet must be programmed to On or Monitor to collect QRS Snapshot data.

6.11.3 How to program Wavelet
1. Select the Params icon.
2. Select Detection (V.)… from the Parameters screen.
3. Select Wavelet…
4. Select the desired values for Wavelet, Match Threshold, and Auto Collection.
5. Return to the V. Detection screen and set the SVT V. Limit if Wavelet was programmed to On.
6. Return to the Parameters screen and select Data Collection Setup….
7. Select the desired values for the EGM 2 Source and the EGM 2 Range.
8. Return to the Parameters screen and select [PROGRAM].

6.11.4 Details about Wavelet

The Wavelet Dynamic Discrimination criterion is applied to ventricular tachyarrhythmia detection if all of the following conditions are true:

- No detected VF, FVT, or VT episode is in progress.
- An Initial Beats to Detect criterion is met (VT Monitor, VT, VF, or combined).
- The V-V median interval equals or exceeds the SVT V. Limit.

When Wavelet is enabled, the device evaluates QRS waveforms during fast ventricular rhythm and compares them to a stored template. If at least 3 of the last 8 QRS complexes match the stored template, Wavelet withholding detection. After withholding detection, the ventricular rhythm is continuously evaluated until tachyarrhythmia detection occurs or the fast ventricular rate ends.

6.11.4.1 Comparing QRS complexes to the stored template

Wavelet begins collecting EGM data from ventricular events when the VT event count reaches 2 or the VF event count reaches 3. After 2 events, Wavelet begins comparing QRS complexes to the stored template.

The device classifies ventricular events by collecting EGM for the QRS complex that corresponds to each sensed ventricular event and performing a mathematical comparison to the stored template. The result of this comparison is a match score.

If the match score is greater than or equal to the programmed Match Threshold, the event is classified as a “Match.” Otherwise, the event is classified as “No Match.”

Notes:
- Wavelet collects EGM data from the EGM 2 channel.
- Ventricular events that are paced or that have intervals less than 240 ms are automatically classified as “Not Measured.”
6.11.4.2 Applying event classifications to detection

When a tachyarrhythmia event counter reaches a Beats to Detect criterion (VF, VT, or combined), Wavelet withholds detection if all of the following conditions occur:

- Wavelet is programmed On.
- 3 or more of the last 8 QRS complexes match the stored template.
- The V-V median interval is greater than or equal to the SVT V. Limit.

Figure 19 shows an example of Wavelet withholding detection.

**Figure 19.** Wavelet withholds detection

1 The patient experiences a fast sinus tachycardia with a ventricular rate that enters the VT detection zone.

2 Wavelet starts classifying QRS complexes on the second event after the VT Event Count reaches 2.

3 The device compares the shape of QRS complexes to the stored template, classifying each using the programmed Match Threshold of 70%. An event is classified as a "Match" (circled scores) unless its match score is less than this value. The Match Count records how many of the previous 8 events were matches.

4 The VT Event Count reaches the VT Initial Beats to Detect criteria of 16 events, but because at least 3 of the previous 8 events match the template (5 events match in this example), Wavelet withholds detection.

**Monitor option** – You can use the Monitor setting for Wavelet to test its potential effectiveness for the patient without enabling it for detection. The device stores QRS waveforms and match scores for episodes but does not use the criterion to withhold detection.
6.11.5 Details about Auto Collection

Wavelet includes the option for the device to automatically collect and maintain the template used to distinguish between ventricular tachyarrhythmia and SVT episodes. Auto Collection includes 3 different operations:

- collecting a template
- confirming the collected template
- monitoring the template quality

The device automatically performs template collection and maintenance operations whenever Wavelet is programmed to On or Monitor and Auto Collection is programmed On. If the stored template is missing or is not consistent with intrinsic rhythm events, the device attempts to collect and confirm a new template. Otherwise, the device continually monitors the quality of the stored template.

**Intrinsic rhythm events** – To ensure that the template collection and maintenance operations use only intrinsic rhythm events, the device does not collect electrogram waveforms for the following events:

- paced events
- intrinsic rhythm events following a paced event
- events with an interval less than or equal to 600 ms, the VT Monitor Interval + 60 ms, or the VT Interval + 60 ms (whichever is greater)

**Note:** Only intrinsic ventricular rhythm events are collected for a template.

** Interruption of Auto Collection** – The device stops any template collection or maintenance operations in progress and postpones them for one hour when any of the following events occurs:

- tachyarrhythmia episode
- system test, EP study, or emergency operation
- programming of the EGM 2 Source or Range to a different value

6.11.5.1 Collecting a template

The device collects samples of EGM data from 6 intrinsic ventricular events. See “Intrinsic rhythm events”, page 120, for information about events for template collection.

After 6 intrinsic samples are collected, the device cross-matches the samples using the programmed Match Threshold value. If fewer than 4 of the samples match each other, the device restarts the collection process. Once at least 4 of the samples match each other, the device calculates a template based on the average of the collected samples.
6.11.5.2 Confirming the collected template

After a template is calculated, the device performs a confirmation process before using the template for detection operations. Every 10 s during template confirmation, the device collects a sample of EGM data from a ventricular event and compares it to the template using the programmed Match Threshold.

If at least 70 events match the template before 100 samples are taken, the template is confirmed and is used by Wavelet. If the template is not confirmed, the device restarts the collection process.

**Note:** Template confirmation takes a minimum of 700 s (approximately 12 min) but could take longer if the intrinsic rhythm changes after the template is collected. Once confirmation is complete, the new template is stored and is used by Wavelet during detection.

6.11.5.3 Monitoring template quality

After a template has been collected and confirmed, the device performs periodic checks to assess the quality of the template. The device uses the same method for checking the template as it does during the confirmation process, except the checks occur every 1000 s (approximately 17 min).

The Template Details screen provides data about the template and the Template Quality Check. See Figure 20 for an example of the Template Details screen. To view the Template Details screen, see Section 11.4.4, “How to evaluate the current template with the Wavelet test”, page 393.

**Figure 20.** Example of the Template Details screen

<table>
<thead>
<tr>
<th>Wavelet Test - Template Details</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Template</strong></td>
<td>22-Jun-2004 20:56:23</td>
</tr>
<tr>
<td><strong>Template Quality Check</strong></td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>OK</td>
</tr>
<tr>
<td>Auto Collection</td>
<td>On</td>
</tr>
<tr>
<td>Auto Collected Templates</td>
<td>0</td>
</tr>
<tr>
<td>(Since Last Session)</td>
<td></td>
</tr>
<tr>
<td>EGM2 Source</td>
<td>Can to HVB</td>
</tr>
<tr>
<td>EGM2 Range</td>
<td>+/- 8 mV</td>
</tr>
</tbody>
</table>

1 Date and time the template was confirmed
If more than 30 of the last 100 checks do not match the template, the template is considered to be inconsistent with the intrinsic rhythm, and the device starts the Auto Collection process (if Auto Collection is enabled) once again. Until the new template is collected, Wavelet continues to use the existing template.

**Note:** When a template is created manually, the template is considered confirmed and ready to be used by detection when it is created.

### 6.12 Enhancing VT detection with the Onset criterion

A sinus tachycardia can sometimes cause the ventricular rate to accelerate into the VT detection zone. The Onset criterion helps prevent detecting sinus tachycardia as a VT by evaluating the acceleration of the ventricular rate.

If the ventricular rate increases gradually, as tends to happen during sinus tachycardia, the device withholds VT event counting. If the ventricular rate accelerates rapidly, as tends to happen during a tachyarrhythmia episode, the device enables VT event counting.

You can use the Monitor setting for Onset to test its potential effectiveness for your patient without enabling it for detection. The device records episodes where it would have applied Onset, but it does not actually use Onset during detection.

#### 6.12.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset –</td>
<td>Enables Onset criterion, which suspends VT event counting until the device identifies a rapid increase in ventricular rate.</td>
<td>Off; On; Monitor</td>
</tr>
<tr>
<td>Onset Percent –</td>
<td>Threshold percentage for the Onset criterion that represents the change in average ventricular rate that is required to enable VT event counting when Onset is on.</td>
<td>72; 75; 78; 81; 84; 88; 91; 94; 97%</td>
</tr>
</tbody>
</table>

#### 6.12.2 Considerations

Review the following information before programming Onset parameters.

**Onset enabled** – Onset may delay detection of true VT in patients who experience exercise-induced VT episodes.

**Onset Percent** – As you decrease the Onset Percent value, the device is less likely to inappropriately detect sinus tachycardia episodes as VT. However, the overall sensitivity of the VT detection algorithm is also decreased.
6.12.3 How to program Onset

1. Select the Params icon.
2. Select Detection (V.)… from the Parameters screen.
3. Select Onset….
4. Select the desired values for the Onset and Percent parameters.
5. Return to the Parameters screen and select [PROGRAM].
### 6.12.4 Details about Onset

The Onset criterion does not allow the device to count VT events unless the device senses a rapid increase in the ventricular rate. The device compares the 4 most recent ventricular intervals to the 4 preceding intervals. If the average of the 4 most recent intervals is shorter than the average of the previous 4, multiplied by the programmed Onset Percent, the device detects a rapid rate increase and enables VT event counting.

For example, Figure 21 shows that after each ventricular event, the device calculates the percentage of change in the ventricular rate, dividing the average of the most recent 4 intervals by the average of the previous 4 intervals. When the calculated percentage is less than the programmed Onset percent, the Onset detects a rapid rate increase and enables VT event counting.

**Figure 21.** Onset enables VT event counting after a rapid rate increase

---

1. The patient’s heart rate exhibits slow, normal activity. The running Onset calculation shows that the rate is very stable.
2. A VT episode starts suddenly, with the first interval falling into the VT zone. However, because the Onset calculation shows that the average ventricular interval is 85% of the previous interval average (greater than the programmed Onset Percent of 81%), the device does not enable VT event classification.
3. On the next event, the Onset calculation shows that the average ventricular interval is 69% of the previous interval average, and the device enables VT event classification.
If the ventricular rate increases gradually, as shown in Figure 22, Onset does not detect a rapid rate increase and does not enable VT event counting.

**Figure 22.** Onset keeps VT event counting disabled during sinus tachycardia

1. The patient displays normal sinus tachycardia. The running Onset calculation shows that the rate is very stable.
2. Even though the V-V interval is shorter than the programmed VT V. Interval (Rate), the device classifies these events as normal because the Onset criterion did not identify a rapid rate increase (the Onset calculation never reached the programmed Onset Percent of 81%).

After Onset enables VT event counting, it remains enabled for the next four events. Beginning with the fifth event, the device again calculates whether Onset should disable VT event counting. Onset can disable counting again only if all of the following conditions occur:

- The most recent 8 intervals do not show a rapid rate increase according to the Onset calculation.
- The average of the most recent 4 intervals exceeds the VT V. Interval (Rate).
- No VF, FVT, or VT episodes are in progress.

**VT Monitor events and Onset** – Onset can also suspend counting of events in the VT Monitoring zone. It suspends VTM event counting independently from its operation on the VT event count. The rules for Onset are the same for VTM events, except that if VTM event counting is enabled, it can be disabled again only if all of the following conditions occur:

- The most recent 8 intervals do not show a rapid rate increase according to the Onset calculation.
- The average of the most recent 4 intervals exceeds the VT Monitor V. Interval (Rate).
- No VT Monitor episodes are in progress.
Onset Monitor option – When the Onset criterion is set to Monitor, the device performs all the calculations associated with Onset but does not suspend VT event counting. If the device detects a VT or FVT via VT episode for which the Onset criterion (had it been turned on) would have withheld detection, it records a notation in the Onset Criterion Result section of the episode text (see Section 10.5.6.5, “Episode Text”, page 353).

Notes:
- If a VT, FVT, or VF episode is detected, the Onset criterion is disabled until the episode terminates.
- Because the Onset criterion can suspend VT event counting, it affects VT detection, FVT via VT detection, and combined count detection. VF event counting is not affected.
- Whenever Onset disables event counting, it also resets the event count to zero.
- To help ensure reliable VT detection, the Onset criterion automatically enables VT event counting whenever any of the following occurs:
  - Any parameter is programmed.
  - VT detection is reenabled after being suspended.
  - A tachyarrhythmia episode reaches termination.

6.13 Enhancing VT detection with the Stability criterion

When atrial fibrillation is rapidly conducted into the ventricles, the resulting ventricular rate can be fast and irregular. Stability is designed to prevent the device from detecting atrial fibrillation episodes as VT by resetting the VT event count if the ventricular rate is unstable.


6.13.1 Parameters

| Stability – Interval threshold used to identify unstable ventricular intervals. | Off; 30; 40 … 100 ms |

6.13.2 Considerations

Review the following information before programming Stability parameters.

Stability interval – A small Stability value may not allow for normal VT interval variation and may decrease the sensitivity of the device to detect VT.
6.13.3 How to program Stability

1. Select the Params icon.
2. Select Detection (V.)… from the Parameters screen.
3. Select a value for the Stability parameter.
4. Return to the Parameters screen and select [PROGRAM].
6.13.4 Details about Stability

The Stability criterion checks all ventricular intervals in the VT or FVT via VT detection zones for stability. An interval is unstable if the difference between it and any of the 3 previous intervals is greater than the programmed Stability interval.

The device does not apply the Stability option until the VT event count reaches at least 3. If the device classifies an event as unstable, it is marked as a normal sensed event, and the VT event count resets to zero (see Figure 23).

**Note:** Stability applies throughout initial detection and redetection of VT and FVT via VT.

**Figure 23.** Stability resets the VT event count during atrial fibrillation

1. Atrial fibrillation starts, which is conducted into the ventricle at a rapid rate.
2. After the VT event count reaches 3, the device applies the Stability criterion. Because the 360 ms interval differs from the 290 ms interval by more than the programmed Stability interval (50 ms, in this case), the Stability criterion resets the VT event count.

**VT Monitor events and Stability** – Stability can also reset the VTM event count but does so independently from its operation on the VT event count. The VTM event count must be at least 3 before Stability is applied to events in the VT Monitor zone. See Section 6.7, “Monitoring VT episodes”, page 96.
6.14 Detecting double tachycardias

To ensure proper detection and therapy during double tachycardia episodes (VT, FVT, or VF in the presence of SVT), the device provides double tachycardia detection whenever PR Logic criteria are enabled. The device detects double tachycardia episodes using both rate and PR Logic pattern and rate analysis information.

6.14.1 Details about double tachycardia detection

The device detects VF or FVT via VF in the presence of SVT if all of the following conditions occur (Figure 5, page 67):

- The AF evidence counter indicates atrial fibrillation.
- Fewer than 10 of the most recent 12 ventricular intervals include a far-field R-wave.
- Ventricular detection occurs using the interval or combined count criterion.
- The V-V median interval is greater than or equal to the SVT V. Limit.
- The rhythm is A:V dissociated.

The device detects VT, VT Monitor, or FVT via VT in the presence of SVT if the ventricular cycle length is very regular (regularity of at least 75%).

6.15 Detecting prolonged tachyarrhythmias with High Rate Timeout

To ensure that fast ventricular rates are treated, the device provides High Rate Timeout. If a fast rhythm occurs and one or more SVT discrimination criteria withhold detection, High Rate Timeout waits a programmable length of time and then suspends these criteria until the episode terminates. High Rate Timeout also includes the option to skip directly to VF therapies during sustained high rate episodes.

6.15.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Rate Timeout</td>
<td>Disables SVT discrimination criteria when high rate episode continues longer than the programmed time limit.</td>
</tr>
<tr>
<td></td>
<td>Off; 0.5; 1 ... 5; 6; 7; 8 ... 20; 22; 24; 26; 28; 30 min</td>
</tr>
<tr>
<td>High Rate Timeout Therapy</td>
<td>Option to treat sustained high rate episodes with the therapies for the detected episode type or to treat all high rate timeout episodes with VF defibrillation therapy (without VF confirmation, ATP During Charging or ATP Before Charging).</td>
</tr>
<tr>
<td></td>
<td>Zone Appropriate; Skip to VF Therapy</td>
</tr>
</tbody>
</table>
6.15.2 Considerations

Review the following information before programming High Rate Timeout parameters.

**High Rate Timeout and inappropriate therapies** – Because High Rate Timeout can disable SVT discrimination criteria, it may cause the device to deliver tachyarrhythmia therapies inappropriately (for example, during sinus tachycardia or atrial fibrillation).
6.15.3 How to program High Rate Timeout

1. Select the Params icon.
2. Select Detection (V.)… from the Parameters screen.
3. Select High Rate Timeout….
4. Select the desired values for High Rate Timeout and Therapy.
5. Return to the Parameters screen and select [PROGRAM].
6.15.4 Details about High Rate Timeout

High Rate Timeout starts a timer when one of the following situations occurs:

- A VF, FVT, or VT episode is detected.
- VF, FVT, or VT detection is withheld by one or more SVT discrimination criteria.

**Note:** Rates within the VT Monitor zone do not start the High Rate Timeout timer.

Once the timer has started, it continues until it reaches the programmed duration or the high rate ends (determined using the ventricular episode termination criteria; see Section 6.9, “Determining episode termination or redetection”, page 103).

If the high rate timer reaches the programmed duration, the device disables all SVT discrimination criteria (such as PR Logic, Wavelet, Onset, and Stability). These criteria remain disabled until the high rate has ended.

6.15.4.1 High Rate Timeout Therapy

If the High Rate Timeout Therapy parameter is set to Skip to VF Therapy, the device delivers only committed VF defibrillation therapies (with no VF confirmation, ATP During Charging, or ATP Before Charging) for sustained high rate episodes, whether these episodes are detected as VT, FVT, or VF.

If set to Zone Appropriate, the device delivers the VT, FVT, or VF therapy for the detected rhythm, and VF Confirmation remains active for the first VF therapy.

**Note:** After the device delivers a defibrillation therapy, it normally suspends VT detection for the next 17 events. However, if the device delivers a defibrillation therapy for a detected VT or FVT episode because High Rate Timeout is set to Skip to VF Therapy, the device does not suspend VT detection.
7 Treating tachyarrhythmia episodes

7.1 Controlling atrial therapy sequencing

Note: Atrial therapies are available only with AT devices. AT devices provide atrial cardioversion (CV) and antitachycardia pacing (ATP). DR and VR devices do not provide atrial therapies.

Atrial therapy sequencing schedules the delivery of atrial therapies throughout a sustained AT/AF episode. Depending on the programmed atrial therapy sequencing values, atrial therapies may not be delivered in the order that they are listed on the programmer screen. Atrial therapies are delivered according to the length of the episode and the rhythm classification during the episode.

Note: Throughout this chapter, “atrial” refers to AT/AF detection and therapies in general. “AT/AF” and “Fast AT/AF” refers to the 2 detection zones and the therapies programmed for each of the zones.


7.1.1 Parameters

<table>
<thead>
<tr>
<th>Episode Duration Before Rx Delivery</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATP</strong> – Atrial ATP therapies cannot be delivered until the episode duration exceeds this value.</td>
<td>0; 1; 2; 3; 4; 5; 7; 10; 15; 20; 25; 30; 40; 50 min; 1; 2; 3; 4; 5; 6; 12; 24 hr</td>
</tr>
<tr>
<td><strong>Automatic CV</strong> – Atrial CV therapies cannot be delivered until the episode duration exceeds this value.</td>
<td>0; 1; 2; 3; 4; 5; 7; 10; 15; 20; 25; 30; 40; 50 min; 1; 2; 3; 4; 5; 6; 12; 24; 48; 72 hr; 7 days</td>
</tr>
</tbody>
</table>

**Automatic CV Limits**

| Delivery Window Start Time – The time each day when CV therapies become available (24-hour clock relative to the device time). | 00:00; 01:00; 02:00; 03:00; … 23:00 |
| Delivery Window Length – The period of time each day during which CV therapies are available. | 1; 2; 3; 4; 6; 8; 10; 12; 16; 20; 24 hr |
| Maximum Shocks per Day – The number of automatic atrial shocks allowed during any day. | 1; 2; 3; 4; 5; No Limit |
Reactive ATP

**Rhythm Change** – Allows the AT/AF detection zone to be divided into smaller zones, each having ATP therapies.

**Time Interval** – Allows the count of ATP therapies delivered to be reset within an atrial episode.

**Stop Atrial Rx After…**

- **Disable atrial ATP if it accelerates V. Rate?**
  - Yes
  - No

- **Disable all atrial therapies if atrial lead position is suspect?**
  - Yes
  - No

**Duration to Stop** – Limits the portion of an atrial episode in which therapies can be delivered.

### 7.1.2 Considerations

Review the following information before programming atrial therapy sequencing.

**Episode Duration Before Rx Delivery** – If the atrial episode fails to terminate spontaneously within the programmed Episode Duration Before Rx Delivery, the device can initiate the first programmed atrial pacing or cardioversion therapy, as appropriate. The Episode Duration values are programmed separately for pacing therapies and cardioversion therapies.

**Duration to Stop** – If the atrial episode continues beyond the programmed Duration to Stop and some therapies have not been used, these therapies are withheld for the remainder of the episode.

**Automatic CV Limits** – You can program the device to deliver automatic atrial cardioversion therapies only during selected hours of the day or night. You can also limit the number of shocks the device can deliver as automatic atrial therapies during a single 24-hour cycle.

**Atrial therapies and AT/AF Detection** – If all atrial therapies are programmed Off and you change the AT/AF Detection parameter value from Monitor to On, the programmer automatically sets the first 2 AT/AF therapies to nominal or previously programmed settings.

### 7.1.3 Restrictions

Review the following information before programming atrial therapy sequencing.

**Lead position check** – The lead position check requires atrial pacing. It will not occur if the programmed pacing mode is VVIR, VVI, VOO, DOO, or ODO.

**Lead position check and Ventricular Safety Pacing** – The lead position check cannot be enabled unless Ventricular Safety Pacing is enabled.
**VF detection backup during AT/AF** – To ensure VF detection backup during AT/AF episodes, AT/AF Detection cannot be On unless VF Detection is also On.

### 7.1.4 How to program atrial therapy sequencing

1. Select the **Params** icon.
2. Set AT/AF Detection to On.
3. Select the Therapies… field for AT/AF to open the AT/AF Detection and Therapies window.
4. Choose desired values for Episode Duration Before Rx Delivery (ATP and Automatic CV).
5. Set up desired Automatic CV Limits (delivery window and maximum shocks per day).
6. Choose desired values for Reactive ATP (Rhythm Change and Time Interval).
7. Choose whether atrial therapies should be disabled if rate acceleration occurs or if lead position is suspect.
8. Choose a desired value for Duration to Stop.
9. Return to the Parameters screen and select [PROGRAM].

Refer to the following procedures for more information on programming atrial detection and therapies:

- Section 6.3.4, “How to program AT/AF Detection”, page 80
- Section 7.2.4, “How to program automatic atrial cardioversion”, page 145
- Section 7.3.4, “How to program patient-activated atrial cardioversion”, page 152
- Section 7.4.7, “How to program atrial ATP therapies”, page 156

**7.1.5 Details about atrial therapy sequencing**

**7.1.5.1 Overview of atrial detection and therapies**

To understand atrial therapy sequencing, it is necessary to know about atrial detection and the phases of an atrial episode. For details, refer to Section 6.3, “Detecting atrial tachyarrhythmias”, page 78. Throughout a sustained atrial episode, atrial therapy sequencing continues as atrial arrhythmias are redetected. Atrial therapy sequencing determines which therapy is delivered following initial detection and following each redetection throughout the episode.

Atrial detection can be programmed with 1 zone (AT/AF) or 2 zones (AT/AF and Fast AT/AF). Each zone has a set of atrial therapies programmed. If 2 detection zones are programmed, both AT/AF therapies and Fast AT/AF therapies can be delivered. Atrial therapy sequencing selects from one set of therapies or the other depending on how the atrial rhythm is classified before delivery.

For information about programming automatic atrial therapies, refer to the following sections:

- Section 7.2.4, “How to program automatic atrial cardioversion”, page 145
- Section 7.4, “Treating atrial arrhythmias with antitachycardia pacing”, page 153

This therapy programming determines which atrial therapies are available and what priorities they have. Atrial therapies are delivered according to the length of the episode and the rhythm classification during the episode.
7.1.5.2 Role of the Sustained Duration timer

From the onset until the termination of an atrial episode, the length of the episode is measured with the Sustained Duration timer. The timer is reset when the episode terminates. Delivery or suspension of therapies does not affect timer operation.

The timer measurement (Sustained Duration value) is a reference for the following sequencing functions:

- ATP therapies become available when the Sustained Duration value exceeds the programmed ATP value of Episode Duration Before Rx Delivery.
- CV therapies become available when the Sustained Duration value exceeds the programmed Automatic CV value of Episode Duration Before Rx Delivery.
- If a time interval is programmed for Reactive ATP, the Reactive ATP function is scheduled each time that the Sustained Duration value equals a multiple of the programmed time interval (see Section 7.1.5.8, “Reactive ATP”, page 140).
- If a time limit is programmed for Duration to Stop, all atrial therapies are suspended for the remainder of the atrial episode when the Sustained Duration value reaches the Duration to Stop value. Regardless of other events, no atrial therapies can be scheduled until a new atrial episode begins.

7.1.5.3 Classification of atrial rhythms

Atrial rhythm classification depends on the following programmable parameters:

- The Zones parameter for atrial detection: One zone provides basic AT/AF detection. Two zones provide both AT/AF detection and Fast AT/AF detection. Each zone has independently programmed therapies.
- The Rhythm Change parameter for Reactive ATP: If Rhythm Change is enabled, the AT/AF zone is subdivided into a series of narrower zones. In addition, rhythms in the AT/AF zone are classified as regular or irregular (see Section 7.1.5.8, “Reactive ATP”, page 140).

7.1.5.4 Scheduling an automatic therapy to deliver

In atrial therapy sequencing, the device schedules an atrial therapy from the types available at initial detection and at each subsequent redetection.

When the atrial episode reaches the Episode Duration value for ATP therapies, these therapies become available for delivery. Subject to additional requirements (see “Atrial ATP therapies”, page 138), the device initiates the next available ATP therapy according to the current atrial rhythm classification. Reactive ATP expands the rhythm classification and delivery of ATP therapies (see Section 7.1.5.8, “Reactive ATP”, page 140).
When the atrial episode reaches the Episode Duration value for automatic CV therapies, these therapies become available for delivery, and they have priority over any unused ATP therapies. Subject to additional requirements (see “CV therapies”, page 138), the device initiates the next available CV therapy according to the current atrial rhythm classification. After all possible CV therapies have been delivered, therapy sequencing continues with the available ATP therapies.

Patient-activated cardioversion is not affected by Episode Duration times and can be delivered at any time during an atrial episode.

7.1.5.5 Requirements for initiating an automatic atrial therapy

Provided that the programmed values for Episode Duration Before Rx Delivery have been met, ATP therapies and Automatic CV therapies each have a set of requirements that must be satisfied before the device can deliver the therapies.

**Atrial ATP therapies** – In addition to meeting the episode duration requirement for ATP, all of the following conditions must also be met in order for the device to initiate an ATP therapy:

- The previous ventricular interval contained 3 or more atrial sensed events, or it contained 2 atrial sensed events with intervals less than the AT/AF Interval.
- The sustained duration has not exceeded the programmed Duration to Stop atrial therapy (see Section 7.1.5.9, “Duration to Stop Therapy”, page 142).
- For a scheduled Fast AT/AF therapy, at least 10 min have elapsed since a Burst+ or Ramp therapy was delivered from the AT/AF zone. This delay allows post-ATP atrial fibrillation to terminate spontaneously.
- The last 5 atrial events are all senses.
- After an automatic atrial 50 Hz Burst therapy, the time before the next therapy can be delivered is extended by 16 ventricular events.
- No atrial therapies are delivered if a ventricular episode is in progress.

**CV therapies** – In addition to meeting the episode duration requirement for Automatic CV and the conditions for initiating an ATP therapy, the following conditions must also be met in order for the device to initiate a CV therapy:

- Of the 12 most recent ventricular intervals, 10 or more intervals are greater than or equal to the programmed R-R Minimum Interval.
- The Automatic CV Limits criteria must be satisfied (see Section 7.1.5.6, “Automatic CV Limits”, page 139).
- Fewer than 15 automatic and patient-activated atrial shocks have been aborted in the episode. This requirement protects the device’s longevity by limiting ineffective cardioversion charges.
7.1.5.6 Automatic CV Limits

Automatic CV Limits sets up a programmable delivery window. This window is a daily interval of time during which automatic atrial cardioversion is an available therapy.

**Maximum Shocks per Day** – When the number of delivered automatic and patient-activated CV therapies reaches the programmed value for Maximum Shocks per Day, further automatic CV attempts are suspended until the next delivery window starts. Regardless of how Automatic CV Limits has been programmed, the following shocks remain available:

- manually-delivered shocks (EP Study)
- patient-activated CV therapies
- ventricular shocks

**Delivery Window for CV Therapy** – If you program the delivery window length for CV therapy to 24 hours, automatic shocks can be delivered at any time of day.

Verify that the device clock is accurately set when setting the Start Time for the CV delivery window. The Start Time is set relative to the device clock.

7.1.5.7 Disabling atrial therapies

By selecting Stop Atrial Rx After Rx/Lead Suspect…, you can program whether 2 situations disable atrial therapies.

**Disable atrial ATP if it accelerates V. Rate** – If this feature is enabled, the device responds when ATP therapies cause the ventricular rate to accelerate. The device makes the following responses:

- After 1 instance of rate acceleration, the device disables all atrial therapies for the remainder of the episode.
- After 3 instances of rate acceleration, the device disables all atrial ATP therapies until the feature is reprogrammed.

The criteria for rate acceleration are that ventricular intervals are shorter than 320 ms, that they decrease by 70 ms, and that the ventricular rate acceleration occurs during the atrial ATP therapy.

**Disable all atrial therapies if atrial lead position is suspect** – The device checks the atrial lead position every 24 hours. The Atrial Lead Position Check occurs only if the pacing mode includes atrial pacing. The check is disabled during mode switching, telemetry sessions, atrial episodes, and ventricular episodes.
The Atrial Lead Position Check increases the atrial amplitude and atrial pulse width to the settings used for atrial ATP (if they exceed the current settings). It examines the AP-VS interval on subsequent events. Each interval that is shorter than 80 ms is classified as an inappropriate event. The Atrial Lead Position Check fails if 32 inappropriate AP-VS events occur before 256 V-events occur. If this happens, the atrial lead position is considered to be suspect.

If this lead check fails, all atrial therapies are disabled until they are reenabled using the programmer.

**VT/VF detection** – If VT/VF is detected during an atrial episode, two results are possible:
- If VT/VF occurs immediately after an AT/AF therapy is delivered, the device disables atrial therapies until they are reenabled using the programmer.
- If VT/VF occurs during an AT/AF episode but this detection is not related to therapy delivery, the device suspends atrial therapies. Atrial therapies can resume when the VT/VF episode ends.

### 7.1.5.8 Reactive ATP

In some cases, an atrial tachyarrhythmia cannot be terminated by the programmed set of atrial ATP therapies. Additional attempts at termination may be successful, particularly if the atrial rhythm changes. You can enable Reactive ATP to allow programmed sequences of ATP therapy to be delivered again during an episode in response to either of the following events:
- a change in the atrial rhythm’s cycle length or regularity
- the expiration of a programmed time interval

The 2 features of Reactive ATP, Rhythm Change and Time Interval, are programmed separately. When AT/AF Detection is programmed On, the Rhythm Change feature is nominally On and applicable, and the Time Interval feature is nominally Off.

**Note:** This section describes the operation of Reactive ATP, which affects the scheduling of atrial ATP therapies. For information about the operation and programming of the atrial ATP therapies themselves, see Section 7.4, “Treating atrial arrhythmias with antitachycardia pacing”, page 153.

**Rhythm Change** – If Rhythm Change is enabled, the device detects changes in the atrial arrhythmia using both regularity and cycle length. The AT/AF zone is subdivided into a series of narrower regions. Each region is supplied with a separate set of the atrial ATP therapies enabled for AT/AF episodes. One series of subdivided regions is identified for regular atrial rhythms. Another series of regions is identified for irregular atrial rhythms. If the rhythm shifts into a different region because of a change in cycle length or regularity, the device delivers therapies from those available in the new region.
The device monitors atrial cycle length regularity with each V-V interval by analyzing the 12 most recent atrial intervals. The atrial cycle length is classified as irregular during a V-V interval if the difference between the second-shortest and the second-longest atrial intervals is greater than 25% of the median atrial interval. The device then classifies the atrial rhythm by examining the last 16 V-V intervals:

- If the atrial cycle length was irregular during any of the last 16 V-V intervals, the rhythm is classified as irregular.
- If the atrial cycle length was regular during all of the last 16 V-V intervals, the rhythm is classified as regular.

When there is 1 atrial detection zone, the AT/AF zone is subdivided, as shown in Figure 24:

- Regular rhythms have 50 ms regions, and 7 regions are used if the AT/AF Interval is set to 450 ms.
- Irregular rhythms have two 100 ms regions and one 150 ms region.

If the AT/AF Interval is shortened, fewer regions may be used. For example, 5 regions are used if the AT/AF Interval is shortened to 350 ms. In this example, 1 of the regions for irregular rhythms is shortened, but the other 2 regions remain the same.

Figure 24. Regions for Reactive ATP with Rhythm Change (AT/AF only)

When there are 2 atrial detection zones, the AT/AF zone is subdivided as shown in Figure 25. The actual number of regular and irregular regions depends on the difference between the Fast AT/AF interval and the AT/AF interval.
Figure 25. Regions for Reactive ATP with Rhythm Change (AT/AF and Fast AT/AF)

AT/AF interval = 350 ms
Fast AT/AF interval = 200 ms

1 Regions of the AT/AF zone (200 to 350 ms) for regular rhythms. Note that Fast AT/AF ATP therapies are not affected by Reactive ATP.
2 Regions of AT/AF zone for irregular rhythms.

Each of these narrower AT/AF regions has the full number of therapy sequences that were programmed in the AT/AF Pacing Therapies window. If the atrial rhythm within an atrial episode varies across a number of these narrower regions, the total number of available ATP sequences is increased accordingly.

The shift from a regular rhythm to an irregular rhythm introduces an additional 10 min scheduling delay to permit spontaneous termination of the irregular rhythm or a shift back to a regular rhythm.

**Time Interval** – The Time Interval feature of Reactive ATP allows for treatment of atrial arrhythmias that may have changed throughout the course of an atrial episode.

If a Reactive ATP Time Interval is programmed, the number of ATP sequences is reset for both the AT/AF zone and the Fast AT/AF zone. The reset occurs when the Sustained Duration value reaches a multiple of the programmed Time Interval. This means that all therapies will be reenabled for delivery. This reset function is available only within the first 48 hours of an atrial episode.

**7.1.5.9 Duration to Stop Therapy**

To limit therapy delivery for a prolonged atrial episode, you can program the Duration to Stop parameter. If an atrial episode exceeds the programmed value, this feature suspends all atrial therapies including patient-activated therapies, for the duration of the atrial episode. Atrial therapies are reenabled upon atrial episode termination.

**7.2 Treating atrial arrhythmias with cardioversion**

**Note:** Atrial therapies, including automatic atrial cardioversion, are available only with AT devices. DR and VR devices do not provide atrial therapies.
The device can be programmed to deliver automatic atrial cardioversion (CV) shocks to treat a detected atrial episode. Each cardioversion shock has separately programmed Energy and Pathway parameters.

Another set of parameters is shared by all automatic and patient-activated atrial cardioversion shocks. These parameters are Minimum R-R Interval, Tilt, and Active Can.

When automatic atrial cardioversion is scheduled in an atrial episode, the device charges the high-voltage capacitors to the programmed energy and attempts to synchronize the shock to a sensed event outside the ventricle’s vulnerable period.

Refer to Section 7.1, “Controlling atrial therapy sequencing”, page 133, and to Section 7.2.5, “Details about automatic atrial cardioversion (CV)”, page 146.

### 7.2.1 Parameters

<table>
<thead>
<tr>
<th>Automatic CV parameters for each therapy</th>
</tr>
</thead>
</table>
| **Automatic CV Status** – Enables Automatic CV therapies. | On; Off
| **Energy** – The energy delivered by the device for cardioversion therapy. | 0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J
| **Pathway** – Direction the electrical current flows through the heart. | AX>B; B>AX

<table>
<thead>
<tr>
<th>Shared CV parameters</th>
</tr>
</thead>
</table>
| **Minimum R-R Interval** – Prevents delivery of CV during a fast ventricular rate. CV is not delivered if the current measured R-R interval is less than this programmed value. | 400; 410 ... 500 ... 600 ms
| **Tilt** – Voltage decay during each phase of the shock. The programmable value applies to both phases of the biphasic waveform. | 30; 40; 50; 65%
| **Active Can** – Option to select the device case as an active electrode for delivering defibrillation and cardioversion therapies. | On; Off

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*a Programmed values of Minimum R-R Interval and Tilt apply to all atrial cardioversion therapies: Automatic CV for AT/AF, Automatic CV for Fast AT/AF, and Patient-Activated CV.

*b The Active Can setting applies to atrial and ventricular high-voltage therapies.
7.2.2 Considerations

Review the following information before programming automatic atrial cardioversion.

Caution: If the Active Can feature is disabled, the device delivers high-voltage therapies between the RV (HVB) and SVC (HVX) electrodes only. To ensure that the device can deliver defibrillation and cardioversion therapies, make sure that a supplementary HVX electrode is implanted and connected to the device before disabling the Active Can feature.

Sensing – To ensure appropriate delivery of atrial cardioversion therapy, program the device to prevent sensing of far-field R-waves.

Automatic CV Limits – You can program the device to deliver automatic atrial cardioversion therapies during selected hours of the day or night. You can also limit the number of shocks the device can deliver as atrial therapies during a single 24-hour cycle.

Note: Atrial cardioversion is programmable only for patient-activated therapy and these automatic therapies: AT/AF therapies 4 and 5, and Fast AT/AF therapies 4 and 5.

7.2.3 Restrictions

Review the following information before programming automatic atrial cardioversion.

VF therapy – You must program VF therapy On before enabling automatic atrial cardioversion.
7.2.4 How to program automatic atrial cardioversion

1. Select the Params icon.
2. Ensure that AT/AF Detection is On.
3. Select the Therapies… field for AT/AF to open the AT/AF Detection and Therapies window.
4. Select the Automatic CV field for AT/AF Rx.
5. Enable therapy Rx4, and choose values for Energy and Pathway. Optionally, make the same choices for therapy Rx5.
6. Choose values for the Shared CV parameters.
7. Select [OK].
8. For 2 detection zones, select the Automatic CV field for Fast AT/AF Rx. Repeat Step 5 for Fast AT/AF therapies.
9. Return to the Parameters screen and select [PROGRAM].

7.2.5 Details about automatic atrial cardioversion (CV)

The device prepares to deliver a CV therapy if these conditions are met:

- Atrial therapy sequencing determines that CV is enabled for the given rhythm classification (AT/AF or Fast AT/AF). See Section 7.1.5, “Details about atrial therapy sequencing”, page 136.
- There is an unused Rx4 or Rx5 therapy remaining for that rhythm classification.
- When an atrial episode is detected or redetected, all requirements are met so that CV can be scheduled. See Section 7.1.5.5, “Requirements for initiating an automatic atrial therapy”, page 138.

7.2.5.1 Cardioversion therapy parameters

This information about atrial cardioversion parameters applies to both automatic cardioversion and patient-activated cardioversion.

Energy – The device can be programmed to provide delivered energies over a range of values. The cardioversion energy level is programmed independently for each therapy. For a comparison of delivered energy levels to energy levels stored by the device, refer to Section 1.7, “High-voltage therapy energy”, page 20.

**Note:** The stored energy of the device is derived from the peak capacitor voltage, which is always greater than the energy delivered by the device.

Biphasic waveform and the Tilt parameter – The waveform of the cardioversion pulse is biphasic, which means that the waveform consists of 2 phases.

In the first phase, current is delivered between the high-voltage electrodes until the pulse decays by a percentage equal to the programmed tilt value, which is common to all atrial cardioversion therapies. The device then truncates the pulse and reverses the current pathway for the second phase by transposing the cathode and anode. After the second phase of the pulse has decayed by the programmed percentage of its original voltage, the device truncates the pulse.

The delivery of biphasic shocks across a single pathway with 50% tilt is shown in Figure 26.
Figure 26. Cardioversion pulse waveform

Pathway Polarity – Pathway Polarity specifies the implanted electrodes that deliver cardioversion pulses, and it defines the direction of current delivered by the electrodes. For example, a device implanted with 2 electrodes, CAN (HVA) and RV (HVB), can be programmed to deliver current from CAN to RV (AX>B) or from RV to CAN (B>AX).

If an optional electrode is used, you can disable the Active Can feature. If you do so, the device delivers cardioversion therapies between the RV (HVB) and SVC (HVX) electrodes only.

Table 25. Modes and polarities for cardioversion

<table>
<thead>
<tr>
<th>Pathway Polarity Options</th>
<th>Two HV Electrodes:</th>
<th>Three HV Electrodes:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAN and RV&lt;sup&gt;a&lt;/sup&gt;</td>
<td>CAN, RV, and SVC</td>
</tr>
<tr>
<td></td>
<td>CAN to RV = AX&gt;B</td>
<td>CAN, SVC to RV = AX&gt;B</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>RV to CAN = B&gt;AX</td>
<td>RV to CAN, SVC = B&gt;AX</td>
</tr>
</tbody>
</table>

<sup>a</sup>The notation “CAN to RV” names the Active Can electrode as the anode and the RV lead as the cathode during the initial segment of the biphasic waveform.
7.2.5.2 Charging the capacitors before atrial cardioversion

The length of time to charge the high-voltage capacitors to the programmed energy (charge time) increases with an increase in programmed energy, battery depletion, or time since the last capacitor formation. Refer to Section 1.7, “High-voltage therapy energy”, page 20.

During the capacitor-charging period, both of these activities may occur:

- The device continues to pace and sense in the programmed bradycardia pacing mode. However, bradycardia pacing changes during charging in the following ways:
  - The device suspends Rate Hysteresis, Atrial Rate Stabilization, and Atrial Preference Pacing.
  - The device freezes rate-responsive operation.
  - Any ongoing Post Mode Switch Overdrive Pacing operations are terminated.
- The telemetry link between the device and the programmer may be lost because of electrical noise.

7.2.5.3 Atrial cardioversion synchronization

Atrial cardioversion is synchronized to a nonrefractory ventricular event if possible. The shock is delivered if the Lower Rate V-V interval expires. The shock aborts in the presence of a high ventricular rate to prevent delivery during the vulnerable period preceding ventricular depolarization.

Figure 27 shows the timing of a typical synchronization for atrial cardioversion.

Figure 27. Atrial Cardioversion Synchronization

1 The device does not deliver the CV therapy on any of the refractory ventricular events. The length of the refractory period is controlled by the Minimum R-R Interval.
2 The device delivers the CV therapy on the second nonrefractory interval.
3 After CV therapy, the device starts a 1200 ms DDI escape interval.
4 Programmed pacing resumes after the next V-event.
Atrial cardioversion attempts to synchronize with sensed ventricular events, but it does not require an R-wave. In the absence of ventricular activity, the device delivers the atrial shock when the V-V interval corresponding to the programmed Lower Rate expires (unless pacing is programmed to ODO mode). This allows treatment of atrial arrhythmias in pacing-dependent patients who may not experience sensed ventricular events.

The device uses a synchronization interval equal to the Lower Rate pacing interval to identify the R-wave to deliver the shock. Each synchronization interval begins with a post-sense or post-pace blanking period, and the shared Minimum R-R Interval programmed for atrial cardioversion.

After charging is complete, the first synchronization interval begins at the next sensed or paced ventricular event. A refractory ventricular event during synchronization restarts the synchronization interval.

The atrial cardioversion therapy is delivered in the following situations:

- at the second nonrefractory ventricular event during synchronization
- if the synchronization interval (Lower Rate escape interval) times out and if the permanent pacing mode is not ODO

The atrial cardioversion therapy aborts in the following situations:

- if 12 refractory sensed ventricular events occur before the therapy can be delivered
- if the synchronization interval (2000 ms) times out and if the permanent pacing mode is ODO

### 7.2.5.4 After a delivered atrial cardioversion therapy

Immediately after delivering a cardioversion therapy, the device starts a post-shock blanking period of 520 ms and a pacing cycle with characteristics defined as follows:

- If the programmed pacing mode is AAIR<=>DDDR, AAI<=>DDD, DDDR, DDD, DDIR, DDI, or DOO, the pacing cycle is in the DDI mode with a 1200 ms pacing interval and a 300 ms PAV.
- If the programmed pacing mode is ODO, the pacing cycle is in the OVO mode with a 2000 ms pacing interval.
- For any other programmed pacing modes, the pacing cycle is in the VVI mode with a 1200 ms pacing interval.

After the first ventricular event, the programmed bradycardia pacing mode resumes, using the Amplitude and Pulse Width parameters programmed for Post Shock Pacing. Refer to Section 8.18, “Post Shock Pacing”, page 271.

The device monitors the episode for an outcome of either termination or redetection as a result of the delivered therapy.
7.2.5.5 After an aborted atrial cardioversion therapy

Following an aborted atrial cardioversion therapy or an aborted charging period, the device reverts immediately to its programmed bradycardia pacing settings.

The device resumes monitoring the cardiac cycle for arrhythmias, using the criteria for atrial detection after the next paced or sensed ventricular event. If the device redetects the same arrhythmia after an aborted therapy, it attempts to synchronize and deliver the same therapy. However, if the device detects episode termination, it resumes normal detection.

Note: If a cardioversion therapy aborts during capacitor charging, energy may continue to be stored on the capacitors. In this case, the delivered energy of a subsequent cardioversion therapy could be higher than the programmed value.

7.3 Providing patient-activated atrial cardioversion

Note: Atrial therapies, including patient-activated cardioversion, are available only with AT devices. DR and VR devices do not provide atrial therapies.

To allow the patient and physician greater control over delivery of atrial cardioversion therapy, the patient can use the Patient Assistant to signal the device to deliver atrial cardioversion therapy.

Refer to Section 7.3.5, “Details about patient-activated cardioversion”, page 153.

7.3.1 Parameters

<table>
<thead>
<tr>
<th>Patient-activated CV parameters only</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Activated CV Status</strong> – Enables Automatic CV therapies</td>
</tr>
<tr>
<td><strong>Therapy Type</strong> – Nonprogrammable. CV is shown for reference.</td>
</tr>
<tr>
<td><strong>Energy</strong> – The energy delivered by the device for cardioversion therapy.</td>
</tr>
<tr>
<td><strong>Pathway</strong> – Direction the electrical current flows through the heart.</td>
</tr>
</tbody>
</table>
Shared CV parameters

**Minimum R-R Interval** – Prevents delivery of CV during the vulnerable period of the ventricle. CV is not delivered if the minimum measured R-R interval is less than this programmed value.\(^a\)

**Tilt** – Voltage decay during each phase of the shock. The programmable value applies to both phases of the biphasic waveform.\(^a\)

**Active Can** – Option to select the device case as an active electrode for delivering defibrillation and cardioversion therapies.\(^b\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum R-R Interval</td>
<td>400; 410 (\ldots) 500 (\ldots) 600 ms</td>
</tr>
<tr>
<td>Tilt</td>
<td>30; 40; 50; 65%</td>
</tr>
<tr>
<td>Active Can</td>
<td>On(^a); Off (^b)</td>
</tr>
</tbody>
</table>

\(^a\)Programmed values of Minimum R-R Interval and Tilt apply to all atrial cardioversion therapies: Automatic CV for AT/AF, Automatic CV for Fast AT/AF, and Patient-Activated CV.

\(^b\)The Active Can setting applies to atrial and ventricular high-voltage therapies.

### 7.3.2 Considerations

Review the following information before programming patient-activated atrial cardioversion.

**Caution:** If the Active Can feature is turned off, the device delivers high-voltage therapies between the RV (HVB) and SVC (HVX) electrodes only. To ensure the device can deliver defibrillation and cardioversion therapies, make sure a supplementary HVX electrode is implanted and connected to the device before turning the Active Can feature off.

### 7.3.3 Restrictions

Review the following information before programming patient-activated atrial cardioversion.

**VF therapy** – You must enable VF therapy before enabling automatic atrial cardioversion.
7.3.4 How to program patient-activated atrial cardioversion

1. Select the Params icon.
2. Ensure that AT/AF Detection is On.
3. Select the Therapies… field for AT/AF to open the AT/AF Detection and Therapies window.
4. Select the Patient Activated CV… field.
5. Enable Patient Activated CV therapy, and choose values for Energy and Pathway.
6. Choose values for the Shared CV parameters.
7. Return to the Parameters screen and select [PROGRAM].

### 7.3.5 Details about patient-activated cardioversion

For general information about atrial cardioversion, refer to Section 7.2.5, "Details about automatic atrial cardioversion (CV)", page 146.

A patient-activated atrial cardioversion is delivered if the following conditions are met:
- The device is programmed to allow patient-activated atrial cardioversion therapy.
- The telemetry command requesting CV therapy is received during an atrial episode.
- The device is able to synchronize to a ventricular event.

**Note:** A pending patient-activated cardioversion takes priority over an automatic atrial therapy.

A patient-activated atrial cardioversion is not delivered if any of the following occur:
- Atrial therapy has been disabled by any of the following events:
  - A ventricular episode is detected or monitored.
  - An Atrial Lead Position Check has failed.
  - A charge circuit failure has occurred.
- The atrial episode length has exceeded the programmed Duration to Stop therapy parameter.
- The device is unable to synchronize the patient-activated shock.
- More than 60 s have elapsed since the patient used the Patient Assistant to request cardioversion.
- 15 automatic and patient-activated atrial shocks have been aborted in the episode. This requirement protects the longevity of the device by limiting ineffective cardioversion charges.
- Of the 12 most recent ventricular intervals, fewer than 10 intervals are shorter than the programmed Minimum R-R Interval.

### 7.4 Treating atrial arrhythmias with antitachycardia pacing

**Note:** Atrial therapies, including atrial ATP, are available only with AT devices. DR and VR devices do not provide atrial therapies.
The device can respond to an atrial episode by delivering antitachycardia pacing (ATP) therapy to the patient’s heart. ATP therapies are designed to interrupt the reentrant activation pattern of an atrial arrhythmia with pacing stimuli, restoring the patient’s normal sinus rhythm. Because ATP therapies use pacing-level stimulation instead of high-voltage shocks, they are much less painful for the patient than cardioversion therapy.

You can program the device to deliver a sequence of up to 3 ATP therapies in the AT/AF zone and up to 3 ATP therapies in the Fast AT/AF zone if that zone is used. You can select Burst+, Ramp, or 50 Hz Burst ATP therapy and can set the parameters for each enabled therapy separately.

Refer to Section 7.1, “Controlling atrial therapy sequencing”, page 133, and to Section 7.4.8, “Details about atrial ATP therapies”, page 157.

### 7.4.1 Parameters common to all ATP therapies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Setting Details</th>
</tr>
</thead>
</table>
| **AT/AF (or Fast AT/AF) Rx Status** | Enables or disables an ATP therapy for Rx1, Rx2, or Rx3. | On; Off
| **Therapy Type** | An ATP therapy to treat atrial episodes selectable for Rx1, Rx2, and Rx3. | 50 Hz; Ramp; Burst+
| | | Rx1: Ramp
| | | Rx2: Burst+
| | | Rx3: 50 Hz
| **A-A Minimum ATP Interval** | Minimum pacing interval for Ramp and Burst+ therapies. | 100; 110; 120; 130; … 400 ms
| **A. Pacing Amplitude** | Voltage of the atrial pacing pulses delivered during all ATP therapies. | 1; 2; … 6; 8 V
| **A. Pacing Pulse Width** | Duration of the atrial pacing pulses delivered during all ATP therapies. | 0.1; 0.2; … 1.5 ms
| **VVI/VOO Backup Pacing** | Selects whether ventricular backup pacing pulses are delivered during all ATP therapies. | Off; On (Always); On (Auto-Enable)
| **VVI/VOO Backup Pacing Rate** | Lower rate of ventricular backup pacing pulses. | 60; 70; … 120 bpm

### 7.4.2 Parameters for Burst+ therapy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Setting Details</th>
</tr>
</thead>
</table>
| **Initial #S1 Pulses** | Number of S1 pulses in each burst sequence. | 1; 2; … 15; 20; 25
| **A-S1 Interval (%AA)** | Pacing interval of the S1 burst pulses, as a percentage of the pre-therapy atrial cycle length. | 28; 31; 34; 38; 41; … 59; 63; 66; … 84; 88; 91; 94; 97%
| **S1-S2 (%AA)** | Pacing interval of the S2 stimulus following the burst as a percentage of the pre-therapy atrial cycle length. | Off; 28; 31; 34; 38; 41; … 59; 63; 66; 69; … 84; 88; 91; 94; 97%
7.4.3 Parameters for Ramp therapy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S2-S3 Decrement</strong> – The S2-S3 interval equals the S1-S2 interval minus this decrement value.</td>
<td>Off; 0; 10; 20 ... 80 ms</td>
</tr>
<tr>
<td><strong>Interval Decrement</strong> – Pacing interval decrement per sequence.</td>
<td>0; 10; 20; 30; 40 ms</td>
</tr>
<tr>
<td><strong># Sequences</strong> – Number of sequences in the Burst+ therapy.</td>
<td>1; 2 ... 6 ... 10</td>
</tr>
</tbody>
</table>

7.4.4 Parameters for 50 Hz Burst therapy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50 Hz Burst Duration</strong> – Duration of each 50 Hz Burst sequence.</td>
<td>0.5; 1; 2; 3 s</td>
</tr>
<tr>
<td><strong># Sequences</strong> – Number of sequences in the 50 Hz Burst therapy.</td>
<td>1; 2 ... 10</td>
</tr>
</tbody>
</table>

7.4.5 Considerations

Review the following information before programming ATP therapy parameters.

**Backup pacing for 50 Hz Burst therapy** – VOO backup pacing will be competitive if there is an intrinsic rate.

7.4.6 Restrictions

Review the following information before programming ATP therapy parameters.

**VF therapy** – You must program VF therapy On before enabling atrial ATP therapies.
7.4.7 How to program atrial ATP therapies

1. Select the Params icon.
2. Ensure that AT/AF Detection is On.
3. Select the Therapies… field for AT/AF to open the AT/AF Detection and Therapies window.
4. Select the Anti-Tachy Pacing (ATP)… field for AT/AF Rx.
5. Enable each desired pacing therapy. Choose values for the subparameters of therapies Rx1, Rx2, and Rx3.
7. Return to the AT/AF Detection and Therapies window. Select the Anti-Tachy Pacing (ATP)… field for Fast AT/AF Rx if that detection zone is used.
8. Optionally, program pacing therapies for Fast AT/AF just as you programmed AT/AF therapies in Step 5.
9. Return to the Parameters screen and select [PROGRAM].

7.4.8 Details about atrial ATP therapies

This section contains information that applies to all ATP therapies followed by details about each of the specific ATP therapies.

Refer to Section 7.1.5, “Details about atrial therapy sequencing”, page 136, to learn how ATP therapies are scheduled and how they can be canceled if the delivery of an ATP therapy leads to an acceleration in the ventricular rate.

7.4.8.1 Common information: all ATP therapies

Pre-therapy atrial cycle length – The Burst+ and Ramp pacing intervals are rate-adaptive because they are percentages of the median of the last 12 P-P intervals prior to therapy delivery. This median value can vary from one sequence in a therapy to the next, and the interval calculations will vary accordingly.

Pacing synchronization – Atrial ATP therapies are synchronized to the first atrial event after the ventricular event upon which the atrial arrhythmia is detected (or redetected). This occurs if the requirements to deliver ATP therapies are met. Refer to Section 7.1.5.2, “Role of the Sustained Duration timer”, page 137. Atrial ATP can be aborted if no atrial event occurs within 500 ms after the therapy is scheduled.

Effects of the A-A Minimum ATP Interval – Burst+ and Ramp pulses are never delivered at less than the programmed A-A Minimum ATP Interval. This minimum pacing interval is the same for all Burst+ and Ramp therapies. If some calculated intervals are shorter than the programmed minimum, the pulses are delivered at the programmed minimum interval. If the median of the last 12 A-A intervals is shorter than the programmed minimum, the device will not deliver Burst+ or Ramp therapies until the atrial rate slows.

Note: If atrial 50 Hz Burst therapy is enabled, it is delivered in this situation.

Pacing output for ATP therapies – The pulse width and amplitude are the same for all atrial ATP therapies, but they are programmed separately from the ventricular ATP and the bradycardia pacing values.
Ventricular backup pacing – Ventricular backup pacing in the VVI and VOO modes is available during atrial ATP therapy delivery. The backup pacing is delivered either at the separately programmed Lower Rate or at the current pacing rate, whichever is faster. The backup pacing output is preset at 6 V and 1.5 ms.

Ventricular backup pacing can be enabled by these options:
- On (Always): backup pacing is delivered during every ATP therapy.
- On (Auto Enable): backup pacing is withheld unless all 4 ventricular events preceding the therapy were paced.

Note: VVI backup pacing could be competitive with intrinsic ventricular activity during the ATP sequence.

VF or VT detected after an atrial pacing therapy – If a ventricular tachyarrhythmia is detected after delivery of an atrial therapy (for example, before either AT/AF redetection or AT/AF episode termination), the remaining sequences of the atrial therapy are not delivered. Instead, the device disables all atrial therapies (automatic and patient-activated), suspends atrial detection during the VT or VF episode, and delivers the first programmed therapy for the ventricular arrhythmia. Atrial therapies must be reenabled using the programmer.

7.4.8.2 Burst+ pacing

Burst+ therapy sequences consist of a programmed number of AOO pulses followed by 2 premature stimuli that are delivered at shorter intervals.

VVI ventricular backup pacing is available during Burst+ pacing.

The AOO sequence is delivered at the programmed A-S1 Interval timed from the first sensed A-event following the V-event that fulfills detection. The first premature stimulus is delivered at the S1-S2 percentage. The second premature stimulus is delivered at the S1-S2 interval minus the programmed S2-S3 Decrement.

If the tachycardia is redetected after an ineffective sequence, the device delivers another Burst+ sequence with shorter pacing intervals. For this sequence, the device calculates these intervals by subtracting the programmed Interval Decrement from the Burst+ parameters (see Figure 28).

Notes:
- Detection is suspended during an atrial ATP therapy sequence.
- S2-S3 pulses are not delivered if S1-S2 pulses are programmed Off.
The device detects AT/AF.
2 The first Burst+ sequence is delivered with 15 pulses at 180 ms intervals. The sequence continues with 2 pulses at intervals shorter than 180 ms. This sequence fails to terminate the AT/AF.
3 The device redetects AT/AF.
4 The second Burst+ sequence is delivered with 15 pulses at 170 ms intervals. The sequence continues with 2 pulses at intervals shorter than 170 ms. This sequence terminates the AT/AF.

7.4.8.3 Ramp pacing
Ramp therapy sequences consist of a programmable number of AOO pulses delivered at decreasing intervals.
VVI ventricular backup pacing is available during Ramp pacing.
The first pulse of each Ramp sequence is delivered at a programmable percentage of the current atrial cycle length (the median of the last 12 P-P intervals). The rest of each sequence is delivered at progressively shorter intervals, based on the programmed Interval Decrement.

If the tachycardia is redetected after an ineffective sequence, the device delivers another Ramp sequence. For this sequence, the device calculates the intervals based on the atrial cycle length at redetection. Each sequence contains one more pacing pulse than the previous sequence contained (see Figure 29).

**Note:** Detection is suspended during an atrial ATP therapy sequence.

**Figure 29.** Ramp pacing operation

1. The device detects AT/AF.
2. The first Ramp sequence is delivered with 6 pulses. The first interval is 240 ms, and the intervals that follow are each decremented 10 ms. This sequence fails to terminate the AT/AF.
3 The device redetects AT/AF.
4 The second Ramp sequence is delivered with 7 pulses. The first interval is 240 ms, and the intervals that follow are each decremented 10 ms. This sequence terminates the AT/AF.

7.4.8.4 50 Hz Burst pacing

A sequence of 50 Hz Burst therapy delivers a burst of AOO pulses at 20 ms intervals for a programmable duration.

VOO ventricular backup pacing is available during 50 Hz Burst therapy.

Each time the atrial arrhythmia is redetected, the device delivers another identical burst sequence up to the programmed number of sequences (see Figure 30).

Atrial therapy scheduling is delayed for 16 ventricular events after each sequence of 50 Hz Burst therapy.

**Note:** Detection is suspended during an atrial 50 Hz sequence.
Figure 30. 50 Hz Burst pacing operation

1 The device detects AT/AF.
2 The first 50 Hz Burst sequence is delivered for a programmed duration. This sequence fails to terminate the AT/AF.
3 The device redetects AT/AF.
4 An identical 50 Hz Burst sequence is delivered. This sequence terminates the AT/AF.

7.5 Treating episodes detected as VF

The device can respond to episodes detected in the VF zone by delivering defibrillation therapy to the patient’s heart. The defibrillation therapy is intended to terminate the episode by simultaneously depolarizing the heart tissue and restoring the patient’s normal sinus rhythm.

You can program the device to deliver a sequence of up to 6 defibrillation therapies, each with specific energy and pathway settings.
You can also program the device to deliver a sequence of ATP therapy before or during charging for the first VF therapy. This allows the device to terminate rapid but stable ventricular tachyarrhythmias that do not require defibrillation therapy for termination.

Refer to Section 6.4.5, “Details about VF detection”, page 87.

7.5.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VF Therapy Status</strong></td>
<td>Turns a specific VF therapy on or off.</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>Amount of energy delivered to the heart by the therapy.</td>
</tr>
<tr>
<td><strong>Pathway</strong></td>
<td>Direction the electrical current flows through the heart.</td>
</tr>
<tr>
<td><strong>Active Can</strong></td>
<td>Option to select the device can as an active electrode for delivering defibrillation and cardioversion therapies.</td>
</tr>
<tr>
<td><strong>ATP</strong></td>
<td>Option to deliver a sequence of ATP therapy before or during charging for the first VF therapy.</td>
</tr>
<tr>
<td><strong>Deliver ATP if last 8 R-R &gt;=</strong></td>
<td>Rate limit for ATP therapy before or during charging. If any of the last 8 R-R intervals is less than this limit, ATP is not delivered.</td>
</tr>
<tr>
<td><strong>ChargeSaver</strong></td>
<td>Option to automatically switch from ATP During Charging operation to ATP Before Charging operation. ChargeSaver makes this switch if ATP therapy successfully terminates the detected arrhythmia on a programmable number of consecutive attempts.</td>
</tr>
<tr>
<td><strong>Switch when number of consecutive ATP successes equals</strong></td>
<td>Threshold value used by the ChargeSaver option for switching from ATP During Charging operation to ATP Before Charging operation.</td>
</tr>
<tr>
<td><strong>Smart Mode</strong></td>
<td>Option to automatically disable ATP therapy during or before charging if it fails to terminate the tachyarrhythmia in 4 consecutive episodes.</td>
</tr>
<tr>
<td><strong>Therapy Type</strong></td>
<td>Type of ATP therapy to be delivered.</td>
</tr>
</tbody>
</table>

| On; Off                          | 0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J |
| AX>B; B>AX                       | Rx1–Rx4: B>AX; Rx5–Rx6: AX>B |

Notes:

- ATP parameters are available for VF therapy only if VF Rx1 is set to On.
- For parameter definitions, programmable ranges and nominal settings for specific ATP therapies, see Section 7.6, “Treating VT and FVT with antitachycardia pacing”, page 176.
- VF Therapy Status, Energy, and Pathway are programmed separately for each VF therapy.
- For VF therapies 3 - 6, energy settings below 10 J are not available.
7.5.2 Considerations

Review the following information before programming VF Therapy parameters.

**Caution:** If the Active Can feature is programmed Off, the device delivers defibrillation and cardioversion therapies between the RV (HVB) and SVC (HVX) electrodes only. To ensure the device can deliver defibrillation and cardioversion therapies, make sure a supplementary electrode is implanted and connected to the SVC (HVX) port before turning Active Can off.

**Active Can** – The programmed setting for Active Can applies to the following high-voltage operations:
- automatic, manual, and emergency ventricular cardioversion
- automatic, manual, and patient-activated atrial cardioversion
- automatic, manual, and emergency defibrillation
- T-Shock inductions

**Energy** – Programming the first VF therapy to an optimized value (for example, the defibrillation threshold plus 10 J) can expedite delivery and help extend battery longevity. All other VF therapies should be programmed to the maximum energy value.

**Energy and ATP During Charging** – When you set the Energy parameter for a therapy to a value less than 20 J, the charge time for that therapy can be short. This may not allow time to detect that ATP During Charging has terminated an episode. Consider programming the Energy parameter for the first VF therapy to at least 20 J if you enable ATP During Charging.

**Smart Mode, ATP During Charging, and ATP Before Charging** – You can select Smart Mode for the ATP During Charging or ATP Before Charging therapy options. This allows the device to disable ATP for VF therapy Rx1 when ATP therapy has been unsuccessful in 4 consecutive episodes.

**ATP Before Charging** – If you enable ATP Before Charging, the defibrillation shock therapy is delayed if the ATP therapy fails to terminate the tachyarrhythmia. The delay occurs because the episode must be redetected after the initial ATP therapy before the charging can begin.

**ChargeSaver feature** – The ChargeSaver feature allows the device to automatically switch from ATP During Charging operation to ATP Before Charging operation. This change occurs when ATP has successfully terminated the detected arrhythmia on a programmable number of consecutive attempts.

**Note:** If any ATP parameter is reprogrammed, the device resets the count of consecutive ATP successes used by the ChargeSaver feature.

**Switchback feature** – The Switchback feature allows the device to automatically switch from ATP Before Charging operation to ATP During Charging operation. This change occurs if ATP Before Charging fails to terminate the detected arrhythmia on 2 consecutive attempts.
The Switchback feature is not programmable; it is always enabled as part of ATP Before Charging operation.

**Progressive Episode Therapies** – If Progressive Episode Therapies is programmed On, the device may deliver a high-voltage therapy at a higher energy level than is programmed. This ensures that each therapy delivered during an ongoing episode is at least as aggressive as the previous therapy (see Section 7.9).

### 7.5.3 Restrictions

Review the following information before programming VF Therapy parameters.

**Energy** – The energy settings for VF therapies Rx3–Rx6 must be programmed to 10 J or greater. In addition, VF therapies must be programmed to be at least equal to the energy of the previous therapy or increasingly aggressive. That is, one VF therapy cannot be followed by another with a lower energy setting.

**VT and FVT therapies** – VT and FVT therapies cannot be enabled unless at least one VF therapy is also enabled.
7.5.4 How to program VF therapies

1. Select the Params icon.
2. Select the Therapies… field for VF.
3. For each therapy (Rx1–Rx6), select the desired values for VF Therapy Status, Energy, and Pathway.
4. Optionally, select ATP… to enable ATP therapy during or before charging and to select ATP therapy parameters.
5. Optionally, select ChargeSaver... to configure the ChargeSaver feature.
6. Optionally, select Shared Settings…to change the Shared V. ATP parameters or the Active Can setting.
7. Return to the Parameters screen and select [PROGRAM].

7.5.5 Details about VF therapy
The device provides several therapy options for treating tachyarrhythmia episodes detected in the VF zone. For the first VF therapy, you can program the device to attempt terminating the rhythm with ATP therapy before it delivers a defibrillation shock. You can choose to deliver this ATP therapy during charging or before charging for the first defibrillation therapy.

The device provides up to 6 defibrillation therapies to treat VF episodes. To deliver a defibrillation therapy, the device must first charge its high-voltage capacitors to the programmed energy. Once the capacitors are charged, the device attempts to deliver the defibrillation shock simultaneously with a sensed ventricular event.

For the first programmed defibrillation therapy, the device attempts to confirm the continued presence of the VF episode before delivering the shock. This allows the device to cancel the therapy if either of the following situations occur:
- The tachyarrhythmia has stopped spontaneously.
- ATP During Charging has terminated the tachyarrhythmia.

For subsequent defibrillation therapies, the device does not confirm the presence of VF. If these therapies cannot be synchronized to a sensed ventricular event, the device delivers them asynchronously.

7.5.5.1 Capacitor charging period
To deliver a defibrillation therapy, the device must first charge its high-voltage capacitors to the programmed energy. The length of time required to charge the capacitors depends on the programmed energy, battery capacity, and the time since the last capacitor formation. For typical full-energy capacitor charging periods, see Section 1.6, “Typical charge times”, page 19.

7.5.5.2 Energy
The delivered energy level is programmed independently for each defibrillation therapy. For a comparison of delivered and stored energy levels, see Section 1.7, “High-voltage therapy energy”, page 20.
7.5.5.3 Waveform

The device delivers defibrillation therapies using a biphasic waveform. In the first phase, current is delivered until the pulse decays by 50% of its original voltage. The device then truncates the phase and reverses the current pathway for the second phase. When the second phase of the pulse decays by 50% of its original voltage, the device truncates the pulse.

**Figure 31. Defibrillation pulse waveform**

1. The voltage of the first segment of the pulse decays by 50% of the original voltage.
2. The pulse is truncated, and the polarity is reversed.
3. The second segment of the pulse decays by 50%, and the pulse is truncated.

7.5.5.4 Pathway Polarity

Pathway Polarity specifies the implanted electrodes that deliver defibrillation pulses, and it defines the direction of current delivered by the electrodes. For example, a device implanted with 2 electrodes, CAN (HVA) and RV (HVB), can be programmed to deliver current from CAN to RV (AX>B) or from RV to CAN (B>AX).

If an optional electrode is used, you can disable the Active Can feature. If you do so, the device delivers defibrillation therapies between the RV (HVB) and SVC (HVX) electrodes only.
### Table 26. Modes and polarities for defibrillation

<table>
<thead>
<tr>
<th>Pathway Polarity Options</th>
<th>Two HV Electrodes:</th>
<th>Three HV Electrodes:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAN and RV&lt;sup&gt;a&lt;/sup&gt;</td>
<td>CAN, RV, and SVC</td>
</tr>
<tr>
<td></td>
<td>CAN to RV = AX&gt;B</td>
<td>CAN, SVC to RV = AX&gt;B</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>RV to CAN = B&gt;AX</td>
<td>RV to CAN, SVC = B&gt;AX</td>
</tr>
</tbody>
</table>

<sup>a</sup>The notation “CAN to RV” names the Active Can electrode as the anode and the RV lead as the cathode during the initial segment of the biphasic waveform.

### 7.5.5.5 Delivering ATP before the first defibrillation

You can program the device to attempt ATP therapy before delivering the first defibrillation therapy. This can prevent delivery of high-voltage shocks for rhythms that can be terminated by ATP (rapid monomorphic VT, for example).

If you set the ATP parameter to During Charging, the device delivers a single sequence of ATP therapy when it starts charging for the defibrillation therapy. If charging completes before the ATP therapy sequence completes, synchronization of the defibrillation therapy is delayed until the ATP therapy is finished.

If you set the ATP parameter to Before Charging, the device delivers 1 sequence of ATP therapy as soon as VF is detected. If VF is redetected, the device begins charging and delivers a second ATP sequence.

The device does not deliver ATP therapies before or during charging unless the last 8 V-V intervals are all greater than or equal to the programmed value for the “Deliver ATP if last 8 R-R >=” parameter.

**Note:** The device does not deliver ATP therapies during or before charging for episodes induced by T-Shock or ventricular 50 Hz Burst. This prevents the ATP therapies from interfering with DFT testing.

**Switchback feature** – The Switchback feature is available whenever ATP Before Charging is enabled. If ATP Before Charging fails to terminate the detected arrhythmia on 2 consecutive attempts, the Switchback feature automatically switches to ATP During Charging operation.

**ChargeSaver feature** – If you enable the ChargeSaver option, the device can automatically switch from ATP During Charging operation to ATP Before Charging operation. This change occurs when ATP has successfully terminated the detected arrhythmia on a programmable number of consecutive attempts.

**Note:** If any ATP parameter is reprogrammed, the device resets the count of consecutive ATP successes used by the ChargeSaver feature.
**Smart Mode** – If you enable the Smart Mode option, the device automatically sets the ATP parameter to Off if ATP therapies delivered before or during charging fail to terminate the tachyarrhythmia in 4 consecutive episodes. See Section 7.8, “Optimizing ventricular ATP therapy with Smart Mode”, page 191.

**Figure 32. ATP During Charging successfully terminates a fast ventricular episode**

1. The device detects a fast ventricular rate as a VF episode and starts charging the capacitors for a defibrillation therapy.
2. While charging, the device delivers 1 sequence of Burst ATP therapy, which terminates the tachyarrhythmia.
3. After charging completes, the device aborts the defibrillation therapy, because VF is not confirmed. See Section 7.5.5.6, “Confirming VF for the first defibrillation”, page 170.

**7.5.5.6 Confirming VF for the first defibrillation**

Before the device delivers the first defibrillation therapy for a VF episode, it monitors the cardiac rhythm to confirm that the VF remains present. If ATP During Charging is disabled, the device applies VF confirmation as soon as charging starts. If ATP During Charging is enabled, the device applies VF confirmation after charging ends.
The device confirms the continued presence of VF using a sequence of confirmation intervals, each lasting 60 ms plus the programmed VT Interval.\textsuperscript{11} It classifies any ventricular event that occurs during the confirmation interval as “arrhythmic” and any events after the interval as “normal.”

On each ventricular event, the device reviews the last 5 ventricular events. If 4 of the last 5 ventricular events were normal, the device cancels the therapy.

If ATP During Charging is enabled, the device reviews the ventricular events since charging ended. If ATP During Charging is disabled, the device reviews the ventricular events since charging started. In this case, if the therapy is canceled before charging is complete, the device terminates charging as well (see Figure 33).

\textbf{Figure 33.} Defibrillation therapy cancelled during charging when VF terminates spontaneously\textsuperscript{12}

\begin{itemize}
  \item [1] The device detects VF and begins confirmation using a confirmation interval of 460 ms (400 ms VT Interval + 60 ms).
  \item [2] The VF spontaneously terminates, and normal sinus rhythm resumes.
  \item [3] Once 4 of 5 events occur that are greater than the confirmation interval, the device cancels the therapy and stops charging.
\end{itemize}

After charging and ATP therapy during charging are complete, the device attempts to synchronize the defibrillation therapy to a qualified ventricular event while confirming the presence of VF. To qualify for delivery, an event must be nonrefractory (see Section 7.5.5.8, “Refractory events”, page 173).

\textsuperscript{11} Or VF Interval, if VT Detection is off.
\textsuperscript{12} ATP During Charging is disabled in this example.
In VR devices, an event qualifies for delivery if it is the second arrhythmic, nonrefractory ventricular event after charging. In AT and DR devices, an event qualifies for delivery if it is nonrefractory and meets one of the following conditions:

- It is the second arrhythmic ventricular event after charging and is outside an AVP interval (see Section 7.5.5.9, “AVP events”, page 174).
- It is the third arrhythmic ventricular event.

The device continues to attempt to synchronize until it delivers the defibrillation therapy (see Figure 34) or until it fails to confirm the presence of VF and cancels the therapy.

**Figure 34. VF confirmed and defibrillation synchronized to an arrhythmic event**

1. The device has detected VF, is charging its capacitors for defibrillation, and is confirming VF using a confirmation interval of 460 ms (400 ms VT Interval + 60 ms).
2. The device completes charging and starts synchronization while continuing VF confirmation.
3. On the second arrhythmic event after charging, the device delivers the defibrillation therapy.

### 7.5.5.7 Synchronizing subsequent defibrillation therapies

If the first defibrillation therapy fails to terminate a VF episode, the device attempts to synchronize each subsequent defibrillation therapy to a ventricular event. If synchronization is not possible, the device delivers the defibrillation therapy asynchronously.

Once the capacitors are charged to the programmed energy, the device starts the synchronization process with a 900 ms delivery timer. If a qualified ventricular sensed event occurs during this period, the device delivers the defibrillation therapy synchronized to the event. Otherwise, the device delivers the therapy asynchronously when the timer expires (see Figure 35).

---

13 ATP During Charging is disabled in this example.
In VR devices, any sensed ventricular event qualifies for therapy delivery unless it is a refractory event. If a refractory event occurs, the device ignores it and continues to attempt to synchronize.

In AT and DR devices, any sensed ventricular event qualifies for therapy delivery unless it is a refractory event or an AVP event. If a refractory event occurs, the device ignores it and continues to attempt to synchronize. If an AVP event occurs, the device resets the delivery timer to 500 ms and continues to attempt to synchronize.

**Figure 35.** Defibrillation delivered asynchronously

1. After redetecting VF, the device completes charging and starts a 900 ms synchronization interval.
2. Several low-amplitude VF events go unsensed.
3. After 900 ms, the device delivers the defibrillation therapy asynchronously.

### 7.5.5.8 Refractory events

During the synchronization process, the device classifies the following ventricular events as refractory:
- events occurring within 400 ms after charging starts
- events occurring within 400 ms after a ventricular or atrial paced event
- the first event after Charge End (if ATP During Charging is enabled)
7.5.5.9 AVP events
The device postpones a defibrillation that is scheduled to be delivered during an Atrial Vulnerable Period (AVP) until the next qualifying event. The AVP is a 250 ms interval, starting 150 ms after a sensed atrial event, during which a high-voltage pulse might induce an atrial tachyarrhythmia. AVP operation can postpone the therapy for only one event during synchronization.

Note: AVP operation applies only to AT and DR devices.

7.5.5.10 Bradycardia pacing during defibrillation
On the first ventricular event after charging, the device changes the pacing mode and sets the pacing interval as shown in Table 27.

Table 27. Pacing mode and interval used during defibrillation

<table>
<thead>
<tr>
<th>Programmed pacing mode</th>
<th>VF Therapy</th>
<th>Pacing mode</th>
<th>Pacing interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODO or OVO(^a)</td>
<td>Rx1–Rx6</td>
<td>OVO</td>
<td>—</td>
</tr>
<tr>
<td>AAIR&lt;=DDD, AAI&lt;=DDD, DDR, DDD, DDIR, DDI, VVIR, VVI, AAIR, AAI</td>
<td>Rx1</td>
<td>VVI</td>
<td>Pacing interval used before charging started</td>
</tr>
<tr>
<td>AAIR&lt;=DDD, AAI&lt;=DDD, DDR, DDD, DDIR, DDI, VVIR, VVI, AAIR, AAI</td>
<td>Rx2–Rx6</td>
<td>VVI</td>
<td>1200 ms (50 bpm)</td>
</tr>
</tbody>
</table>

\(^a\) ODO mode can be programmed in AT and DR devices only. OVO mode can be programmed in VR devices only.

7.5.5.11 After delivering the defibrillation therapy
After the defibrillation therapy is delivered, the device monitors for the end of the episode or redetection. The device suspends VT detection and combined count detection (see Section 6.8, “Detecting tachyarrhythmia episodes with combined count”, page 101) for 17 events following a defibrillation therapy that is delivered in response to a detected VF. Suspending VT detection helps avoid detecting transient VTs that can follow high-voltage therapies.\(^{14}\)

\(^{14}\) If the defibrillation therapy is delivered as a result of a High Rate Timeout therapy operation or Progressive Episode Therapies operation, VT detection is not suspended (see Section 6.15.4.1, “High Rate Timeout Therapy”, page 132).
Immediately after delivering the shock, the device starts a post-shock blanking period of 520 ms and a pacing cycle with characteristics defined as follows:

- If the programmed pacing mode is AAIR\ <=>\ DDDR, AAI\ <=>\ DDD, DDDR, DDD, DDIR, DDI, or DOO, the pacing cycle is in the DDI mode with a 1200 ms pacing interval and a 300 ms PAV.
- If the programmed pacing mode is ODO or OVO\textsuperscript{15}, the pacing cycle is in the OVO mode with a 2000 ms pacing interval.
- For any other programmed pacing modes, the pacing cycle is in the VVI mode with a 1200 ms pacing interval.

After the first ventricular event, the bradycardia pacing resumes as follows:

- The device switches to the programmed pacing mode.

  Note: If the programmed pacing mode is an MVP mode (AAIR\ <=>\ DDDR or AAI\ <=>\ DDD), the device operates in DDDR or DDD mode for 1 min after a cardioversion or defibrillation therapy. See Section 8.4.4, “Details about MVP”, page 222.

- The Post Shock Pacing parameters are applied. See Section 8.18, “Post Shock Pacing”, page 271.
- If Post VT/VF Shock Pacing is programmed On, the device paces at the programmed Overdrive Rate. See Section 8.17, “Post VT/VF Shock Pacing”, page 269.

7.5.5.12 After a cancelled defibrillation therapy

If the device cancels a defibrillation therapy, it reverts immediately to the programmed bradycardia pacing settings, not the Post Shock Pacing parameters.

The device resumes monitoring for arrhythmias after the next paced or sensed ventricular event. If the device detects the same arrhythmia again, it attempts to synchronize and deliver the same therapy. However, if the episode ends, the device resumes normal detection.

Note: If the device cancels the defibrillation therapy leaving energy stored on the capacitors, the delivered energy of the next high-voltage therapy may be higher than the programmed value.

\textsuperscript{15} ODO mode can be programmed in AT and DR devices only. OVO mode can be programmed in VR devices only.
7.6 Treating VT and FVT with antitachycardia pacing

The device can respond to a VT or FVT episode by delivering antitachycardia pacing (ATP) therapy to the patient’s heart. ATP therapies are designed to interrupt the reentrant activation pattern of a VT or FVT with pacing stimuli, restoring the patient’s normal sinus rhythm. Because ATP therapies use pacing-level stimulation instead of high-voltage shocks, they are much less painful for the patient than cardioversion therapy.

You can program the device to deliver a sequence of up to 6 VT therapies and 6 FVT therapies and you can program a portion of these as ATP therapies. You can select Burst, Ramp, or Ramp+ ATP therapy and can set the parameters for each enabled therapy separately.

7.6.1 Parameters for all ATP therapies

| VT (or FVT) Therapy Status – Enables or disables a VT therapy or FVT therapy. | On; Off
| Therapy Type – Cardioversion or ATP therapy to treat VT or FVT episodes (choose Burst, Ramp, or Ramp+ to enable ATP therapy). | CV; Burst; Ramp; Ramp+
| V-V Minimum ATP Interval – Minimum pacing interval for all ventricular ATP therapies. | 150; 160 … 200\(\) … 400 ms
| V. Amplitude – Voltage of the ventricular pacing pulses delivered during all ATP pacing therapies. | 1; 2 … 6; 8\(\) V
| V. Pulse Width – Duration of the ventricular pacing pulses delivered during all ATP therapies. | 0.1; 0.2 … 1.5\(\) ms
| V. Pace Blanking – Ventricular blanking period following the pacing pulses delivered during all ATP therapies. | 150; 160 … 240\(\) … 450 ms

7.6.2 Parameters for Burst therapy

| Initial # Pulses – Number of pulses in all Burst therapy sequences. | 1; 2 … 8\(\) … 15
| R-S1 Interval=(%RR) – Pacing interval of the first Burst therapy sequence as a percentage of the tachycardia cycle length. | 50; 53; 56; 59; 63; 66 … 84; 88\(\) … 91; 94; 97\%
| Interval Dec – Pacing interval decrement per sequence for the remaining Burst sequences. | 0; 10\(\) … 40 ms
| # Sequences – Number of sequences in the Burst therapy. | 1; 2 … 10
| VT Therapies: 3\(\) | FVT Therapies: 1\(\) |
7.6.3 Parameters for Ramp therapy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial # Pulses</td>
<td>Number of pulses in first Ramp sequence.</td>
<td>1; 2 ... 8; ... 15</td>
</tr>
<tr>
<td>R-S1 Interval=(%RR)</td>
<td>Pacing interval of the first Ramp pulse as a percentage of the tachycardia cycle length.</td>
<td>50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>Interval Dec</td>
<td>Pacing interval decrement per pulse during a Ramp sequence.</td>
<td>0; 10; ... 40 ms</td>
</tr>
<tr>
<td># Sequences</td>
<td>Number of sequences in the Ramp therapy.</td>
<td>1; 2 ... 10</td>
</tr>
</tbody>
</table>

7.6.4 Parameters for Ramp+ therapy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial # Pulses</td>
<td>Number of pulses in first Ramp+ sequence.</td>
<td>1; 2; 3; ... 15</td>
</tr>
<tr>
<td>R-S1 Interval=(%RR)</td>
<td>Pacing interval of the first Ramp+ pulse as a percentage of the tachycardia cycle length.</td>
<td>50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S1S2(Ramp+)=(%RR)</td>
<td>Pacing interval of the second Ramp+ pulse as a percentage of the tachycardia cycle length.</td>
<td>50; 53; 56; 59; 63; 66; 69; ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S2-SN(Ramp+)=(%RR)</td>
<td>Pacing interval of the remaining Ramp+ pulses as a percentage of the tachycardia cycle length.</td>
<td>50; 53; 56; 59; 63; 66; 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td># Sequences</td>
<td>Number of sequences in the Ramp+ therapy.</td>
<td>1; 2 ... 10</td>
</tr>
</tbody>
</table>

7.6.5 Considerations

Review the following information before programming ATP therapy parameters.

**VT and FVT therapies** – You should not use ATP therapies exclusively to treat VT or FVT episodes. At least 1 VT therapy and 1 FVT therapy should be programmed to a maximum energy cardioversion.

7.6.6 Restrictions

Review the following information before programming ATP therapy parameters.

**Cardioversion therapies for FVT** – You cannot program all FVT therapies as ATP therapies. If any FVT therapies are on, then at least 1 of them must be programmed to cardioversion (any energy).

**Therapy aggressiveness** – VT and FVT therapies must be programmed to be increasingly aggressive. For example, you cannot program 1 VT therapy to cardioversion and a subsequent VT therapy to an ATP therapy. Likewise, a VT cardioversion therapy cannot be followed by another VT cardioversion therapy with a lower energy setting.
VF therapies – VT and FVT therapies cannot be enabled unless at least one VF therapy is also enabled.

7.6.7 How to program ATP therapies

1. Select the Params icon.
2. Select the Therapies… parameter for VT or FVT.
3. For each ATP therapy, set Therapy Type to Burst, Ramp, or Ramp+, and select therapy parameter values.
4. Optionally, select Shared Settings...to change the Shared V. ATP parameters.
5. Return to the Parameters screen and select [PROGRAM].

7.6.8 Details about ATP therapies
The pulse width, amplitude, and pace blanking period for antitachycardia pacing pulses are the same for all ventricular ATP therapies but are programmed separately from the Bradycardia pacing pulse widths, amplitudes, and pace blanking periods.

7.6.8.1 ATP therapy pacing rate
The ATP pacing interval is rate adaptive to the average of the last 4 intervals prior to FVT and VT detection or redetection. However, ATP pulses are never delivered at less than the programmed V-V Minimum ATP Interval. If the calculated interval is shorter than the programmed minimum, the pulses are delivered at the programmed minimum interval.

If the intrinsic tachycardia interval is less than or equal to the V-V Minimum ATP Interval, it is impossible for the device to deliver an ATP therapy that is faster than the intrinsic rate. The device cancels the rest of the ATP therapy and skips to the next programmed cardioversion therapy. If no cardioversion therapy is programmed, no therapy is delivered.

If the intrinsic tachycardia interval is greater than the V-V Minimum ATP Interval, but all the intervals of an ATP therapy sequence are delivered at the minimum interval, the therapy is fully rate-limited. The device cancels the rest of the ATP therapy and skips to the next programmed therapy (or the next programmed cardioversion therapy, if FVT was detected).

7.6.8.2 Redetection of another tachyarrhythmia
After delivering each ATP therapy sequence, the device monitors for an outcome. If it detects a different arrhythmia, or if the ventricular cycle length shortens by at least 60 ms (VT episodes only), the remaining sequences of the pacing therapy are not delivered. Instead, the device delivers the next programmed therapy for the new arrhythmia.

7.6.8.3 Burst pacing therapy
The pacing interval for the first Burst sequence is a calculated percentage of the tachycardia cycle length. Each pulse in the sequence is delivered at the same interval. Each time the tachycardia is redetected after an unsuccessful sequence, the device applies the programmed Burst percentage to the new cycle length. It then subtracts the programmed interval decrement (once per sequence) to calculate the pacing interval for the next Burst sequence.
Note: The Burst pacing therapy is delivered in VOO pacing mode.

In Figure 36, 2 Burst therapy sequences are delivered. The second therapy sequence terminates the VT.

Figure 36. Device delivers 2 sequences of Burst pacing therapy

1. The device detects VT.
2. The first Burst sequence is delivered with a pacing interval of 290 ms but fails to terminate the VT.
3. The device redetects VT.
4. The second Burst sequence is delivered with a pacing interval of 280 ms (the interval decrement is set to 10 ms per sequence) and terminates the VT.

7.6.8.4 Ramp pacing therapy

The first pulse of each Ramp sequence is delivered at a calculated percentage of the current tachycardia cycle length. Each remaining pulse in that sequence is then delivered at progressively shorter intervals by subtracting, per pulse, the programmed interval decrement.
Each time the tachycardia is redetected after an unsuccessful sequence, the device applies the programmed Ramp percentage to the new cycle length to calculate the initial pacing interval for the next sequence. Each sequence adds 1 pacing pulse per sequence.

Sensed ventricular events are counted as individual pulses of the Ramp sequence, even though they are not output pulses. Whenever a sensed event inhibits the scheduled Ramp Pacing VVI pulse, the next pulse is scheduled at the calculated or minimum interval.

In Figure 37, 2 Ramp therapy sequences are delivered. The second therapy sequence terminates the VT.

**Figure 37.** Device delivers 2 sequences of Ramp pacing therapy

1. The device detects VT.
2. The first Ramp sequence is delivered with an initial pacing interval of 310 ms. The pacing interval decrements 10 ms per pulse. Eight pacing pulses are delivered, but the VT is not terminated.
3. The device redetects VT.
4. The second Ramp sequence is delivered with an initial pacing interval of 310 ms. The pacing interval decrements 10 ms per pulse. Nine pacing pulses are delivered, and the VT terminates.
7.6.8.5 Ramp+ pacing therapy

The first pulse of each Ramp+ sequence occurs at a programmed percentage of the tachycardia cycle length, timed from the sensed event that fulfills tachycardia detection. The second pulse interval is calculated using the S1S2 percentage. Any remaining pulses in the sequence are delivered at the S2SN percentage.

If the tachycardia is redetected, the device applies the programmed percentages to the new cycle length to calculate the pacing intervals for the next Ramp+ sequence. Each sequence adds 1 pacing pulse per sequence.

**Note:** The Ramp+ pacing therapy is delivered in VOO pacing mode.

In Figure 38, 2 Ramp+ therapy sequences are delivered. The second therapy sequence terminates the VT.

**Figure 38.** Device delivers 2 sequences of Ramp+ pacing therapy

1. The device detects VT.
2. The first Ramp+ sequence consists of 3 pacing pulses with intervals of 260, 230, and 220 ms. The VT is not terminated.
3 The device redetects VT.
4 The second Ramp+ therapy repeats the first 3 intervals and adds another pulse with a 220 ms interval, which terminates the VT.

### 7.7 Treating VT and FVT with ventricular cardioversion

The device can respond to a VT or FVT episode by delivering ventricular cardioversion therapy to the patient’s heart. Cardioversion, like defibrillation, is intended to terminate the episode by simultaneously depolarizing the heart tissue and restoring the patient’s normal sinus rhythm. However, cardioversion requires that the device synchronize the therapy to an arrhythmic ventricular event.

You can program the device to deliver a sequence of up to 6 VT therapies and 6 FVT therapies, and you can select cardioversion for some or all of these therapies. You can set the energy and pathway parameters individually for each cardioversion therapy.

### 7.7.1 Parameters

<table>
<thead>
<tr>
<th>VT (or FVT) Therapy Status –</th>
<th>Turns a specific VT or FVT therapy on or off.</th>
</tr>
</thead>
<tbody>
<tr>
<td>On; Off</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Therapy Type –</th>
<th>Cardioversion or ATP therapy to treat VT or FVT episodes (choose CV to enable cardioversion).</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV; Burst; Ramp; Ramp+</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy –</th>
<th>Amount of energy delivered to the heart by the therapy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4; 0.6 ... 1.8; 2; 3 ... 16;</td>
<td></td>
</tr>
<tr>
<td>18; 20; 22; 24; 25; 26; 28; 30;</td>
<td></td>
</tr>
<tr>
<td>32; 35 J</td>
<td></td>
</tr>
<tr>
<td>VT Rx1–Rx2: 20 J</td>
<td></td>
</tr>
<tr>
<td>VT Rx3–Rx6: 35 J</td>
<td></td>
</tr>
<tr>
<td>FVT Rx1–Rx6: 35 J</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pathway –</th>
<th>Direction the electrical current flows through the heart.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AX&gt;B; B&gt;AX</td>
<td></td>
</tr>
<tr>
<td>Rx1–Rx4: B&gt;AX</td>
<td></td>
</tr>
<tr>
<td>Rx5–Rx6: AX&gt;B</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Active Can –</th>
<th>Option to select the device case as an active electrode for delivering defibrillation and cardioversion therapies.</th>
</tr>
</thead>
<tbody>
<tr>
<td>On; Off</td>
<td></td>
</tr>
</tbody>
</table>

### 7.7.2 Considerations

Review the following information before programming cardioversion parameters.

**Caution:** If the Active Can feature is programmed Off, the device delivers defibrillation and cardioversion therapies between the RV (HVB) and SVC (HVX) electrodes only. To ensure the device can deliver defibrillation and cardioversion therapies, make sure a supplementary HVX electrode is implanted and connected to the device before turning the Active Can feature Off.
**Active Can** – The programmed setting for the Active Can feature applies to the following high-voltage operations:
- automatic, manual, and emergency ventricular cardioversion
- automatic, manual, and patient-activated atrial cardioversion
- automatic, manual, and emergency defibrillation
- T-Shock inductions

**Energy** – Programming the cardioversion therapy energy to an optimized value (lower than the maximum energy but high enough to terminate VT) can expedite delivery and help preserve battery longevity. However, at least one VT therapy and one FVT therapy should be programmed to a maximum energy cardioversion.

### 7.7.3 Restrictions

Review the following information before programming cardioversion parameters.

**Cardioversion therapies for FVT** – If FVT therapies are on, then at least one must be programmed to cardioversion (at any energy).

**Therapy aggressiveness** – VT and FVT therapies must be programmed to be increasingly aggressive. For example, you cannot program one VT therapy to cardioversion and a subsequent VT therapy to an ATP therapy. Likewise, a VT cardioversion therapy cannot be followed by another VT cardioversion therapy with a lower energy setting.

**VF therapies** – VT and FVT therapies cannot be enabled unless at least one VF therapy is also enabled.
7.7.4 How to program ventricular cardioversion therapies

1. Select the Params icon.
2. Select the Therapies… field for VT or FVT.
3. For each cardioversion therapy, set Therapy Type to CV and select Energy and Pathway values.
4. Optionally, select Shared Settings…to change the Active Can setting.
5. Return to the Parameters screen and select [PROGRAM].

7.7.5 Details about ventricular cardioversion therapy

When a VT or FVT episode is detected and the next programmed therapy is a cardioversion, the device begins charging its high-voltage capacitors and attempts to confirm the continued presence of the tachyarrhythmia. If the arrhythmia terminates, the device cancels the therapy.

If the arrhythmia is still present when the capacitors are charged to the programmed energy, the device delivers the cardioversion pulse synchronized to a sensed ventricular event. If synchronization is not possible, the device cancels the therapy.

7.7.5.1 Capacitor charging period

To deliver a cardioversion therapy, the device must first charge its high-voltage capacitors to the programmed energy. The length of time required to charge the capacitors depends on the programmed energy, battery depletion, and the length of time since the last capacitor formation. For typical full-energy capacitor charging periods, see Section 1.6, “Typical charge times”, page 19.

7.7.5.2 Energy

The delivered energy level is programmed independently for each cardioversion therapy. For a comparison of delivered and stored energy levels, see Section 1.7, “High-voltage therapy energy”, page 20.

7.7.5.3 Waveform

The device delivers cardioversion therapies using a biphasic waveform. In the first phase, current is delivered until the pulse decays by 50% of its original voltage. The device then truncates the phase and reverses the current pathway for the second phase. When the second phase of the pulse decays by 50% of its original voltage, the device truncates the pulse.
7.7.5.4 Confirming VT or FVT after detection

When the device begins charging its capacitors for a cardioversion therapy, it monitors the cardiac rhythm to ensure that the arrhythmia remains present before delivering the therapy.

The device confirms the continued presence of the tachyarrhythmia using a sequence of confirmation intervals, each lasting 60 ms plus the programmed VT Interval. It classifies any ventricular event that occurs within the confirmation interval as “arrhythmic” and any events after the interval as “normal.”

On each ventricular event during charging, the device reviews the last 5 events since charging started. If 4 of the last 5 ventricular events were normal, the device stops charging and cancels the therapy (see Figure 40).
Figure 40. Cardioversion therapy cancelled when VT terminates spontaneously

1 The device has detected VT, is charging its capacitors for cardioversion, and is confirming the arrhythmia using a confirmation interval of 460 ms (400 ms VT Interval + 60 ms).
2 The VT spontaneously terminates, and normal sinus rhythm resumes.
3 The charging period ends, and synchronization starts. At this point, the device stops the confirmation process and disregards the normal event ratio. Any normal event after charging will abort the cardioversion therapy.
4 The cardioversion therapy aborts when a normal event occurs during synchronization.

7.7.5.5 Synchronizing cardioversion after charging

Once charging ends, the device attempts to synchronize the cardioversion therapy to a qualified ventricular event but also continues to confirm the presence of the arrhythmia.

In VR devices, an event qualifies for delivery if it is nonrefractory and is the second arrhythmic ventricular event after charging.

In DR and AT devices, an event qualifies for delivery if it is nonrefractory and meets one of the following conditions:
- It is the second arrhythmic ventricular event after charging and is outside an AVP interval (see “AVP events”, page 189).
- It is the third arrhythmic ventricular event.

The device confirms the presence of the detected arrhythmia differently after charging than it does during charging. After charging, the device aborts the cardioversion therapy if one of the following events occur:
- a normal ventricular event
- 3 consecutive V-V intervals less than 200 ms
The device continues to attempt to synchronize until it delivers the cardioversion therapy or it fails to confirm the presence of the arrhythmia and cancels the therapy.

**Figure 41. VT confirmed and cardioversion synchronized to an arrhythmic event**

1. The device has detected VT, is charging its capacitors for cardioversion, and is confirming the arrhythmia using a confirmation interval of 460 ms (VT Interval + 60 ms).
2. The device completes charging while continuing confirmation.
3. An arrhythmic ventricular event occurs, and the device starts a 200 ms refractory period.
4. On the second arrhythmic event after charging, the device delivers the cardioversion therapy.

**Refractory events** – During the synchronization process, the device classifies events as refractory if they occur during any of the following refractory periods:

- 400 ms after charging starts
- 400 ms after a ventricular or atrial paced event
- 200 ms after a ventricular sensed event

**AVP events** – DR and AT devices postpone a defibrillation or cardioversion therapy that is scheduled to be delivered during an Atrial Vulnerable Period (AVP) until the next qualifying event. The AVP is a 250 ms interval that starts 150 ms after a sensed atrial event, during which a high-voltage pulse might induce an atrial tachyarrhythmia. AVP operation can postpone the therapy for only one event during synchronization.
7.7.5.6 Bradycardia pacing during cardioversion

On the first ventricular event after charging, the device changes the pacing mode and sets the pacing interval as shown in Table 28.

Table 28. Pacing mode and interval used during cardioversion

<table>
<thead>
<tr>
<th>Programmed pacing mode</th>
<th>Pacing Mode</th>
<th>Pacing interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODO, OVO</td>
<td>OVO</td>
<td>—</td>
</tr>
<tr>
<td>AAIR&lt;=&gt;DDDR, AAI&lt;=&gt;DDD, DDRR, DDD, DDIR, DDI, VVIR, VVI, AAIR, AAI</td>
<td>VVI</td>
<td>Pacing interval used before charging started</td>
</tr>
</tbody>
</table>

7.7.5.7 After a cardioversion therapy

After the cardioversion therapy is delivered, the device monitors for the end of the episode or redetection. Immediately after delivering the shock, the device starts a post-shock blanking period of 520 ms and a pacing cycle with characteristics defined as follows:

- If the programmed pacing mode is AAIR<=>DDDR, AAI<=>DDD, DDRR, DDD, DDIR, or DDI, the pacing cycle is in the DDI mode with a 1200 ms pacing interval and a 300 ms PAV.
- If the programmed pacing mode is ODO or OVO\(^\text{16}\), the pacing cycle is in the OVO mode with a 2000 ms pacing interval.
- For any other programmed pacing modes, the pacing cycle is in the VVI mode with a 1200 ms pacing interval.

After the first ventricular event, the bradycardia pacing resumes as follows:

- The device switches to the programmed pacing mode.

**Note:** If the programmed pacing mode is an MVP mode (AAIR<=>DDDR or AAI<=>DDD), the device operates in DDDR or DDD mode for 1 min after a cardioversion or defibrillation therapy. See Section 8.4.4, “Details about MVP”, page 222.

- The Post Shock Pacing parameters are applied. See Section 8.18, “Post Shock Pacing”, page 271.
- If Post VT/VF Shock Pacing is programmed On, the device paces at the programmed Overdrive Rate. See Section 8.17, “Post VT/VF Shock Pacing”, page 269.

7.7.5.8 After a cancelled cardioversion therapy

If the device cancels a cardioversion therapy, it reverts immediately to the programmed bradycardia pacing settings, not the Post Shock Pacing parameters.

\(^{16}\) ODO mode can be programmed in AT and DR devices only. OVO mode can be programmed in VR devices only.
The device resumes monitoring for arrhythmias after the next paced or sensed ventricular event. If the device detects the same arrhythmia again, it attempts to synchronize and deliver the same therapy. However, if the episode ends, the device resumes normal detection.

**Note:** If the device cancels the cardioversion therapy, leaving energy stored on the capacitors, the delivered energy of the next high-voltage therapy may be higher than the programmed value.

### 7.8 Optimizing ventricular ATP therapy with Smart Mode

Smart Mode disables a ventricular ATP therapy that has been unsuccessful in 4 consecutive episodes so that the device can treat subsequent episodes more quickly with therapies that have been effective. Therapies disabled by Smart Mode are displayed on the therapy parameters screens with the Off-SM indicator.

#### 7.8.1 Parameters

<table>
<thead>
<tr>
<th><strong>Smart Mode</strong></th>
<th>Disables a programmed ventricular ATP therapy if it has been unsuccessful in terminating tachyarrhythmias.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On; Off</td>
</tr>
</tbody>
</table>

**Note:** For ATP Before Charging and ATP During Charging, the nominal value for the Smart Mode is On.

#### 7.8.2 Considerations

Review the following information before programming Smart Mode.

**Smart Mode, ATP During Charging, and ATP Before Charging** – You can select Smart Mode for the ATP During Charging or ATP Before Charging therapy options. This allows the device to disable ATP for VF therapy Rx1 when ATP therapy has been unsuccessful in 4 consecutive episodes.

**Smart Mode and therapy selection** – If Smart Mode disables an ATP therapy, either select a different therapy or modify the current therapy settings to improve therapy effectiveness.

**Smart Mode unsuccessful therapy count** – The device resets its count of unsuccessful therapies if any parameter of any automatic ventricular therapy is reprogrammed, including ATP, VF, FVT, or VT therapies.

#### 7.8.3 Restrictions

Review the following information before programming Smart Mode.

**Smart Mode** – Smart mode is not available for the last 2 VT or FVT therapies.
7.8.4 How to program Smart Mode for VT and FVT therapies

1. Select the Params icon.
2. Select the Therapies… field for VT or FVT.
3. For each enabled ATP therapy, select a value for Smart Mode.
4. Return to the Parameters screen and select [PROGRAM].
7.8.5 How to program Smart Mode for ATP During Charging

1. Select the Params icon.
2. Select the Therapies… field for VF.
3. Select ATP…
4. Select a value for Smart Mode.
5. Return to the Parameters screen and select [PROGRAM].
7.8.6 Details about Smart Mode

When Smart Mode is On for an ATP therapy, the device monitors the success of that therapy. If there are 4 consecutive episodes in which all sequences of the ATP therapy are delivered but are unsuccessful, the device disables that ATP therapy. For an example of Smart Mode operation, see Table 29.

Table 29. Smart Mode operation example

<table>
<thead>
<tr>
<th>Episode</th>
<th>Therapy sequence</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. VT</td>
<td>VT Rx1 to VT Rx2</td>
<td>VT Rx1 unsuccessful.</td>
</tr>
<tr>
<td>2. VT to VF</td>
<td>VT Rx1 to VF Rx1</td>
<td>VT Rx1 unsuccessful in second consecutive episode.</td>
</tr>
<tr>
<td>3. VT</td>
<td>VT Rx1 to VT Rx2</td>
<td>VT Rx1 unsuccessful in third consecutive episode.</td>
</tr>
<tr>
<td>4. VT</td>
<td>VT Rx1 to VT Rx2</td>
<td>VT Rx1 unsuccessful in fourth consecutive episode: Smart Mode disables VT Rx1.</td>
</tr>
<tr>
<td>5. VT</td>
<td>VT Rx2</td>
<td>Device delivers VT Rx2 (skipping the disabled VT Rx1).</td>
</tr>
</tbody>
</table>

An ATP therapy disabled by Smart Mode is designated by “Off-SM” in the counter data and parameter screens and reports. You can reenable a therapy disabled by Smart Mode by setting the Therapy Status parameter for that therapy to On.

Smart Mode is a programmable option for any automatic ventricular ATP therapy, including VT therapies, FVT therapies, and VF Rx1 with ATP During Charging or ATP Before Charging enabled.

Note: The device resets the count of unsuccessful therapy attempts for an ATP therapy if any of the following situations occur:

- The ATP therapy successfully treats an arrhythmia.
- Any parameter of any automatic ventricular therapy is reprogrammed (including ATP, VF, FVT, or VT therapies).
- A VT, FVT, or VF episode occurs during which the therapy is not delivered.

7.9 Optimizing therapy with Progressive Episode Therapies

Progressive Episode Therapies skips therapies or modifies high-voltage energy levels to ensure that each therapy that is delivered during a ventricular tachyarrhythmia episode is at least as aggressive as the previous therapy.

7.9.1 Parameters

Progressive Episode Therapies – Ensures each ventricular therapy delivered during an episode is at least as aggressive as the previous therapy.

On; Off

7.9.2 Considerations

Review the following information before programming Progressive Episode Therapies.

Progressive Episode Therapies – If Progressive Episode Therapies is On, the device may skip programmed ATP therapies and deliver cardioversion, or it may deliver a high-voltage therapy at a higher energy level than is programmed. This ensures that each therapy delivered during an ongoing episode is at least as aggressive as the previous therapy.
7.9.3 How to program Progressive Episode Therapies

1. Select the Params icon.
2. Select the Therapies… field for VF, FVT, or VT.
3. Select Shared Settings….
4. Select a value for Progressive Episode Therapies.
5. Return to the Parameters screen and select [PROGRAM].
7.9.4 Details about Progressive Episode Therapies

Progressive Episode Therapies ensures that, if a ventricular therapy is unsuccessful, all subsequent ventricular therapies in an ongoing episode are at least as aggressive as preceding therapies. Therapies are ranked by aggressiveness as follows:

- Defibrillation therapies are considered more aggressive than cardioversion therapies and are ranked by energy level.
- Cardioversion therapies are considered more aggressive than ATP therapies and are ranked by energy level.
- ATP therapies are considered least aggressive and are ranked equally in aggressiveness.

When a therapy is delivered, Progressive Episode Therapies makes ventricular therapies in the slower detection zones unavailable for the remainder of the episode. For example, if a VF defibrillation therapy is delivered, only VF therapies are available for the remainder of the episode.

If a defibrillation or cardioversion therapy is delivered, Progressive Episode Therapies makes any ATP therapies unavailable for the remainder of the episode. For example, if a VT cardioversion therapy is delivered, and the FVT therapies contain an ATP therapy, that ATP therapy is skipped if the arrhythmia is redetected as FVT.

If a defibrillation or cardioversion therapy is unsuccessful and the next scheduled therapy is a lower energy therapy, Progressive Episode Therapies does not skip that therapy. Instead, it resets the energy value for the next therapy to that of the last delivered therapy.

Notes:

- Progressive Episode Therapies operation does not cause the device to skip ATP During Charging (see Section 7.5.5.5, “Delivering ATP before the first defibrillation”, page 169).
- If ATP Before Charging is enabled, Progressive Episode Therapies operation causes the device to skip the ATP sequence before charging. The subsequent ATP sequence during charging is delivered.
- After the device delivers a defibrillation therapy, it normally suspends VT detection for the next 17 events. However, if the device delivers a defibrillation therapy because of Progressive Episode Therapies operation, the device does not suspend VT detection.
8 Treating bradycardia

8.1 Providing basic pacing therapy

The device provides pacing therapies to support pacemaker-dependent patients, to correct certain arrhythmias, and to ease the heart back into an intrinsic rhythm after high-voltage therapy.

Basic pacing is programmed by selecting a pacing mode and pacing rates. Additional parameters are also used to control and enhance pacing based on the pacing mode selected.

8.1.1 Parameters

8.1.1.1 Parameters for the DR and AT devices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>AAIR&lt;&gt;DDDR; AAI&lt;&gt;DDD; DDDR; DDD; DDIR; DDI; ODO; DOO; AAIR; AAI; AOO; VVIR; VVI; VOO</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 … 60; 70; 75 … 150 bpm</td>
</tr>
<tr>
<td>Atrial Amplitude</td>
<td>0.5; 1 … 3; 3.5; 4; 5; 6 V</td>
</tr>
<tr>
<td>Atrial Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4 … 1.5 ms</td>
</tr>
<tr>
<td>RV Amplitude</td>
<td>0.5; 1 … 3; 3.5; 4; 5; 6 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4 … 1.5 ms</td>
</tr>
<tr>
<td>Atrial Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2; 1.5; 2.1 mV</td>
</tr>
<tr>
<td>RV Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
</tr>
<tr>
<td>A. Blank Post AP</td>
<td>150; 160 … 200 … 250 ms</td>
</tr>
<tr>
<td>A. Blank Post AS</td>
<td>100; 110 … 170 ms</td>
</tr>
</tbody>
</table>
8.1.1.2 Parameters for the VR devices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode</strong></td>
<td>VVIR, VVI, OVO, VOO</td>
</tr>
<tr>
<td><strong>Lower Rate</strong></td>
<td>30; 35; 40; ... 60; 70; 75; ... 150 bpm</td>
</tr>
<tr>
<td><strong>RV Amplitude</strong></td>
<td>0.5; 1; 3; 3.5; 4; 5; 6; 8 V</td>
</tr>
<tr>
<td><strong>RV Pulse Width</strong></td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4; ... 1.5 ms</td>
</tr>
<tr>
<td><strong>RV Sensitivity</strong></td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
</tr>
<tr>
<td><strong>V. Blank Post VP</strong></td>
<td>150; 160; 200; ... 450 ms</td>
</tr>
<tr>
<td><strong>V. Blank Post VS</strong></td>
<td>120; 130; ... 170 ms</td>
</tr>
</tbody>
</table>

8.1.2 Considerations

Review the following information before programming basic bradycardia parameters.

**Sensitivity** – Programming the atrial and ventricular sensitivities to 0.3 mV is recommended to ensure adequate tachyarrhythmia detection. The programmed sensitivity values apply to both tachyarrhythmia detection and bradycardia pacing. For more information, see Section 6.2, “Setting up sensing”, page 70.

**Pulse Width and Amplitude** – These parameters are independently programmable for atrial and ventricular pacing and for post-shock pacing. Consider the following information when programming pulse width and amplitude parameters:

- Pacing pulses must be delivered at an adequate safety margin above the stimulation thresholds.
- The pulse width and amplitude settings affect the longevity of the device, particularly if the patient requires bradycardia pacing therapy most of the time.
Pulse width and amplitude settings can affect cross-chamber sensing. If you set the pulse width and amplitude values too high, pacing in one chamber may be sensed in the other chamber, which could cause inappropriate inhibition of pacing.

A separately programmable set of pacing parameters is used after delivery of a high-voltage therapy. See Section 8.18, “Post Shock Pacing”, page 271.

Pacing Mode – Determine the appropriate pacing mode based on the patient’s current cardiac condition (see Table 30).

Table 30. Determining the appropriate pacing mode

<table>
<thead>
<tr>
<th>Reliable pacing and sensing in atrium?</th>
<th>Adequate AV conduction?</th>
<th>Adequate SA node function?</th>
<th>Suggested mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO&lt;sup&gt;a&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>VVIR; VVI</td>
</tr>
<tr>
<td>YES</td>
<td>NO&lt;sup&gt;b&lt;/sup&gt;</td>
<td>NO</td>
<td>AAIR&lt;&gt;DDDR; DDDR</td>
</tr>
<tr>
<td>YES</td>
<td>NO&lt;sup&gt;b&lt;/sup&gt;</td>
<td>YES</td>
<td>AAIR&lt;&gt;DDDR; DDDR; AAI&lt;&gt;DDD; DDDR; DDD</td>
</tr>
<tr>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>AAIR&lt;&gt;DDDR; DDDR; DDIR</td>
</tr>
<tr>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>AAIR&lt;&gt;DDDR; DDDR; AAI&lt;&gt;DDD; DDDR; DDD; DDIR; DDI</td>
</tr>
</tbody>
</table>

<sup>a</sup> Example: persistent atrial fibrillation or unexcitable atrium.

<sup>b</sup> Example: transient or complete AV block.

8.1.3 Restrictions

Review the following information before programming basic bradycardia parameters.

Bradycardia pacing and tachyarrhythmia detection – To ensure reliable detection of atrial and ventricular tachyarrhythmias, the programmer software regulates the programmable values that are available for bradycardia pacing and tachyarrhythmia detection.
8.1.4 How to program bradycardia pacing parameters

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select the pacing Mode.
4. Set the desired atrial and ventricular Amplitude, Pulse Width, and Sensitivity, if available for the selected mode.
5. To set the Blanking parameters, select Blanking ….
6. Return to the Parameters screen, and select [PROGRAM].

Refer to the remaining sections in this chapter for more information on programming individual pacing features.

### 8.2 Dual chamber pacing

Dual chamber pacing modes rely on the basic pacing parameters and several additional atrial parameters.

#### 8.2.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper Tracking Rate</strong></td>
<td>Maximum ventricular pacing rate in response to sensed atrial events.</td>
<td>80; 85 … 130 … 150 bpm</td>
</tr>
<tr>
<td><strong>Paced AV</strong></td>
<td>Time interval between a paced atrial event and the following paced ventricular event.</td>
<td>30; 40 … 180 … 350 ms</td>
</tr>
<tr>
<td><strong>Sensed AV</strong></td>
<td>Time interval between a sensed atrial event and the following paced ventricular event.</td>
<td>30; 40 … 150 … 350 ms</td>
</tr>
<tr>
<td><strong>Post Ventricular Atrial Refractory Period</strong></td>
<td>Time interval after a ventricular event during which atrial events are classified as refractory, are not tracked, and do not inhibit atrial pacing.</td>
<td>Varied; 150; 160 … 310 … 500 ms</td>
</tr>
<tr>
<td><strong>Post-Ventricular Atrial Blanking (PVAB)</strong></td>
<td>Time interval after a ventricular event during which atrial events are either ignored by pacing operations or are not sensed (depending on the selected PVAB Method).&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10; 20 … 150 … 300 ms</td>
</tr>
<tr>
<td><strong>PVAB Method</strong></td>
<td>Option that defines how the device responds to atrial events that occur during the PVAB interval. Depending on the selected method, such events are either sensed by the device and ignored by pacing operations, or they are not sensed at all.</td>
<td>Partial; Partial+; Absolute</td>
</tr>
</tbody>
</table>

<sup>a</sup>For information about PVAB operation with single chamber pacing, refer to Section 8.3.5.7, “Post Ventricular Atrial Blanking interval (single chamber)”, page 220.

#### 8.2.2 Considerations

Review the following information before programming dual chamber pacing parameters.

**Paced AV and Sensed AV** – The Sensed AV should usually be programmed to a shorter duration than the Paced AV (typically 30 to 50 ms shorter). In patients with normal AV nodal conduction, AV intervals should be programmed to promote intrinsic AV conduction and ventricular depolarization.
**Upper Tracking Rate** – The Upper Tracking Rate should be programmed to a value less than the 2:1 block rate. See Section 8.2.7, “Programming considerations for atrial rates”, page 211.

**Upper rates and refractory periods** – A combination of high Upper Sensor Rate, high Upper Tracking Rate, and a long refractory period may result in competitive atrial pacing. See Section 8.9, “Non-Competitive Atrial Pacing”, page 242.

### 8.2.3 Restrictions

Review the following information before programming dual chamber pacing parameters.

**Absolute PVAB** – PVAB Method cannot be set to Absolute when the programmed pacing mode is ODO, AAI, AAIR, AAIR<=>DDDR, or AAI<=>DDD.

**Varied setting for PVARP** – PVARP cannot be set to Varied when the programmed pacing mode is DDD or AAI<=>DDD.
8.2.4 How to program dual-chamber pacing parameters

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Set the desired Upper Tracking Rate.
4. Set the AV interval settings (fixed or adaptive) available for the selected mode.
5. Set the PVARP setting, if available for the selected mode.
6. To set the PVAB parameters, select Blanking ....
7. Return to the Parameters screen and select [PROGRAM].

8.2.5 Details about dual chamber pacing modes

8.2.5.1 AAIR<=>DDDR and AAI<=>DDD modes
For information about the AAIR<=>DDDR and AAI<=>DDD modes, see Section 8.4, “MVP (Managed Ventricular Pacing)”, page 220.

8.2.5.2 DDDR and DDD modes
DDDR and DDD are atrial tracking pacing modes. Atrial tracking means that when the device senses an intrinsic atrial event, it schedules a ventricular pace in response. The delay between the sensed atrial event and the corresponding ventricular pace is the programmed Sensed AV interval.

If the current pacing interval ends before the device senses an atrial event, the device paces the atrium and then schedules a ventricular pace after the Paced AV interval.

If a ventricular sensed event occurs during the Sensed AV interval or the Paced AV interval, ventricular pacing is inhibited.

Note: A sensed atrial event that occurs during the Post Ventricular Atrial Refractory Period (PVARP) is classified as refractory, does not inhibit atrial pacing, and is not tracked (see Figure 42).
**Figure 42. Example of dual chamber pacing: DDDR mode**

1 Atrial paced event starts a Paced AV interval.
2 Atrial sensed event starts a Sensed AV interval.
3 Atrial event that is sensed during PVARP is not tracked.

---

**8.2.5.3 DDIR and DDI modes**

In the DDIR and DDI modes, sensed atrial events are not tracked. When an atrial event is sensed, atrial pacing is inhibited, but a Sensed AV interval is not started. Instead, ventricular pacing is delivered at the current pacing rate (for example, at the Lower Rate or sensor-indicated rate).
If the current pacing interval ends before the device senses an atrial event, the device paces the atrium and then schedules a ventricular pace after the Paced AV interval. If a ventricular sensed event occurs during the Paced AV interval, ventricular pacing is inhibited.

**Note:** A sensed atrial event that occurs during the Post Ventricular Atrial Refractory Period (PVARP) is classified as refractory and does not inhibit atrial pacing (see Figure 43).

**Figure 43.** Example of dual chamber pacing: DDIR mode

1. Atrial paced event starts a Paced AV interval.
2. Atrial sensed event inhibits the scheduled atrial pace but does not start a Sensed AV interval (is not tracked).
3. Atrial event that is sensed during PVARP does not inhibit the scheduled atrial pace.
8.2.5.4 ODO mode (bradycardia pacing off)

When pacing is set to ODO mode, the device will not deliver ventricular or atrial pacing outputs, regardless of the intrinsic rate. ODO mode is intended only for those situations where the physician wishes to turn off bradycardia pacing outputs from the device.

**Caution:** Use ODO mode only in clinical situations where bradycardia pacing is not necessary for, or is detrimental to, the patient.

**Note:** Dual-chamber sensing, atrial detection, ventricular detection, ATP therapy, defibrillation, and cardioversion operate as programmed when pacing is programmed to ODO mode. VVI and VOO backup pacing is available only during automatic and manual atrial therapies.

8.2.5.5 DOO mode

The DOO mode provides AV sequential pacing at the programmed lower rate with no inhibition by intrinsic events.

**Warning:** In DOO mode, no sensing or detection is provided in either chamber.

In order to program the device to DOO mode, all ventricular detection must be programmed Off and AT/AF detection must be programmed to Monitor.

8.2.6 Details about dual chamber pacing intervals

8.2.6.1 Paced AV interval

The programmable Paced AV interval is the time between a paced atrial event and the following paced ventricular event. The ventricle is paced at the end of the Paced AV interval unless a ventricular event is sensed.

**Note:** The Paced AV interval is programmable only for dual chamber pacing modes.

The programmed duration for the Paced AV interval may change, depending on how the following parameters are programmed:

- Rate Adaptive AV changes the Paced AV interval as the overall pacing rate changes.
- Non-Competitive Atrial Pacing may shorten the Paced AV interval while maintaining a stable ventricular rate.
- Ventricular Safety Pacing may shorten the Paced AV interval.

To ensure reliable ventricular tachyarrhythmia detection, the device may adjust the Paced AV interval and pacing rate in the presence of fast ventricular sensed events.
When 3 ventricular events occur within the ventricular detection zone, the device maintains an interval between a ventricular sense and an atrial pace that is greater than the ventricular detection interval. The device does this by first adjusting the Paced AV interval. If needed, the device decreases the pacing rate.

8.2.6.2 Sensed AV interval

The Sensed AV interval is the time between a sensed atrial event and the following paced ventricular event. The ventricle is paced at the end of the Sensed AV interval unless a ventricular event is sensed.

Note: The Sensed AV interval is applicable only when the device is operating in DDDR or DDD mode.

The programmed duration for the Sensed AV interval may change depending on either of the following conditions:

- Wenckebach operation, which extends the Sensed AV interval while tracking a fast intrinsic atrial rate.
- Rate Adaptive AV, which changes the Sensed AV interval as the overall atrial rate changes.

8.2.6.3 Post Ventricular Atrial Refractory Period

The Post Ventricular Atrial Refractory Period (PVARP) follows a paced, sensed, or refractory sensed ventricular event. An atrial event that is sensed during this interval is classified as refractory; it does not inhibit a scheduled atrial pace or start a Sensed AV interval. The PVARP setting is programmable only for dual chamber pacing modes (except DOO mode).

- When the device is operating in the DDDR or DDD mode, the PVARP setting prevents the tracking of retrograde P-waves that could initiate a pacemaker-mediated tachycardia.
- When the device is operating in the DDIR or DDI mode, the PVARP setting prevents the inhibition of atrial pacing based on sensed retrograde P-waves. PVARP should be programmed to a value longer than the VA interval (retrograde) conduction time.

PVARP and PR Logic – The PVARP setting does not affect the PR Logic criteria.

Extension of the PVARP setting – The PVARP setting may be extended by the PVC Response feature or the PMT Intervention feature.

Using the Varied setting – If the PVARP parameter is set to Varied, the duration of the PVARP is based on the current pacing rate. As the pacing rate increases, the PVARP
becomes shorter. The Varied setting provides different uses, depending on the programmed pacing mode:

- When the device is operating in the DDDR mode, the varied PVARP is based on the sensor-indicated rate. The Varied setting has these results:
  - It enhances protection against PMT at lower rates by providing longer PVARPs at low sensor-indicated rates.
  - It tracks higher atrial rates (providing a higher 2:1 block rate) by shortening the PVARP at high sensor-indicated rates.
- When the device is operating in the DDIR or DDI mode, the varied PVARP is based on the current rate. The Varied setting has these results:
  - It improves AV synchrony by preventing inhibition of atrial pacing by an atrial sense early in the VA interval.
  - It reduces the likelihood of competitive atrial pacing at high sensor-indicated rates.

In DDDR, DDIR, or DDI mode, the varied PVARP has these limits:

- The minimum limit (at high rates) is equal to the longest of these intervals: 150 ms or the programmed PVAB value.
- The maximum limit (at low rates) is equal to 400 ms.
- Within the minimum and maximum boundaries, the PVARP is automatically adjusted to maintain 300 ms between the end of PVARP and the next scheduled atrial pace.

8.2.6.4 Post Ventricular Atrial Blanking interval (dual chamber)

PVAB is a programmable interval during which atrial events are ignored by bradycardia pacing operations (and, if the Method is Absolute, by arrhythmia detection).

In dual chamber pacing modes (AAIR<=>DDDR, AAI<=>DDD, DDR, DDD, DDIR, and DDI), the PVAB interval must be less than or equal to the PVARP interval, and PVARP operation also applies to the PVAB interval.

**Interactions with other features** – Atrial events falling within the PVAB do not affect Rate Adaptive AV, NCAP, PMT Intervention, PVC Response, or Atrial Rate Stabilization.

Based on how the PVAB Method parameter is set, PVAB has 3 modes of operation: Partial, Partial+, and Absolute PVAB.

Refer also to Section 8.3.5.7, “Post Ventricular Atrial Blanking interval (single chamber)”, page 220.

**Partial PVAB** – Partial PVAB causes sensed atrial events that fall within the programmable PVAB interval to be ignored by bradycardia pacing features. These features include Rate Adaptive AV, NCAP, PMT Intervention, PVC Response, and Atrial Rate Stabilization.
Atrial events sensed during Partial PVAB are used by PR Logic Criteria, and they are used for AT/AF detection and monitoring criteria. AT/AF detection may declare an atrial event sensed within PVAB to be a far-field R-wave as described in Section 6.2.4.3, “Post-ventricular atrial blanking and far-field R-waves”, page 75.

**Partial+ PVAB** – Partial+ PVAB is a programmable interval during which the auto-adjusting atrial sensitivity threshold is increased to provide amplitude-based discrimination of far-field R-waves from intrinsic atrial events.

Like Partial PVAB, Partial+ PVAB causes the sensed atrial events falling within the programmable PVAB interval to be ignored by bradycardia pacing features. These features include Rate Adaptive AV, NCAP, PMT Intervention, PVC Response, and Atrial Rate Stabilization.

In single chamber modes, Partial+ PVAB does not affect bradycardia pacing timing. See Section 8.3.5.7, “Post Ventricular Atrial Blanking interval (single chamber)”, page 220.

Atrial events sensed during Partial+ PVAB are used by PR Logic Criteria, and they are used for AT/AF detection and monitoring criteria. AT/AF detection may declare an atrial event sensed within PVAB to be a far-field R-wave as described in Section 6.2.4.3, “Post-ventricular atrial blanking and far-field R-waves”, page 75.

Partial+ PVAB also causes a brief increase in atrial sensitivity after atrial sensed events.

**Absolute PVAB** – Absolute PVAB is a programmable interval during which atrial events are blanked for both bradycardia therapy and arrhythmia detection.

Atrial events that occur during an Absolute PVAB interval are not used by PR Logic criteria or by atrial arrhythmia detection and monitoring.

**Warning**: Programming Absolute as the PVAB Method means that no atrial sensing occurs during the blanking interval. Absolute blanking may reduce the ability to sense AT/AF, and reduce the ability to discriminate between VT and SVT. Use Partial or Partial+ methods unless you are sure that Absolute blanking is appropriate.

### 8.2.7 Programming considerations for atrial rates

When the device is operating in the DDDR or DDD modes, the fastest atrial rate that the device can track is determined by the sum of the Sensed AV interval and the Post Ventricular Atrial Refractory Period. This is referred to as the Total Atrial Refractory Period (TARP).

Device behavior at high atrial rates in these modes is determined by the relationship between the TARP and the Upper Tracking Rate interval or Upper Sensor Rate interval.

**Note**: The Upper Sensor Rate also applies to DDD mode if Mode Switch is enabled.
**2:1 block rate** – If the intrinsic atrial interval is shorter than the TARP, some atrial events occur during the PVARP. These refractory events are not tracked and do not start a Sensed AV interval. At the rate where this change first occurs, ventricular tracking occurs only on alternate beats, resulting in 2:1 block (see Figure 44).

Because only half of the atrial events are tracked, the ventricular rate drops significantly during 2:1 block.

The 2:1 block rate is determined by the following equation: \( \text{2:1 block rate} = \frac{60000}{\text{TARP}} \).

**Figure 44.** Atrial rate higher than the 2:1 block rate

![Diagram](image)

1 One of every 2 atrial events occurs during PVARP and is not tracked.

You can cause 2:1 block to occur at a higher rate by programming PVARP to Varied, which shortens PVARP, or by enabling Rate Adaptive AV. Both of these features shorten the TARP and raise the 2:1 block rate.

When Rate Adaptive AV is enabled, the Sensed AV interval shortens at high atrial rates, shortening the TARP and raising the 2:1 block rate.

A precipitous rate drop at the 2:1 block point can be prevented by rate-responsive pacing in the DDDR mode and also by Ventricular Rate Stabilization.

**Note:** When the 2:1 block rate is less than the Upper Tracking Rate, the Upper Tracking Rate cannot be achieved. In the DDDR mode, atrial competition may occur if the Upper Sensor Rate exceeds the 2:1 block rate.

**Wenckebach operation** – If the 2:1 block rate is higher than the programmed Upper Tracking Rate, Wenckebach operation may occur. When the intrinsic atrial rate exceeds the Upper Tracking Rate, the device cannot pace the ventricle after the SAV interval because this would cause the pacing rate to be faster than the Upper Tracking Rate.
In order to maintain the Upper Tracking Rate, the Sensed AV interval is extended until the Upper Tracking Rate interval expires. Subsequent Sensed AV intervals require greater extension until an atrial event falls within the PVARP and is not tracked, as shown in Figure 45.

In the DDDR or DDD mode, the normal result is a ratio between atrial and ventricular events (3:2, 4:3, and so forth).

**Figure 45. Atrial events in PVARP are not tracked during Wenckebach**

1. Sensed AV intervals extend so that ventricular paces do not violate the Upper Tracking Rate.
2. An atrial event occurs during PVARP and is not tracked.
3. The Lower Rate interval expires, and the device paces the atrium.
The Wenckebach rate can be smoothed by sensor-driven ventricular pacing in the DDDR mode and also by Ventricular Rate Stabilization.

### 8.3 Single chamber pacing

For DR and AT devices, single chamber pacing modes are used to pace either the atrium or the ventricle. These modes rely on the basic pacing parameters defined in Section 8.1.1.

For VR devices, single chamber pacing modes are used to pace the ventricle. For VR devices, these modes rely on the basic pacing parameters defined in Section 8.1.1.2.

See Section 8.3.5, “Details about single chamber pacing”, page 217 and Section 8.7, “Rate Hysteresis”, page 236.

#### 8.3.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Refractory</strong> – Atrial refractory period</td>
<td>150; 160 … 310 ms</td>
</tr>
<tr>
<td>that prevents atrial inhibition due to sensed far-field R-waves or noise. This parameter applies to AAIR and AAI modes only.</td>
<td></td>
</tr>
<tr>
<td><strong>Post-Ventricular Atrial Blanking (PVAB)</strong> – Time</td>
<td>10; 20 … 300 ms</td>
</tr>
<tr>
<td>interval after a ventricular event during which atrial events are either ignored by pacing operations or are not sensed (depending on the selected PVAB Method).</td>
<td></td>
</tr>
<tr>
<td><strong>PVAB Method</strong> – Option that defines how the device responds to atrial events that occur during the PVAB interval. Depending on the selected method, such events are either sensed by the device and ignored by pacing operations, or they are not sensed at all.</td>
<td>Partial; Partial+; Absolute</td>
</tr>
</tbody>
</table>

#### 8.3.2 Considerations

Review the following information before programming single chamber pacing parameters.

**Warning:** Do not use the AAIR or AAI mode in patients with impaired AV nodal conduction because paced atrial events may not trigger intrinsic ventricular events.

**Atrial parameters** – Some atrial parameters are used even when using ventricular pacing modes. For example, atrial sensitivity is used even when the pacing mode is VVI because atrial sensed events are used to detect tachyarrhythmias.
Ventricular parameters – Some ventricular parameters are used even when using atrial pacing modes. For example, ventricular sensitivity is used even when the pacing mode is AAIR or AAI because ventricular sensed events are used to detect tachyarrhythmias.

VR devices – Atrial Refractory Period and Post-Ventricular Atrial Blanking are not available in VR devices.

Single chamber atrial pacing and tachycardia detection – In the AAIR and AAI modes, atrial timing is not based on ventricular events. Thus, if there is a loss of AV synchrony, there are several ways that atrial pacing pulses can affect detection accuracy:

- Atrial pacing pulses can cause crosstalk.
- Atrial pacing pulses can mask arrhythmic ventricular events with cross-chamber blanking.

Note: If cross-chamber blanking affects the detection of ventricular events, then the Stability criterion is also affected. For information, see Section 6.13, “Enhancing VT detection with the Stability criterion”, page 126.

8.3.3 Restrictions

Review the following information before programming devices in single chamber modes.

Absolute PVAB – PVAB Method cannot be set to Absolute when the programmed pacing mode is ODO, AAI, AAIR, AAIR<->DDDR, or AAI<->DDD.
8.3.4 How to program single chamber pacing parameters

1. Select the Params icon.
2. Select Pacing... from the Parameters screen.
3. Set A. Refractory to the desired value.
4. To set the PVAB parameters, select Blanking ....
5. Return to the Parameters screen and select [PROGRAM].
8.3.5 Details about single chamber pacing

8.3.5.1 AAIR<=>DDDR and AAI<=>DDD modes
For information about the AAIR<=>DDDR and AAI<=>DDD modes, see Section 8.4, “MVP (Managed Ventricular Pacing)”, page 220.

8.3.5.2 AAI and AAIR modes
In the AAI or AAIR mode, the atrium is paced if no intrinsic events are sensed. Pacing occurs at the programmed Lower Rate in the AAI mode and at the sensor-indicated rate in the AAIR mode (see Figure 46).

Note: During single chamber atrial pacing modes, the device continues sensing ventricular events for tachyarrhythmia detection purposes.
8.3.5.3 VVIR and VVI modes

In the VVIR and VVI modes, the ventricle is paced if no intrinsic events are sensed. Pacing occurs at the programmed Lower Rate in the VVI mode and at the sensor-indicated rate in VVIR mode (see Figure 47).

Note: During single chamber pacing modes, atrial sensing, atrial detection, ventricular sensing, ventricular detection, and PR Logic criteria operate.
8.3.5.4 VOO mode

The VOO mode provides ventricular pacing at the programmed lower rate with no inhibition by intrinsic ventricular events.

**Note:** When the device is programmed to VOO mode, it offers no ventricular detection even though it offers atrial sensing and monitoring. Atrial detection must be programmed to Monitor and ventricular detection must be programmed Off in order to program the device to the VOO mode.

8.3.5.5 AOO mode

The AOO mode provides atrial pacing at the programmed lower rate with no inhibition by intrinsic atrial events.

**Note:** When the device is programmed to AOO mode, it provides no atrial detection even though it offers ventricular sensing and monitoring. Atrial detection must be programmed to Monitor and ventricular detection must be programmed Off in order to program the device to the AOO mode.
8.3.5.6 Atrial Refractory Period

The Atrial Refractory Period setting is programmable only for the AAI and AAIR single chamber pacing modes.

The Atrial Refractory Period prevents the inhibition of atrial pacing due to sensed far-field R-waves or noise and occurs after paced and nonrefractory sensed atrial events in the AAIR and AAI modes only.

8.3.5.7 Post Ventricular Atrial Blanking interval (single chamber)

PVAB is a programmable interval during which atrial events are ignored by bradycardia pacing operations (and, if the Method is Absolute, by arrhythmia detection).

Based on how the PVAB Method parameter is set, PVAB has 3 modes of operation: Partial, Partial+, and Absolute PVAB. Refer to Section 8.2.6.4, “Post Ventricular Atrial Blanking interval (dual chamber)”, page 210, for detailed descriptions of each method.

In the AAIR, AAI, VVIR, VVI, or VOO mode, Partial PVAB and Partial+ PVAB do not affect bradycardia pacing timing.

Atrial events sensed during Partial PVAB and Partial+ PVAB are used by PR Logic criteria, and they are used for AT/AF detection and monitoring criteria.

Absolute PVAB cannot be programmed in the following modes: ODO, AAI, AAIR, AAIR<=>DDDR, or AAI<=>DDD. Absolute PVAB is available in VVIR, VVI, or VOO mode, but you should consider using either Partial or Partial+ PVAB instead.

Warning: Programming Absolute as the PVAB Method means that no atrial sensing occurs during the blanking interval. Absolute blanking may reduce the ability to sense AT/AF, and may reduce the ability to discriminate between VT and SVT. Use Partial or Partial+ methods unless you are sure that Absolute blanking is appropriate.

8.4 MVP (Managed Ventricular Pacing)

The MVP modes promote intrinsic conduction by reducing unnecessary right ventricular pacing. The MVP modes are indicated by AAIR<=>DDDR and AAI<=>DDD on the mode selection screen. These modes provide atrial-based pacing with ventricular backup. For loss of AV conduction, the device switches to DDDR or DDD mode. Periodic checks are performed, and if AV conduction resumes, the device switches back to AAIR or AAI mode.

See Section 8.4.4, “Details about MVP”, page 222.
8.4.1 Considerations
Review the following information related to programming MVP modes.

V-V cycle variations – Depending on the patient’s intrinsic rhythm and conduction, the MVP mode allows V-V cycle variations and occasional pauses of up to twice the lower rate interval. See Figure 48 and Figure 50.

PAV and SAV – For MVP modes, it is not necessary to program longer PAV and SAV values to promote intrinsic AV conduction. PAV and SAV apply only when loss of AV conduction is detected.

Lower Rate programming – Upon abrupt loss of AV conduction, prior to switching to DDDR or DDD mode, ventricular pacing support can be as low as one-half the programmed Lower Rate for 2 consecutive intervals. For patients with sinus bradycardia or frequent loss of AV conduction, program the Lower Rate to 50 bpm or higher.

Complete heart block – For patients with complete heart block, the device will drop 1 beat every 16 hours (AV conduction check). See Figure 50. If this is undesirable, permanent DDDR or DDD modes may be more appropriate.

Long PR intervals – For patients with long PR intervals, the device will remain in the AAIR or AAI mode. Permanent DDDR or DDD modes may be more appropriate for patients with symptomatic first-degree AV block.

8.4.2 Restrictions
Review the following information related to programming MVP modes.

Absolute PVAB and MVP modes – You cannot program the PVAB method to Absolute when the device is programmed to an MVP mode.
8.4.3 How to program MVP modes

1. Select the Params icon.
2. Select one of the MVP modes:
   - AAIR<=>DDDR (rate responsive)
   - AAI<=>DDD (not rate-responsive)
3. Select [PROGRAM].

8.4.4 Details about MVP

The MVP modes, AAIR<=>DDDR and AAI<=>DDD, provide AAIR or AAI mode pacing while monitoring AV conduction. For persistent loss of AV conduction, the device switches to DDDR or DDD mode. If AV conduction resumes, the device switches back to AAIR or AAI mode.

For transient loss of AV conduction, the device remains in the AAIR or AAI mode and provides a backup ventricular pace in response to an A-A interval that is missing a ventricular sense. The backup pace is timed 80 ms after the A-A escape interval.
If 2 of the 4 most recent A-A intervals are missing a ventricular event, the device identifies a persistent loss of AV conduction and switches to the DDDR or DDD mode (see Figure 48).

If Mode Switch is enabled, it continues to operate by switching to DDIR during AT/AF episodes.

When MVP is operating in DDDR or DDD mode, the device operates as follows:
- All programmable parameters associated with DDDR or DDD mode apply.
- The device performs periodic one-cycle checks for AV conduction and for the opportunity to resume AAIR or AAI therapy. See Figure 49 and Figure 50.
- The first check for AV conduction occurs after 1 min. Subsequent checks occur at progressively longer intervals (2; 4; 8; 16 min …16 hours) up to 16 hours and then occur every 16 hours thereafter.

When MVP is operating in AAIR or AAI mode, the device operates as follows:
- Only programmable parameters associated with AAIR or AAI mode apply.
- The Atrial Refractory Period (ARP) is nonprogrammable, and it dynamically changes as a function of the current heart rate. ARP is 600 ms for heart rates below 75 bpm and 75% of the cardiac cycle length for heart rates above 75 bpm.
- Ventricular backup paces occur following A-A intervals without a valid ventricular sense. The backup paces are timed 80 ms after the A-A escape interval. A ventricular sense that occurs within 80 ms after an atrial pace is considered invalid.
- Atrial pacing is inhibited and new VA escape intervals are started in response to PVCs, PVC runs, and VT/VF episodes.
- After cardioversion or defibrillation therapy, the device operates in the DDDR or DDD mode for 1 min.

In AAIR<=>DDDR mode, the programmer status bar displays either AAIR+ or DDDR as the current pacing mode. In AAI<=>DDD mode, it displays either AAI+ or DDD. In either case, the atrial mode is followed by a “+” symbol, which indicates that backup ventricular pacing is available.
**Figure 48.** Switching from AAIR mode to DDDR mode

1. The device operates in AAIR mode.
2. At the onset of AV block, the device supplies ventricular backup paces.
3. The device switches to DDDR mode.

**Figure 49.** Switching from DDDR mode to AAIR mode

1. The device operates in DDDR mode.
2. The device performs an AV conduction check. AV conduction is detected.
3. The device switches to AAIR mode.
**Figure 50.** Remaining in DDDR mode after an AV conduction check

1. The device operates in DDDR mode.
2. The device performs an AV conduction check. AV conduction is not detected.
3. The device continues to operate in DDDR mode.

### 8.5 Rate Response

Rate Response varies the pacing rate in response to a patient’s physical activity. This feature is useful in patients whose spontaneous pacing rate does not change in response to their exercise demands. Rate Response is available when the device is operating in the DDDR, DDIR, AAIR, or VVIR mode. It is also available when the operating mode is DDD and Mode Switch is enabled.

#### 8.5.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rate Response</strong></td>
<td>Level of rate response; higher numbers indicate a more aggressive increase in rate for a given level of sensed physical activity.</td>
<td>1; 2 … 7; … 10</td>
</tr>
<tr>
<td><strong>Activity Threshold</strong></td>
<td>Minimum physical activity level detected.</td>
<td>Low; Medium Low; Medium High; High</td>
</tr>
<tr>
<td><strong>Activity Acceleration</strong></td>
<td>Acceleration time for increasing the pacing rate, measured in seconds.</td>
<td>15; 30; 60 s</td>
</tr>
<tr>
<td><strong>Activity Deceleration</strong></td>
<td>Deceleration time for decreasing the pacing rate, measured in minutes.</td>
<td>Exercise; 2.5; 5; 10 min</td>
</tr>
<tr>
<td><strong>Upper Sensor Rate</strong></td>
<td>Maximum upper limit for the sensor-indicated rate during physical activity.</td>
<td>80; 85 … 130; … 150 bpm</td>
</tr>
</tbody>
</table>
8.5.2 Considerations

Review the following information before programming Rate Response.

**Rate-responsive pacing and DDD or AAI<=>DDD mode** – When the programmed pacing mode is DDD or AAI<=>DDD and Mode Switch is enabled, the Rate Response parameters are programmable. However, these parameters apply only during Mode Switch episodes.

**Adjusting the Activity Threshold** – For many patients the nominal value for Activity Threshold is adequate.

- If the patient has an elevated pacing rate at rest, Activity Threshold may need to be programmed to a higher (less sensitive) setting.
- If the patient has minimal rate response during exercise, Activity Threshold may need to be programmed to a lower (more sensitive) setting.

**Fixed sensor-indicated rate** – The sensor-indicated rate does not change during the following events:

- automatic tachyarrhythmia therapies
- system tests
- EP study inductions and manual therapies
- A patient alert alarm
8.5.3 How to program Rate Response

1. Select the Params icon.
2. Set the Upper Sensor Rate to the desired value.
3. Select Pacing… from the Parameters screen.
4. Select Rate Response… from the Pacing screen.
5. Set Rate Response, Activity Threshold, Activity Acceleration, and Activity Deceleration to the desired values.
6. Return to the Parameters screen and select [PROGRAM].

8.5.4 Details about rate-responsive pacing

Rate-responsive pacing can be used to vary the pacing rate in response to detected physical activity. The device accelerometer provides sensed activity information by detecting body movement.

The programmed Activity Threshold screens out activity signals below the selected setting. Detected sensor signals vary from patient to patient because of differences in body structure and device placement. Only sensor signals with amplitudes that exceed the programmed Activity Threshold affect the sensor-indicated rate. As the Activity Threshold is lowered, smaller activity levels influence the sensor-indicated rate.

When a rate-responsive pacing mode is enabled, pacing is delivered at a sensor-indicated rate. The sensor-indicated rate is determined by the sensed activity and the Rate Response parameter setting, and it can range between the programmed Lower Rate and the Upper Sensor Rate.

The Rate Response parameter is set to a number between 1 and 10 (see Figure 51). If this parameter is set to a larger number, the indicated pacing rate is higher for a specified level of detected activity.\(^\text{17}\)

- If the sensor-indicated rate is greater than the current pacing rate, the pacing rate accelerates toward the sensor-indicated rate. The speed of this increase is determined by the Activity Acceleration parameter setting.
- If the sensor-indicated rate decreases, the pacing rate decelerates to the sensor-indicated rate. The rate of deceleration is determined by the programmed Activity Deceleration setting.

---
\(^{17}\) The actual beat-to-beat change is also influenced by the Rate Response Activity Acceleration setting and the sensed level of activity.
**Figure 51.** Effect of the Rate Response parameter on sensor-indicated rate

![Graph showing Rate range, Upper Sensor Rate, Lower Rate, and Increasing activity]

**Activity Acceleration setting** – The Activity Acceleration setting determines the amount of time required to reach 90% of the new pacing interval at the onset of strenuous exercise. The acceleration curves are illustrated in Figure 52.
Figure 52. Activity Acceleration curves for Rate Response

**Activity Deceleration setting** – The Activity Deceleration setting determines the amount of time required to reach 90% of the new pacing interval when exercise is abruptly ended. The deceleration curves are illustrated in Figure 53.
Exercise Deceleration option – If the Activity Deceleration parameter is set to Exercise, the device extends the rate-slowing period following an exercise episode, providing up to 20 min of rate deceleration. When it is programmed On, the device uses activity sensor data to detect periods of vigorous, prolonged exercise. At the end of this type of exercise period, the device uses a longer deceleration curve for the central portion of the programmed rate range. The actual deceleration rate is determined dynamically based on the intensity and duration of exercise and the new level of activity. The composite deceleration curve is shown in Figure 54.
8.6 Rate Adaptive AV

Rate Adaptive AV can be used to mimic the natural AV conduction time in response to heart rate. Normally, as the heart rate increases, the AV conduction time decreases; as the heart rate decreases, the AV conduction time increases. Rate Adaptive AV is available when the device is operating in the DDDR, DDIR, DDD, or DDI mode.

8.6.1 Parameters

| Rate Adaptive AV     | On; Off
|----------------------|--------
| Start Rate – Rate value that starts the Rate Adaptive AV operation. | 50; 55 ... 80 ... 145 bpm
| Stop Rate – Rate value that stops the Rate Adaptive AV operation. | 55; 60 ... 130 ... 150 bpm
Minimum Paced AV – Shortest allowable Paced AV interval; used at or above the Stop Rate.

Minimum Sensed AV – Shortest allowable Sensed AV interval; used at or above the Stop Rate.

8.6.2 Considerations

Review the following information before programming Rate Adaptive AV.

Suspension of Rate Adaptive AV – Rate Adaptive AV is suspended during automatic therapies, system tests, and EP Studies. Rate Adaptive AV operation resumes once these functions are complete.
8.6.3 How to program Rate Adaptive AV

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Paced AV… or Sensed AV… from the Pacing screen to open the AV Intervals window.
4. Set the Rate Adaptive AV parameter to On and select values for Start Rate, Stop Rate, Minimum Paced AV, and Minimum Sensed AV.
5. Return to the Parameters screen and select [PROGRAM].

8.6.4 Details about Rate Adaptive AV
Rate Adaptive AV can be used to mimic the natural AV conduction time in response to heart rate. Normally, as the heart rate increases, the AV conduction time decreases; as the heart rate decreases, the AV conduction time increases.

Rate Adaptive AV shortens the Sensed AV interval in response to the R-R Median\textsuperscript{18} and shortens the Paced AV interval in response to the current pacing rate. The current pacing rate can be any of these rates:
- the programmed Lower Rate
- the sensor-indicated rate
- the rate controlled by Atrial Rate Stabilization
- the rate controlled by Atrial Preference Pacing
- the programmed Overdrive Rate for Post Mode Switch Overdrive Pacing
- the rate controlled by Ventricular Rate Stabilization
- the programmed Overdrive Rate for Post VT/VF Shock Pacing

The way that Rate Adaptive AV parameters interact to shorten the AV intervals in response to higher rates is shown in Figure 55.

\textsuperscript{18} The median of the last 12 R-R intervals.
8.7 Rate Hysteresis

Rate Hysteresis is available when the device is operating in the VVI or AAI mode. This feature allows intrinsic heart rates to fall below the programmed Lower Rate during extended periods of patient inactivity, such as when the patient is sleeping.

8.7.1 Parameters

| Rate Hysteresis | Off; 30; 40 … 80 bpm |

8.7.2 Considerations

Review the following information before programming Rate Hysteresis.

**Verify adequate cardiac support** – Before programming Rate Hysteresis, verify that the selected hysteresis rate is adequate to support the patient’s cardiac condition.
8.7.3 Restrictions

Review the following information before programming Rate Hysteresis.

Compatibility – Rate Hysteresis cannot be enabled at the same time as any of these features: Atrial Rate Stabilization, Atrial Preference Pacing, and Ventricular Rate Stabilization.
8.7.4 How to program Rate Hysteresis

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Program the pacing mode to VVI or AAI.
4. Select Additional Features… from the Pacing screen.
5. Set the Rate Hysteresis parameter to the desired value.
6. Return to the Parameters screen and select [PROGRAM].

8.7.5 Details about Rate Hysteresis

Rate Hysteresis is available when the device is operating in the VVI or AAI mode. This feature allows intrinsic heart rates to fall below the programmed Lower Rate during extended periods of patient inactivity, such as when the patient is sleeping. Hysteresis is programmed to a rate below the Lower Rate in order to support slow but appropriate intrinsic rhythms.

Rate Hysteresis temporarily provides a new Lower Rate when the intrinsic rate is below the programmed Lower Rate. If the intrinsic rate drops below the hysteresis rate, then pacing resumes at the programmed Lower Rate.

Note: The difference between the Hysteresis Rate and the programmed Lower Rate is typically not greater than 30 bpm.

If a tachyarrhythmia episode is detected, hysteresis is suspended. Hysteresis remains suspended until the episode terminates.

Figure 56. Operation of Rate Hysteresis

1 The device paces in VVI mode at the programmed Lower Rate.
2 After a ventricular sensed event, the device applies the hysteresis interval (shaded bar).
3 A sensed event occurs before the hysteresis interval expires, so hysteresis operation continues.
4 The hysteresis interval expires, and the device paces the ventricle and reapplies the Lower Rate interval.
5 The ventricle is paced at the Lower Rate.
8.8 Mode Switch

Use Mode Switch to avoid tracking sensed atrial events during atrial arrhythmias. If Mode Switch is enabled, the device responds to the onset of an atrial tachyarrhythmia by switching the pacing mode to DDIR until the arrhythmia terminates.

8.8.1 Parameters

| Mode Switch  | On; Off |

8.8.2 Considerations

Review the following information before enabling Mode Switch.

Caution: Mode Switch is not recommended for patients with chronic, refractory atrial tachyarrhythmias.

Interactions with other pacing features – The Mode Switch feature temporarily suspends the NCAP, PMT Intervention, and PVC Response features.

During Mode Switch episodes, varied PVARP is used temporarily to help maintain atrial non-competition.

Atrial Rate Stabilization – During Mode Switch episodes, Atrial Rate Stabilization is not applicable because of changes in the pacing mode. Refer to Section 8.13, “Atrial Rate Stabilization”, page 256.

Atrial Preference Pacing – During Mode Switch episodes, Atrial Preference Pacing is not applicable because of changes in the pacing mode. Refer to Section 8.14, “Atrial Preference Pacing”, page 259.

Post Mode Switch Overdrive Pacing (PMOP) – When Mode Switch is enabled, PMOP can be programmed to extend pacing in DDIR mode once the atrial tachyarrhythmia ends. Refer to Section 8.15, “Post Mode Switch Overdrive Pacing (PMOP)”, page 264.

Interactions with atrial or ventricular therapies and T-Shock induction – If a Mode Switch episode was not in progress before the therapy, Mode Switch detection is suspended during the therapy. Mode Switch detection resumes after the therapy.

If a Mode Switch episode was in progress before the therapy, Mode Switch operation continues during charging but is suspended when charging ends. Mode Switch operation remains suspended until the high-voltage shock is delivered or aborted.
8.8.3 Restrictions
Review the following information before programming Mode Switch On.

Upper Sensor Rate – To ensure appropriate atrial tachyarrhythmia detection when Mode Switch is enabled, the Upper Sensor Rate must be less than or equal to the Upper Tracking Rate.

8.8.4 How to program Mode Switch

1. Select the Params icon.
2. Set the Mode Switch parameter to On.
3. Select [PROGRAM].
8.8.5 Details about Mode Switch

If Mode Switch is programmed On, a Mode Switch episode begins at onset of an atrial tachyarrhythmia. In a Mode Switch episode, the device switches from the programmed mode (DDDR, DDD, AAIR<=>DDDR, or AAII<=>DDD) to a nontracking mode (DDIR) based on criteria for the onset of an atrial tachyarrhythmia. This ensures that an inappropriate atrial rate does not influence the ventricular pacing rate.

The device starts Mode Switch operations when it identifies an atrial tachyarrhythmia using the AT/AF onset criteria (see page 81). When these criteria are met and the Mode Switch episode starts, the device smoothly reduces the pacing rate from the atrial synchronous rate to the sensor-indicated rate. The smooth rate reduction prevents an abrupt drop in the ventricular rate. See Figure 57.

Mode Switch identifies the end of the atrial arrhythmia using AT/AF episode termination criteria (see “AT/AF episode termination”, page 82). When the termination criteria are met, the device returns to either DDDR or DDD mode. If the device is programmed to an MVP mode (AAIR<=>DDDR or AAII<=>DDD), MVP resumes operation after the Mode Switch episode. See Section 8.4, “MVP (Managed Ventricular Pacing)”, page 220.

Figure 57. Beginning of a Mode Switch operation

1 An atrial tachyarrhythmia starts, causing rapid ventricular pacing in response.
2 The onset of atrial tachyarrhythmia occurs, and Mode Switch changes the pacing mode to DDIR.
3 The device gradually changes from the faster ventricular pacing rate to the slower sensor-indicated rate.

8.9 Non-Competitive Atrial Pacing

Non-Competitive Atrial Pacing (NCAP) is designed to prevent atrial tachycardias from being triggered. If an atrial pace is scheduled to fall within the vulnerable period of the atrium, NCAP delays the pace. NCAP is applicable when the device is operating in the DDDR or DDD mode.
See Section 8.9.5, “Other methods of preventing competitive atrial pacing”, page 246.

### 8.9.1 Parameters

<table>
<thead>
<tr>
<th>Non-Comp Atrial Pacing</th>
<th>On(\checkmark); Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCAP Interval</td>
<td>200; 250; 300(\checkmark); 350; 400 ms</td>
</tr>
</tbody>
</table>

### 8.9.2 Considerations

Review the following information before programming Non-Competitive Atrial Pacing.

**Ventricular pacing** – When a relatively high Lower Rate and long PVARP are programmed, NCAP operation may result in ventricular pacing slightly below the Lower Rate.

**NCAP Extended Interval** – A separate nonprogrammable parameter controls the NCAP interval for one pacing cycle whenever a PVC Response or a PMT Intervention occurs. If NCAP is enabled, a longer NCAP interval is provided after these specific events.
8.9.3 How to program Non-Competitive Atrial Pacing

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Additional Features….
4. Set Non-Comp Atrial Pacing to On.
5. Select a value for the NCAP Interval.
6. Return to the Parameters screen and select [PROGRAM].

8.9.4 Details about Non-Competitive Atrial Pacing

Non-Competitive Atrial Pacing (NCAP) delays an atrial pace that is scheduled to fall within the vulnerable period of the atrium to prevent triggering an atrial tachyarrhythmia. NCAP is available when the device is operating in the DDDR or DDD mode. Using the NCAP Interval parameter, you can program how long to delay an atrial pace if a refractory atrial event is sensed within the PVARP.\textsuperscript{19}

- If an atrial pace is scheduled to occur during the NCAP interval, the atrial pace is delayed until the NCAP interval expires.
- If an atrial pace is not scheduled to occur during the NCAP interval, timing is unaffected.

If another atrial refractory sensed event occurs during the NCAP interval, a new NCAP interval begins.

When an atrial pace is delayed by the NCAP feature, the Paced AV interval decreases to maintain a stable ventricular rate. The minimum value of the Paced AV interval is 30 ms.

\textsuperscript{19} Atrial refractory senses that occur within the programmable PVAB interval do not start an NCAP interval (see Section 8.2.6.4).
Figure 58. Non-Competitive Atrial Pacing operation

1 The device is pacing at the Upper Sensor Rate of 120 bpm.
2 An atrial refractory event occurs, starting an NCAP interval (300 ms in this case).
3 After the NCAP interval expires, the device paces the atrium and then paces the ventricle after a shortened Paced AV interval.

8.9.5 Other methods of preventing competitive atrial pacing

If NCAP is disabled, the device does not respond to atrial events during an atrial refractory period. The result is that an atrial pace may fall immediately after a refractory event and cause competitive atrial pacing.

The bradycardia pacing parameters should be programmed to provide 300 ms between the end of the atrial refractory period and the next scheduled atrial pace.

Lowering the Upper Sensor Rate, shortening the PAV interval, and shortening the PVARP provides a 300 ms interval with no atrial pacing after the PVARP.

Certain pacing parameters can be reprogrammed to prevent competitive atrial pacing, as listed in Table 31.
Table 31. Preventing competitive atrial pacing by reprogramming

<table>
<thead>
<tr>
<th>Pacing mode</th>
<th>Pacing parameter</th>
<th>Possible reprogramming</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAIR and AAI</td>
<td>Pacing interval</td>
<td>• Reduce Upper Sensor Rate (AAIR only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce Lower Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce A. Refractory Period</td>
</tr>
<tr>
<td>Atrial Refractory Period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDDR; DDD;</td>
<td>Pacing escape interval</td>
<td>• Reduce Upper Sensor Rate</td>
</tr>
<tr>
<td>DDIR; and DDI</td>
<td></td>
<td>• Reduce Lower Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reprogram Ventricular Rate Stabilization(^a)</td>
</tr>
<tr>
<td>PAV</td>
<td></td>
<td>• Reduce PAV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Enable Rate Adaptive AV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce Minimum PAV if Rate Adaptive AV is enabled</td>
</tr>
<tr>
<td>PVARP</td>
<td></td>
<td>• Reduce PVAR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Set PVARP to Varied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce PVAB if PVARP is Varied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Disable PVC Response</td>
</tr>
</tbody>
</table>

\(^a\) If Ventricular Rate Stabilization is enabled, either disable it or decrease its Maximum Rate.

8.10 PMT Intervention

A pacemaker-mediated tachycardia (PMT) may occur when retrograde P-waves are sensed and tracked in an atrial tracking mode (due to a loss of AV synchrony). PMT Intervention is designed to detect and interrupt PMT automatically. This feature is applicable when the device is operating in the DDDR or DDD mode.

PVC Response can also be used to prevent PMT. See Section 8.11, “PVC Response”, page 250.

Caution: Some PMTs may require intervention such as device reprogramming, drug therapy, or lead evaluation.

8.10.1 Parameters

| PMT Intervention | On; Off\(^\oplus\) |

8.10.2 Considerations

Review the following information before enabling PMT Intervention.

NCAP Extended Interval – An extended NCAP interval is automatically enabled for 1 pacing cycle whenever NCAP is enabled and either PVC Response or PMT Intervention occurs.
8.10.3 How to program PMT Intervention

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Additional Features… from the Pacing screen.
4. Set PMT Intervention to On.
5. Return to the Parameters screen and select [PROGRAM].
8.10.4 Details about PMT Intervention

PMT Intervention is applicable when the device is operating in the DDDR or DDD mode. The device detects a PMT after sensing 8 VA intervals with the following characteristics:

- The interval duration is less than 400 ms.
- Each interval starts with a ventricular paced event.
- Each interval ends with a nonrefractory atrial sensed event.

PMT Intervention forces a 400 ms PVARP after the ninth paced ventricular event. This ensures that the next atrial sensed event occurring within 400 ms will fall within the refractory period. Because this refractory event is not tracked to the ventricle for one cycle, the PMT is interrupted as shown in Figure 59.

PMT Intervention is suspended for 90 s following an intervention in order to prevent unnecessary intervention in the presence of fast intrinsic atrial rates. PMT Intervention is also suspended during automatic tachyarrhythmia therapies, system tests, EP Study inductions, and manual therapies.

Note: A sinus tachycardia may initiate a PMT Intervention, causing a single P-wave to fall in the PVARP where it is not tracked by the device.

Figure 59. PMT Intervention extends the PVARP

1 A PVC occurs and is conducted from the ventricle into the atria.
2 The device senses the atrial depolarization caused by the retrograde event.
3 The device detects the PMT after 8 VP-AS intervals occur that are shorter than 400 ms. After the ninth ventricular paced event, the device extends the PVARP to 400 ms for 1 event. The atrial event is not tracked, and the PMT terminates.

8.11 PVC Response

PVC Response detects premature ventricular contractions (PVCs) and extends the PVARP. Because PVCs are known to initiate a pacemaker-mediated tachycardia (PMT), PVC Response can be used to prevent PMT. PVC Response is applicable when the device is operating in the DDDR, DDD, DDIR, or DDI mode.

PMT Intervention can also be used to detect and interrupt PMT automatically. See Section 8.10, “PMT Intervention”, page 247.

Caution: Some PMTs may require intervention such as device reprogramming, drug therapy, or lead evaluation.

8.11.1 Parameters

| PVC Response | On; Off |

8.11.2 Considerations

Review the following information before enabling PVC Response.

NCAP Extended Interval – An extended NCAP interval is automatically enabled for 1 pacing cycle whenever NCAP is enabled and either PVC Response or PMT Intervention occurs.
8.11.3 How to program PVC Response

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Additional Features… from the Pacing screen.
4. Set PVC Response to On.
5. Return to the Parameters screen and select [PROGRAM].
### 8.11.4 Details about PVC Response

The device defines a PVC as any ventricular sensed event that follows a ventricular event without an intervening atrial event. PVC Response is applicable when the device is operating in the DDDR, DDD, DDIR, or DDI mode.

When PVC Response is enabled, a PVC starts an extended PVARP of 400 ms if the current PVARP (either the programmed PVARP or the varied PVARP) is less than 400 ms. This extended PVARP causes retrograde P-waves that occur within 400 ms to fall into the refractory period, as shown in Figure 60. The refractory atrial event is not tracked and does not inhibit atrial pacing.

PVC Response is suspended during automatic tachyarrhythmia therapies, system tests, EP Study inductions, and manual therapies.

**Figure 60.** PVC Response starts an extended PVARP

1. A PVC occurs.
2. The device extends the PVARP to 400 ms, and the subsequent atrial event is classified as refractory.

---

20Atrial refractory events falling within the programmable PVAB interval are ignored by PVC detection.
8.12 Ventricular Safety Pacing

Ventricular Safety Pacing (VSP) prevents inappropriate inhibition of ventricular pacing due to cross-chamber sensing of atrial paced events. If an atrial paced event is followed by a ventricular sensed event that occurs during the VSP interval, the device delivers a backup ventricular pace.

Caution: For pacemaker-dependent patients, always program Ventricular Safety Pacing On.

8.12.1 Parameters

<table>
<thead>
<tr>
<th>V. Safety Pacing</th>
<th>On®; Off</th>
</tr>
</thead>
</table>
8.12.2 How to program Ventricular Safety Pacing

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Additional Features… from the Pacing screen.
5. Return to the Parameters screen and select [PROGRAM].
8.12.3 Details about Ventricular Safety Pacing

Ventricular Safety Pacing is applicable when the device is operating in the DDDR, DDD, DDIR or DDI mode. A Ventricular Safety Pace is delivered if a ventricular event is sensed within the current Ventricular Safety Pace (VSP) interval after an atrial pace.

The device determines the VSP interval by comparing the current ventricular rate to the VSP switch rate:

- If the ventricular rate is lower than the VSP switch rate, the VSP interval is 110 ms.
- If the ventricular rate is at or above the VSP switch rate, the VSP interval is 70 ms.

The device automatically calculates the VSP switch rate using the following equation:

\[ \text{VSP switch rate} = \frac{60000}{2 \times (\text{V. Blank Post VP} + 110 \text{ ms})} \]

The delivery and timing of Ventricular Safety Pace depends on the length of the Paced AV interval. The ventricle is paced at the end of the Paced AV interval or at the end of the current VSP interval, whichever occurs first.

**Figure 61. Ventricular Safety Pacing below and above the switch rate**

1. The pacing rate is 60 bpm, which is below the VSP switch rate, so the VSP Interval is 110 ms.
2. An atrial pace is followed by a ventricular sense that falls within the VSP interval, so the device delivers a ventricular safety pace synchronized with the sensed event.

3. The pacing rate is 115 bpm, which is above the VSP switch rate, so the VSP Interval is 70 ms.

4. For 2 beats, an atrial pace is followed by a ventricular sense that falls within the VSP interval, so the device delivers a ventricular safety pace at the end of the VSP interval.

8.13 Atrial Rate Stabilization

Atrial Rate Stabilization is a programmable feature designed to eliminate the long sinus pause that commonly follows a premature atrial contraction (PAC).

8.13.1 Parameters

| A. Rate Stabilization | On; Off
| Maximum Rate – Sets a minimum limit on the pacing interval controlled by this feature. | 80; 85 ... 100 ... 150 bpm
| Interval Percentage Increment – The pacing interval increment per beat, as a percentage of the preceding interval. | 12.5; 25%; 50%

8.13.2 Considerations

Review the following information before programming Atrial Rate Stabilization.

Interactions with other device operations – Both Atrial Rate Stabilization and Atrial Preference Pacing are suspended during these operations:

- mode switching (including PMOP)
- a detected arrhythmia episode

If a combination of Atrial Rate Stabilization, Atrial Preference Pacing, and Ventricular Rate Stabilization is enabled, the device uses the algorithm that produces the shortest escape interval.

8.13.3 Restrictions

Review the following information before programming Atrial Rate Stabilization.

Maximum Rate, Upper Rate, and Ventricular Arrhythmia Monitoring – To ensure reliable tachyarrhythmia detection, the system regulates the values that you can select for the Maximum Rate, Upper Rate, AT/AF Detection Interval, VT/VF Detection Interval, and Ventricular Monitor interval.
Rate Hysteresis – Atrial Rate Stabilization and Rate Hysteresis cannot be enabled at the same time.

8.13.4 How to program Atrial Rate Stabilization

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Arrhythmia/Post Shock... from the Pacing screen.
4. Set A. Rate Stabilization to On.
5. Select Additional A Settings....
6. Select values for the Maximum Rate and Interval Percentage Increment.
7. Return to the Parameters screen and select [PROGRAM].

8.13.5 Details about Atrial Rate Stabilization

Atrial Rate Stabilization is available when the device is operating in the DDDR, DDD, AAIR, or AAI mode. When Atrial Rate Stabilization is enabled, at each atrial event (AS event, AP event, or pertinent AR event\(^{21}\)), the device calculates a new pacing interval, which is equal to the current pacing interval increased by the Interval Percentage Increment.

If the current pacing interval ends before the device senses an atrial event, the device delivers an atrial pace and recalculates its interval using the current atrial interval. The current pacing interval will be the shorter of the sensor rate interval or the calculated interval. The programmed Maximum Rate value provides a rate limit for operation of the feature.

After a PAC, the calculated escape interval stabilizes the atrial rate and gradually slows it to the intrinsic rate, sensor-indicated rate, or programmed Lower Rate (whichever is attained first). This prevents the “short/long” sequences of atrial cycle lengths that have been clinically observed to precede the onset of some spontaneous atrial tachyarrhythmias.

**Marker Channel annotation** – Atrial pacing pulses that are delivered under Atrial Preference Pacing or Atrial Rate Stabilization operation are annotated on the Marker Channel with PP (proactive pace) rather than AP (see Section 9.7.4.1, “Marker Channel telemetry annotations”, page 302).

The manner in which Atrial Rate Stabilization operates when its parameters are set to nominal values is shown in Figure 62.

---

\(^{21}\) When the device is operating in DDDR or DDD mode, the first AR event that is outside the PVAB and inside the PVARP is pertinent.
Figure 62. Operation of Atrial Rate Stabilization

1 Pacing occurs at the programmed escape interval.
2 The premature beat initiates a shorter escape interval. This interval ends with a programmed pace, which is determined by the maximum rate.
3 The device uses this atrial interval to calculate the next escape interval.
4 This atrial interval is 25% longer than the preceding one. It ends with the second programmed pace.
5 When the calculated pacing interval exceeds the programmed escape interval, normal pacing resumes.

8.14 Atrial Preference Pacing

Atrial Preference Pacing is designed to reduce the incidence of atrial tachyarrhythmias by providing rate-variable continuous pacing, closely matched to the intrinsic sinus rate whenever it exceeds the sensor-indicated rate.

8.14.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Preference Pacing</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Maximum Rate</strong></td>
<td>On; Off(^\oplus) 80; 85 ... 100(^\oplus) ... 150 bpm</td>
</tr>
<tr>
<td><strong>Interval Decrement</strong></td>
<td>30; 40; 50(^\oplus) ... 100; 150 ms</td>
</tr>
<tr>
<td><strong>Search Beats</strong></td>
<td>5; 10(^\oplus); 15 ... 25; 50</td>
</tr>
</tbody>
</table>
8.14.2 Considerations

Review the following information before programming Atrial Preference Pacing.

**Device longevity** – When Atrial Preference Pacing is enabled, the device tends to provide a higher ratio of paced to sensed events, which may decrease battery longevity.

**Interval Decrement parameter** – When choosing a value for the Interval Decrement parameter, be aware of these considerations:

- A larger value (for example, 100 ms) provides a more aggressive response to a sinus rate increase. This means that Atrial Preference Pacing occurs more often, more quickly, and lasts longer than with a smaller Interval Decrement value.
- A smaller value decreases the response to isolated PACs and sinus variability near the lower (or sensor) rate. A sustained rate increase is required to evoke Atrial Preference Pacing.

**Non-Competitive Atrial Pacing (NCAP)** – The NCAP feature may delay an atrial pace that results from Atrial Preference Pacing.

**Interactions with other device operations** – Both Atrial Rate Stabilization and Atrial Preference Pacing are suspended during these operations:

- mode switching (including PMOP)
- a detected arrhythmia episode

If a combination of Atrial Rate Stabilization, Atrial Preference Pacing, and Ventricular Rate Stabilization is enabled, the device uses the algorithm that produces the shortest escape interval.

8.14.3 Restrictions

Review the following information before programming Atrial Preference Pacing.

**Rate Hysteresis** – Atrial Preference Pacing and Rate Hysteresis cannot be enabled concurrently.

**Maximum Rate, Upper Rate, and Ventricular Arrhythmia Monitoring** – To ensure reliable tachyarrhythmia detection, the system regulates the values you can select for the Maximum Rate, Upper Rate, AT/AF Detection Interval, VT/VF Detection Interval, and Ventricular Monitor interval.
8.14.4 How to program Atrial Preference Pacing

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Arrhythmia/Post Shock… from the Pacing screen.
5. Select Additional A Settings…
6. Select values for the Maximum Rate, Interval Decrement, and Search Beats.
7. Return to the Parameters screen and select [PROGRAM].

8.14.5 Details about Atrial Preference Pacing

Atrial Preference Pacing is available when the device is operating in the DDDR, DDD, AAIR, or AAI mode. When Atrial Preference Pacing is enabled, the device responds to changes in the atrial rate by accelerating its pacing rate until a steady paced rhythm, slightly faster than the intrinsic rate, is obtained. Compare Figure 63 and Figure 64.

**Figure 63. DDDR operation without Atrial Preference Pacing**

<table>
<thead>
<tr>
<th>Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

1 Intrinsic activation when the sinus rate exceeds the sensor-indicated rate.
2 Atrial pacing at the sensor-indicated rate when that rate exceeds the sinus rate.
Figure 64. DDDR operation with Atrial Preference Pacing

<table>
<thead>
<tr>
<th>Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

- **Overdrive Atrial Pacing rate**
- **Sensor-indicated rate**
- **Sinus rate**

1. Atrial pacing slightly faster than the sinus rate when the sinus rate exceeds the sensor-indicated rate.
2. Atrial pacing at the sensor-indicated rate when that rate exceeds the sinus rate.

On every nonrefractory atrial sensed event, the device shortens its pacing escape interval by the programmed Interval Decrement value, accelerating the pacing rate. If the next atrial event is another nonrefractory sensed event, the pacing interval is again decremented. This progression continues until the pacing rate exceeds the intrinsic rate, resulting in an atrial paced rhythm; however, the programmed Maximum Rate value provides a rate limit for Atrial Preference Pacing.

When the number of consecutive paced atrial events reaches the programmed Search Beats value, the device adds 20 ms to the pacing escape interval, slowing the pacing rate. After the same number of consecutive paces at the new rate, the escape interval is again extended.
This progression continues until one of the following conditions occurs:

- The pacing rate reaches the Lower Rate.
- The pacing rate reaches the sensor-indicated rate.
- Pacing is interrupted by intrinsic atrial activity.

At the next nonrefractory atrial sensed event or when any atrial sensed event occurs during the deceleration, rate acceleration under Atrial Preference Pacing resumes as described above.

**Marker Channel annotation** – Atrial pacing pulses that are delivered under Atrial Preference Pacing or Atrial Rate Stabilization are annotated on the Marker Channel with PP (proactive pace) rather than AP (see Section 9.7.4.1, “Marker Channel telemetry annotations”, page 302).

### 8.15 Post Mode Switch Overdrive Pacing (PMOP)

Post Mode Switch Overdrive Pacing (PMOP) is available when the device is operating in the DDDR or DDD mode. PMOP supplements the Mode Switch feature. At the termination of a mode switch, PMOP causes the device to continue to pace in DDIR mode. It paces at the higher of the programmable Overdrive Rate or the sensor-activated rate. When the programmable Overdrive Duration elapses, the device returns to the programmed pacing mode.

#### 8.15.1 Parameters

<table>
<thead>
<tr>
<th>Post Mode Switch</th>
<th>On; Off◊</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overdrive Rate</strong> - The pacing rate when the feature is active.</td>
<td>70; 75; 80◊...120 bpm</td>
</tr>
<tr>
<td><strong>Overdrive Duration</strong> - The duration for which pacing occurs at the Overdrive Rate.</td>
<td>0.5; 1; 2; 3; 5; 10◊; 20; 30; 60; 90; 120 min</td>
</tr>
</tbody>
</table>

#### 8.15.2 Restrictions

Review the following information before programming Post Mode Switch Overdrive Pacing.

**Mode Switch** – Post Mode Switch Overdrive Pacing can be programmed only if the Mode Switch feature is enabled.
8.15.3 How to program Post Mode Switch Overdrive Pacing

1. Select the Params icon.
2. Enable Mode Switch if it is disabled.
3. Select Pacing… from the Parameters screen.
4. Select Arrhythmia/Post Shock… from the Pacing screen.
5. Set Post Mode Switch to On.
6. Select values for the Overdrive Rate and Overdrive Duration.
7. Return to the Parameters screen and select [PROGRAM].

8.16 Ventricular Rate Stabilization (VRS)

Ventricular Rate Stabilization is a programmable feature designed to eliminate the long pause that commonly follows a premature ventricular contraction (PVC).

8.16.1 Parameters

| V. Rate Stabilization | On; Off◊
|-----------------------|-------
| Maximum Rate – Determines a minimum interval that limits the new calculated interval. | 80; 85 … 120◊ bpm
| Interval Increment – Adds to the previous V-V interval to calculate the new interval. | 50; 60 … 150◊ … 400 ms

8.16.2 Considerations

Review the following information before programming Ventricular Rate Stabilization.

Varied PVARP and Ventricular Rate Stabilization – In the DDIR or DDI mode, when Ventricular Rate Stabilization increases the pacing rate, varied PVARP reduces the likelihood of competitive atrial pacing at high sensor-indicated rates.

Interactions with other device operations – If a combination of Atrial Rate Stabilization, Atrial Preference Pacing, and Ventricular Rate Stabilization is enabled, the device uses the algorithm that produces the shortest escape interval.

8.16.3 Restrictions

Review the following information before programming Ventricular Rate Stabilization.

Rate Hysteresis – Rate Hysteresis and Ventricular Rate Stabilization cannot be enabled at the same time.
### 8.16.4 How to program Ventricular Rate Stabilization

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Arrhythmia/Post Shock… from the Pacing screen.
4. Set V. Rate Stabilization to On.
5. Select Additional V Settings… for this feature.
6. Select values for the Interval Increment and Maximum Rate.
7. Return to the Parameters screen and select [PROGRAM].

8.16.5 Details about Ventricular Rate Stabilization

Ventricular Rate Stabilization is available when the device is operating in the DDDR, DDD, DDIR, DDI, VVIR, or VVI mode. When Ventricular Rate Stabilization is enabled, it acts as a constant rate-smoothing algorithm. The VRS operates when the rate that corresponds to the R-R Median interval is less than or equal to a fixed rate of 85 bpm.

The R-R Median interval is the median value of the last 12 measured ventricular intervals. An upper limit is placed on Ventricular Rate Stabilization operation because it is intended as a response to a premature ventricular beat. It does not respond to sustained fast heart rates.

On each ventricular event, the device calculates a new ventricular interval as the sum of the previous ventricular interval plus the programmed Interval Increment value (or a predetermined minimum interval, if it is larger than this sum). This minimum interval is determined from the programmed Maximum Rate.

If the calculated interval is shorter than the current pacing interval and no intrinsic ventricular event occurs, the device delivers a ventricular pace when the interval ends. The interval is then recalculated based on the last ventricular interval. The calculated interval lengthens, from beat to beat, by a value equal to the programmable Interval Increment.

If Ventricular Rate Stabilization is enabled while one of the following is in progress, no VRS pacing will occur for a minimum of 12 ventricular beats:

- ATP therapies
- manual therapies
- manual inductions
- system tests

**Note:** In dual chamber pacing modes, Ventricular Rate Stabilization automatically shortens the atrial pacing interval so the ventricular pacing pulse is delivered at the required escape interval.

An example of how the feature smooths the ventricular rate after a PVC is shown in Figure 65.
**Figure 65.** Operation of Ventricular Rate Stabilization

1. A PVC occurs, causing a short V-V interval.
2. The feature paces the ventricle at the previous V-V interval plus the programmed Interval Increment. The feature schedules the atrial pace early to maintain AV synchrony.
3. With each successive pace, the feature increases the pacing interval by the programmed Interval Increment.

### 8.17 Post VT/VF Shock Pacing

Post VT/VF Shock Pacing provides overdrive pacing after a shock is delivered to the ventricle. For post-shock pacing, the overdrive pacing rate for overdrive duration are programmable. This feature does not change the pacing mode from its programmed setting. The feature may help to restore normal hemodynamics after ventricular arrhythmia episodes that are shock-terminated.

Post VT/VF Shock Pacing is available in all modes except DOO, AOO, and VOO.

#### 8.17.1 Parameters

| Post VT/VF Shock Pacing        | On; Off
|-------------------------------|--------
| **Overdrive Rate** – The pacing rate when Post VT/VF Shock Pacing is active | 70; 75; 80; ... 120 bpm
| **Overdrive Duration** – The interval in which Post VT/VF Shock Pacing occurs | 0.5; 1; 2; 3; 5; 10; 20; 30; 60; 90; 120 min
8.17.2 How to program Post VT/VF Shock Pacing

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Arrhythmia/Post Shock… from the Pacing screen.
5. Select values for the Overdrive Rate and Overdrive Duration.
6. Return to the Parameters screen and select [PROGRAM].

8.17.3 Details about Post VT/VF Shock Pacing

Post VT/VF Shock Pacing may help to restore normal hemodynamics after ventricular arrhythmia episodes. This feature elevates the pacing rate of the device following a VT/VF shock. The shock can be an automatic, manual, or emergency delivery of either cardioversion or defibrillation.

Pacing continues at the Overdrive Rate through the Overdrive Duration unless one of the following operations occurs first:

- atrial or ventricular pacing therapies or inductions—delivered either manually or automatically
- ATP During Charging or ATP Before Charging
- the start of atrial or ventricular high-voltage therapy synchronization—delivered either manually or automatically
- T-Shock
- Pacing Threshold Test
- Sensing Test
- Underlying Rhythm Test
- Wavelet Morphology Test (VR devices only)

8.18 Post Shock Pacing

In order to ensure capture following a high-voltage therapy, a separate set of basic pacing parameters is available for pacing support after atrial and ventricular high-voltage therapies. Post Shock Pacing works differently than Post VT/VF Shock Pacing.

8.18.1 Parameters

- **A. Amplitude** – Voltage of atrial post-shock pacing pulses.
  - 0.5; 1 ... 4; 5; 6; 8 V
- **A. Pulse Width** – Duration of atrial post-shock pacing pulses.
  - 0.1; 0.2 ... 1.5 ms
- **RV Amplitude** – Voltage of ventricular post-shock pacing pulses.
  - 0.5; 1 ... 4; 5; 6; 8 V
- **RV Pulse Width** – Duration of ventricular post-shock pacing pulses.
  - 0.1; 0.2 ... 1.5 ms
8.18.2 Considerations

Review the following information before programming Post Shock Pacing.

**Adequate safety margin** – Considering the post-shock rise in pacing thresholds, be sure to program an adequate safety margin for post-shock pacing parameters.
8.18.3 How to program Post Shock Pacing

1. Select the Params icon.
2. Select Pacing… from the Parameters screen.
3. Select Arrhythmia/Post Shock… from the Pacing screen.
4. Set the desired atrial and ventricular Amplitude and Pulse Width for Post Shock Pacing.
5. Return to the Parameters screen and select [PROGRAM].
8.18.4 Details about Post Shock Pacing

Post Shock Pacing is enabled following an atrial or ventricular high-voltage shock. The shock can be an automatic, manual, or emergency delivery of either cardioversion or defibrillation. Post Shock Pacing remains in effect for 25 ventricular events, and it ends if another type of therapy starts.

Post Shock Pacing pulses are delivered as appropriate for the programmed pacing mode. For example, in the AAIR or AAI mode, the Post Shock Pacing pulses are delivered only to the atrium.\textsuperscript{22}

If the programmed pacing mode is AAIR<=>DDDR, the device paces in DDDR mode for 1 min after the high-voltage shock. If the programmed pacing mode is AAI<=>DDD, the device paces in DDD mode for 1 min after the high-voltage shock.

\textsuperscript{22} For one event after the shock, the device paces in VVI mode.
Part IV
Evaluating and managing patient treatment

9 Using the programmer

9.1 Setting up and using the programmer
Patient sessions for this device can be managed with either a Medtronic CareLink Model 2090 programmer or a Medtronic Model 9790C programmer.

The programmer reference guides provide instructions on setting up the programmer for a patient session, using printers, use of the between-sessions screens, and setting programmer preferences.

9.1.1 Programmer functions before and after patient sessions
Before you start a patient session, you can set the following programmer preferences:

- set the programmer time and date
- set the audio preferences
- change the language preference for the software display
- check the software version number

Once you have started a patient session, you can set printing preferences, reports preferences, and test preferences.
9.1.2 Using the programming head

When the programming head is placed over the device and telemetry is established, the amber light on the programming head turns off, and 1 or more of the green indicator lights turn on. You can find the optimum position for the programming head by moving it around the implanted device until the greatest number of green lights turn on. To ensure proper telemetry, make sure to position the programming head so at least 2 of the green lights are on.

If the programming head slides off the patient, the session is not terminated. Place the programming head back over the device to resume programming or interrogating the device.

Notes:
- Any successful interrogation or programming verifies proper communication between the device and the programmer.
- The programming head contains a magnet that can suspend tachyarrhythmia detection. However, if telemetry between the device and programmer is established, detection is not suspended.
- More information about the general use of the programming head is available in the programmer reference guide.

9.1.2.1 Episodes in progress

If you position the programming head over the device when a detected arrhythmia episode is in progress, the device detects and treats the arrhythmia normally after telemetry between the device and the programmer is established. If telemetry cannot be established, the magnet inside the programming head causes the device to suspend detection.

9.1.2.2 Marker transmissions

The device continuously transmits Marker Channel and supplementary marker data using telemetry while the programming head is positioned over the device. The device stops these transmissions when you lift the programming head unless the Holter Telemetry feature is programmed On. If Holter Telemetry is programmed On, the device transmits telemetry regardless of the position of the programming head.

9.1.2.3 How capacitor charging affects the light array

The programming head indicator lights may turn off during charging periods. This is caused by interference generated by the charging circuit, and it happens normally.
Note: The programming head “P” button is disabled during all EP Study functions and manual system tests. The “I” button is also disabled during EP Study inductions, but it is available during manual system tests.

9.2 Display screen features

The programmer display screen is an interactive device that displays text and graphics. It is also a control panel that displays buttons and menu options that you can select using the touch pen.

This section provides an overview of the features of the display screen. Figure 66 shows the main elements of a typical display screen during a patient session.

Figure 66. Main elements of a display screen

| 1 | Task bar |
| 2 | Status bar |
| 3 | Live Rhythm Monitor window |
| 4 | Task area |
| 5 | Command bar |
| 6 | Tool palette |

Note: For information on changing the language (for example, from English to German), see the programmer reference guide.
9.2.1 Task bar

The Medtronic CareLink Model 2090 programmer has a task bar at the top of the screen. It has a graphical representation of the light array on the programming head. The remainder of the task bar is reserved for programmer-specific features (such as Remote View).

**Note:** No task bar appears on Model 9790C programmers.

9.2.2 Status bar

Once the device has been interrogated, the status bar at the top of the display screen provides some basic functions and indicates the current status of the device (see Figure 67).

**Figure 67. Status bar display**

1. Currently active pacing mode
2. Programmed detection and therapy configuration
3. Buttons used to Resume or Suspend detection
4. Automatic detection status
5 Indicator that a tachyarrhythmia episode is in progress
6 Current episode, therapy, or manual operation status

9.2.3 Live Rhythm Monitor window

The Live Rhythm Monitor window displays ECG, Marker Channel, and telemetered EGM waveform traces. In addition to waveform traces, the Live Rhythm Monitor shows the following information:

- Heart rate and rate interval are displayed if the programming head is positioned over the device.
- Annotations above the waveform trace show the point of programmed parameter changes.

By default, the Live Rhythm Monitor appears in the partial view, as shown in Figure 68. You can expand this window to its full size by selecting the small square button in the upper-right corner of the window or by selecting the [Adjust...] button. For more information about the Live Rhythm Monitor, see Section 9.7, “Viewing live waveform traces”, page 299.

Figure 68. Live Rhythm Monitor window

![Live Rhythm Monitor window]

1 Select the square button or the [Adjust...] button to switch the Live Rhythm Monitor between partial view and full-screen view.

The waveform trace or traces displayed in this window depend on the selected task screen and how traces have been arranged in the full-screen view.

9.2.4 Task area

The portion of the screen between the Live Rhythm Monitor window (top of screen) and the command bar (bottom of screen) changes according to the task or function you select.

An example of a task area is the Parameters screen, which is shown in Figure 69. This screen is used to program detection and therapy parameters as described in Section 9.4.1, “Using the Parameters screen”, page 289.

---

23 Manual operations are EP Study functions, manual system tests, and emergency tachyarrhythmia therapies.
Task areas are different for other functions such as diagnostics and tests.

**Figure 69.** Task area of a screen

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Lower Rate 60 bpm</th>
<th>A. Sensitivity 0.3 mV</th>
<th>RV Sensitivity 0.3 mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>AAIR&lt;=DDDR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode Switch</td>
<td>On</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacing...</td>
<td>Upper Track 130 bpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Sensor 130 bpm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detection</th>
<th>Interval (Rate)</th>
<th>Initial</th>
<th>Therapies...</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>On 320 ms (188 bpm)</td>
<td>18/24</td>
<td>ATP During Charging, 35J x 6</td>
</tr>
<tr>
<td>FVT</td>
<td>via VF 240 ms (250 bpm)</td>
<td></td>
<td>Burst(1), 35J x 5</td>
</tr>
<tr>
<td>VT</td>
<td>On 400 ms (150 bpm)</td>
<td>16</td>
<td>Burst(3), Ramp(4), 35J x 4</td>
</tr>
<tr>
<td>Detection (V.)...</td>
<td>AF/All, Sinus Tach, Stability, Onset, High Rate Timeout, VT Monitor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AT/AF</th>
<th>On 350 ms (171 bpm)</th>
<th>2 Zones...</th>
<th>Burst+, Ramp, 50 Hz, 35J x 4, Patient Activate</th>
</tr>
</thead>
</table>

**9.2.5 Tool palette**

The buttons and icons along the right edge of the screen are referred to as the “tool palette”. Use these tools to display a task or function screen. After starting a patient session, the tool palette is displayed on all but the Emergency or Live Rhythm Monitor Adjust... screens, making it quick and easy to move to the desired task or function.

Each of the icons acts like a button. To select an icon, touch the icon with the touch pen. Figure 70 describes each option in the tool palette.
Figure 70. Tool palette options

1 [Freeze] button: freezes a segment of the Live Rhythm Monitor display (see Section 9.9).
2 [Strips…] button: accesses the waveform strips saved since the start of the session (see Section 9.10).
3 [Adjust…] button: opens a window of options for adjusting the Live Rhythm Monitor display (see Section 9.7).
4 Checklist icon: opens the Checklist screen for simplified navigation through a set of programmer related tasks (see Section 9.3).
5 Checklist double-arrow button: navigates to the next programmer screen in the active Checklist (see Section 9.3).
6 Data icon: displays options for retrieving information about the device (see Section 10.1).
7 Params icon: displays the Parameters screen for programming device parameters (see Section 9.4).
8 Tests icon: displays options for performing system tests (see Section 11.1).
9 Reports icon: displays options for printing reports (see Section 9.12).
10 Patient icon: displays the Patient Information screen (see Section 10.12).
11 Session icon: displays options for managing and ending the session (see Section 9.6).
9.2.6 Buttons

Buttons, like those shown in Figure 71, respond when you use the stylus. You can “press” a button by touching it with the tip of the touch pen.

Figure 71. Display screen buttons

![Display screen buttons]

1 Buttons having a less distinct shaded label are not presently active.

Two types of responses happen when you select a button:

- Buttons like the [PROGRAM] button execute a command directly.
- Buttons like the [Interrogate] and [End Session...] buttons open a window that prompts another action. The labels on these buttons end with an ellipsis.

A procedure may instruct you to “press and hold” a button. In such cases, touch the tip of the touch pen to the button and continue to maintain pressure against the button. The button continues to respond to the touch pen until you “release” it.

9.2.7 Command bar

The bar at the bottom of the screen always shows the buttons for programming Emergency parameters, interrogating the device, and ending the patient session.

Note: The [Interrogate] and [End Session...] buttons do not appear on the Emergency screen.

9.3 Streamlining follow-up and implant sessions with Checklist

The Checklist feature provides a method of cataloging tasks that are performed during routine procedures. When you select a task from the Checklist, the programmer displays the screen used for that task. To go to the next task in the selected checklist without returning to the Checklist screen, select the double-arrow icon next to the Checklist icon.

The Checklist screen displays check marks next to the names of any programmer screens that were visited during a session. These check marks provide a general indication of the tasks that were performed during a session.
Two standard checklists are provided: the Medtronic Standard Implant checklist and the Medtronic Standard Followup checklist. In addition to these standard checklists, you can create customized checklists.

This section contains the following procedures:

- selecting and using a checklist
- creating a new checklist
- editing a checklist
- deleting a checklist

### 9.3.1 How to select and use a checklist

1. Select the Checklist icon and review the tasks displayed for that list.
2. To choose a different checklist, select the Checklist field.
3. To start using the checklist, select either [Go To Task] or the double-arrow icon.
4. Perform the selected task. Continue to the next task by selecting the double-arrow icon next to the Checklist icon.

---

24 When starting a new session, the checklist used during the last programming session becomes the active checklist.
5. To perform a task out of order or repeat a task from the selected Checklist, first select the Checklist icon. Then select the task, and select either [Go To Task] or the double-arrow icon.25

25 You can select a task whether it is marked with a checkmark or not. If you perform the last task in a checklist, the double-arrow icon and the [Go To Task] button are disabled. You can still select an earlier task from the Checklist screen and use the double-arrow icon button to cycle through all the tasks below it.
9.3.2 How to create a new checklist

1. Select the Checklist icon.
2. Select [New...] from the Checklist screen.
3. Assemble a new list in the right-hand box by selecting the tasks in the left-hand box.
   (Tasks can be added more than once to a new checklist.)
4. Each selected task appears at the end of the new checklist box. To add a task higher in the list, highlight the task it should follow. Select the new task to add, and it will appear below the highlighted task.

5. To delete a task, select it and then select [Delete Task].

6. Select the Checklist name field, and enter a name for the list.

7. Select [Save].
9.3.3 How to edit a checklist

1. Select the Checklist icon.
2. Select a checklist to edit.
3. Select [Edit…].
4. Add new tasks to the list in the right-hand box by selecting the tasks in the left-hand box. (Tasks can be added more than once to a new checklist.)
5. Each selected task appears at the end of the new checklist box. To add a task higher in the list, highlight the task it should follow. Select the new task to add, and it will appear below the highlighted task.

6. To delete a task, select it and then select [Delete Task].

7. To rename the edited checklist, select the Checklist name field, and enter a name for the list.

8. Select [Save].

9.3.4 How to delete a checklist

1. Select the Checklist icon.
2. Select the checklist to delete from the Checklist menu.
3. Select [Delete].

Note: The Medtronic Standard Followup and Medtronic Standard Implant checklists cannot be edited or deleted, so the [Edit...] and [Delete] buttons are unavailable when these checklists are selected.
9.4 Viewing and programming device parameters

9.4.1 Using the Parameters screen

The Parameters screen is used for viewing and reprogramming parameters that control both device functions and data collection. All of these parameters are accessed from this screen.

All device parameters that you can view and reprogram are shown in “active fields” in the task area. Active fields, which appear as unshaded boxes next to parameter names, respond to the touch pen. Some active fields pertain only to 1 parameter. Other fields, shown in Figure 72, provide access to groups of parameters. If a parameter cannot be programmed, no active field appears next to its name.

Figure 72. Access to groups of parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Lower Rate</th>
<th>A. Sensitivity</th>
<th>RV Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>60 bpm</td>
<td>0.3 mV</td>
<td></td>
</tr>
<tr>
<td>Mode Switch</td>
<td>130 bpm</td>
<td></td>
<td>0.3 mV</td>
</tr>
<tr>
<td>Pacing...</td>
<td>130 bpm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detection (V.)...</th>
<th>Interval (Rate)</th>
<th>Initial</th>
<th>Therapies...</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>320 ms (188 bpm)</td>
<td>18/24</td>
<td>ATP During Charging, 35J x 6</td>
</tr>
<tr>
<td>FVT</td>
<td>240 ms (250 bpm)</td>
<td></td>
<td>Burst(1), 35J x 5</td>
</tr>
<tr>
<td>VT</td>
<td>400 ms (150 bpm)</td>
<td>16</td>
<td>Burst(3), Ramp(4), 35J x 4</td>
</tr>
<tr>
<td>AT/AF</td>
<td>350 ms (171 bpm)</td>
<td>2 Zones...</td>
<td>Burst+, Ramp, 50 Hz, 35J x 4, Patient Activate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data Collection Setup...</td>
<td>Patient Alert... 9 On</td>
</tr>
</tbody>
</table>

After you have selected different values for parameters, they are designated as pending values. A field containing pending values has a dashed rectangle as its border. The values remain pending until they are programmed to device memory. All parameter changes are programmed at the main parameter screen.

Parameters with 2 values – If a parameter has only 2 values (for example, Off or On), selecting the parameter makes the alternate value pending. Refer to Figure 73.
### Parameters with more than 2 values

If a parameter has more than 2 values, a window opens when you select the parameter, and the window displays a set of values for that parameter. Refer to Figure 74.

For example, touching the RV Sensitivity value 0.3 mV in the RV Sensitivity field with the tip of the touch pen opens a window of sensitivity values. Selecting any one of these options replaces the original value with the selected one and makes it pending.

#### Figure 74. Selecting one parameter value from a group of values

1. When you select the RV Sensitivity field, a window opens that shows the available values for that parameter.
2. You can select a pending value for RV Sensitivity from this window.
Parameter field ending in an ellipsis – If the name of the parameter field ends in an ellipsis (for example, Rate Response…), selecting the field opens a window that displays additional fields. Refer to Figure 75.

Figure 75. Selecting values from a secondary window

1 Selecting the Rate Response… field opens the Rate Response window.
2 You can choose pending values for the desired Rate Response subparameters.
3 Selecting [OK] closes the Rate Response window.

Secondary parameters screens – Secondary parameters screens allow you to set up the parameters for a group of related features. The detection and therapy screens are examples.

The field that you select to open a secondary parameter screen typically lists a series of parameters settings. The list of settings summarizes the highlights of the detailed settings that appear on the underlying screen.

For example, the field labeled Detection (V.)… in Figure 76 summarizes many of the settings appearing on the V. Detection screen.
### Figure 76. Using a secondary parameters screen

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>AAIR&lt;-&gt;DDDR</td>
<td>Lower Rate: 60 bpm</td>
</tr>
<tr>
<td>Mode Switch</td>
<td>On</td>
<td>Upper Track: 130 bpm</td>
</tr>
<tr>
<td>Pacing...</td>
<td></td>
<td>Upper Sensor: 130 bpm</td>
</tr>
<tr>
<td>Detection</td>
<td></td>
<td>Therapies...</td>
</tr>
<tr>
<td>VF</td>
<td>On</td>
<td>320 ms (188 bpm)</td>
</tr>
<tr>
<td>FVT</td>
<td>via VF</td>
<td>18/24</td>
</tr>
<tr>
<td>VT</td>
<td>On</td>
<td>400 ms (150 bpm)</td>
</tr>
<tr>
<td>Detection (V)</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>AT/AF</td>
<td>On</td>
<td>350 ms (171 bpm)</td>
</tr>
<tr>
<td>Data Collection Setup...</td>
<td></td>
<td>Burst(1), 35J x 5</td>
</tr>
<tr>
<td>Patient Alert... 9 On</td>
<td></td>
<td>Burst(5), Ramp(4), 35J x 4</td>
</tr>
</tbody>
</table>

1. Selecting the Detection (V.)... field opens the V. Detection screen.
2. From this screen, you can choose parameter values related to VF, FVT, and VT detection.
3. Selecting [OK] closes the V. Detection screen and returns you to the Parameters screen.

Throughout this manual, each section that describes a specific feature includes a procedure about programming the feature’s parameters.

### 9.5 Saving and retrieving a set of parameter values

A complete custom set of parameter values can be saved in the programmer and retrieved at a later time. The [Save...] button opens a window where you can assign a name to the set of parameter values presently displayed by the Parameters screen. A saved parameters set can include both programmed and pending values.
The [Get...] button opens the Get Parameter Set window to retrieve any of the following parameter sets:

- **Medtronic Nominals**: Values chosen as nominal values for the device by Medtronic. The Medtronic Nominals set cannot be customized or deleted.
- **Initial Interrogation Values**: The permanently programmed parameter values as determined by the first interrogation of the device during the patient session.
- **Custom sets of values**: All custom sets of values that were saved previously.
9.5.1 How to save a set of parameter values

1. Select the Params icon. Make the desired parameter selections.
2. Select the [Save…] button to open the Parameter Set Name window.
3. Type a name for the parameter set, and select either [Enter] or [OK].
4. If a parameter set exists with that name, you will need to confirm that you wish to replace the existing set with a new set.
9.5.2 How to retrieve a set of parameter values

1. Select the Params icon.
2. Select the [Get...] button to open the Get Parameter Set window.
3. Select the parameter set you wish to retrieve.
4. Select [Set Pending].
5. Optionally, to remove an unneeded parameter set from the list, select it and select [Delete].

9.6 Starting and ending patient sessions

Because the programmer collects and stores data on a session-by-session basis, you need to start a new session for each patient. At the start of a session, the programmer interrogates the patient’s device. Before starting a session with another patient, you must end the previous session.

If the programmer detected a device serial number that is different from the one it sensed during the initial interrogation, it forces you to end the current session.
**Note:** Connect the programmer skin electrodes to the patient if you would like to display surface ECG signals on the programmer. See the programmer user manual for more information.

**Initial interrogation** – After starting the programmer and placing the programming head over the device, you can use either of these methods to start a patient session:

- Select [Find Patient…]. The programmer determines the device model, starts the correct software application, and interrogates the device.
- After selecting the device model from a list on the Select Model screen, select [Start]. The programmer starts the software application and interrogates the device.

During an initial interrogation, only Emergency programmer functions are available.

### 9.6.1 How to start a patient session using [Find Patient]

1. Display the Select Model screen. If the Select Model icon is not displayed, a patient session is in progress. You must end that session before starting a new one.
2. Position the programming head over the patient’s device, and hold it steady. The number of green indicator lights indicates how to position the programming head for reliable telemetry.
3. Select the [Find Patient] button at the bottom of the screen, or press the [I] programming head button. The programmer loads the appropriate software application, displays the Quick Look screen, and immediately begins to interrogate the device.

9.6.2 How to start a patient session using [Start]

1. Display the Select Model screen. If the Select Model icon is not displayed, a patient session is in progress. You must end that session before starting a new one.
2. Choose to view tachyarrhythmia devices.
3. Select EnTrust from the list of devices.
4. Position the programming head over the patient’s device, and hold it steady. The number of green indicator lights indicates how to position the programming head for reliable telemetry.
5. Select the [Start] button. The programmer loads the EnTrust software application, displays the Quick Look screen, and immediately begins to interrogate the device.
9.6.3 How to end a patient session

1. To review or print a list of changes made during this session, select Session > Changes This Session.
   a. Review the programming changes made during the patient session.
   b. To print a record of the changes, select [Print…].
2. Select [End Session…].
3. To save session data to a disk, select [Save To Disk…].
4. To end the session and return to the Select Model screen, select the [End Now] button.
9.7 Viewing live waveform traces

The Live Rhythm Monitor window displays live ECG and EGM waveform traces. The window normally appears above the task area, but you can select an icon in the upper right-hand corner of the window to expand it to cover the task area.

You can use the waveform adjustment button bar to change the appearance of the waveforms in view. With the Adjust window, you can make additional changes to the waveform display.

See Section 9.7.4, “Details about the Live Rhythm Monitor”, page 302.

9.7.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clipping</strong></td>
<td>Truncates the tops and bottoms of waveform traces at a 22 mm boundary.</td>
<td>enable; disable</td>
</tr>
<tr>
<td><strong>Sweep Speed</strong></td>
<td>Sets sweep speed.</td>
<td>12.5; 25; 50; 100 mm/ s</td>
</tr>
<tr>
<td><strong>ECG Filter</strong></td>
<td>Changes the bandwidth of waveforms to improve the clarity of the displayed ECG in the presence of interference.</td>
<td>disable (0.05 to 100 Hz) enable (0.5 to 40 Hz)</td>
</tr>
<tr>
<td><strong>Show Artifacts</strong></td>
<td>Displays pacing artifacts superimposed over waveform traces.</td>
<td>enable; disable</td>
</tr>
<tr>
<td><strong>Normalize</strong></td>
<td>Equalizes the spacing between the waveform traces and resizes each trace to its default setting.</td>
<td></td>
</tr>
</tbody>
</table>
9.7.2 How to use the waveform adjustment button bar

1. Select the up arrow button to increase the size of the waveform trace.
2. Select the Normalize button to restore the waveform trace to its default size.
3. Select the down arrow button to decrease the size of the waveform trace.
4. Select the waveform Source button to select the source of the waveform trace to be displayed.
5. Select the waveform Print Selection button to enable or disable the trace for printing. Up to two traces can be selected.
9.7.3 How to use the Adjust window

1. Select [Adjust...] to display the full screen Live Rhythm Monitor and the Adjust window.
2. Adjust the size, source, and print selection options for each waveform trace using the waveform adjustment bar. See Section 9.7.2.
3. Select the color field in the waveform trace area to change the color of a waveform.
4. Select [Clipping], [ECG Filter], and [Show Artifacts] to enable or disable these options as desired.
5. Select the Sweep Speed if desired.
6. Select [Normalize] to equalize the trace spacing and adjust the size of each trace to the default setting.
7. Use the Calibrate button to add a reference signal to the analog output.26
8. When you are finished making adjustments, select [OK].

9.7.4 Details about the Live Rhythm Monitor

This Live Rhythm Monitor can display up to 6 different waveforms during a patient session:

- ECG leads I, II, and III are available when you attach ECG leads to the patient’s skin and connect them to the programmer.
- Marker annotations showing device operations are telemetered from the device to the programmer when the programming head is over the device.
- EGM1 and EGM2 signals are telemetered from the device. You can choose the sources of EGM1 and EGM2 when you set up data collection. See Section 10.2.4.1, “EGM source”, page 327.

The programmer cannot display (or record) an EGM trace until the current EGM Range setting has been interrogated from the device.

Table 32. Waveform trace information

<table>
<thead>
<tr>
<th>Trace</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG Lead I</td>
<td>ECG signals are detected using skin electrodes attached to the patient. The ECG cable attached to these electrodes must be connected to the programmer.</td>
</tr>
<tr>
<td>ECG Lead II</td>
<td></td>
</tr>
<tr>
<td>ECG Lead III</td>
<td></td>
</tr>
<tr>
<td>Marker annotations</td>
<td>Marker annotations indicate events occurring in pacing, sensing, detection, and therapy delivery.</td>
</tr>
<tr>
<td>EGM1</td>
<td>EGM signals are telemetered from the device. The signals are selected from programmable EGM sources.</td>
</tr>
<tr>
<td>EGM2</td>
<td></td>
</tr>
</tbody>
</table>

9.7.4.1 Marker Channel telemetry annotations

Marker Channel telemetry annotations appear as 2 characters above or below the Marker Channel trace of the waveform display. These annotations indicate events such as pacing, sensing, detection, and delivered therapies.

In addition to annotations, the Marker Channel trace uses symbols to indicate specific events. Marker Channel symbols appear only on real-time waveform recordings, not on screens or in episode recordings. These symbols sometimes appear compressed, depending on the printout speed of the programmer strip chart recorder.

26 This button appears in the Adjust window on the Medtronic CareLink Model 2090 programmer. The Model 9790C programmer has a blue push button located next to its analog output connector.
Refer to the following figures for definitions of the Marker Channel annotations and symbols:

- For bradyarrhythmia, see Figure 77.
- For atrial detection and therapies, see Figure 78.
- For ventricular detection and therapies, see Figure 79.

**Note:** Because the displayed waveforms depend on telemetry with the device, marker annotations are not displayed unless the programming head is positioned over the device. Therefore, any interruption in telemetry may result in missing markers on the trace display.

**Figure 77.** Marker Channel symbols and annotations (bradyarrhythmia)
Figure 78. Marker Channel symbols and annotations (atrial detection and therapies)

AT/AF sense | Fast AT/AF sense | AT/AF detection | Fast AT/AF detection

Atrial tachy pace | Atrial 50 Hz burst | Cardioversion pulse | Charge end

Figure 79. Marker Channel symbols and annotations (ventricular detection and therapies)

VT sense | FVT sense via VT | FVT sense via VF | VF sense

VT detection | FVT detection | VF detection | VT monitor detection

Ventricular tachy pace | 50 Hz Burst induction | Charge end | Cardioversion/defibrillation pulse
9.7.4.2 Decision Channel annotations

Decision Channel annotations provide supplementary information about the operation of device ventricular detection and monitoring algorithms. Decision Channel annotations are saved with the EGM data for episode records and printed on real-time recordings.

Refer to Section 10.5.6.4, “EGM Strip”, page 350, for information on how Decision Channel annotations appear in EGM strips for episode records.

Table 33 provides a list of Decision Channel annotations. If an annotation is different for an episode record than it is for a real-time recording, the two cases are separated by a “/” symbol. Figure 80 shows these annotations on a real-time recording.

Table 33. Decision Channel annotations

<table>
<thead>
<tr>
<th>Situation</th>
<th>Episode record/real-time recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF detected or redetected</td>
<td>VF</td>
</tr>
<tr>
<td>FVT detected or redetected</td>
<td>FVT</td>
</tr>
<tr>
<td>VT detected or redetected</td>
<td>VT</td>
</tr>
<tr>
<td>VF+SVT double tachycardia detected</td>
<td>VF+SVT</td>
</tr>
<tr>
<td>FVT+SVT double tachycardia detected</td>
<td>FVT+SVT</td>
</tr>
<tr>
<td>VT+SVT double tachycardia detected</td>
<td>VT+SVT</td>
</tr>
<tr>
<td>High rate timeout</td>
<td>HT/High Rate Timeout</td>
</tr>
<tr>
<td>VT Monitor detection</td>
<td>VTM/VT Monitor</td>
</tr>
<tr>
<td>VT Monitor+SVT double tachycardia detection</td>
<td>VTM+SVT/VT Monitor+SVT</td>
</tr>
<tr>
<td>Stability Criterion resets VT Initial Beats</td>
<td>Reset: Stability</td>
</tr>
<tr>
<td>Onset criterion withholds detection</td>
<td>Reset: Onset</td>
</tr>
<tr>
<td>AFib/AFlutter rule withholds detection(^a)</td>
<td>AF</td>
</tr>
<tr>
<td>Sinus Tach rule withholds detection(^a)</td>
<td>ST</td>
</tr>
<tr>
<td>Other 1:1 SVTs rule withholds detection(^a)</td>
<td>SV</td>
</tr>
<tr>
<td>Wavelet Rejection rule withholds detection(^b)</td>
<td>WV</td>
</tr>
<tr>
<td>A PR Logic criterion is active, but the detection criterion is no longer met, or a PR Logic criterion becomes inactive.</td>
<td>none/--</td>
</tr>
</tbody>
</table>

\(^a\)PR Logic criteria apply to AT and DR devices.
\(^b\)The Wavelet Rejection rule applies only to VR devices.
Figure 80. Decision Channel annotations on a real-time recording

1 Sinus Tach SVT detection criterion is active.
2 VT is detected.

Note: PR Logic criteria apply to AT and DR devices.

PR Logic criteria annotations – PR Logic criteria annotations (AF, ST, and SV) are displayed if both of the following conditions apply:

- Either the VT Initial Beats to Detect or the VF Initial Beats to Detect detection criterion is met.
- A PR Logic criterion determines whether VT/VF detection occurs or is withheld.

These annotations are displayed differently on the real-time recording than they are in the stored episode record data.

- On the real-time recording, PR Logic criteria annotations are printed when one of the following situations occur:
  - VT/VF detection is first withheld by a criterion.
  - Real-time recording is initiated when a criterion is already withholding VT/VF detection.
  - A criterion that is currently withholding VT/VF detection changes.
- In the stored episode record, PR Logic criteria annotations are recorded and displayed under every event during which a rule is active.

If more than one PR Logic criterion is withholding detection, only annotations for the highest priority criteria are printed. The order of priority from highest to lowest is AFib/AFlutter, Sinus Tach, Other 1:1 SVTs.
9.8 Recording live waveform strips

At any time during a patient session, you can record a continuous, live strip of the patient’s ECG and EGM\textsuperscript{27} from the programmer strip chart recorder.

\textbf{Note:} Because the printed waveform strip provides a higher resolution, it may show artifacts and events that do not appear on the programmer display.

A printout of the live ECG includes the following items:

- ECG and EGM traces
- an indication of an executed command when confirmation of the command is received
- test values during system tests
- telemetry markers that show active transmissions between the device and the programmer
- Decision Channel annotations

Figure 81 shows how these items appear on a typical live waveform strip.

\textsuperscript{27} The programmer cannot display or record an EGM trace until the device has been interrogated.
9.8.1 Printing a report while recording a live waveform strip

If you select an option from the Print menu while recording a live strip, the report goes to the print queue. Alternatively, if you start recording a live strip while the programmer is printing a report, the report stops printing and is sent to wait in the print queue.

Note: This interruption to printing applies only to reports printed on the programmer strip chart recorder. Printing to a full-size printer is not affected.

9.8.2 Automatic programming attempts

If telemetry between the programmer and device is not successful, the programmer automatically attempts to establish telemetry up to 2 times. This may result in multiple sets of programming and confirmation indicators being recorded.
9.8.3 EGM and Marker Channel telemetry

The programmer cannot display or record an EGM trace until the current EGM Range setting has been interrogated from the device.

If you program an EGM Range setting during a recording, the programmer marks the change with a vertical dotted line on the paper recording and annotates it with the new gain setting.

9.9 Freezing and analyzing a waveform strip

The Freeze feature enables you to “freeze” the last 15 s of all waveform traces that show in the expanded Live Rhythm Monitor window. Selecting the [Freeze] button at the top of the tool palette captures the previous 15 s of the trace signals and opens the frozen strip viewing window.

You can use controls in the frozen strip viewing window to perform the following functions:

- View earlier or later portions of the strip by scrolling horizontally.
- See waveform traces not visible in the window by scrolling vertically.
- Measure a time interval by defining the interval with on-screen calipers.

Figure 82 shows the viewing window for a frozen waveform strip.
**Figure 82. The viewer for a frozen waveform strip**

1. **[Freeze] button**: freezes a strip and displays it in the strip viewer.
2. **[Adjust…] button**: opens the Adjust… window for the strip viewer.
3. **Adjust… window**: offers display options for the strip viewer, which is similar to the Adjust… window for the Live Rhythm Monitor (see Section 9.7.3).
4. **Button bar**: allows you to normalize the trace, resize the trace, and change the source being displayed (see Section 9.7.2).
5. **On-screen calipers**: define time intervals to measure.
6. **Arrow buttons**: move the on-screen calipers to show the beginning and end of a time interval.
7. **Calipers measurement**: the interval between the calipers.
8. **[Strips…] button**: opens a list of other frozen strips (see Section 9.10.1).
9. **[Save] button**: saves the frozen strip being viewed.
10. **[Delete] button**: deletes the frozen strip being viewed (if it was saved).
11. **[Print…] button**: prints the frozen strip being viewed.
12. **[Close] button**: closes the frozen strip viewing window.

### 9.10 Recalling and viewing waveform strips

Before ending the patient session, you can recall and view any waveform strip collected and saved during the session. For example, threshold tests collect and save strips automatically.
9.10.1 How to view a previously collected strip

1. Select the [Strips…] button in the tool palette (or the [Strips…] button in the strip viewer).
2. Select a strip to view.
3. Select [Open]. The strip viewer displays the selected strip (see Figure 82).

9.11 Saving and retrieving device data

The programmer allows you to save interrogated data to a diskette. Later, while no patient session is in progress, you can use the Read From Disk Application on the programmer to retrieve and view data saved on the diskette.

9.11.1 Saving device data to a diskette

Review the following information before saving data to a disk:

**Emergency functions while saving** – During the save operation, the [Emergency] button remains displayed, and all Emergency functions are available. If a disk error occurs during a save, there may be a delay in initiating the Emergency screens.
Therefore, it is suggested that you not save to disk during EP studies or when it is possible that Emergency functions will be needed immediately.

**Interrogate first** – Make sure to interrogate the device before saving data to a diskette because the programmer saves only the data it has interrogated. If you wish to save all of the information from the device, select the All option from the interrogation window.

### 9.11.1.1 Diskette requirements

The diskette you use for saving data from the programmer must satisfy these requirements:

- It must be a formatted, IBM-compatible, 3.5-inch diskette.
- Its capacity must be 720 KB (DS, DD) or 1.44 MB (DS, HD).

If you save data to a diskette that is corrupt or is not IBM-formatted, the programmer may become unresponsive. If this occurs, remove the diskette, and turn the programmer off and then on again. Normal operation should resume. Please inform your Medtronic representative of this occurrence.

### 9.11.1.2 Data file names

Saved files are automatically named with a file name representing the date and time the file was saved. The file name takes the following form DDHHMMSS.PDD:

- DD represents the day of the month (01 to 31).
- HH represents hours (24 hour clock).
- MM represents minutes.
- SS represents seconds.
- PDD is the extension for the programmer data file.
9.11.2 How to save device data to a disk

1. Interrogate the device.
2. Select Session > Save to Disk….
3. Insert a diskette into the programmer floppy disk drive.
4. Select [Save].

**Note:** You also have the option to Save to Disk when you select [End Session…].

9.11.3 Reading device data from a diskette

After the programmer has read data that was saved during a patient session, it presents the information in a read-only view similar to the way it presents “live” information during a patient session. In this read-only mode, the programmer enables you to view the saved data, print reports, and display all programmed parameter values. You cannot program the device or perform tests on the device when reading data from a diskette.

**Warning:** The Read From Disk Application is designed only for viewing saved data while no patient session is in progress. You cannot program a device or deliver Emergency therapies from the Read From Disk Application.
9.11.4 How to read device data from a disk

1. Insert a diskette that contains information saved during a patient session.
2. From the Select Model screen, select Tachyarrhythmia devices.
3. Select EnTrust - Read From Disk.
4. Select [Start].
5. Select [OK] from the warning message.
6. Select [Open File…].
7. Select the data record that displays the desired device serial number, date, and time.
8. Select [Open File]. The read-from-disk screen displays information from the saved session. See Figure 83.

Figure 83 shows a typical screen in a read-from-disk session, and it compares screens in read-from-disk sessions with screens in patient sessions.

**Figure 83.** Quick Look screen in a read-from-disk session

1. The status bar displays the device serial number.
2. The status bar displays time and date information from the data file.
3. No Live Rhythm Monitor is displayed.
4. Each icon contains a diskette, indicating a read-from-disk session.

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### 9.12 Printing reports

This section describes how to print reports and how to use the Print Queue. Before you start printing reports, you should understand how to set Printing preferences and Initial Reports preferences. They control how reports are printed.
9.12.1 Printing preferences

Printing preferences determine the settings for print options and allow you to print reports without seeing the Print Options window each time.

By setting Printing preferences, you can select the number of copies, the default printer, and whether to print now or later. You can also choose to apply these preferences automatically when you select the [Print…] button. If you select the [Pop up these options when any Print button is selected] checkbox, a Print Options window is displayed each time you select the [Print…] button.

For more information about setting up an external full-size printer, see the *Medtronic CareLink Model 2090 Programmer Reference Guide*.

9.12.2 How to set Printing preferences

1. After starting a patient session, select Session > Preferences….
2. From the Index selection box, select the Printing option.
3. Set the printing preferences as desired.
4. Select [OK].
9.12.3 Initial Reports preferences

Initial Reports preferences select whether the Initial Interrogation Report is printed automatically after the first interrogation in a patient session. The Quick Look Report is always part of the Initial Interrogation Report, and you can select a number of other reports. The setting for automatic printing remains the same in the next patient session.

Note: If you need an Initial Interrogation Report for the current patient session, you must enable its automatic printing preference and restart the patient session to have one printed.

9.12.4 How to set Initial Reports preferences

1. After starting a patient session, select Session > Preferences….
2. From the Index selection box, select the Initial Report option.
3. Set whether Initial Interrogation Reports will be printed. Printing occurs at the beginning of a patient session (after the device is interrogated).
4. Select the individual reports to include in the Initial Interrogation Report.
5. Select [OK].
6. To print an Initial Interrogation Report for the current patient, end the session and start a new session.
9.12.5 Types of reports

You can use the following methods to print reports at any time during a patient session:

- Select [Available Reports…] from the Reports icon to open a window where the reports are listed.
- Select [Print…] from individual programmer screens. Refer to Section 9.12.7, “How to print a report from a programmer screen”, page 320.
- Select [Final Report…] from the Reports icon. This option prints the Session Summary Report which is also available from the Available Reports window.

**Note:** A report can be printed only if its data has been collected. If there is missing data, the name of the report appears gray.
9.12.6 How to print from the Available Reports window

1. To print a report, select Reports > Available Reports.…
2. Use the check boxes to select the desired reports.
3. If present, select [Print Options…]. Otherwise, continue with Step 9.
4. Select the Number of Copies.
5. Select the Printer. The default printer is determined by the Printing Preferences.
6. To print to the strip printer, select Programmer.
7. To print to a connected full-size printer, select Full Size and select a print driver.

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28 The Printing Preferences control whether the [Print Options…] button appears.
8. Select [OK].
9. Select [Print Now] for immediate printing, or select [Print Later] to add the print request to the print queue.

9.12.7 How to print a report from a programmer screen

1. To print a report, select [Print...] on the programmer screen.
2. If the Print - Options window is not displayed, the print request is printed immediately or added to the print queue.²⁹

²⁹ The Printing Preferences control whether the Print - Options window appears.
3. If the Print - Options window is displayed, continue with the remaining steps.
4. Select the Number of Copies.
5. Select the Printer. The default printer is determined by the Printing Preferences.
6. To print to the strip printer, select Programmer.
7. To print to a connected full-size printer, select Full Size and select a print driver.
8. Select [Print Now] for immediate printing, or select [Print Later] to add the print request to the print queue.

9.12.8 Print Queue

When printing, if you select [Print Later], the print job is held in the print queue. Select the Reports icon to display the Print Queue window. From this window, you can check the status of print jobs from only the current patient session. You can print or delete a print job from the queue. A report cannot be deleted if its status is “printing” or “waiting”.

Note: When you end a patient session, the print queue is still available. It lists any reports held from that session and other previous sessions.

Figure 84 shows the Print Queue window as it appears during a patient session. At the start of a session, the Print Queue is empty because it lists only reports requested in the current session.
The Print Queue Status column lists the print status for each report to be printed by the programmer:

- **Printing**: Indicates that a report is currently printing.
- **Deleting**: Indicates that a report is currently being deleted (after the [Delete] button was selected).
- **Waiting**: Indicates that a report is waiting for another report to finish printing.
- **Hold-Later**: Indicates that a report is on hold until you request that it be printed (using the [Print] button). A Hold-Later status could also mean that a report was interrupted by the start of a recording or the printer is not operational (because it is out of paper, for example).
- **Done**: Indicates that a report has been printed. Up to 25 of the most recently completed print jobs are listed.
10 Setting up and viewing collected data

10.1 A summary of data collection

The device collects and stores various types of data and provides a range of diagnostic tools to manage patient care. The following information summarizes the data and diagnostic tools, which are described in detail in the rest of the chapter.

Note: AT/AF episode data is available only in AT and DR devices. AT/AF treated episode data is available only in AT devices.

Quick Look – Summarizes patient and system information collected since the last session that may merit further investigation (see Section 10.3, “Viewing Quick Look data”, page 331).

Patient Alert events – Logs up to 10 Patient Alert events (see Section 10.4, “Using the Patient Alert feature”, page 335).

Clinical diagnostics – Includes information about the following types of data collection:

- Arrhythmia Episodes:
  - episode summary logs for Treated VT, FVT, VF, Monitored AT/AF, Treated AT/AF, SVT, VT Monitor, VT-NS, and patient symptom episodes
  - interval plot, EGM strip, episode text, and QRS data (QRS data available only in VR devices)

- Flashback Memory: a graphical report of collected interval and marker data prior to the most recent occurrences of interrogation, VF episodes, VT episodes, and, for AT and DR devices only, AT/AF episodes (see Section 10.6, “Viewing Flashback Memory data”, page 354).

- Cardiac Compass Trends (Report Only): a graphical report showing up to 14 months of treated ventricular episodes and shocks, heart rate, percentage of pacing, and patient activity (see Section 10.7, “Using Cardiac Compass to view long-term clinical trends”, page 356).

- Rate Histograms (Report Only): a graphical report showing heart rate ranges since the last session and prior to the last session (see Section 10.8, “Using Rate Histograms reports”, page 363).

- Counters:
  - episode counts for VF, FVT, VT, VT Monitor, AT/AF (AT and DR devices only), SVTs, and VT-NS episodes
  - data about delivered, aborted, successful, and unsuccessful therapy
  - VRS pacing and PVC counters
  - VT/VF therapy summary counters prior to the last session, since the last session, and for the lifetime of the device, and therapy efficacy counters since the last session
- AT/AF therapy summary (AT devices only), including therapies delivered and percent of termination since the last session
- AT/AF summary data counters such as percentage of time in AT/AF and the average number of episodes per day prior to the last session and since the last session and AT/AF durations and AT/AF start times counters since the last session

Device/Lead diagnostics – Includes information about the following types of data collection:

- Battery and Lead Measurements: battery voltage, last capacitor formation, last charge, sensing integrity counter, Atrial Lead Position Check (AT devices only), lead impedance, sensing measurements, and last high-voltage therapy (see Section 10.10, “Viewing Battery and Lead Measurement data”, page 374)
- Lead Performance Trends: lead impedance and sensing graphs for up to 80 weeks and the last 14 days (see Section 10.11.1, “How to view Lead Performance Trends graphs”, page 379, for the different methods that can be used to access this data)

10.2 Setting up data collection

Although data collection is automatic, some parameters related to data collection are programmable. The device allows you to do the following tasks:

- Select the EGM source and amplifier range.
- Specify EGM storage prior to onset.
- Set the device date and time.
- Enable the Holter Telemetry feature.

10.2.1 Parameters

<table>
<thead>
<tr>
<th>EGM Source – Electrodes between which the device records the EGM signal for each EGM channel.</th>
<th>EGM 1 (A or RV) AT &amp; DR devices</th>
<th>EGM 2 (RV) AT &amp; DR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can to HVB</td>
<td>Can to HVB</td>
<td>Can to HVB</td>
</tr>
<tr>
<td>Can to Vring</td>
<td>Can to Vring</td>
<td>Vtip to HVB</td>
</tr>
<tr>
<td>Can to Aring</td>
<td>Vtip to Vring&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Vtip to Vring&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vtip to HVB</td>
<td>Vtip to Vring&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Can to SVC&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vtip to Vring</td>
<td>Atip to Vring</td>
<td>HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Atip to Vring</td>
<td>Atip to Aring&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Atip to Aring&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Aring to Vring</td>
<td></td>
</tr>
<tr>
<td>Aring to Vring</td>
<td>Aring to HVB</td>
<td></td>
</tr>
<tr>
<td>Aring to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Aring to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Can to SVC&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>Can to SVC&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>EGM 1 (RV) VR devices</td>
<td>EGM 2 (RV) VR devices</td>
<td></td>
</tr>
<tr>
<td>Can to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Aring to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>
EGM Range – EGM amplifier signal range. Smaller settings result in higher resolution telemetered and stored EGM waveforms.

Pre-arrhythmia EGM – Specifies EGM storage prior to the start of an episode for a period of time.

Device Date/Time – Sets the date and time of the device internal clock.

Holter Telemetry – Transmits EGM and Marker Channel data continuously for a selectable number of hours, regardless of whether the programming head is positioned over the device.

10.2.2 Considerations

Review these programming considerations before programming data collection parameters.

Effect on device longevity – Using certain EGM storage features decreases the longevity of the device. To maximize longevity, disable Pre-arrhythmia EGM, or limit the time it is enabled. Using the Holter Telemetry also decreases the longevity of the device.
10.2.3 How to set up data collection

1. Select the Params icon.
2. Select Data Collection Setup… from the Parameters screen.
3. Select the EGM Source, EGM Range, Pre-arrhythmia EGM, and Holter Telemetry parameters.
4. Select the Device Date/Time....
5. Use the up and down arrow buttons to select hour, minute, and date settings. Use 24-hour notation (midnight is 00:00; noon is 12:00).
6. Return to the Parameters screen and select [PROGRAM].

10.2.4  Details about data collection parameters

10.2.4.1  EGM source

The device has 2 programmable EGM channels (EGM 1 and EGM 2) that define the lead pathways used for real-time (telemetered) and stored EGM.

- EGM 1 and EGM 2 channels are displayed in real-time and are always on.
- EGM 1 storage is available for atrial (AT and DR devices only) or ventricular lead and high-voltage pathways.
- EGM 2 storage is available only for ventricular and high-voltage pathways.

Note: The cardiac interval measurements of the device are always based on the signals sensed through the tip and ring electrodes of the implanted leads. Therefore, tachyarrhythmia interval criteria, synchronization, and therapy are not affected by your selection of EGM sources. See Table 34 for the EGM source options available for AT and DR devices. See Table 35 for the EGM source options available for VR devices.

Table 34. EGM source options: AT and DR devices

<table>
<thead>
<tr>
<th></th>
<th>EGM 1</th>
<th>EGM 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near-Field</td>
<td>Atip to Aring(\dagger)</td>
<td>Vtip to Vring(\dagger)</td>
</tr>
<tr>
<td></td>
<td>Vtip to Vring</td>
<td></td>
</tr>
<tr>
<td>Far-Field</td>
<td>Can to HVB(\text{a})</td>
<td>Can to HVB(\text{a})</td>
</tr>
<tr>
<td></td>
<td>Can to Vring</td>
<td>Can to Vring</td>
</tr>
<tr>
<td></td>
<td>Can to Aring</td>
<td>Vtip to HVB(\text{a, b})</td>
</tr>
<tr>
<td></td>
<td>Vtip to HVB(\text{a, b})</td>
<td>Can to SVC(\text{c})</td>
</tr>
<tr>
<td></td>
<td>Atip to Vring</td>
<td>HVB to SVC(\text{c})</td>
</tr>
<tr>
<td></td>
<td>Aring to Vring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aring to HVB(\text{a})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aring to SVC(\text{c})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HVB to SVC(\text{c})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can to SVC(\text{c})</td>
<td></td>
</tr>
</tbody>
</table>

\(\text{a}\) HVB indicates high-voltage coil.

\(\text{b}\) Far-field if using a true bipolar lead, near-field if using an integrated bipolar lead.

\(\text{c}\) A lead must be connected to the SVC port for this configuration.
Table 35. EGM source options: VR devices

<table>
<thead>
<tr>
<th>Near-Field</th>
<th>EGM 1</th>
<th>EGM 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vtip to Vring</td>
<td>Vtip to Vring</td>
<td></td>
</tr>
<tr>
<td>Can to Vring</td>
<td>Can to Vring</td>
<td></td>
</tr>
<tr>
<td>Vtip to HVB</td>
<td>Vtip to HVB</td>
<td></td>
</tr>
<tr>
<td>HVB to SVC</td>
<td>Can to SVC</td>
<td></td>
</tr>
<tr>
<td>Can to SVC</td>
<td>HVB to SVC</td>
<td></td>
</tr>
</tbody>
</table>

**a** HVB indicates high-voltage coil.

**b** Far-field if using a true bipolar lead, near-field if using an integrated bipolar lead.

**c** A lead must be connected to the SVC port for this configuration.

**Leadless ECG signal** – If a supplementary high-voltage electrode is placed in the SVC, the device provides the Leadless ECG signal through either the Can to SVC or the HVB to SVC EGM source. The Can to SVC EGM source is recommended to provide the most atrial and ventricular data in AT and DR devices, and ventricular and QRS data in VR devices.

This EGM source approximates an ECG signal, displaying both P- and R-waves. See Figure 85 for an example of the Leadless ECG in AT and DR devices. In VR devices, the atrial sensing markers and Atip to Aring EGM are not displayed.

**Figure 85.** An example of Leadless ECG (CAN-SVC EGM) during a short run of VT

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**10.2.4.2 Device clock**

The device uses an internal clock, separate from the programmer clock, to mark the date and time of significant events throughout the life of the device. It stores these date and time stamps in memory along with other event data. The device clock should be set during the implant procedure and when the patient changes time zones for a length of time.
For devices that are capable of delivering atrial therapies, the device clock is used to schedule atrial cardioversion therapies during specific times of the day or night to minimize patient discomfort. The scheduled hours when atrial cardioversion may occur is based on the device clock hours.

### 10.2.4.3 Holter Telemetry

The Holter Telemetry feature transmits EGM and Marker Channel data continuously for a selectable number of hours, regardless of whether the programming head is positioned over the device. The EGM and Marker Channel data that is transmitted using Holter Telemetry is not stored in device memory. Additional equipment is required to record the data. Please contact your Medtronic representative for more information about the use of the Holter Telemetry feature.
10.2.5 How to clear collected data

1. Select the Params icon.
2. Select Data Collection Setup ....
3. Select [Clear Data...].
4. Select [Clear Data] to clear data in the device and the programmer memory and to reset the Last Session date.
Selecting [Clear Data] does not clear device trends, Cardiac Compass trends, and lifetime counters. Cleared information includes counters, episode records, histograms, Flashback Memory, and Patient Alert event log.

Generally, clearing collected data is not suggested.

10.3 Viewing Quick Look data

The Quick Look screen provides a summary of the episode data, device and lead status information, programmed bradycardia pacing parameters, conduction status, and device observations since the last patient session.

The Quick Look screen is automatically displayed after the application is started. To update Quick Look data during a session, reinterrogate the device, and select Quick Look from the Data icon.

The observations section of the Quick Look screen highlights significant device status events, lead status events, Patient Alert events, parameter programming, diagnostic data, and clinical status data.
10.3.1 How to use Quick Look

1. Select Data > Quick Look.
2. Select the Treated [>>] button to view data for treated arrhythmia episodes.
3. Select the Monitored [>>] button to view data for monitored arrhythmia episodes.
4. Highlight a specific observation. If available, select the Observations [>>] button to quickly view related information.
5. Select the Lead [>>] button to view lead performance trends.
10.3.2 Details about Quick Look

10.3.2.1 Percentage of Time section, AT and DR devices

If the device is programmed to a dual chamber mode, the Percentage of Time section reports the patient’s atrial and ventricular pacing and sensing as the percentage of the total time during the reporting period. This data is reported using the AS-VS, AS-VP, AP-VS, and AP-VP event sequence categories. If the device is programmed to a single chamber mode, this section reports the patient’s pacing and sensing as the percentage of the total time during the reporting period.

The Percentage of Time section of the Quick Look screen also reports if the device is programmed to a Managed Ventricular Pacing (MVP) mode. If the present programmed pacing mode is AAIR<=>DDDR or AAII<=>DDD, the message “MVP On” appears on the Quick Look screen. Otherwise, the screen displays “MVP Off”.

If the device is programmed to an MVP mode during the reporting period, a high percentage of ventricular pacing may indicate that the patient has heart block.

The Percentage of Time section of the Quick Look screen also reports the percentage of the total time the patient was experiencing AT/AF during the reporting period.

Notes:
• The paced and sensed event counters do not count refractory senses, VRS pacing pulses, events immediately preceded by Charge End, or events occurring during a detected tachyarrhythmia episode. Due to rounding, percentages may not add up to 100%.
• The Percentage of Time section of the Quick Look screen reports on the current usage of the MVP mode settings for the pacing mode, not the usage of the MVP mode settings since the last session.

10.3.2.2 Percentage of Time section, VR devices

In VR devices, the Percentage of Time section reports the patient’s ventricular pacing and sensing as the percentage of the total time during the reporting period.

Note: The paced and sensed event counters do not count refractory senses, VRS pacing pulses, events immediately preceded by Charge End, or events occurring during a detected tachyarrhythmia episode. Due to rounding, percentages may not add up to 100%.

30 MVP modes (AAIR<=>DDDR and AAII<=>DDD) are considered dual chamber modes for this purpose.
31 AT/AF is defined as when atrial onset criteria are met.
10.3.2.3 Quick Look observations

Observations that are provided by Quick Look are based on an analysis of interrogated data since the last session and programmed parameters. The following types of observations are provided: device status, lead status, Patient Alert, parameter, and diagnostic and clinical status data.

**Device status observations** – The following are examples of device status observations:
- active Device Status Indicators (such as electrical reset, Charge Circuit Inactive, or Charge Circuit Timeout)
- replacement indicator warnings (ERI and EOL)
- atrial therapies disabled

**Lead status observations** – The following are examples of lead status observations include the following types of observations:
- pacing lead impedance of greater than 3000 Ω or less than 200 Ω (each lead)
- high-voltage lead impedance of greater than 200 Ω or less than 20 Ω (each lead)
- sensing integrity counter exceeds 300 counts
- Atrial Lead Position Check failed

**Patient Alert observations** – The following are examples of Patient Alert observations include the following types of observations:
- programmable and non-programmable Patient Alert conditions have been met
- invalid Patient Alert data

**Parameter observations** – The following are examples of parameter observations:
- cautionary messages about the programmed detection and therapy configuration
- cautionary messages about the programmed parameters
- pending parameter values exist
- invalid parameter values exist

**Diagnostic data observations** – The following are examples of diagnostic and clinical status data observations include the following types of observations:
- monitored episodes
- number of VT/VF shocks and failed VT/VF shocks
- number of AT/AF shocks and failed AT/AF shocks (AT devices only)
- For programmed VT/VF detection zones, the following types of episodes are listed:
  - episodes with unsuccessful therapies, in which more than one therapy was attempted
  - episodes longer than 30 seconds
  - episodes that accelerated to VF
  - episodes where High Rate Timeout occurred
  - episodes with VT/VF detected during AT/AF (AT and DR devices only)
  -VF ATP Charging reprogrammed
• invalid arrhythmia, histogram, and long-term clinical trends data
• Patient Check episodes during an arrhythmia
• If more than one episode has occurred for a particular type, the Episode Data Observations section highlights the most recent episode and the total number of episodes of that type.

Clinical status observations – The following are examples of clinical status observations include the following types of observations:
• high night heart rate
• low patient activity
• fast ventricular rate during AF (AT and DR devices only)
• time in AT/AF is more than 6 hours per day (AT and DR devices only)

10.4 Using the Patient Alert feature

The Patient Alert monitoring feature is designed to alert the patient if his or her implanted device meets certain preprogrammed status conditions. The patient should be instructed to notify his or her physician if an alert sounds. The alerts are programmed to sound at a specific time of the day when the patient or a companion will hear them.

There are 3 types of alerts:
• High urgency alerts emit a dual, high-low tone for 10 s.
• Low urgency alerts emit an intermittent on-off tone for 10 s.
• Test alerts emit a steady tone for 10 s when the Patient Magnet or programming head is applied to the device to verify that the device alerts are operational and that no alert conditions are met.

Select [Demonstrate Tones…] from the Patient Alert Setup screen to listen to the various alert tones.

High urgency alerts are always on, while others can be set to use either high or low alert tones or programmed completely off. High urgency alerts indicate there is a serious problem with the device that needs immediate attention.

10.4.1 Parameters

<table>
<thead>
<tr>
<th>Alert Time</th>
<th>Time of day (24 hour clock) when Patient Alerts are programmed to respond. 00:00; 00:10 ... 08:00 ... 23:50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Impedance Out of Range</td>
<td>Reports that the daily impedance measurement is out of range, which could indicate a dislodged or improperly connected lead. This alert can be enabled for each lead.</td>
</tr>
<tr>
<td>Alert Urgency</td>
<td>Low; High</td>
</tr>
</tbody>
</table>

32 Refer to the Patient Magnet user manual for more information.
A. Pacing lead impedance (AT and DR devices only)
   On; Off
   Less than 200Ω; 300; 400; 500Ω
   Greater than 1000; 1500; 2000; 3000Ω

RV Pacing lead impedance
   On; Off
   Less than 200Ω; 300; 400; 500Ω
   Greater than 1000; 1500; 2000; 3000Ω

RV Defibrillation lead impedance
   On; Off
   Less than 20Ω; 30; 40; 50Ω
   Greater than 100; 130; 160; 200Ω

SVC (HVX) Defibrillation lead impedance
   On; Off
   Less than 20Ω; 30; 40; 50Ω
   Greater than 100; 130; 160; 200Ω

Low Battery Voltage ERI – Indicates that the daily automatic battery voltage measurement has been at or below the 2.61 V (the Elective Replacement Indicator voltage level) for 3 consecutive days.
   Alert Enable - Urgency Off; On-Low; On-High
   Battery Voltage Threshold 2.61 V (ERI) (fixed)

Excessive Charge Time EOL – Indicates that the charging period equals or exceeds the Charge Time Threshold.
   Alert Enable - Urgency Off; On-Low; On-High
   Charge Time Threshold 16 s (fixed)

Number of Shocks Delivered in an Episode – Indicates that the number of shocks delivered in a VT/VF episode is greater than or equal to the programmed Number of Shocks Threshold.a
   Alert Enable - Urgency Off; On-Low; On-High
   Number of Shocks Threshold 1; 2; 3; 4; 5; 6

All Therapies in a Zone Exhausted for an Episode – Indicates that a specific VT/FVT/VF episode was redetected after all programmed therapies for that type of episode were delivered.
   Alert Enable - Urgency Off; On-Low; On-High

VF Detection/Therapy Off – Indicates that 1 or more of the following has occurred for at least 6 hours since the last programming:
   • VF detection has been disabled.
   • Three or more VF therapies have been disabled.
   • FVT is enabled to via VF, and three or more FVT therapies have been disabled.
   This alert is enabled in the shipped device and sounds with a High urgency alert tone every 6 hours.b
   Alert Enable - Urgency Off; On-High

---
a Note that VF, VT, and FVT therapies could be delivered during a single episode (from initial detection until episode termination).
b This alert can be disabled if necessary. When the alert is enabled, it does not sound when a magnet is applied unless VF detection or 3 or more VF therapies are disabled.
Some Patient Alerts are not programmable. See Table 36 for information about the nonprogrammable Patient Alerts.

Table 36. Nonprogrammable Patient Alerts

<table>
<thead>
<tr>
<th>Alert Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical Reset</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Indicates that the device has been reset and may require reprogramming. The device immediately sounds a High urgency alert tone that repeats every 20 hours or every 9 hours, depending on the type of electrical reset.&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Pacing Mode DOO, VOO, or AOO</strong></td>
<td>Indicates that the DOO, VOO, or AOO pacing mode is enabled. The device sounds a High urgency alert tone daily at the programmed time.</td>
</tr>
<tr>
<td><strong>Active Can Off without SVC</strong></td>
<td>Indicates that the Active Can feature is disabled without an SVC lead in place. The device sounds a High urgency alert tone daily at the programmed time.</td>
</tr>
<tr>
<td><strong>Charge Circuit Timeout</strong></td>
<td>Indicates that a charging period has exceeded the maximum time allowed for circuit charging. The device immediately sounds a High urgency alert tone that repeats every 20 hours.</td>
</tr>
</tbody>
</table>

<sup>a</sup>Contact your Medtronic representative if the device has been reset.

<sup>b</sup>In some cases, an electrical reset may disable tachyarrhythmia detection and therapy. If this occurs, the electrical reset Patient Alert sounds every 9 hours, and the device operates as a simple bradycardia pacing device (in VVI mode, 65 bpm).

10.4.2 Considerations

Review the following information before programming the Patient Alert feature.

**Electrical Reset** – This alert indicates that the device has been electrically reset. Stored data is cleared, and programmable parameters may have changed to Reset settings. See Appendix B, “Device Parameters”, page 451, for reset values. For details about reset conditions, see Section 10.13, “Automatic device status monitoring”, page 383.

**Rate Response is suspended** – When the Patient Alert sounds, the Rate Response feature is suspended. Any pacing that occurred just before the alert sounds is maintained at the same rate.

**Low Battery Alert** – This alert is based only on the daily automatic voltage measurements performed by the device. Other voltage measurements do not trigger a Patient Alert.

**Multiple alerts** – If more than 1 alert condition has occurred, the most urgent alert is announced at the programmed alert time.

**Lead Impedance alerts** – These alerts are based on the automatic daily impedance measurements. Impedance measurements that are recorded during a manual test or high-voltage therapy do not trigger a Patient Alert.

All enabled lead impedance alerts are programmed to the same urgency.

For AT and DR devices, the atrial lead impedance alert can be enabled if the device is programmed to the VVI or VVIR bradycardia pacing mode.

A lead impedance alert can be triggered by a dislodged or improperly connected lead.
Condition at the time of alert – The alert condition does not need to be present when the alert is announced. The alert tone continues to announce each day at the programmed alert time until the device is interrogated.

Alert tone description – The alert tone is designed to be slightly louder than typical living room noise. The alert duration continues for several seconds, up to a maximum of 10 s.

Programming the Alert Time – The programmed Alert Time is based on the device internal clock. Select an Alert Time when the patient can clearly recognize the alert, taking into consideration the following patient factors:

- predictably quiet setting
- daily schedule, for example, medication routines
- hearing acuity
- presence or absence of companions

Alert frequency – Alerts are set to sound at specific intervals depending on the urgency of the alert condition.

Table 37. Alert frequency

<table>
<thead>
<tr>
<th>Alerts that sound Immediately</th>
<th>Alerts that sound every 6 hours</th>
<th>Alerts that sound daily at programmed time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge Circuit(^a) Timeout</td>
<td>VF Detection/Therapy Off</td>
<td>Pacing Lead Impedance</td>
</tr>
<tr>
<td>Electrical Reset(^b)</td>
<td></td>
<td>Defibrillation and SVC Lead Impedance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Battery Voltage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Excessive Charge Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of Shocks Delivered in an Episode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All Therapies in a Zone Exhausted for an Episode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active Can Off without SVC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pacing Mode DOO, VOO, or AOO</td>
</tr>
</tbody>
</table>

\(^a\) A Charge Circuit Timeout alert sounds immediately and then every 20 hours. Contact your Medtronic representative if this alert sounds.

\(^b\) An electrical reset alert sounds immediately and then every 20 hours. However, if the electrical reset disables tachyarrhythmia detection and therapy, the alert sounds every 9 hours. Contact your Medtronic representative if an electrical reset alert sounds.

Note: If a programmable Patient Alert is triggered so often that it loses its clinical value, adjust the alert threshold, improve therapy efficacy, or disable the alert.
10.4.3 How to program the Patient Alert feature

1. Select the Params icon.
2. Select Patient Alert… from the Parameters screen.
3. Select the alert enable button for the desired alert, and set the appropriate thresholds.
4. Select Alert Time… and set the time in 24-hour format.
5. Select [Demonstrate Tones...], and demonstrate the alert tones to the patient. If the patient cannot hear the tones, repeat the demonstration in a quieter environment.
6. Return to the Parameters screen and select [PROGRAM].

10.4.4 Instructing patients

Patients should understand the alert tones from the device and what to do if they hear them (see Table 38). Patients should be advised about the following information when alerts are programmed:

- Patients should be aware of the time of day the alerts will be announced and that the alert will be announced at the same time each day until the device is interrogated during an office visit.
- Patients should contact their physician immediately if they hear alert tones.
- The Alert Time does not adjust for time zone changes.
- The “Test” tone may announce if the device is near a strong electromagnetic field, such as a store theft detector. This indicates that the device operation is temporarily impaired and that the patient should move away from the interference source to restore normal operation.

Patients should understand what the Patient Magnet is used for and when to use it. Advise patients that when the Patient Magnet is placed over the device, any current alert conditions will be announced.

Demonstrate to patients how to place the Patient Magnet over the device to replay the alert tones, and review the Patient Magnet manual. Patients can use this manual as a folded reference card.

Table 38. Responding to Patient Alert tones

<table>
<thead>
<tr>
<th>Tones</th>
<th>Alert Status</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent on/off tone</td>
<td>Low urgency</td>
<td>Patient: Arrange follow-up. Clinician: Interrogate device and evaluate alert condition.</td>
</tr>
<tr>
<td>Steady tone</td>
<td>Test</td>
<td>No Patient Alert condition has occurred (sounds only when in the presence of a strong magnet).</td>
</tr>
</tbody>
</table>

Warning: Be sure patients understand that they must not carry, store, or leave the Patient Magnet positioned over their device.

33 For a description of this temporary state, see Section 1.5, “Magnet application”, page 19.
10.4.5 Viewing Patient Alert events

The device stores up to 10 Patient Alert events as log entries. To avoid redundant log entries, an entry is recorded only the first time each Patient Alert condition is met.

Each log entry includes the date and time of the alert event, a description of the alert event, and the measurement or information that caused the alert event (if applicable). The log is also annotated with the date of the last session.

Interrogating the device resets the audible alert tone but does not clear Patient Alert events from the log. You must manually clear the Patient Alert event log.

**Note:** The Patient Alert Events screen reports “Open Circuit” if an open circuit interferes with the automatic daily measurement. Check lead connections and lead integrity, and reconnect or replace leads as necessary. See Section 11.5, “Measuring lead impedance”, page 396.

10.4.6 How to view Patient Alert events

1. Select Data > Patient Alert Events.
2. To print the event log, select [Print…].
10.5 Viewing Arrhythmia Episode data

The Arrhythmia Episode data that is recorded by the device includes episode logs; episode records such as interval plots, EGM strips, text data, and QRS data (VR devices only); and Flashback Memory interval data. See Section 1.8, “Stored data and diagnostics”, page 21, for information about the number of episode logs stored, the amount of time episode records are stored, and the number of Flashback Memory intervals stored.
10.5.1 How to view episode data

1. Interrogate the device.
2. Select Data > Clinical Diagnostics.
3. Select Arrhythmia Episodes.
4. Select [Open Data].
5. Select the type of events to view (VT/VF, AT/AF, and SVT).

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6. Select the View fields to apply a filter to the episodes displayed in the episode log of the selected types.
7. Select an episode from the episode log. The shaded row indicates which episode is displayed.
8. Choose [Plot], [EGM], [Text], or [QRS] (available only for VR devices) to display more details.
9. Select Previous or Next to move to the previous or next episode in the episode log.
10. To print a report based on the displayed episode information, select [Print…].

10.5.2 How to view an Interval Plot

1. Select the type of events to view (VT/VF, AT/AF, and SVT).
2. Select an episode from the log. The shaded row indicates which episode is displayed.
3. Select [Plot].
4. Select interval or rate to adjust the plot display method.
5. Select the plots to display.
6. Compare the recorded intervals or rates to the programmed detection intervals or rates.
7. Use the maximize and minimize buttons to adjust the size of the display if desired.
8. Move the magnification window with the arrow buttons to select an area for the EGM Strip display.
9. Select [Print…] to print the displayed information.
10.5.3 How to view an EGM Strip

1. Select the type of events to view (VT/VF, AT/AF, and SVT).
2. Select an episode from the log; note the EGM column indicating if an EGM strip is available for that episode.
3. Select [EGM].
4. Use the maximize and minimize buttons to adjust the size of the display if desired.
5. For AT and DR devices, if the display is maximized, select the atrial interval display area to select an interval to display.

---

1. Select the type of events to view (VT/VF, AT/AF, and SVT).
2. Select an episode from the log; note the EGM column indicating if an EGM strip is available for that episode.
3. Select [EGM].
4. Use the maximize and minimize buttons to adjust the size of the display if desired.
5. For AT and DR devices, if the display is maximized, select the atrial interval display area to select an interval to display.
6. Scroll the display using the scroll bars.
7. Select [Print...] to print the displayed information.

10.5.4 How to display the episode text information

1. Select the type of events to view (VT/VF, AT/AF, and SVT).
2. Select an episode from the log. The shaded row indicates which episode is displayed.
3. Select [Text].
4. Use the maximize and minimize buttons to adjust the size of the display if desired.
5. Scroll the display using the scroll bar.
6. Select [Print...] to print the displayed information.
10.5.5 How to display the QRS data

1. Select the type of events to view (VT/VF and SVT).
2. Select an episode from the log with QRS data. The shaded row indicates which episode is displayed.
3. Select [QRS].
4. Use the maximize and minimize buttons to adjust the size of the display if desired.
5. Select [Print...] to print the displayed information.

10.5.6 Details about episode data

10.5.6.1 Episode log

See Section 1.8, “Stored data and diagnostics”, page 21, for the types of episodes stored and episode log storage capacities. For each type of episode, when the log capacity is filled, newly detected episode data overwrites the oldest episode data in the log. Use the scroll buttons on the right side of the log area to scroll through the list of stored episodes.

The episodes displayed in the episode log can be filtered to display only certain types of episodes. Select the check box next to “VT/VF”, “SVT”, or “AT/AF” (not available in VR devices) to display only the episodes of that type.
The View filter can be used to further filter the displayed episodes of the types selected ("VT/VF", "SVT", or "AT/AF") in the episode log. This feature can be used to display only episodes with specific characteristics that are longer than a specific amount of time. These characteristics include treated episodes, monitored episodes, episodes that include patient-activated episodes, and EGM availability. The time interval options for filtering by episode duration include seconds, minutes, and hours. For example, you can select EGM as a characteristic and select a one-minute time interval to display only episodes that have an available EGM and were longer than 1 min.

**Note:** If the type of event check boxes are not all selected, then the View All Selected Types selection of the View filter does not display all of the events in the episode log. For example, if only the check box for VT/VF is selected and All Selected Types is selected for the View filter, only the VT/VF episodes display in the episode log.

If a patient-activated episode is induced and no episode is in progress, a Symptom episode is included in the episode log. The episode log data for Symptom episodes include the date and time of the episode and the average atrial and ventricular cycle lengths (atrial cycle length is not available in VR devices). These episodes can only be viewed by selecting “Symptom” in the View filter. If a patient-activated episode is induced while an episode is in progress, the data of the episode in progress includes data about the activation; there is not a separate log for the patient-activated episode.

The data available in the episode log includes the following types of data:

- type of episode
- ATP Sequences delivered
- shocks delivered
- success of the last therapy delivered
- date and time of episode
- duration of episode
- average atrial and ventricular cycle lengths (atrial cycle length data is not available for VR devices)
- maximum ventricular cycle length
- EGM availability

The following are details about the episode data displayed in the episode log.

**Average atrial and ventricular cycle lengths (Avg bpm A/V)** – For AT/AF, VT Monitor, and VT-NS episodes, the average atrial and ventricular cycle length is the average cycle length throughout the entire episode. This helps determine if the ventricular rate is high. For VT/VF and SVT episodes, the average atrial and ventricular cycle length is the average of the 4 beats at detection or just prior to withholding detection. This helps determine the rate of the detected episode (therapy is based on the ventricular rate).
Maximum ventricular cycle length (Max V bpm) – If the ventricle was paced during an AT/AF episode, the maximum ventricular cycle length value appears in the log as “VP”. For VT-NS episodes, the maximum ventricular cycle length is not displayed.

10.5.6.2 Episode records

The episode record displays detailed information about the episode selected in the log. For a particular episode, you can display the episode record data in one of the following formats:

- an interval plot
- a strip chart of the stored EGM
- a text summary

Episode records for VR devices may also include QRS data. When the Wavelet criterion is programmed to On or Monitor, the device stores QRS data in the episode record. See Section 10.5.6.6, “QRS data (VR devices only)”, page 353.

Note: Episode data is not fully updated in device memory until the episode terminates.

Episode records are stored in the order the episodes occur, with new data overwriting the oldest data when the storage capacity is filled for each episode type.

Storing SVT and VT-NS episodes – SVT and VT-NS episodes are high-rate episodes that do not fulfill VF, VT, or FVT episode detection.

An SVT or VT-NS event is counted when the ventricular interval is less than the VT Interval, and the count resets to zero when an interval is greater than or equal to the VT Interval.

This counter differs from the VT event counter in that it advances for intervals in the VF and FVT zones and it does not reset for intervals rejected by the VT Stability or Onset criterion.

10.5.6.3 Interval Plot

When you first select an episode from an episode log, the programmer displays a graph that plots the V-V and A-A intervals versus time and indicates the following information:

- programmed detection intervals
- point of detection or detection withheld
- point of onset for AT/AF
- point of first therapy delivery

Note: A-A intervals are plotted and the point of AT/AF onset is shown only in AT and DR devices.

---

34 VT Monitor Interval and VT Monitor Initial Beats to Detect criterion, if VT detection is disabled.
The y-axis of plot graphs is selectable to display either the intervals (ms) or rates (bpm). The time value for each interval is plotted in seconds along the x-axis. Zero on the x-axis marks different points in the episode depending on the type of episode you are viewing.

**Note:** If the device truncates data storage during an episode, the interval plot displays time labels that follow the truncation as asterisks for VT/VF episodes. See Section 10.5.6.4, “EGM Strip”, page 350.

**10.5.6.4 EGM Strip**

When the VT, VT Monitor, or VF interval count reaches 3, the device starts storing EGM data. If Pre-arrhythmia EGM storage is enabled, the device stores up to 10 s of EGM data prior to onset and detection of the VT/VF, VT Monitor, or SVT episode. If Pre-arrhythmia EGM storage is disabled, the device stores only interval data prior to the onset of the ventricular episode.

When the device detects AT/AF Onset, it starts storing EGM data. For Treated or Monitored AT/AF episodes (available only in AT and DR devices), the device stores up to 5 s of EGM data prior to detection, regardless of whether Pre-arrhythmia EGM storage is enabled or disabled.

To conserve device memory, the EGM is stored only during specific parts of an episode. See Table 39 for information about EGM storage for different episode types.

**Table 39. EGM storage durations**

<table>
<thead>
<tr>
<th>Episode type</th>
<th>Length of episode storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT/FVT/VF</td>
<td>Prior to detection: 10 s maximum</td>
</tr>
<tr>
<td></td>
<td>After detection and each therapy: 2.5 s</td>
</tr>
<tr>
<td></td>
<td>Prior to the next therapy or termination: 10 s</td>
</tr>
<tr>
<td></td>
<td><strong>Total VT/VF EGM storage:</strong> 2 min</td>
</tr>
<tr>
<td>VT Monitor</td>
<td>Prior to detection: 10 s maximum</td>
</tr>
<tr>
<td></td>
<td>Prior to termination: 5 s^a</td>
</tr>
<tr>
<td></td>
<td><strong>Total VT Monitor EGM storage:</strong> 15 s</td>
</tr>
<tr>
<td>SVT</td>
<td>Prior to withholding detection: 10 s maximum</td>
</tr>
<tr>
<td></td>
<td>Prior to termination: 5 s</td>
</tr>
<tr>
<td></td>
<td><strong>Total SVT EGM storage:</strong> 15 s</td>
</tr>
<tr>
<td>VT-NS</td>
<td>Prior to termination: 10 s maximum^b</td>
</tr>
</tbody>
</table>

---

^a^ This is applicable only when Pre-arrhythmia EGM storage is disabled.

^b^ This is applicable only when Pre-arrhythmia EGM storage is enabled.
Table 39. EGM storage durations (continued)

<table>
<thead>
<tr>
<th>Episode type</th>
<th>Length of episode storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated AT/AF (AT devices only)</td>
<td>Prior to detection(^c): 5 s maximum</td>
</tr>
<tr>
<td></td>
<td>Prior to start of therapy: 2.5 s maximum</td>
</tr>
<tr>
<td></td>
<td>After start of therapy: 5 s</td>
</tr>
<tr>
<td></td>
<td>Prior to termination: 10 s</td>
</tr>
<tr>
<td>Total Treated AT/AF EGM storage:</td>
<td>22.5 s maximum</td>
</tr>
<tr>
<td>Monitored AT/AF (AT and DR devices only)</td>
<td>Prior to detection(^c): 5 s maximum</td>
</tr>
<tr>
<td></td>
<td>Prior to termination: 10 s</td>
</tr>
<tr>
<td>Total Monitored AT/AF EGM storage:</td>
<td>15 s maximum</td>
</tr>
</tbody>
</table>

\(^a\) If Pre-arrhythmia EGM storage is disabled, EGM storage stops after 30 min.

\(^b\) If less than 10 s were stored prior to termination, additional data is stored after termination until a total of 10 s has been stored.

\(^c\) Prior to AT/AF Onset, the device stores 60 sets of intervals and marker data. EGM prior to AT/AF Onset is not stored.

**Note:** To view all of the EGM strip data, use the scroll bar on the bottom of the screen.

**Atrial interval display options** – The EGM Strip screen provides three options for displaying atrial intervals in AT and DR devices. These include A-A intervals, AV intervals, and VA intervals. The EGM display must be maximized to select the atrial interval display options.

**Decision Channel annotations** – Decision Channel annotations appear below the ventricular intervals as appropriate when the maximize button is used to adjust the size of the display (see Figure 86).
Annotations for detection criteria applied during the episode.

EGM Strip memory – The device automatically performs as follows to conserve storage space for EGM information:

- The device truncates EGM storage for single, unusually long episodes.
- The device records only up to 12.5 s of EGM between therapy deliveries, or between the last therapy delivery and episode termination, for VT/FVT/VF episodes. If more than 12.5 s lapse between therapy deliveries or therapy delivery and termination of the episode, the EGM recording is suspended. The amount of time the EGM was suspended is displayed (see Figure 87). The maximum amount of episode storage for VT/FVT/VF episodes is 2 min.
- The device records only up to the most recent 2.5 s of data since the detection criteria were met prior to the start of therapy delivery for Treated AT/AF episodes. The device continues to save data for an additional 5 s after the start of therapy delivery and 10 s prior to termination of the episode.
Figure 87. Suspended EGM recording

10.5.6.5  Episode Text

The Episode Text screen provides a summary of the episode. The episode text for a VT, FVT, or VF episode includes information such as the delivered therapy sequence, parameter settings, and notation of SVT criterion met if the episode is in the VT or VF detection zone.

The episode text for an AT/AF episode includes information such as a summary of the ATP therapy sequence (if the device has ATP therapy capabilities), summary of the number of ATP therapies delivered, and parameter settings.

To view all of the episode text, use the scroll bar on the right side of the screen.

10.5.6.6  QRS data (VR devices only)

The QRS screen is available for SVT, VF, VT, and FVT episodes if the Wavelet criterion is programmed to On or Monitor when they occur.

When selected, the QRS screen displays diagrams of up to 8 recorded QRS complexes with the template used for that episode overlaid on each waveform. For each QRS complex, the match percentage and classification (“Match” or “No Match”) is also displayed.
10.6 Viewing Flashback Memory data

Flashback Memory is available from the Data screen. This feature allows you to analyze a patient’s heart rate leading up to a VF, VT, or AT/AF episode and compare the pre-VF, pre-VT, and pre-AT/AF rhythms to the patient’s normal sinus rhythm and to other episodes.

In AT and DR devices, Flashback Memory automatically records up to 2000 V-V and A-A intervals and stored marker data for the following events:

- the most recent VF episode
- the most recent VT episode
- the most recent AT/AF episode
- the most recent interrogation

In VR devices, Flashback Memory automatically records up to 2000 V-V intervals and stored marker data for the following events:

- the most recent VF episode
- the most recent VT episode
- the most recent interrogation

Flashback Memory is not programmable and is always enabled.

Note: If FVT Detection is enabled while recording, the device records an FVT episode as either a VT episode (if detected via the VT zone) or a VF episode (if detected via the VF zone).

Note: The events in the Flashback Memory may have less than 2000 intervals and stored marker data available if 2 episodes are detected within 15 min of each other.

Interval storage is suspended when a VF, FVT, or VT episode is in progress.
10.6.1 How to view Flashback Memory

1. Select Data > Clinical Diagnostics.
2. Select Flashback Memory.
3. Select [Open Data].

You can also display the Flashback Memory screen by selecting [Flashback] from the most recent VT, VF, FVT, or AT/AF record detail screens.
4. Select a set of intervals to display.
5. Select interval or rate to adjust the plot display method.
6. Select the plots to display.
7. View the programmed detection intervals or rates, shown as horizontal lines in the graph area.
8. Note the zoom window.
9. Resize the zoom window if desired.
10. Move the zoom window if desired.
11. Magnify the zoom window if desired.
12. Select [Print…] to print the displayed information.

10.7 Using Cardiac Compass to view long-term clinical trends

The Cardiac Compass report provides up to 14 months of clinically significant data including arrhythmia episodes, therapies delivered, physical activity, heart rate, and bradycardia pacing activity. The report can be useful, for example, in correlating changes in data trends to changes in programmed parameters, drug regimen, or patient condition.

The Cardiac Compass report provides an overall view of clinically significant data based on the following daily checks or measurements:

- programming and interrogation annotations, including annotations for home monitor sessions
- treated VT/FVT/VF episodes
- indication of a cardioversion or defibrillation therapy delivered
- ventricular rate during VF, FVT, VT episodes
- number of VT-NS episodes per day
- total time in AT or AF (AT and DR devices only)
- ventricular rate during AT or AF (AT and DR devices only)
- percentage of atrial and ventricular pacing (AT and DR devices only)
- average day and night ventricular rate
- overall patient activity
- heart rate variability

See Figure 88 for an example of a Cardiac Compass report.

Data storage for the Cardiac Compass report is automatic. No setup is required. The device begins storing data when VF Detection is enabled at implant. Each day thereafter, the device stores a set of Cardiac Compass data. Storage continues until the 14-month storage capacity is filled. At that point, the oldest stored data is overwritten with new data.

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36 Indication of a delivered atrial cardioversion therapy is available only for AT devices.
The times displayed on the report are based on the device clock.
You can print the report from either a full-size printer connected to the programmer or from the programmer strip chart recorder.

For AT and DR devices, a report that is printed from the strip chart includes all 11 trends on several printer pages. A report printed on a full-size printer includes only 10 trends on 1 page. When printing to a full-size printer, you can select to include either the Heart Rate Variability trend or the VT-NS trend in the report.

For VR devices, a report that is printed from either the strip chart or a full-size printer includes all of the available trends.
Figure 88. Cardiac Compass report example

Cardiac Compass Report

Device: EnTrust D154ATG
Patient: John Smith
ID: 12345
Serial Number: PNR733010Q
Date of Visit: 03-Jan-2004 12:04:35
Physician: Johnson

Mar 2003
May 2003
Jul 2003
Sep 2003
Nov 2003
Jan 2004
Mar 2004

1 = Program
2 = Interrogate
_ = Remote

One or more shocks/day
Treated VT/VF episodes/day
AT/AF total hours/day
Avg V rate (bpm)
Patient activity hours/day

V rate during AT/AF (bpm)
VT
VF
Non-sustained VT episodes/day
AT/AF total hours/day
V rate during VT/VF (bpm)
Non-sustained VT episodes/day

% Pacing/day
AV
FVT
VF
VT

Heart rate variability (ms)

1 Last session indicator
2 Current session indicator
3 High-voltage therapy indicator
10.7.1 How to print a Cardiac Compass report

1. Interrogate the device.
2. Select Data > Clinical Diagnostics.
3. Select Cardiac Compass Trends (Report Only) in the Data list.
4. Select [Open Data].
5. Select print options if you have not already set the programmer printing preferences (see Section 9.12.2, “How to set Printing preferences”, page 316). Select the number of copies to print and the type of printer to use.

**Note:** If the programmer printing preferences are not already set and the full-size printer option is selected, select either Non-sustained VT episodes or Heart rate variability.

6. Select [Print Now] or [Print Later] to print the Cardiac Compass report.

**10.7.2 Details about Cardiac Compass trend data**

**10.7.2.1 Programming and interrogation annotations**

The programming and interrogation annotations provide all of the following indications:

- when the patient has been evaluated during an office visit
- when the patient has been evaluated during a home monitor session
- when device parameters have been changed
- possible cause and effect correlations between device parameter changes and other clinical trends

When the patient has been evaluated during an office visit, the report records an “I” value for a day on which the device is interrogated and a “P” value for a day on which any programmable parameter is changed (except for temporary changes such as changes to test parameters). When the patient has been evaluated during a home monitor session, the report records the same “I” value, but it is displayed with a line beneath it to indicate that the device was interrogated during a home monitor session. If both “I” and “P” values are recorded for a day, only the “P” is displayed on the report.

**10.7.2.2 Treated VT/VF episodes per day**

The Treated VT/VF episodes per day trend provides a history of ventricular tachyarrhythmias and may be helpful in revealing correlations between clusters of episodes and other clinical trends. Each day, the device records the total number of spontaneous VT and VF episodes. The episode counts are provided in histogram format on the report.

**10.7.2.3 One or more shocks per day**

The device records a shock indicator for any day on which it delivers an automatic defibrillation therapy, cardioversion therapy, or atrial shock therapy (AT devices only). The Cardiac Compass report displays an annotation for the day on which a defibrillation therapy, cardioversion therapy, or atrial shock therapy was delivered.

---

37 If using a 9790C programmer and the report has been printed using the full-size printer type, the underlining that distinguishes the office visit and home monitor session interrogation value does not display.
10.7.2.4 Ventricular rate during VF, FVT, and VT

The Cardiac Compass report displays a graph of the daily median ventricular rate for spontaneous VF, FVT, and VT episodes which may have occurred. This graph may provide an indication of the effects of antiarrhythmic drugs on VF, FVT, and VT rates and a better understanding of the safety margins for detection.

Every day, the device stores each unique ventricular median interval occurring on that day. The stored median interval values are converted to ventricular rate and displayed on the report as points on the graph. The report also plots the programmed VF, FVT, and VT interval values for each day.

10.7.2.5 Non-sustained VT (VT-NS) episodes per day

The non-sustained VT episodes trend may help correlate patient symptoms (such as palpitations) to VT-NS episodes and may indicate a need for further investigation of the status of the patient. Each day, the device records the total number of spontaneous VT-NS episodes. The episode counts are provided in histogram format on the report. Episodes during which detection is withheld due to SVT criteria are not counted as VT-NS episodes.

10.7.2.6 AT/AF total hours per day (AT and DR devices only)

The AT/AF total hours per day trend may help to assess the need for antiarrhythmic drugs to reduce AT/AF episode occurrences or for anti-coagulant drugs to reduce the risk of stroke.

The device records a daily total for the time the patient spent in AT or AF. It defines AT or AF episodes using the AT/AF Onset criterion. The time (in hours) is provided in histogram format on the report. This trend may be reported in minutes (1 to 60) per day depending on the maximum duration per day.

10.7.2.7 Ventricular rate during AT/AF (AT and DR devices only)

The ventricular rate during AT/AF trend can be used to do one of the following tasks:

- correlate patient symptoms to rapid ventricular responses to AT/AF
- assess VT/VF detection safety margins and modify programming to avoid treating rapidly conducted AT/AF as VT/VF
- prescribe or titrate antiarrhythmic and rate control drugs
- assess the efficacy of an AV node ablation procedure

The device records average and maximum ventricular rates during episodes of AT and AF each day. The values are plotted on the Cardiac Compass report along with the average ventricular rates.
10.7.2.8 Percent pacing per day
The percent pacing per day graph provides a view of pacing over time that can help identify pacing changes and trends. It displays the percentage of events occurring during each day that are atrial paces (AT and DR devices only) and ventricular paces.

For AT and DR devices that are programmed to a dual chamber pacing mode\(^{38}\), these percentages are calculated from the stored daily totals of the AS-VS, AS-VP, AP-VS, and AP-VP counters. If the device is programmed to a single chamber pacing mode, these percentages are calculated from the stored daily totals of the paced and sensed counters. For VR devices, these percentages are calculated from the stored daily totals of the VS and VP counters.

10.7.2.9 Patient activity
The patient activity trend can be evaluated for the following types of information:
- an early indicator of symptoms due to progressive diseases like heart failure, which cause fatigue and a consequent reduction in patient activity
- an objective measurement of patient response to changes in therapy
- a way to study outcomes in ICD patients (along with measures like quality of life)
- a way to monitor a patient’s exercise regimen

The device uses activity count data derived from the rate response accelerometer signal to determine patient activity. The activity values are stored daily. For each 7 days of stored data, the device calculates a 7-day average. This average is plotted for the Cardiac Compass report.

10.7.2.10 Day and night heart rates
The day and night heart rates provide the following information that may be clinically useful:
- gradual increases in heart rate, which indicate decompensation, a symptom of heart failure
- objective data to correlate with patient symptoms
- indications of autonomic dysfunction or heart failure
- information regarding diurnal variations
- the patient’s true heart rate, independent of influences like “white coat syndrome”

For this trend, the device defines “day” as the 12-hour period between 8:00 AM and 8:00 PM and “night” as the 4-hour period between midnight and 4:00 AM (as indicated by the device clock).

\(^{38}\) MVP modes (AAIR<=>DDDR and AAI<=>DDD) are considered dual chamber modes for this purpose.
The device calculates the daytime and nighttime averages of interval length from the stored data and converts these values to rates for graphing. The values exclude any ventricular intervals that meet the following criteria:

- occur during a manual temporary operation
- are identified by the device as VF, FVT, or VT events
- occur during a detected episode (between detection and episode termination)

### 10.7.2.11 Heart rate variability
In AT and DR devices, the device measures the median atrial interval value every five minutes and calculates a variability value each day. In VR devices, the device measures the median ventricular interval value every 5 min and calculates a variability value each day. The variability value (ms) is plotted on the Cardiac Compass report.

### 10.8 Using Rate Histograms reports
Rate histograms count and collect atrial events (AT and DR devices only) or ventricular events and classify them by rate range and the percentage of time that the device was pacing and sensing in specific rate ranges. The device automatically collects the histogram data without any programming by the clinician. This diagnostic is intended for ambulatory monitoring uses, such as monitoring rate distribution.

Rate histograms also collect the ventricular rate during AT/AF (AT and DR devices only). This diagnostic may be used to evaluate drug titration.

For an example of a Rate Histograms report, see Figure 89.
Figure 89. Rate Histograms report example

Rate Histograms

Device: EnTrust D154ATG
Serial Number: PNR730110Q
Date of Visit: 27-Jul-2003 12:04:35

Patient: John Smith
ID: 12345
Physician: Dr. Johnson

Prior to Last Session
22-Jul-2003 to 23-Jul-2003
1 day

% of Time
AS-VS 94.8%
AS-VP 1.9%
AP-VS 1.3%
AP-VP 2.0%

2% to 5% of AS may be due to FFRW

Since Last Session
24-Jul-2003 to 27-Jul-2003
3 days

% of Time
AS-VS 98.8%
AS-VP 0%
AP-VS 1.2%
AP-VP 0%

Atrial Rate (bpm)

Ventricular Rate During AT/AF

% of AT/AF
VS VP

Time in AT/AF = 89 minutes

Ventricular Rate (bpm)

Time in AT/AF = 18 hours

<40 60 80 100 120 140 160 180 200 220>

<40 60 80 100 120 140 160 180 200 220>

<40 60 80 100 120 140 160 180 200 220>

<40 60 80 100 120 140 160 180 200 220>

9987 Software Version 1.2
Copyright Medtronic, Inc. 2002

Printed: 27-Jul-2003 12:12:10
10.8.1 Rate Histograms reports data collection

Rate histograms show the percentage of time that the device was pacing and sensing in specific rate ranges. There are a total of 20 rate ranges, or bins, that are each 10 bpm in length. The slowest range is 40 to 49 bpm, and the fastest range is 210 to 219 bpm (rates slower than 40 bpm are included in the <40 bpm bin; rates faster than 220 bpm are included in the >220 bpm bin). The rate histograms show what percentage of the time the device was pacing or sensing in each bin. Refractory sensed events are included in the histograms.

The Rate Histograms report consists of 2 parts: patient data prior to the last session and patient data since the last session. The collection period for the rate histograms is indicated by the starting and ending dates when the device is interrogated. Once any rate bin is full, data collection stops. This behavior is unlikely since the device can collect several million events.

The 3 possible types of histograms included in the Rate Histograms report are atrial rate histograms, ventricular rate histograms, and ventricular rate during AT/AF histograms.

**Note:** The atrial histograms and ventricular rate during AT/AF histograms are not available in VR devices.

The atrial rate histograms count atrial senses and paces. The ventricular rate histograms count ventricular paces and senses. The ventricular rate during AT/AF histograms count ventricular paces and senses that occur during detected atrial arrhythmias.

The atrial rate histograms may also include a percentage range of atrial senses that may be due to far-field R-wave sensing. This range is reported above the atrial histograms for both prior to the last session and since the last session. The range is reported as one of the following: 2% to 5% or greater than 5%.

The rate histograms report also shows the patient’s conduction status as the percentage of the total time for the prior to the last session and since the last session. In AT and DR devices, if the device was programmed to a dual chamber mode, the conduction status reports the percentage of collected AV sequence data for the categories AS-VS, AS-VP, AP-VS, and AP-VP. If the device was programmed to a single chamber mode, the percent paced and sensed is reported. In VR devices, this section reports the percentage of ventricular pacing and sensing.

10.8.2 Retrieving rate histograms

When an interrogation of the device is performed, the programmer retrieves the histogram data. The histogram data can be displayed only by printing the data. When printed, the histogram report displays the “prior to last session” histograms and the “since last session” histograms on rate distribution profile graphs.
10.8.3 How to print a Rate Histograms report

1. Interrogate the device.
2. Select Data > Clinical Diagnostics.
3. Select Rate Histograms (Report Only).
4. Select [Open Data].
5. Select print options if you have not already set the programmer printing preferences (see Section 9.12.2, “How to set Printing preferences”, page 316). Select the number of copies to print and the type of printer to use.
6. Select [Print Now] or [Print Later] to print the Rate Histograms report.
10.9 Viewing the counters

The device continuously stores the number of significant events such as detected episodes and therapy deliveries as counter data in memory. The programmer allows you to view the counters on the screen and print the counter data in several ways.
10.9.1 How to view and print counter data

1. Interrogate the device.
2. Select Data > Clinical Diagnostics.
3. Select Counters.
4. Select [Open Data].
5. Select the type of counters to display.
6. Select [Print...] to print the displayed counters.

10.9.2 Details about the counter data

In AT, DR, and VR devices, there are counters for VT/FVT/VF episodes and therapies. AT and DR devices also include counters for AT/AF summary data, and AT devices further include counters for AT/AF therapy summary data.

For VT/VF episode counters, the device maintains cumulative counters of the number of tachyarrhythmias and supraventricular tachycardias (SVT)\textsuperscript{39} for the prior session, the last session, and the device lifetime. The VT/VF therapy counters include therapy efficacy counters since the last session and therapy summary counters for the prior session, the last session, and the device lifetime.

For AT/AF summary data counters, counters include such data as detected AT/AF episodes and the amount of time spent in AT/AF. The AT/AF therapy summary data counters include such data as the number of treated and monitored episodes per day and the number of AT-NS episodes per day. The following information discusses these counters in detail.

Note: The up or down arrows to the right of the data in the last session column represent a higher or lower value for the prior session.

10.9.2.1 VT/VF episode counters

The device maintains cumulative counters of the number of tachyarrhythmias (VF, FVT, and VT episodes) and supraventricular tachycardias (SVT)\textsuperscript{39} for the prior session, the last session, and the device lifetime. The device also maintains cumulative counters of the number of Monitored VT episodes, non-sustained episodes (VT-NS), PVCs, and VRS Paces for the prior session and the last session.

\textsuperscript{39} Only SVTs with rates in the treated zones are counted.
Figure 90. VT/VF episode counters

The following episode counter data is available:

**VF, FVT, VT, and Monitored VT** – Reports the number of episodes of each arrhythmia, based on the initial detection.

**VT-NS** – Reports the number of non-sustained tachyarrhythmias.

**PVC Runs** – Reports “runs” of PVCs in which 2, 3, or 4 consecutive ventricular events are premature.

**PVC Singles** – Reports premature events.\(^{40}\)

**Runs of VRS Paces** – Reports “runs” of VRS pacing pulses per hour in which two or more consecutive ventricular events are VRS pacing pulses (see Section 8.16, “Ventricular Rate Stabilization (VRS)”, page 266).

**Single VRS Paces** – Reports VRS pacing pulses (VRS escape interval timeouts) per hour (see Section 8.16, “Ventricular Rate Stabilization (VRS)”, page 266).

**SVT: VT/VF Therapy Withheld** – Reports the number of episodes where an SVT discrimination criterion was met, causing VT/FVT/VF detection and therapy to be withheld. If more than 1 of the criteria was applied to withhold detection, the criterion most frequently applied is counted.

\(^{40}\) A sensed event is classified as premature if the interval is less than 69% of the average intrinsic rate of the most recent 4 intervals.
### 10.9.2.2 VT/VF therapy counters

VT/VF therapy counters include the VT/VF Therapy Summary for the prior session, the last session, and the device lifetime. VT/VF therapy counters also include the VT/VF Therapy Efficacy Since Last Session.

#### Figure 91. VT/VF therapy counters

The following VT/VF therapy counter data is available:

**VT/VF Therapy Summary** – Reports the number of pace-terminated arrhythmias, shock-terminated arrhythmias, total VT/VF shocks, and aborted charges for the prior session, the last session, and the device lifetime.

**VT/VF Therapy Efficacy Since Last Session** – Reports the number and type of VF, FVT, and VT therapy delivered and successful. The VT Therapy counter includes VT episodes that accelerated during the therapy or were redetected as an FVT or VF episode. The FVT therapy counter includes FVT episodes that were redetected as a VF episode.

### 10.9.2.3 AT/AF summary data counters

AT/AF summary data counters include the AT/AF Summary for the prior session and the last session. AT/AF summary data counters also include AT/AF episode data per duration and AT/AF episode data per start time since the last session.

**Note:** AT/AF summary data counters are not available in VR devices.
The AT/AF Summary reports such data as the total time in AT/AF and AT/AF episodes. AT/AF Summary data include the following types of information:

- percentage of total time in AT/AF
- average time in AT/AF per day
- average number of monitored AT/AF episodes per day
- average number of treated AT/AF episodes per day (AT devices only)
- percentage of pace-terminated episodes (AT devices only)
- percentage of time atrial pacing was performed
- percentage of time atrial pacing was performed due to atrial intervention pacing (Atrial Rate Stabilization or Atrial Preference Pacing)
- average number of non-sustained AT (AT-NS) per day

**Figure 92. AT/AF summary data counters**

AT/AF summary data counters also include episode data per duration and episode data per start time.

**AT/AF Durations** – Reports the lengths of time spent in AT/AF, such as 1 to 4 hours or 10 min to 1 hour, and the number of episodes that occurred during these durations.

**AT/AF Start Times** – Reports the hour of the day that AT/AF was detected, such as 6:00 to 9:00 and 15:00 to 18:00, and the number of episodes that occurred during these hours.

---

41 AT/AF is defined as when atrial onset criteria are met.
42 AT/AF is defined as when atrial detection criteria are met.
43 AT/AF is defined as when atrial detection criteria are met.
10.9.2.4 AT/AF therapy summary counters

Therapy counters since the last session are available for AT/AF therapies. AT/AF therapy counters include data for both treated AT/AF and treated Fast AT/AF episodes. These counters also include data about atrial ATP sequences, automatic shocks, and Patient Activated shocks since the last session.

**Note:** AT/AF therapy counters are not available in DR and VR devices.

**Figure 93. AT/AF therapy counters**

<table>
<thead>
<tr>
<th>Data - Counters</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT/VF Episodes</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Since Last Session: 12-Jul-2004 to 18-Jul-2004</td>
</tr>
<tr>
<td>Fast AT/AF Rx</td>
</tr>
<tr>
<td>Treated episodes</td>
</tr>
<tr>
<td>% Terminated</td>
</tr>
<tr>
<td>AT/AF Rx</td>
</tr>
<tr>
<td>Treated episodes</td>
</tr>
<tr>
<td>% Terminated</td>
</tr>
<tr>
<td>ATP Rx versus ms</td>
</tr>
<tr>
<td>Treated episodes</td>
</tr>
<tr>
<td>% Terminated</td>
</tr>
</tbody>
</table>

**Fast AT/AF Zone 100-199 ms:** 0 treated episodes, 0.0 % terminated

**Note:** Above table does not include Fast AT/AF therapies.

ATP Sequences: 17 delivered, 0 aborted
Automatic Shocks: 0 delivered, 0 healed
Patient Activated Shocks: 0 delivered, 0 healed

The following therapy counter data is available:

**AT/AF therapies** – Reports the number of AT/AF episodes that had a therapy delivered per programmed therapy and the percentage of successfully terminated episodes per programmed therapy.

**Fast AT/AF therapies** – Reports the number of Fast AT/AF episodes that had a therapy delivered per programmed therapy and the percentage of successfully terminated episodes per programmed therapy. This information is displayed only if AT/AF detection is programmed to 2 zones (see Section 6.3, “Detecting atrial tachyarrhythmias”, page 78).

**Treated episodes per cycle length** – Reports the number of episodes that had a therapy delivered per atrial cycle length and the percentage of successfully terminated episodes per atrial cycle length.
Note: Fast AT/AF is not included in this data. A statement displays below the treated episodes per cycle length data providing similar type of information about the number of treated Fast AT/AF in the programmed Fast AT/AF cycle length and the percentage of successfully terminated episodes.

**ATP Sequences** – Reports the number of atrial ATP sequences delivered and the number aborted.

**Automatic Shocks** – Reports the number of automatic atrial shocks delivered and the number failed.

**Patient Activated Shocks** – Reports the number of Patient Activated atrial shocks delivered and the number failed.

### 10.10 Viewing Battery and Lead Measurement data

The device automatically and continuously monitors its battery and lead status throughout the life of the device. After you interrogate the device, the Battery and Lead Measurements screen allows you to view and print the following data:

- current battery voltage
- last capacitor formation
- last capacitor charge
- sensing integrity counter data
- last Atrial Lead Position Check (AT devices only)
- last lead impedance data
- last sensing data
- last high-voltage therapy

Note: If the device has been reset, certain measurements may not be available, and the message “No measurement since reset” is displayed until a new measurement is taken.
10.10.1 How to view battery and lead status data

1. Interrogate the device.
2. Select Data > Device/Lead Diagnostics.
3. Select Battery and Lead Measurements.
4. Select [Open Data].
5. To print the Battery and Lead Measurements screen, select [Print…].
10.10.2 Details about viewing Battery and Lead Measurement data

Following are the details about battery voltage, sensing integrity counter, and Atrial Lead Position Check.

For information about lead impedance and sensing measurements, see Section 10.11.2, “Details about viewing Lead Performance Trends data”, page 380.

For information about optimizing capacitor charge time, see Section 5.3, “Optimizing charge time”, page 58. For information about optimizing device longevity, see Section 4.12, “Optimizing device longevity”, page 55.

10.10.2.1 Battery voltage and replacement indicators

The device measures the battery voltage when telemetry is initiated and a magnet is applied, when a lead impedance test is performed, and as part of the automatic measurements at 2:15 AM daily based on the device clock.

Note: The measured battery voltage may be lower if the device is cold or if it recently performed a high-voltage charge. Do not assess device status based on such a battery voltage measurement.

The programmer displays the following information if the battery voltage is less than or equal to the Elective Replacement Indicator (ERI) value:

- an observation recommending that you replace the device
- an ERI symbol on the Quick Look and the Battery and Lead Measurements screen
- a date on the Quick Look and Battery and Lead Measurements screen indicating when the battery reached ERI

When the device reaches ERI, contact your Medtronic representative and schedule an appointment to replace the device.

If 90 days have passed since the device reached ERI, the device is at End of Life (EOL). The programmer displays the following information if the device is at EOL:

- an observation recommending immediate replacement of the device
- an EOL symbol on the Quick Look and Battery and Lead Measurements screen

Warning: If the programmer indicates that the device is at EOL, replace the device immediately.

---

44 A magnet must be applied for battery voltage measurement at the start of a session. If the session is exited and reentered without moving the programmer head, the battery voltage measurement is not taken.

45 EOL may be indicated before the end of 90 days if actual battery usage exceeds the post-ERI operating conditions or if the charge time of the device exceeds the EOL charge time. See Section 1.3, “Replacement indicators”, page 16.
10.10.2.2 Sensing integrity counter

The sensing integrity counter records the number of short ventricular intervals that occur between patient sessions. The sensing integrity counter records any sensed ventricular event with a V-V interval less than 20 ms greater than the programmed V. Blank Post VS parameter since the last session.

Note: If the number of short intervals that are displayed exceeds 300, the programmer displays a Quick Look observation, and sensing issues should be checked. A large number of short ventricular intervals may indicate situations like oversensing, lead fracture, or a loose set screw.

10.10.2.3 Atrial Lead Position Check

The device measures the position of the atrial lead to verify that the atrial lead is in the correct position. The Atrial Lead Position Check occurs once daily unless Mode Switch, a ventricular or an atrial episode, or a telemetry session is in progress. The Atrial Lead Position Check begins at 2:30 AM, based on the internal device clock.

Note: The Atrial Lead Position Check is only applicable to AT devices.

See “Disable all atrial therapies if atrial lead position is suspect”, page 139, for details about the Atrial Lead Position Check.

10.11 Viewing Lead Performance Trends data

The automatic daily lead impedance and sensing measurements are used to generate lead performance graphs based on up to 82 weeks of measurements.

A separate graph is provided for each of the following measurements:
- atrial pacing lead impedance (AT and DR devices only)
- ventricular pacing lead impedance
- defibrillation lead impedance
- SVC lead (if used) impedance
- P-wave sensing amplitude (AT and DR devices only)
- R-wave sensing amplitude

Each graph displays values above the graph area for the measurement at implant, the last measured value, the highest value collected for the measurement, and the lowest value collected for the measurement.

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46 Defined as intervals since stored data was cleared or the last session ended.
The impedance information that is graphed includes this information:

- the weekly minimum and maximum values for up to 80 weeks
- the last 14 days of measured values

Every seventh day after the device is implanted, weekly minimum and maximum measurements are recorded, and the lifetime minimum and maximum values are updated.
10.11.1 How to view Lead Performance Trends graphs

1. Select Data > Device/Lead Diagnostics.
2. Select Lead Performance Trends.
3. Select [Open Data].
4. To change to another graph, select a graph from the pull-down menu in the top left corner of the graph.

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Note: The lead performance trends can also be viewed by selecting the [>>] button next to the lead impedance or sensing data that is displayed on the “Data - Battery and Lead Measurements” screen, next to Lead Performance Trends on the “Tests - Lead Impedance” screen, next to Lead Performance Trends on the “Tests - Sensing” screen, and next to Lead on the “Data - Quick Look” screen.

10.11.2 Details about viewing Lead Performance Trends data

The device collects electrical data about the lead system that allows you to assess lead integrity over the time between patient sessions. This data is collected automatically (with no setup required) and can be viewed or printed during a patient session. The device automatically measures lead impedances and sensing amplitudes each day starting at 2:15 AM based on the internal device clock.

The lead impedance and sensing amplitude values are stored in device memory and may be viewed during a patient session using Lead Performance Trends, Battery and Lead Measurements, and various displays and reports. Lead impedance values are also used by the Patient Alert feature to notify the patient in the event that an impedance value is out of range.

**Lead impedances** – The device measures the atrial and ventricular pacing and high-voltage lead impedances using subthreshold electrical pulses that are synchronized to sensed or paced events but do not capture the heart. If the patient is experiencing a ventricular tachyarrhythmia episode (or undergoing programmer-initiated inductions, therapies, or tests) during a scheduled measurement, the device defers the measurement until the next day and logs the value as “Not Taken.” For example, the atrial lead impedance measurement is logged as “Not Taken” when atrial senses occur during the post-ventricular atrial blanking (PVAB) period.

**SVC lead detection** – The device will detect the status of the SVC lead as either “Present” or “Not Present.” The device uses the manual or automatic high-voltage lead impedance measurement to determine the status of the SVC lead.

**Note:** If an SVC lead is not implanted, Active Can must be enabled.

The SVC lead status is “Not Present” until a manual or automatic SVC lead impedance measurement is less than 200 Ω. When this occurs, the SVC lead status changes to “Present.” After the SVC lead status is set to “Present,” it remains at this setting regardless of subsequent SVC lead impedance measurements.

**Note:** If the SVC lead status is “Not Present,” automatic SVC lead impedance measurements are reported and displayed on the programmer as “Not Taken.”
Note: If an electrical reset occurs and the lead impedance measurement data is cleared, the SVC lead status is set to “Not Present” until another SVC lead impedance measurement occurs that is less than 200 Ω.

A high urgency Patient Alert tone sounds at the programmed alert time if the SVC lead status is “Not Present” and the following conditions occur:

- at least 1 manual or automatic lead impedance measurement has been taken
- SVC lead impedance is greater than or equal to 200 Ω
- Active Can is disabled

Sensing amplitudes – Starting at 2:15 AM, the device attempts to measure the sensing amplitudes for up to 5 normal intrinsic atrial and ventricular sensed events. After 24 hours, the device calculates and stores the median of any measured atrial and ventricular events. If no sensed events are measured throughout the day, the device stores the measurement value as “Not Taken”.

10.12 Viewing and entering patient information

Patient information is typically entered at the time of initial implant, and it can be revised at any time. This information is stored in the device and can be accessed by the programmer. Patient information includes the following information:

- patient name, ID number, date of birth, medical history, and physician and hospital name
- device and lead system identification and implant information
- implant testing data

Note: The Patient Information screen should not be used in the place of the patient’s medical chart (see “Notice”, page 13).

Table 40. Description of Patient Information parameters

<table>
<thead>
<tr>
<th>Information field</th>
<th>Description and required action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
<td>Enter the patient name (up to 30 characters).</td>
</tr>
<tr>
<td>ID</td>
<td>Enter the patient ID (up to 15 characters).</td>
</tr>
<tr>
<td>Date of Birth</td>
<td>Select patient’s date of birth.</td>
</tr>
<tr>
<td>Serial Number (Not selectable)</td>
<td>Displays serial number for implanted device after interrogation.</td>
</tr>
<tr>
<td>Lead 1…</td>
<td>Enter detailed information for leads 1, 2, and 3: Model; Position (pick from list of positions, or enter position); Manufacturer; Serial Number; and Implant Date.</td>
</tr>
<tr>
<td>Lead 2…</td>
<td></td>
</tr>
<tr>
<td>Lead 3…</td>
<td></td>
</tr>
<tr>
<td>Implant…</td>
<td>Enter measured values from implant. Using the displayed submenu, enter new information including lead data from the Pacing System Analyzer (PSA).</td>
</tr>
<tr>
<td>Notes</td>
<td>Enter notes about the patient or other information.</td>
</tr>
</tbody>
</table>
**Table 40. Description of Patient Information parameters (continued)**

<table>
<thead>
<tr>
<th>Information field</th>
<th>Description and required action</th>
</tr>
</thead>
<tbody>
<tr>
<td>History (2 fields)</td>
<td>Select medical history from list box. If necessary, you can indicate that more information is located in the Notes field.</td>
</tr>
<tr>
<td>EF, on</td>
<td>Select the ejection fraction from a table of values. Then, enter the date in the following field.</td>
</tr>
<tr>
<td>Physician</td>
<td>Select or add the name of the physician. You can also enter the physician’s phone number at the same time.</td>
</tr>
<tr>
<td>Phone</td>
<td>Enter the phone number of the physician.</td>
</tr>
<tr>
<td>Hospital</td>
<td>Select or add the hospital information.</td>
</tr>
<tr>
<td>Last Update (Not selectable)</td>
<td>Displays the date of the last Patient Information update.</td>
</tr>
</tbody>
</table>

**Note:** The device serial number, patient name, and ID number are printed on each page of all full-size and strip chart reports.

### 10.12.1 How to view and enter new patient information

![Patient Information screenshot](image)
1. Select the Patient icon. The Patient Information screen is displayed.
2. Select the data field you want to change, and enter the text for the field, or if a display list appears, do one of the following:
   - Select an option from the display list.
   - Select [Modify List...] and [Add...]. Then type in your addition and select [OK].
3. When all the information has been entered, select [PROGRAM].

10.12.2 Details about patient information
If you make an entry that does not fit in the parameter display area, the entry is truncated. The full entry may be visible if printed from the Patient Information screen.

When displayed or printed from the Session - Changes This Session screen, information may be truncated, which is indicated by an ellipsis (…) following the last character.

Note: The device serial number, patient, and ID number fields are printed on all full-size and strip chart reports.

10.13 Automatic device status monitoring
During each interrogation, the device is monitored for adequate charge time performance, possible electrical reset conditions, and disabled therapies. If a condition is detected that requires attention, the programmer displays a Device Status Indicator warning in a pop-up window and on the Quick Look screen.

10.13.1 Device Status Indicator warnings
Caution: The Device Status Indicators are important. Please inform your Medtronic representative if any of the indicators are displayed after interrogating a device.

The Device Status Indicators are defined below:

**Warning - Charge Circuit Timeout** – Indicates that the charging period has exceeded 30 s. The charge circuit is still active. Inform a Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

**Warning - Charge Circuit Inactive** – Indicates that 3 consecutive charging periods have each exceeded 30 s. The charge circuit is inactive, and all automatic therapy functions, EP Study functions, and manual system tests are disabled except for Emergency VVI pacing. Inform a Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

**Warning - Device Electrical Reset** – Indicates that an electrical reset has occurred. Programmed parameters may have been set to electrical reset values. See Appendix B,
“Device Parameters”, page 451, for reset settings. Read the message accompanying the indicator, and follow the screen instructions carefully. Also see Section 10.13.2, “How to respond to an electrical reset”, page 384, for how to respond to an electrical reset. If the error message does not indicate that parameters have been reprogrammed, then the reset did not affect any programmed parameters.

An electrical reset is a device-activated safety feature that can reset device parameters to values that provide basic device functionality. These basic parameters are considered safe for the vast majority of patients. Pacing remains active during a reset condition.

An electrical reset may occur when the device is exposed to extreme conditions, such as cold temperatures (before implant); intense, direct x-ray exposure; electrocautery; or external defibrillation.

In some cases, an electrical reset may disable tachyarrhythmia detection and therapy. If this occurs, the electrical reset patient alert sounds every 9 hours, and the device operates as a simple bradycardia pacing device (in VVI mode, 65 bpm). Tachyarrhythmia detection and therapy can be reprogrammed after the Electrical Reset Indicator has been cleared.

**Warning - SERIOUS ERROR** – Indicates an error has occurred from which the device cannot recover. If this message is displayed, immediate replacement is recommended.

**AT/AF Therapies Disabled** – Atrial therapy can be disabled for the following reasons:
- A ventricular episode was detected following delivery of an automatic atrial therapy prior to either redetection of AT/AF or termination of AT/AF. Atrial therapy is disabled to prevent further atrial therapy if it appears that an atrial therapy has initiated a ventricular arrhythmia.
- The Atrial Lead Position Check failed.
- The device detected an accelerated ventricular rate during ATP therapy.

See Section 7.1.5.7, “Disabling atrial therapies”, page 139.

**Note:** AT/AF therapies and this device status indicator are available in AT devices only.

### 10.13.1.1 Clearing displayed status indicators

To clear the displayed status indicator, select [Clear] from the pop-up window displaying the Device Status Indicator message.

### 10.13.2 How to respond to an electrical reset

If the programmer reports that an electrical reset occurred and the device is not yet implanted, do not implant the device. Contact a Medtronic representative. If the device is implanted, follow these steps:
1. Remove any sources of electromagnetic interference (EMI).
2. Notify a Medtronic representative.
3. Select [Clear] in the pop-up window to clear the reset indicator and the Patient Alert alarm. A confirmation window appears indicating that all previously interrogated data in the programmer will be cleared.
4. Select [Continue].
5. Interrogate the device.
   a. Note the time and date when counter data was last cleared, because this indicates when the electrical reset occurred.
   b. Determine, if possible, what the patient was doing at that time and date.
   c. Save your session data to disk. You should give this saved data file to your Medtronic representative; it will be helpful in determining the events leading up to the reset.
6. Verify the programmed device parameters. Depending on the type of reset that occurred, you may need to reprogram the device parameters.
   If the electrical reset did reprogram certain parameters, the reprogrammed values are displayed in the error message. After this type of reset, the device operates as a simple defibrillator (in VOE-VVI mode) until reprogrammed. For a list of electrical reset parameter settings, see Appendix B, “Device Parameters”, page 451.
7. Verify the correct Device Date/Time. If necessary, reprogram the date and time.
8. Perform a manual capacitor formation to reset the capacitor formation timer and to ensure that the capacitor formation schedule is not compromised.
9. Interrogate the device again. Check the Battery and Lead Measurements screen to verify that the battery voltage and charge time are acceptable.
10. Conduct Lead Impedance and Pacing Threshold tests as desired.
11 Testing the system

11.1 System test overview

The device provides several test functions that allow you to assess the integrity of the implanted system. You can access system test functions using the Tests icon.

Detection and system test functions – The device suspends tachyarrhythmia detection while system test operations are in progress. Detection resumes after the system test is complete.

Temporary parameter values – System test operations use test values that do not change the programmed parameters of the device. Test values are not in effect until you begin the system test operation. After the test is finished, the device reverts to its programmed parameter values.

Tests preferences – You can configure the programmer to automatically adjust the live rhythm monitor display and the chart recorder printing options when you open system test or EP Study screens. The programmer selects the optimal live rhythm monitor and chart recorder settings for the type of system test or EP Study function you select.
11.1.1 How to set Tests preferences

1. Select Tests > Preferences… or Session > Preferences….
2. Select Tests.
3. Set the waveform configuration option as desired.
4. Select [OK].

11.2 Evaluating the underlying rhythm
Using the Underlying Rhythm Test, you can inhibit the pacing output of the device to evaluate the patient’s natural heart rhythm.

11.2.1 Considerations
Review the following information before performing the Underlying Rhythm Test.

Caution: Use caution when performing the Underlying Rhythm Test on patients who depend on pacing for adequate cardiac output. The device delivers no pacing as long as you press and hold the [INHIBIT Press and Hold] button.
11.2.2  How to perform an Underlying Rhythm test

1. Select Tests > Underlying Rhythm.
2. Press and hold [INHIBIT Press and Hold].
3. To print a recording of the patient’s natural rhythm, press the desired paper speed key on the printer/recorder. The ECG trace should not show any pacing.

11.3  Measuring pacing thresholds

You can determine the patient’s pacing stimulation thresholds using the Pacing Threshold Test. The test consists of 3 parts:

- selecting temporary pacing parameters for the test
- delivering pacing pulses that capture the heart
- gradually decreasing the pacing output until pacing capture is lost

The Pacing Threshold Test can decrease pacing output in 2 selectable ways: by reducing amplitude or by reducing pulse width. The test decreases pacing output automatically for as long as you press and hold the [TEST Press and Hold] button and the pacing output remains above minimum values.
You can retain a record of the threshold values obtained during this test by printing a Pacing Threshold Test report.

### 11.3.1 Parameters

<table>
<thead>
<tr>
<th><strong>Test Type</strong> – Method to use for modifying the pacing outputs.</th>
<th><strong>AT and DR devices</strong></th>
<th><strong>VR devices</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber – The chamber of the heart where the pacing threshold is tested.</td>
<td>RV; Atrium</td>
<td>RV</td>
</tr>
<tr>
<td>Decrement after – The number of pacing pulses delivered to the heart between pacing output reductions.</td>
<td>2; 3 … 15 pulses</td>
<td>2; 3 … 15 pulses</td>
</tr>
<tr>
<td>Mode(^a) (RV test) – Pacing mode used during the ventricular threshold test.</td>
<td>DDD; DDI; DOO; VVI; VOO</td>
<td>VVI; VOO</td>
</tr>
<tr>
<td>Mode(^a) (atrial test) – Pacing mode used during the atrial threshold test.</td>
<td>DDD; DDI; DOO; AAI; AOO</td>
<td>—</td>
</tr>
<tr>
<td>Lower Rate(^b) – Minimum pacing rate used during the threshold test.</td>
<td>30; 35 … 60; 70; 75 … 150 bpm</td>
<td>30; 35 … 60; 70; 75 … 150 bpm</td>
</tr>
<tr>
<td>RV Amplitude – Voltage setting for ventricular pacing pulses delivered during the test.</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>RV Pulse Width – Duration of the ventricular pacing pulses delivered during the test.</td>
<td>0.03; 0.06; 0.1; 0.2 … 1.5 ms</td>
<td>0.03; 0.06; 0.1; 0.2 … 1.5 ms</td>
</tr>
<tr>
<td>RV Pace Blanking – Time interval during which sensing is disabled after a ventricular pacing pulse.</td>
<td>150; 160 … 450 ms</td>
<td>150; 160 … 450 ms</td>
</tr>
<tr>
<td>AV Delay – Interval between an atrial event and a following ventricular pace.</td>
<td>30; 40 … 350 ms</td>
<td>—</td>
</tr>
<tr>
<td>PVARP – Atrial refractory period that prevents tracking of retrograde P-waves in DDD mode. In DDI mode, PVARP prevents atrial inhibition caused by retrograde P-waves.</td>
<td>150; 160 … 500 ms</td>
<td>—</td>
</tr>
<tr>
<td>A. Amplitude – Voltage setting for atrial pacing pulses delivered during the test.</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
<td>—</td>
</tr>
<tr>
<td>A. Pulse Width – Duration of the atrial pacing pulses delivered during the test.</td>
<td>0.03; 0.06; 0.1; 0.2 … 1.5 ms</td>
<td>—</td>
</tr>
<tr>
<td>A. Pace Blanking – Time interval during which sensing is disabled after an atrial pulse.</td>
<td>150; 160 … 250 ms</td>
<td>—</td>
</tr>
</tbody>
</table>

\(^a\)The selectable values for this parameter depend on the programmed pacing mode.

\(^b\)The maximum Lower Rate value is 145 bpm if you perform the test in DDD mode.

**Note:** The selectable and default values provided by the Pacing Threshold test depend on the programmed values for bradycardia pacing therapy.
11.3.2 Considerations
Review the following information before performing the Pacing Threshold Test.

**Pacing threshold and safety margin** – After performing a Pacing Threshold Test, make sure that the permanently programmed pulse width and amplitude parameters provide an adequate safety margin above the measured pacing threshold value.

11.3.3 How to perform a Pacing Threshold test
1. Interrogate the device.
2. Select Tests > Pacing Threshold.
3. Select Test Type, Chamber, and starting test values, or accept the values displayed.
4. Press and hold [TEST Press and Hold].
5. Observe the ECG for loss of capture.
6. When capture is lost, immediately release [TEST Press and Hold]. The device resumes its original pacing values and displays the test results screen.
7. To change the detected pacing threshold, select the Threshold value.
8. To view a test strip from the Pacing Threshold test, select the Test Strip icon. See Section 9.9, “Freezing and analyzing a waveform strip”, page 309.
9. To program new amplitude or pulse width values, set the desired parameters in the permanent column and select [PROGRAM].
10. To print a Pacing Threshold Test report, select the [Print…] button.

11.4 Testing the Wavelet criterion

Note: The Wavelet test is only available in VR devices.

You can use the Wavelet test to collect and evaluate the stored template that is used by the Wavelet detection criterion. The [COLLECT Template] option creates a new stored template. The [SHOW Match Scores] option applies the stored template to intrinsic ventricular events and displays match scores and classifications on the screen in real time.

To increase the likelihood that sensed events will occur during the test, you can select temporary pacing settings that evoke the patient’s intrinsic rhythm.

11.4.1 Parameters

<table>
<thead>
<tr>
<th>Temporary parameters</th>
<th>Programmable parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode</strong> – Pacing mode used during the test.</td>
<td><strong>Wavelet</strong> – Enables the Wavelet Dynamic Discrimination criterion, which withholds detection if enough QRS complexes during an episode match the stored template.</td>
</tr>
<tr>
<td>VVI; OVO</td>
<td><strong>Match Threshold</strong> – Threshold percentage representing the degree to which a sensed event must match the stored template to be considered a match.</td>
</tr>
<tr>
<td><strong>Lower Rate</strong> – Minimum pacing rate used during the test.</td>
<td>On; Off; Monitor</td>
</tr>
<tr>
<td>30; 35 … 60; 70; 75 … 120 bpm</td>
<td><strong>Auto Collection</strong> – Option to have the device automatically collect and maintain the stored template.</td>
</tr>
<tr>
<td>On; Off</td>
<td></td>
</tr>
<tr>
<td>40; 43 … 70; 97%</td>
<td></td>
</tr>
<tr>
<td>Off</td>
<td></td>
</tr>
</tbody>
</table>
11.4.2 Considerations

Review the following information before performing the Wavelet test.

**Patient comfort** – Reduce the pacing rate gradually to minimize symptoms associated with abrupt changes in heart rate.

**Pacing modes** – Available modes depend on the permanently programmed pacing mode.

**Intrinsic events** – The Wavelet test cannot collect a template unless enough intrinsic events occur during the template collection process. You may need to adjust the Lower Rate or Mode to promote intrinsic events. The test ends automatically after a few seconds and restores the programmed settings if no intrinsic events occur and you make no changes to the Lower Rate.

**High or low EGM amplitude** – The Wavelet test cannot collect a template from EGM samples with very low or very high amplitude. You may need to adjust the EGM 2 Range setting to decrease or increase the EGM amplitude.

**Too few matches** – If too few of the EGM waveform samples that are collected during the Wavelet test match each other, the programmer displays the Template Collection Problem window. Select [Close], and try to collect the template again. If you cannot collect a template automatically, you can use the Template Collection Problem window to manually select a set of waveforms for the template.

**Template usage** – After you successfully collect a template using the Wavelet test, the template is ready to be used by Wavelet criterion operations. No confirmation process occurs for manually collected templates.

**QRS Snapshot data** – In addition to Wavelet test results, you can use QRS Snapshot data that is stored with episode data records to evaluate Wavelet performance.

**Clearing data and template details** – If you clear device data, the number of automatic templates that were collected since the last session (displayed on the Template Details screen) will be lost.

11.4.3 Restrictions

**VOO pacing mode** – The Wavelet test cannot be performed if the programmed pacing mode is VOO.
11.4.4 How to evaluate the current template with the Wavelet test

1. Interrogate the device.
2. Select Tests > Wavelet.
3. Set the Mode and Lower Rate for the test, or accept the values displayed.
4. Select [SHOW Match Scores].
5. Observe the Live Rhythm Monitor and device status line for intrinsic rhythm and to view match scores for each compared event.
6. If consistent pacing is still occurring, decrease the Lower Rate.
7. If necessary, you can abort the test by selecting [ABORT]. Pacing settings will return to the programmed values.
8. To view details about the stored template, select [Details].
11.4.5 How to collect a template with the Wavelet test

1. Interrogate the device.
2. Select Tests > Wavelet.
3. Set the Mode and Lower Rate for the test, or accept the values displayed.
4. Select [COLLECT Template].
5. If consistent pacing is still occurring, decrease the Lower Rate.
6. After a template is collected, observe the Live Rhythm Monitor and device status line to view match scores for each compared event.
7. If necessary, you can abort the test by selecting [ABORT]. Pacing settings will return to the programmed values.

If too few of the EGM waveform samples that are collected during the Wavelet test match each other, the programmer displays the Template Collection Problem window. Select [Close], and try to collect the template again. If you cannot collect a template automatically, you can use the Template Collection Problem window to manually select a set of waveforms for the template.
11.4.6 How to calculate a template from the Template Collection Problem window

1. Deselect the checkbox next to the color bar for each dissimilar waveform sample.
2. Select [Calculate Template].
3. Select [SHOW Match Scores] to evaluate the newly collected template.
11.5 Measuring lead impedance

You can test the integrity of the implanted lead system by measuring the impedance across the pacing and high-voltage electrodes with the Lead Impedance test. These measurements are made without delivering a high-voltage shock or pacing pulses that capture the heart. Instead, the device uses low-voltage, subthreshold pulses that result in painless testing for the patient.

You can determine if the lead impedance has changed by comparing the measured values to those reported on the Lead Performance Trends screen and those measured at previous follow-ups.

11.5.1 Considerations

Review the following information before performing the Lead Impedance Test.

**Sensing measurement pulses** – When the device performs a lead impedance measurement, it may sense the subthreshold test pulses as atrial refractory events (or atrial sensed events in VVI mode). These pulses may also cause very small variations on one or more of the EGM channels. However, pulses delivered by a Lead Impedance Test do not capture the heart or affect tachyarrhythmia detection.
11.5.2 How to perform a Lead Impedance test

1. Select Tests > Lead Impedance.
2. Select [START Measurement]. Wait for programming confirmation and an in-progress message and graphic display.
3. If necessary, you can abort the test by selecting [STOP]. Lead impedance measurements are not updated from an aborted test.

11.5.3 Details about the Lead Impedance Test

The Lead Impedance Test delivers small subthreshold pulses between several electrode combinations and then measures any changes in voltage. The electrical current is measured across the electrodes and converted to an impedance value.

11.5.3.1 Impedance measurement synchronization

The Lead Impedance test synchronizes ventricular pacing lead measurements and high-voltage electrode measurements to ventricular paced or sensed events. Atrial pacing lead measurements are synchronized to atrial paced or sensed events.
The device cannot synchronize lead impedance measurements to the following events:

- atrial sensed events that occur during the PVAB
- ventricular sensed events that occur during a VSP interval

For each measurement, the Lead Impedance Test waits up to 3 s for an event that qualifies for synchronization. If no qualifying event occurs, the measurement is delivered asynchronously.

### 11.5.3.2 Automatic lead impedance testing

In addition to manually-initiated impedance measurements, the device performs daily automatic lead impedance measurements.

### 11.5.3.3 High-voltage therapy impedance

When a high-voltage therapy is delivered, the high-voltage lead impedance is measured based on the shock delivery rather than on subthreshold pulses. This measurement is displayed under the Last High Voltage Therapy category on the Battery and Lead Measurements screen.

### 11.6 Performing a Sensing Test

You can use the Sensing Test to measure the base-to-peak voltage of sensed events. To increase the likelihood that sensed events will occur, you can select temporary pacing settings that evoke the patient’s intrinsic rhythm.

#### 11.6.1 Parameters

<table>
<thead>
<tr>
<th>Mode – Pacing mode used during the test.</th>
<th>AT and DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAI; DDD; DDI; VVI; ODO</td>
<td></td>
<td>VVI; OVO</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AV Delay – Interval between an atrial event and a following ventricular pace.</th>
<th>AT and DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>30; 40 … 350 ms</td>
<td></td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Rate – Minimum pacing rate used during the test.</th>
<th>AT and DR devices</th>
<th>VR devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>30; 35 … 60; 70; 75 … 120 bpm</td>
<td></td>
<td>30; 35 … 60; 70; 75 … 120 bpm</td>
</tr>
</tbody>
</table>

**Note:** The selectable and default values provided by the Sensing Test depend on the programmed values for bradycardia pacing therapy.
11.6.2 Considerations

Review the following information before performing the Sensing Test.

Selecting sensitivity values – Do not adjust the values for Atrial Sensitivity and RV Sensitivity based on the results of this test. See Section 6.2, “Setting up sensing”, page 70.

Patient comfort – Reduce the pacing rate gradually to minimize symptoms associated with abrupt changes in heart rate.

Automatic timeout – The test ends automatically after a few seconds and restores the programmed settings if no intrinsic events occur and you make no changes to the pacing rate.

Maximum measured values – When the sensitivity is set between 0.3 mV and 2.1 mV, the maximum amplitude values that the Sensing Test can measure are 10.7 mV for atrial (P-wave) and 18.8 mV for ventricular (R-wave) measurements. However, if the sensitivity setting is set to 0.15 mV, the maximum amplitude values that the Sensing Test can measure are 5.35 mV for atrial (P-wave) and 9.4 mV for ventricular (R-wave) measurements.

11.6.3 Restrictions

Review the following information before performing the Sensing Test.

DOO, VOO, and AOO pacing modes – The Sensing Test cannot be performed if the programmed pacing mode is DOO, VOO, or AOO.
11.6.4 How to perform a Sensing test

1. Interrogate the device.
2. Select Tests > Sensing.
3. Set the test values for pacing parameters, or accept the values displayed.
4. Select [START Measurement].
5. Observe the Live Rhythm Monitor for intrinsic rhythm. If consistent pacing is still occurring, decrease the Lower Rate.
6. If necessary, you can abort the test by selecting [STOP and Restore]. Pacing settings will return to the programmed values.

11.7 Testing the device capacitors

The Charge/Dump test allows you to test charge time, manually form the device capacitors, and dump any charge remaining on the capacitors.

After a test charge, the charge remains on the capacitors until it is dumped, it is delivered by a cardioversion or defibrillation therapy, or it dissipates.
11.7.1 Considerations

Review the following information before performing the Charge/Dump test.

**Manual capacitor formation** – If you allow a test charge to dissipate for 10 min, the device records it as a capacitor formation and resets the automatic capacitor formation interval.
11.7.2 How to perform a Charge/Dump test

1. Select Tests > Charge/Dump.
2. Select [DUMP Capacitors] to remove any charge from the capacitors.
4. When charging is complete, the Charge End symbol (CE) appears on the Marker Channel display, and the Manual operation charging message disappears from the screen heading.

5. Select [RETRIEVE Data] to collect the charge time data from the device.

6. If necessary, you can abort the test charge by selecting [ABORT Test].
12 Conducting electrophysiologic studies

12.1 EP Study overview

**Warning:** Perform EP Study functions only under careful patient monitoring and control. Keep an external defibrillator immediately available and on standby during EP Study operations. An induced ventricular tachycardia may degenerate to ventricular fibrillation.

**Caution:** A programmer failure (e.g. a faulty touch pen) could result in inappropriate programming or inability to terminate an action or an activity in process. In the event of a programmer failure, immediately turn the programmer power off to deactivate telemetry and terminate any programmer controlled activity in process.

The device provides several electrophysiologic study (EP Study) functions, including cardiac stimulation protocols that induce tachyarrhythmias and manual therapies that terminate tachyarrhythmias. You can access EP Study functions using the Tests icon.

**Telemetry and EP Study functions** – Ensure that a telemetry link exists between the device and the programmer before performing EP Study functions. Any successful interrogation or programming verifies proper communication between the device and the programmer.

**Detection and EP Study functions** – Tachyarrhythmia detection is automatically suspended during an induction or manual therapy. All EP Study inductions provide the option to automatically resume detection after the induction is delivered. Select the [Resume at BURST] or [Resume at DELIVER] check box to enable auto resume for an induction. To resume detection after a manual therapy or after an induction delivered with auto resume disabled, press the on-screen [Resume] button or remove the programming head from the implanted device.

**Temporary parameter values** – EP Study operations use test values that do not change the programmed parameters of the device. Test values are not in effect until you begin the induction or therapy. After the induction or therapy, the device reverts to its programmed parameter values for bradycardia pacing and tachyarrhythmia therapy.

**Programmed parameters check** – Before displaying an induction screen, the system checks to verify that the device is programmed to detect and treat an induced arrhythmia. If the detection or therapy features are not programmed appropriately, a warning message appears on screen.

**EP Study feature availability** – VR devices provide only ventricular inductions and manual therapies. Both AT and DR devices provide atrial and ventricular inductions and manual therapies.
Selecting a chamber (DR devices only) – The programmer requires you to select a default chamber (atrium or ventricle) before it allows access to EP Study functions that can be delivered in either chamber. Figure 94 shows the chamber selection window.

Figure 94. EP Study chamber selection window (DR devices only)

Programming head buttons – The Program button on the programming head is disabled during all EP Study operations. The Interrogate button on the programming head is disabled during EP Study inductions. Use the appropriate on-screen delivery button to deliver an induction or manual therapy.

12.2 Inducing VF with T-Shock

The T-Shock induction is designed to induce VF by delivering a shock simultaneously with a T-wave, the vulnerable period of the cardiac cycle. You can use T-Shock inductions to test the effectiveness of the programmed detection and therapy parameters, for example, during defibrillation threshold (DFT) testing (see Section 4.8, “Testing ventricular defibrillation operation and effectiveness”, page 47).

To simplify DFT testing, you can perform the following tasks using the T-Shock screen:

- Monitor the time between inductions.
- Reprogram sensing and VF therapy settings.
- Adjust the induction settings.
- Retrieve episode records after therapy.

12.2.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resume at DELIVER</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>Enable</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>#S1</td>
<td>2; 3; 4; 5; 6; 7; 8</td>
</tr>
<tr>
<td>S1S1</td>
<td>300; 310 ... 400 ... 2000 ms</td>
</tr>
</tbody>
</table>
### Delay
- Maximum interval between the final VOO pulse and the T-Shock.\(^a\)
  - 10; 20; 30; \(\ldots\) 300; \(\ldots\) 600 ms

### Energy
- Energy delivered by the T-Shock induction.
  - 0.4; 0.6; \(\ldots\) 1; \(\ldots\) 2; 3; 4; \(\ldots\) 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J

### Waveform
- Voltage pattern of the delivered shock.
  - Monophasic; Biphasic

### Pathway
- Direction that current travels through the heart.
  - AX>B; B>AX\(^a\)

### Amplitude
- Voltage of each pulse in the pacing sequence.
  - 8 V (fixed)

### Pulse Width
- Duration of each pulse in the pacing sequence.
  - 1.5 ms (fixed)

\(^a\) The T-Shock is delivered on a ventricular sensed event or at the end of the selected Delay interval, whichever comes first.

## 12.2.2 Considerations
Review the following information before performing the T-Shock induction.

**Warning:** Keep an external defibrillator immediately available and on standby.

**Aborting an induction or therapy** – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

**ATP Before/During Charging and T-Shock** – ATP Before Charging and ATP During Charging are automatically disabled for 30 s after a T-Shock induction is delivered. This prevents ATP therapies from interfering with defibrillation threshold testing.

## 12.2.3 Restrictions
Review the following information before performing the T-Shock induction.

**[Enable] check box** – As a safety measure, you cannot select the [DELIVER T-Shock] button until you have selected the [Enable] check box. After you deliver a shock or exit the T-Shock screen, you must reselect the [Enable] check box before delivering another T-Shock induction.
12.2.4 How to deliver a T-Shock induction

2. Select T-Shock from the Inductions/Therapies box.
3. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
4. Confirm that the [Resume at DELIVER] check box is selected (for automatic detection and therapy) or is deselected (for manual therapy).
5. Accept the test values displayed on the screen, or choose new test values.
6. To view and adjust VF detection and therapy parameters, select [Adjust Permanent...].
7. Select the [Enable] check box.
8. Select [DELIVER T-Shock].
9. If necessary, you can use the [ABORT] button to terminate the induction or any therapy in progress.
12.2.5 Details about T-Shock induction

A T-Shock VF induction delivers 2 to 8 VOO pacing stimuli, then delivers a shock. The shock is delivered on a ventricular sensed event or at the end of the selected Delay interval, whichever comes first. The intent of this protocol is to force the ventricular cycle into a predictable rhythm and then deliver the shock simultaneously with a T-wave, the vulnerable period of the cardiac cycle, in order to induce VF.

If the stored energy on the capacitors is higher than the energy level you selected, the programmer displays a warning when you select the [DELIVER T-Shock] button. To clear this warning from the screen, select either [DUMP] or [CANCEL].

12.3 Inducing VF with 50 Hz Burst

The 50 Hz Burst induction, when delivered to the ventricle, is designed to induce VF by delivering a rapid burst of pacing pulses. The amplitude and pulse width of these pulses are selectable, but the pacing interval is fixed at 20 ms. You can use ventricular 50 Hz Burst inductions to test the effectiveness of the programmed detection and therapy parameters, for example, during defibrillation threshold (DFT) testing (see Section 4.8, “Testing ventricular defibrillation operation and effectiveness”, page 47).

To simplify DFT testing, you can perform the following tasks using the 50 Hz Burst screen:

- Monitor the time between inductions.
- Reprogram sensing and VF therapy settings.
- Adjust the induction settings.
- Retrieve episode records after therapy.

12.3.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resume at BURST</td>
<td>(check box) Option to resume detection automatically after the induction is delivered.</td>
</tr>
<tr>
<td>Chamber</td>
<td>Chamber of the heart where the 50 Hz Burst is delivered (select RV for inducing VF).</td>
</tr>
<tr>
<td>Interval</td>
<td>Pacing interval of the 50 Hz Burst induction.</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Voltage of each pulse in the pacing sequence.</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>Duration of each pulse in the pacing sequence.</td>
</tr>
</tbody>
</table>

*In VR devices, the chamber parameter has a fixed value of RV.*
12.3.2 Considerations

Review the following information before performing the 50 Hz Burst induction.

**Warning:** Keep an external defibrillator immediately available and on standby.

**Abort an induction or therapy** – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

**ATP Before or During Charging and 50 Hz Burst** – ATP Before Charging and ATP During Charging are automatically disabled for 30 s after a ventricular 50 Hz Burst induction is delivered. This prevents ATP therapies from interfering with defibrillation threshold testing.
12.3.3 How to deliver a ventricular 50 Hz Burst induction

2. Select 50 Hz Burst from the Inductions/Therapies box.
3. Select [RV] if the chamber selection dialog box appears. Otherwise, ensure that the Chamber parameter is set to RV.
4. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
5. Confirm that the [Resume at BURST] check box is selected (for automatic detection and therapy) or is deselected (for manual therapy).
6. Accept the test values displayed on the screen, or choose new test values.
7. To view and adjust VF detection and therapy parameters, select [Adjust Permanent...].
8. Press and hold the [50 Hz BURST Press and Hold] button. Release the button to end the induction.

9. If necessary, you can use the [ABORT] button to terminate a therapy in progress.

### 12.3.4 Details about ventricular 50 Hz Burst induction

The 50 Hz Burst pacing protocol is designed to induce VF by delivering VOO pacing pulses to the ventricle with an interval of 20 ms. As long as you press and hold the [50 Hz BURST Press and Hold] button on the programmer screen, the device continues delivering the induction (up to a maximum of 10 s).

**Note:** Because so many paced events are delivered during a 50 Hz Burst induction, the programmer screen or real-time recording strip may display a Marker Buffer Full (ER) symbol. This is normal behavior and should be expected during 50 Hz Burst delivery.

### 12.4 Delivering an atrial 50 Hz Burst

The 50 Hz Burst pacing protocol, when delivered to the atrium, is designed to induce AT/AF or treat AF episodes by delivering a rapid burst of pacing pulses. The amplitude and pulse width of these pulses are selectable, but the pacing interval is fixed at 20 ms.

#### 12.4.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resume at BURST</strong></td>
<td>(check box) Option to resume detection automatically after the induction is delivered.</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td><strong>Chamber</strong></td>
<td>Chamber of the heart where the 50 Hz Burst is delivered (select Atrium for atrial delivery).</td>
<td>RV; Atrium</td>
</tr>
<tr>
<td><strong>Interval</strong></td>
<td>Pacing interval of the 50 Hz Burst induction.</td>
<td>20 ms (fixed)</td>
</tr>
<tr>
<td><strong>Amplitude</strong></td>
<td>Voltage of each pulse in the pacing sequence.</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
</tr>
<tr>
<td><strong>Pulse Width</strong></td>
<td>Duration of each pulse in the pacing sequence.</td>
<td>0.1; 0.2 … 0.5; 1.5 ms</td>
</tr>
<tr>
<td><strong>VOO Backup</strong></td>
<td>Enables backup asynchronous ventricular pacing during the atrial 50 Hz Burst.</td>
<td>On; Off</td>
</tr>
<tr>
<td><strong>Pacing Rate</strong></td>
<td>Pacing rate for backup pacing.</td>
<td>60; 70; 120 bpm</td>
</tr>
<tr>
<td><strong>RV Amplitude</strong></td>
<td>Voltage of each backup pacing pulse.</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
</tr>
<tr>
<td><strong>RV Pulse Width</strong></td>
<td>Duration of each backup pacing pulse.</td>
<td>0.1; 0.2 … 1.5 ms</td>
</tr>
</tbody>
</table>

The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing.

Crosstalk may occur when atrial pacing amplitude is greater than 6.0 V.
12.4.2 Considerations

Review the following information before performing the 50 Hz Burst induction.

**Warning:** Keep an external defibrillator immediately available and on standby.

**Aborting an induction or therapy** – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.
12.4.3 How to deliver an atrial 50 Hz Burst

2. Select 50 Hz Burst from the Inductions/Therapies box.
3. Select [Atrium] if the chamber selection dialog box appears. Otherwise, ensure that the Chamber parameter is set to Atrium.
4. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
5. Confirm that the [Resume at BURST] check box is selected (for automatic detection and therapy) or is deselected (for manual therapy).
6. Accept the test values displayed on the screen, or choose new test values.
7. If you wish to provide VOO Backup pacing during the pacing burst, select VOO Backup… to set VOO backup pacing parameters.
8. Press and hold the [50 Hz BURST Press and Hold] button. Release the button to end the 50 Hz Burst.
9. If necessary, you can use the [ABORT] button to terminate a therapy in progress.

12.4.4 Details about atrial 50 Hz Burst

The atrial 50 Hz Burst pacing protocol delivers AOO pacing pulses to the atrium with an interval of 20 ms. As long as you press and hold the [50 Hz BURST Press and Hold] button on the programmer screen, the device continues delivering the pacing burst (up to a maximum of 10 s).

When delivering an atrial 50 Hz Burst, you can choose to enable VOO Backup pacing, which provides VOO mode pacing to the ventricle during the atrial pacing burst. VOO Backup pacing has separately selectable amplitude, pulse width, and rate values.

Note: Because so many paced events are delivered during 50 Hz Burst operation, the programmer screen or real-time recording strip may display a Marker Buffer Full (ER) symbol. This is normal behavior and should be expected during 50 Hz Burst delivery.

12.5 Inducing an arrhythmia with Fixed Burst

The Fixed Burst induction is designed to induce atrial and ventricular tachyarrhythmias by delivering a set of pacing pulses at a uniform, selectable interval to either the ventricle or the atrium. The amplitude and pulse width of the pulses are also selectable. When performing an atrial Fixed Burst induction, you can choose to have the device deliver backup ventricular pacing.

12.5.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resume at BURST</td>
<td>(check box) Option to resume detection automatically after the induction is delivered.</td>
<td>Enabled®; Disabled</td>
</tr>
<tr>
<td>Chamber</td>
<td>Chamber of the heart where the pacing burst is delivered.</td>
<td>RV; Atrium^</td>
</tr>
<tr>
<td>Interval</td>
<td>Pacing interval of the Fixed Burst induction.</td>
<td>100; 110 … 600 ms</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Voltage of each pulse in the pacing sequence.</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
</tr>
</tbody>
</table>
**Pulse Width** – Duration of each pulse in the pacing sequence.  
0.1; 0.2 … 0.5 ... 1.5 ms

**VVI Backup** – Enables backup ventricular pacing during an atrial induction (AT and DR devices only).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pacing Rate</strong></td>
<td>60; 70 ... 120 bpm</td>
</tr>
<tr>
<td><strong>RV Amplitude</strong></td>
<td>0.5; 1 ... 4; 5; 6; 8 V&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>RV Pulse Width</strong></td>
<td>0.1; 0.2 ... 1.5 ms&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>In VR devices, the chamber parameter has a fixed value of RV.

<sup>b</sup>The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing.

### 12.5.2 Considerations

Review the following information before performing the Fixed Burst induction.

**Warning:** Keep an external defibrillator immediately available and on standby.

**Aborting an induction or therapy** – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

**Atrial Amplitude and VVI Backup pacing** – VVI Backup pacing during an atrial Fixed Burst induction may be inhibited by crosstalk if the test value for atrial Amplitude is greater than 6 V.
12.5.3 How to deliver a Fixed Burst induction

2. Select Fixed Burst.
4. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
5. Confirm that the [Resume at BURST] check box is selected (for automatic detection and therapy) or is deselected (for manual therapy).
6. Accept the test values displayed on the screen, or choose new test values.
7. If you wish to provide VVI Backup pacing during an atrial induction, select VVI Backup… to set VVI backup pacing parameters.
8. Press and hold the [Fixed BURST Press and Hold] button. Release the button to end the induction.
9. If necessary, you can use the [ABORT] button to terminate a therapy in progress.

12.5.4 Details about Fixed Burst induction

The Fixed Burst induction is designed to induce arrhythmias by delivering asynchronous pacing pulses at a uniform, selectable interval. The amplitude and pulse width of the pulses are also selectable. As long as you press and hold the [Fixed BURST Press and Hold] button on the programmer screen, the device continues delivering the induction.

When delivering a Fixed Burst induction to the atrium, you can choose to enable VVI Backup pacing, which provides VVI mode pacing to the ventricle during the atrial induction. VVI Backup pacing has separately selectable amplitude, pulse width, and rate values.

12.6 Inducing an arrhythmia with PES

Programmed Electrical Stimulation (PES) delivers sequences of premature stimuli to induce atrial and ventricular tachyarrhythmias. The chamber, amplitude, pulse width, and pacing intervals for the induction are all selectable. When performing an atrial PES induction, you can also choose to have the device deliver backup ventricular pacing.

12.6.1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resume at DELIVER</td>
<td>(check box) Option to resume detection automatically after the induction is delivered.</td>
</tr>
<tr>
<td>Chamber</td>
<td>Chamber of the heart where the pacing burst is delivered.</td>
</tr>
<tr>
<td>#S1</td>
<td>Number of paced or sensed beats in the initial sequence.</td>
</tr>
<tr>
<td>S1S1</td>
<td>Pacing interval of the initial sequence.</td>
</tr>
<tr>
<td>S1S2</td>
<td>Pacing interval of the first asynchronous pacing pulse.</td>
</tr>
<tr>
<td>S2S3</td>
<td>Pacing interval of the second asynchronous pacing pulse.</td>
</tr>
<tr>
<td>S3S4</td>
<td>Pacing interval of the third asynchronous pulse.</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Voltage of each pulse in the pacing sequence.</td>
</tr>
</tbody>
</table>

Values: Enabled; Disabled; RV; Atrium; 1; 2 ... 8; 15; 100; 110 ... 2000 ms; Off; 100; 110 ... 600 ms; Off; 0.5; 1 ... 8 V

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Pulse Width – Duration of each pulse in the pacing sequence. 0.1; 0.2 … 0.5* … 1.5 ms

VVI Backup – Enables backup ventricular pacing during an atrial induction (AT and DR devices only).
  Pacing Rate – Pacing rate for backup pacing. 60; 70* … 120 bpm
  RV Amplitude – Voltage of each backup pacing pulse. 0.5; 1 … 4; 5; 6; 8 V
  RV Pulse Width – Duration of each backup pacing pulse. 0.1; 0.2 … 1.5 ms

a In VR devices, the chamber parameter has a fixed value of RV.
b The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing.

12.6.2 Considerations

Review the following information before performing the PES induction.

Warning: Keep an external defibrillator immediately available and on standby.

Aborting an induction or therapy – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

Atrial Amplitude and VVI Backup pacing – VVI Backup pacing during an atrial PES induction may be inhibited by crosstalk if the test value for atrial Amplitude is greater than 6 V.
12.6.3 How to deliver a PES induction

2. Select PES.
4. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
5. Confirm that the [Resume at DELIVER] check box is selected (for automatic detection and therapy) or is deselected (for manual therapy).
6. Accept the test values displayed on the screen, or choose new test values.
7. If you wish to provide VVI Backup pacing during an atrial induction, select VVI Backup… to set VVI backup pacing parameters.
8. Select the [DELIVER PES] button.
9. If necessary, you can use the [ABORT] button to terminate the induction or any therapy in progress.

12.6.4 Details about PES induction
The PES induction is designed to induce arrhythmias by delivering a selectable number of paced or sensed events in the VVI or AAI pacing mode, followed by up to 3 premature VOO or AOO paced events. The pulse amplitude and pulse width are programmed in common for all the pulses.

When delivering a PES induction to the atrium, you can choose to enable VVI Backup pacing, which provides VVI mode pacing to the ventricle during the atrial induction. VVI Backup pacing has separately selectable amplitude, pulse width, and rate values.

12.7 Delivering a manual therapy
During defibrillation threshold testing at implant, the EP Study screen can provide backup therapy for the induced VF episodes, in addition to the external defibrillator.

At follow-up, manual therapies can be used to assess or manipulate therapy effectiveness as part of chronic care.

12.7.1 Parameters for manual defibrillation and ventricular cardioversion

| Energy – Amount of energy delivered to the heart by the therapy. | 0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35... J |
| Pathway – Direction the electrical current flows through the heart. | AX>B; B>AX |

12.7.2 Parameters for manual ventricular ATP therapies

| General ventricular ATP therapy parameters |
| Minimum Interval – Minimum pacing interval for all ventricular ATP therapies. | 150; 160 ... 200... 400 ms |
| Amplitude – Voltage of the pacing pulses delivered during all ventricular ATP therapies. | 0.5; 1 ... 4; 5; 6... 8 V |
### Pulse Width
Duration of the pacing pulses delivered during all ventricular ATP therapies.

### Ramp therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td># Pulses</td>
<td>1; 2; 6; 15</td>
</tr>
<tr>
<td>%RR Interval</td>
<td>50; 53; 56; 59; 63; 66; 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>Dec/Pulse</td>
<td>0; 10; 40 ms</td>
</tr>
</tbody>
</table>

### Burst therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td># Pulses</td>
<td>1; 2; 8; 15</td>
</tr>
<tr>
<td>%RR Interval</td>
<td>50; 53; 56; 63; 66; 84; 88; 91; 94; 97%</td>
</tr>
</tbody>
</table>

### Ramp+ therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td># Pulses</td>
<td>1; 2; 3; 15</td>
</tr>
<tr>
<td>R-S1 (%RR)</td>
<td>50; 53; 56; 63; 66; 75; 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S1-S2 (%RR)</td>
<td>50; 53; 56; 63; 66; 69; 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S2-SN (%RR)</td>
<td>50; 53; 56; 63; 66; 84; 88; 91; 94; 97%</td>
</tr>
</tbody>
</table>

12.7.3 Parameters for manual atrial cardioversion (AT and DR devices)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>0.4; 0.6; 1.8; 2; 3; 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J</td>
</tr>
<tr>
<td>Pathway</td>
<td>AX&gt;B; B&gt;AX</td>
</tr>
<tr>
<td>Minimum R-R</td>
<td>400; 410; 500; 600 ms</td>
</tr>
<tr>
<td>Tilt</td>
<td>30; 40; 50; 65%</td>
</tr>
</tbody>
</table>

12.7.4 Parameters for manual atrial ATP therapies (AT and DR devices)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Interval</td>
<td>100; 110; 120; 130; 400 ms</td>
</tr>
<tr>
<td>Amplitude</td>
<td>0.5; 1; 4; 5; 6; 8 V</td>
</tr>
</tbody>
</table>
**Pulse Width** – Duration of the pacing pulses delivered during all atrial ATP therapies. 0.1; 0.2 … 1.5 ms

**VVI Backup** – Enables backup ventricular pacing during an atrial ATP therapy. On; Off

**VVI Backup Pacing Rate** – Pacing rate for backup pacing. 60; 70 … 120 bpm

**VVI Backup RV Amplitude** – Voltage of each backup pacing pulse. 0.5; 1 … 4; 5; 6; 8 V

**VVI Backup RV Pulse Width** – Duration of each backup pacing pulse. 0.1; 0.2 … 1.5 ms

**Ramp therapy parameters**

- **# Pulses** – Number of pulses in the Ramp pacing therapy. 1; 2 … 6 … 15; 20; 30 … 100
- **%AA Interval** – Pacing interval of the first Ramp pulse as a percentage of the atrial cycle length. 28; 31; 34; 38; 41 … 59; 63; 66 … 84; 88; 91; 94; 97%
- **Dec/Pulse** – Pacing interval decrement per pulse during a Ramp sequence. 0; 10 … 40 ms

**Burst+ therapy parameters**

- **# S1 Pulses** – Number of S1 pulses in the Burst+ pacing therapy. 1; 2 … 6 … 15; 20; 30 … 100
- **%AA Interval** – Pacing interval of the S1 burst pulses, as a percentage of the atrial cycle length. 28; 31; 34; 38; 41 … 59; 63; 66 … 84; 88; 91; 94; 97%
- **S1S2** – Pacing interval of the S2 stimulus following the burst, as a percentage of the pre-therapy atrial cycle length. Off; 28; 31; 34; 38; 41 … 59; 63; 66 … 84; 88; 91; 94; 97%
- **S2S3 Dec** – The S2-S3 interval equals the S1-S2 interval minus this decrement value. Off; 0; 10; 20 … 80 ms

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The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing.

### 12.7.5 Considerations

Review the following information before delivering a manual therapy.

**Warning:** Keep an external defibrillator immediately available and on standby.

**Aborting an induction or therapy** – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

**Atrial Amplitude and VVI Backup pacing** – VVI Backup pacing during a manual atrial ATP therapy may be inhibited by crosstalk if the test value for atrial Amplitude is greater than 6 V.
2. Select the desired manual therapy.
4. Accept the test values displayed on the screen, or choose new test values.
5. If you wish to provide VVI Backup pacing during an atrial therapy, select VVI Backup…
   to set VVI backup pacing parameters.
6. Select [DELIVER].
7. If necessary, you can abort the manual therapy by pressing [ABORT].

12.7.7 Details about manual therapies

12.7.7.1 Defibrillation

Manual defibrillation therapy charges the device capacitors and delivers a biphasic shock. The device does not attempt to confirm the presence of VF before delivering the shock, which is synchronized to a sensed R-wave if possible. See Section 7.5.5.7, “Synchronizing subsequent defibrillation therapies”, page 172.

12.7.7.2 Ventricular cardioversion

Manual ventricular cardioversion therapy charges the capacitors and attempts to synchronize the shock to a nonrefractory ventricular event. If the cardioversion therapy cannot be synchronized, the device aborts the therapy. See Section 7.7.5.5, “Synchronizing cardioversion after charging”, page 188.

12.7.7.3 Atrial cardioversion

Manual atrial cardioversion therapy charges the capacitors and attempts to synchronize the shock to a nonrefractory ventricular event. If the ventricular interval is shorter than the selected Minimum R-R Interval, the device aborts the therapy. See Section 7.2.5.3, “Atrial cardioversion synchronization”, page 148.

12.7.7.4 Antitachycardia pacing therapies (ATP)

Manual ATP therapies deliver one sequence of the selected antitachycardia pacing therapy. For information about the operation of ATP therapies, see Section 7.4, “Treating atrial arrhythmias with antitachycardia pacing”, page 153, and Section 7.6, “Treating VT and FVT with antitachycardia pacing”, page 176.
13 Solving system problems

13.1 Overview
This chapter describes problems that can occur with the system and suggests some corrective actions. These problems are classified into the following categories:

- sensing
- atrial tachyarrhythmia detection
- ventricular tachyarrhythmia detection
- atrial tachyarrhythmia therapy
- ventricular tachyarrhythmia therapy
- bradycardia pacing
- device status

To solve a system problem, you must follow these steps:

1. Define the problem.
2. Identify the cause of the problem.
3. Perform a corrective action.

The system provides a set of diagnostic tools to help you accomplish these tasks, including stored data from tachyarrhythmia episodes, clinical and lead performance trend data, therapy and episode counters, system tests and EP Study functions.

Note: The following information is not intended to be all-inclusive lists of system problems. Rather, it is presented as an aid to use in an overall problem-solving strategy.

13.2 Solving sensing problems
Sensing is a vital component of nearly all device operations. Problems with detection, therapy, and bradycardia pacing may often be traced to a problem with sensing. The following tables list some potential problems with sensing, their probable causes, and some corrective actions that may solve those problems.

<table>
<thead>
<tr>
<th>Table 41. No normal sense markers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptom:</strong> no, or too few, normal sense markers are displayed in the Live Rhythm Monitor</td>
</tr>
<tr>
<td><strong>Possible cause</strong></td>
</tr>
<tr>
<td>A lead is disconnected from the device connector port.</td>
</tr>
<tr>
<td>A lead is dislodged from the implant site.</td>
</tr>
</tbody>
</table>
Table 41. No normal sense markers (continued)

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>A lead is fractured or has an insulation defect.</td>
<td>Replace the lead.</td>
</tr>
<tr>
<td>The telemetry link between the device and programmer has been lost.</td>
<td>Reposition the programming head. Remove any sources of EMI.</td>
</tr>
</tbody>
</table>

Table 42. Double sensing of ventricular events

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The device is sensing T-waves after intrinsic events.</td>
<td>Increase the sensitivity threshold. Reposition the lead.</td>
</tr>
<tr>
<td>The device is sensing T-waves or R-waves after paced events.</td>
<td>Increase the V. Blank Post VP value.</td>
</tr>
</tbody>
</table>

Table 43. Extra ventricular sensing after atrial pacing

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosstalk from atrial pacing is occurring.</td>
<td>Decrease atrial pacing output. Increase RV Sensitivity threshold. Reposition atrial or ventricular lead.</td>
</tr>
</tbody>
</table>

Table 44. Extra atrial sensing after ventricular paced or sensed events

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far-field R-wave sensing is occurring.</td>
<td>Increase the A. Sensitivity threshold. Set the PVAB Method to Partial+. Set the PVAB Method to Absolute at the shortest PVAB interval that eliminates extra counts. Reposition atrial or ventricular lead, if possible.</td>
</tr>
<tr>
<td>Crosstalk from ventricular pacing is occurring.</td>
<td>Decrease ventricular pacing output. Increase the A. Sensitivity threshold. Set the PVAB Method to Partial+. Set the PVAB Method to Absolute at the shortest PVAB interval that eliminates extra counts. Reposition atrial or ventricular lead, if possible.</td>
</tr>
</tbody>
</table>
Table 45. Simultaneous atrial and ventricular sensing

| Symptom: atrial sensed events occur simultaneously with ventricular events and are not synchronized with ECG |
|---|---|
| Possible cause | Suggested corrective action |
| The atrial lead has been dislodged and is now in the ventricle. | Reposition the atrial lead. |

Table 46. Ventricular oversensing during patient movement

| Symptom: extra ventricular sensed events, especially when the patient moves or the device or lead is manipulated |
|---|---|
| Possible cause | Suggested corrective action |
| There is a poor connection to the device connector port. | Verify all connections, especially the setscrew contact. |
| The lead is fractured or has an insulation defect. | Replace the lead. |

Table 47. Oversensing in stored episodes only

| Symptom: stored episode shows extra ventricular sensed events, but the Live Rhythm Monitor shows normal sensing. |
|---|---|
| Possible cause | Suggested corrective action |
| The device was temporarily exposed to an EMI source. | Counsel the patient to keep away from sources of EMI. |
| There is a poor connection to the device connector port. | Verify all connections, especially the setscrew contact. |
| A lead is fractured or has an insulation defect. | Replace the lead. |

13.3 Solving atrial tachyarrhythmia detection problems

The following tables list some potential problems with atrial tachyarrhythmia detection, their probable causes, and some corrective actions that may solve those problems.

Table 48. Normal atrial events during an atrial episode

| Symptom: normal atrial markers (AS, AR, Ab) are seen during an atrial tachyarrhythmia episode |
|---|---|
| Possible cause | Suggested corrective action |
| Detection is suspended. | Select [Resume]. |
| Atrial undersensing is causing the device to miss some atrial intervals. | Verify atrial sensing. |
| The atrial rhythm has slowed so that the atrial cycle length is longer than AT/AF Interval. | This is normal operation. Consider reprogramming the AT/AF Interval, if desired. |
| AT/AF Detection is set to Monitor. | None. This is normal operation for monitor mode. |
### Table 49. Tachyarrhythmia events but no atrial detection

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The rhythm has a 1:1 atrial to ventricular pattern.</td>
<td>None. This is normal operation. The device does not detect 1:1 rhythms as atrial tachyarrhythmia episodes.</td>
</tr>
</tbody>
</table>

### Table 50. Stored atrial episode without EGM or AT/AF Onset indicator

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset and detection occurred on the same ventricular event.</td>
<td>None. This is normal operation.</td>
</tr>
</tbody>
</table>

### 13.4 Solving ventricular tachyarrhythmia detection problems

The following tables list some potential problems with ventricular tachyarrhythmia detection, their probable causes, and some corrective actions that may solve those problems.

### Table 51. Too few VF events during a VF episode

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF Interval is too short.</td>
<td>Increase the VF Interval.</td>
</tr>
<tr>
<td>Undersensing of VF due to decreased amplitude is occurring.</td>
<td>Decrease the RV Sensitivity threshold.</td>
</tr>
</tbody>
</table>

### Table 52. No VF events during a VF episode

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF Detection is off.</td>
<td>Turn VF Detection on.</td>
</tr>
<tr>
<td>Detection is suspended.</td>
<td>Select [Resume] on the programmer screen.</td>
</tr>
<tr>
<td>The VF Interval is shorter than the VF cycle length.</td>
<td>Increase the VF Interval.</td>
</tr>
</tbody>
</table>
Table 53. No VT detection after defibrillation

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT Detection is suspended for 17 events after</td>
<td>None. This is normal operation.</td>
</tr>
<tr>
<td>defibrillation therapy.a</td>
<td></td>
</tr>
</tbody>
</table>

aIf the defibrillation therapy is delivered as a result of a High Rate Timeout therapy operation or Progressive Episode Therapies operation, VT detection is not suspended.

Table 54. No VT events during a VT episode

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT Detection is off.</td>
<td>Turn VT Detection on.</td>
</tr>
<tr>
<td>Detection is suspended.</td>
<td>Select [Resume] on the programmer screen.</td>
</tr>
<tr>
<td>The VT Interval is shorter than the VT cycle length.</td>
<td>Increase the VT Interval.</td>
</tr>
<tr>
<td>Onset is on and has not identified a rapid rate increase.</td>
<td>Turn Onset off. Choose a larger Onset Percent value.</td>
</tr>
</tbody>
</table>

Table 55. Occasional normal sensed events during a VT episode

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The VT cycle length is too close to the VT Interval.</td>
<td>Increase the VT Interval.</td>
</tr>
<tr>
<td>Stability criterion is on and is too sensitive.</td>
<td>Turn Stability off. Choose a larger Stability interval.</td>
</tr>
</tbody>
</table>

13.5 Solving atrial tachyarrhythmia therapy problems

The following tables list some potential problems with atrial tachyarrhythmia therapy, their probable causes, and some corrective actions that may solve those problems.
### Table 56. Programmed atrial ATP therapies are delayed

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ventricular cycle length is shorter than the VT Monitor Interval.</td>
<td>None. This is normal operation. Atrial ATP is not delivered for a detected atrial arrhythmia while there is a fast ventricular rhythm that meets the criteria for VT Monitor episodes.</td>
</tr>
<tr>
<td>The time since AT/AF detection has not exceeded the programmed Episode Duration Before Rx Delivery.</td>
<td>None. This is normal operation. Atrial ATP therapies are not delivered until the episode duration exceeds the programmed Episode Duration Before Rx Delivery value.</td>
</tr>
<tr>
<td>The Rhythm Change feature of Reactive ATP is enabled, and the device detects a change from a regular rhythm to an irregular rhythm.</td>
<td>None. This is normal operation. If a regular rhythm changes to an irregular rhythm, the device delays atrial ATP delivery for 10 min.</td>
</tr>
<tr>
<td>A Fast AT/AF therapy is scheduled within 10 min of a previously delivered atrial ATP therapy.</td>
<td>None. This is normal operation. The device delays Fast AT/AF therapies for 10 min after an atrial ATP therapy is delivered.</td>
</tr>
<tr>
<td>One or more criteria for atrial ATP delivery are not met at the scheduled time. See Section 7.1.5, “Details about atrial therapy sequencing”, page 136.</td>
<td>None. This is normal operation.</td>
</tr>
</tbody>
</table>

### Table 57. Programmed atrial ATP therapies are not delivered

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT/AF Detection is set to Monitor.</td>
<td>Program AT/AF Detection to On.</td>
</tr>
<tr>
<td>The atrial cycle length is less than the atrial ATP Minimum Interval, so the ATP therapy paces are inhibited.</td>
<td>Decrease the atrial ATP Minimum Interval.</td>
</tr>
<tr>
<td>The atrial cycle length is less than the Fast AT/AF Interval, and no atrial ATP therapies are enabled for Fast AT/AF episodes.</td>
<td>Enable atrial ATP therapies for the Fast AT/AF detection zone.</td>
</tr>
<tr>
<td>The AT/AF episode has been in progress for longer than the programmed Duration to Stop value.</td>
<td>None. This is normal operation.</td>
</tr>
<tr>
<td>The atrial ATP therapy was aborted when a pause was detected in the atrial rhythm, possibly due to atrial undersensing.</td>
<td>Verify atrial sensing. Atrial ATP can be aborted if no atrial event occurs within 500 ms after the therapy is started or scheduled.</td>
</tr>
<tr>
<td>Atrial ATP therapies have been delayed.</td>
<td>See Table 56.</td>
</tr>
<tr>
<td>Atrial ATP therapies have been disabled.</td>
<td>See Table 58.</td>
</tr>
</tbody>
</table>

Stored AT/AF episodes for which therapy is not delivered are recorded as “Monitored” episodes.
### Table 58. Atrial ATP therapies are disabled

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The “Disable Atrial ATP if it accelerates V. Rate” option was enabled and the</td>
<td>The device has responded as intended to a potential problem with atrial ATP therapy. Evaluate</td>
</tr>
<tr>
<td>ventricular rate was accelerated by an atrial ATP therapy.</td>
<td>the patient’s response to atrial ATP therapy and check the atrial lead position.</td>
</tr>
<tr>
<td>All atrial therapies are disabled because a VT/VF episode is detected after an</td>
<td>The device has responded as intended to a potential problem with atrial therapy. Evaluate</td>
</tr>
<tr>
<td>atrial therapy.</td>
<td>the patient’s response to atrial therapy and check the atrial lead position.</td>
</tr>
<tr>
<td>All atrial therapies are disabled due to a failed Atrial Lead Position Check.</td>
<td>Evaluate the atrial lead position. Consider disabling Atrial Lead Position Check if the atrial</td>
</tr>
<tr>
<td></td>
<td>lead position is correct.</td>
</tr>
</tbody>
</table>

### Table 59. Extra atrial ATP therapies

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactive ATP has reenabled atrial ATP therapies.</td>
<td>None. This is normal operation when Reactive ATP is enabled.</td>
</tr>
<tr>
<td>Atrial therapies were reprogrammed while the atrial episode was in progress.</td>
<td>None. This is normal operation. The device reenables therapies for an episode in progress if therapy parameters are reprogrammed.</td>
</tr>
</tbody>
</table>

### Table 60. More than one atrial CV therapy required

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal AT/AF resistance to cardioversion is occurring.</td>
<td>None. Atrial cardioversion is not always effective on the first shock.</td>
</tr>
<tr>
<td>Atrial defibrillation threshold has increased due to a change in the patient’s</td>
<td>Set the therapy energy level higher, if possible. Change pathway polarity.</td>
</tr>
<tr>
<td>status (new medications, myocardial infarction).</td>
<td>Add a supplementary high-voltage electrode.</td>
</tr>
<tr>
<td>Lead dislodgement has occurred.</td>
<td>Titrate drugs, if possible.</td>
</tr>
<tr>
<td>Lead fracture or insulation defect has occurred.</td>
<td>Reposition the lead.</td>
</tr>
</tbody>
</table>

---

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### Table 61. Atrial CV with high impedance and low delivered energy

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead is disconnected from the device connector port.</td>
<td>Verify all connections, especially the setscrew contact.</td>
</tr>
<tr>
<td>Lead fracture has occurred.</td>
<td>Replace the lead.</td>
</tr>
<tr>
<td>The Active Can feature is turned off and no lead is connected to the SVC (HVX) port.</td>
<td>Enable the Active Can feature. Implant a supplementary high-voltage lead and connect it to the SVC (HVX) port.</td>
</tr>
</tbody>
</table>

### Table 62. Programmed atrial CV therapies are not delivered

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The time since AT/AF detection has not exceeded the programmed Episode Duration Before Rx Delivery.</td>
<td>None. This is normal operation. Atrial CV therapies are not delivered until the episode duration exceeds the programmed Episode Duration Before Rx Delivery value.</td>
</tr>
<tr>
<td>The time of day is not within the programmed delivery window.</td>
<td>None. This is normal operation. Consider reprogramming the Delivery Window Start Time or the Delivery Window Length parameters, if desired.</td>
</tr>
<tr>
<td>The number of atrial shocks per day limit has been exceeded.</td>
<td>None. This is normal operation. Consider reprogramming the Maximum shocks per day parameter, if desired.</td>
</tr>
<tr>
<td>The number of atrial shocks per day limit has been exceeded due to Patient Activated shock.</td>
<td>None. This is normal operation. Consider reprogramming the Maximum shocks per day parameter, if desired. Note that the programmed limit on number of shocks does not prevent a Patient Activated shock from being delivered.</td>
</tr>
<tr>
<td>The ventricular rate is faster than the programmed Minimum R-R Interval.</td>
<td>None. This is normal operation. Consider reprogramming the Minimum R-R Interval parameter, if desired.</td>
</tr>
</tbody>
</table>

### Table 63. Atrial CV therapies are disabled

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>All atrial therapies are disabled because a VT/VF episode is detected after an atrial therapy.</td>
<td>The device has responded as intended to a potential problem with atrial therapy. Evaluate the patient’s response to atrial therapy and check the atrial lead position.</td>
</tr>
<tr>
<td>All atrial therapies are disabled due to a failed Atrial Lead Position Check.</td>
<td>Evaluate the atrial lead position. Consider disabling Atrial Lead Position Check if the atrial lead position is correct.</td>
</tr>
</tbody>
</table>
13.6 Solving ventricular tachyarrhythmia therapy problems

The following tables list some potential problems with ventricular tachyarrhythmia therapy, their probable causes, and some corrective actions that may solve those problems.

Table 64. More than one high-voltage therapy required

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defibrillation threshold has increased due to a change in the patient’s status</td>
<td>Set the therapy energy level higher, if possible.</td>
</tr>
<tr>
<td>(new medications, myocardial infarction).</td>
<td>Change pathway polarity.</td>
</tr>
<tr>
<td>Lead dislodgement has occurred.</td>
<td>Reposition the lead.</td>
</tr>
<tr>
<td>Lead fracture or insulation defect has occurred.</td>
<td>Replace the lead.</td>
</tr>
</tbody>
</table>

Table 65. High-voltage therapy with high impedance and low delivered energy

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead has disconnected from the device connector port.</td>
<td>Verify all connections, especially the setscrew contact.</td>
</tr>
<tr>
<td>Lead fracture has occurred.</td>
<td>Replace the lead.</td>
</tr>
<tr>
<td>The Active Can feature is turned off and no lead is connected to the SVC</td>
<td>Enable the Active Can feature.</td>
</tr>
<tr>
<td>(HVX) port.</td>
<td>Implant a supplementary high-voltage lead and connect it to the</td>
</tr>
<tr>
<td></td>
<td>SVC (HVX) port.</td>
</tr>
</tbody>
</table>

Table 66. Programmed ventricular ATP therapies are not delivered

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATP pacing is inhibited because the VT cycle length is less than the programmed</td>
<td>Decrease ATP Minimum Interval.</td>
</tr>
<tr>
<td>ATP Minimum Interval.</td>
<td></td>
</tr>
<tr>
<td>Smart Mode is on and has disabled an unsuccessful ATP therapy.</td>
<td>Choose a different therapy.</td>
</tr>
<tr>
<td></td>
<td>Reprogram ATP therapy parameters.</td>
</tr>
</tbody>
</table>
Table 67. ATP During Charging therapy is not delivered

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>One of the 8 V-V intervals prior to VF Detection is shorter than the programmed value for the “Deliver ATP if last 8 R-R &gt;=” parameter.</td>
<td>None. This is normal operation. Consider reducing the value for the “Deliver ATP if last 8 R-R &gt;=” parameter, if desired.</td>
</tr>
<tr>
<td>ATP pacing is inhibited because the VT cycle length is less than the programmed ATP Minimum Interval.</td>
<td>Decrease the ATP Minimum Interval.</td>
</tr>
<tr>
<td>Smart Mode is on and has disabled an unsuccessful ATP therapy.</td>
<td>Choose a different therapy. Reprogram ATP therapy parameters.</td>
</tr>
</tbody>
</table>

13.7 Solving bradycardia pacing problems

The following tables list some potential problems with bradycardia pacing therapy, their probable causes, and some corrective actions that may solve those problems.

Table 68. High-rate pacing without patient activity

<table>
<thead>
<tr>
<th>Symptom: the device is pacing at a high rate in the absence of patient activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible cause</td>
</tr>
<tr>
<td>A pacemaker-mediated tachycardia (PMT) is in progress.</td>
</tr>
<tr>
<td>The selected Rate Response pacing parameters are too sensitive.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Table 69. Atrial paced events sensed as ventricular tachyarrhythmia events

<table>
<thead>
<tr>
<th>Symptom: AAI or AAIR paced events are sensed as ventricular tachyarrhythmia events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible cause</td>
</tr>
<tr>
<td>Loss of AV synchrony and crosstalk have occurred.</td>
</tr>
</tbody>
</table>
### Table 70. High atrial rate but slow ventricular pacing

**Symptom:** there is a high intrinsic atrial rate but slow ventricular pacing in response

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The atrial rate is faster than the 2:1 block rate.</td>
<td>Decrease PVARP. Decrease SAV. Enable Rate Adaptive AV. Set PVARP to Varied.</td>
</tr>
<tr>
<td>The atrial rate is faster than the Upper Tracking Rate.</td>
<td>Increase the Upper Tracking Rate.</td>
</tr>
</tbody>
</table>

### Table 71. Fast ventricular pacing during an atrial tachyarrhythmia

**Symptom:** high ventricular pacing rate occurs during atrial fibrillation or flutter

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The device is pacing the ventricle in response to atrial events.</td>
<td>Enable Mode Switch. Set the pacing mode to DDIR or DDI. Decrease the Upper Tracking Rate.</td>
</tr>
</tbody>
</table>

### Table 72. Ventricular sensing immediately after atrial pacing

**Symptom:** atrial paced events are followed immediately by ventricular sense markers, but the ECG shows a slow ventricular rate

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventricular pacing is inhibited by crosstalk from atrial pacing.</td>
<td>Enable Vent. Safety Pacing. Decrease the atrial pacing amplitude or pulse width. Increase the RV Sensitivity threshold. Reposition the atrial or ventricular lead.</td>
</tr>
</tbody>
</table>

### 13.8 Responding to device status indicators

The device performs self-diagnostics to identify problems with its critical functions. If it detects a problem, it sets a device status indicator, which appears on the programmer screen during interrogation. The following tables list the device status indicators, their probable causes, and some suggested actions to take.

**Table 73. Device Electrical Reset indicator**

<table>
<thead>
<tr>
<th>Device status indicator: Warning - Device Electrical Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Possible cause</strong></td>
</tr>
<tr>
<td>Device memory was corrupted by EMI, electrocautery, external defibrillation, or some other environmental effect.</td>
</tr>
</tbody>
</table>
### Table 74. Serious Device Error indicator

**Device status indicator:** SERIOUS DEVICE ERROR

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device memory was corrupted by EMI, electrocautery, external defibrillation,</td>
<td>Contact a Medtronic representative and replace the device</td>
</tr>
<tr>
<td>or some other environmental effect. This corruption was serious enough that</td>
<td>immediately.</td>
</tr>
<tr>
<td>the device cannot recover.</td>
<td></td>
</tr>
</tbody>
</table>

### Table 75. Charge Circuit Timeout indicator

**Device status indicator:** Warning - Charge Circuit Timeout

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>A single long charging period has</td>
<td>Contact a Medtronic representative and replace the device</td>
</tr>
<tr>
<td>occurred.</td>
<td>immediately.</td>
</tr>
</tbody>
</table>

### Table 76. Charge Circuit Inactive indicator

**Device status indicator:** Warning - Charge Circuit Inactive

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three consecutive long charging</td>
<td>Contact a Medtronic representative and replace the device</td>
</tr>
<tr>
<td>periods have occurred.</td>
<td>immediately.</td>
</tr>
</tbody>
</table>

### Table 77. Elective Replacement Indicator (ERI)

**Device status indicator:** Quick Look screen displays an ERI message

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The battery voltage measurement</td>
<td>Schedule an appointment to replace the device</td>
</tr>
<tr>
<td>was lower than the ERI voltage</td>
<td></td>
</tr>
<tr>
<td>threshold for 3 consecutive days.</td>
<td></td>
</tr>
</tbody>
</table>

### Table 78. End of Life (EOL) indicator

**Device status indicator:** Quick Look screen displays an EOL indicator

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three months have passed since the</td>
<td>Replace the device immediately.</td>
</tr>
<tr>
<td>device reached ERI.</td>
<td></td>
</tr>
<tr>
<td>A long charging period (&gt;16 s) has</td>
<td>Contact a Medtronic representative and replace the device</td>
</tr>
<tr>
<td>triggered the EOL indicator.</td>
<td>immediately.</td>
</tr>
</tbody>
</table>

---

*a EOL may be indicated before the end of three months if actual battery usage exceeds the post-ERI operating conditions (see Section 1.3, “Replacement indicators”, page 16).*
Table 79. Atrial therapy disabled

<table>
<thead>
<tr>
<th>Possible cause</th>
<th>Suggested corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The “Disable Atrial ATP if it accelerates V. Rate” option was enabled and the</td>
<td>The device has responded as intended to a potential problem with atrial ATP therapy. Evaluate</td>
</tr>
<tr>
<td>ventricular rate was accelerated by an atrial ATP therapy.</td>
<td>the patient’s response to atrial ATP therapy and check the atrial lead position.</td>
</tr>
<tr>
<td>All atrial therapies are disabled because a VT/VF episode is detected after</td>
<td>The device has responded as intended to a potential problem with atrial therapy. Evaluate</td>
</tr>
<tr>
<td>an atrial therapy.</td>
<td>the patient’s response to atrial therapy and check the atrial lead position.</td>
</tr>
<tr>
<td>All atrial therapies are disabled due to a failed Atrial Lead Position Check.</td>
<td>Evaluate the atrial lead position. Consider disabling Atrial Lead Position Check if the atrial lead position is correct.</td>
</tr>
</tbody>
</table>
A  Warnings and precautions

A.1  General

Anti-coagulation – Use of the device should not change the application of established anti-coagulation protocols.

Avoiding shock during handling – Disable tachyarrhythmia detection during implant, explant, or postmortem procedures. The device can deliver a high-voltage shock if the defibrillation terminals are touched.

Electrical isolation during implant – Do not allow the patient to have contact with grounded equipment that might produce electrical current leakage during implant. Electrical current leakage may induce arrhythmias that may result in the patient’s death.

External defibrillation equipment – Keep external defibrillation equipment nearby for immediate use whenever arrhythmias are possible or intentionally induced during device testing, implant procedures, or post-implant testing.

Lead compatibility – Do not use another manufacturer’s leads without demonstrated compatibility with Medtronic devices. If a lead is not compatible with a Medtronic device, the result may be undersensing of cardiac activity, failure to deliver necessary therapy, or a leaking or intermittent electrical connection.

Occurrence of stroke – Following an ischemic or cerebrovascular accident, disable atrial cardioversion therapies until the patient has stabilized.

A.2  Handling and storage instructions

Follow these guidelines when handling or storing the device.

Device storage – Store the device in a clean area, away from magnets, kits containing magnets, and sources of electromagnetic interference. Exposing the device to magnets or electromagnetic interference may damage the device.

Dropped device – Do not implant the device if it has been dropped on a hard surface from a height of 30 cm (12 in) or more after it is removed from its packaging.

Device temperature – Allow the device to reach room temperature before it is programmed or implanted. Device temperature above or below room temperature may affect initial device function.

Ethylene oxide resterilization – The device and accessories were sterilized with ethylene oxide before shipment. If the integrity of the sterile package has been compromised, resterilize the device and accessories using ethylene oxide. Resterilization does not affect
the “Use by” date. To avoid resterilization techniques that may damage the device, observe
the following recommendations:

- Do not use gamma radiation, organic cleaning agents, ultrasonic cleaners, or an
  autoclave to resterilize the device and accessories.
- Repackage the device and accessories in a gas permeable container before
  resterilization.
- Refer to the sterilizer product literature for operating instructions.
- Do not exceed 55 °C (131 °F).
- Do not exceed 103 kPa (15 psi).
- Use an acceptable method for determining sterilizer effectiveness, such as biological
  indicators.
- After resterilization, allow the device and accessories to aerate ethylene oxide residues.
- Do not resterilize more than twice.

**Explant and disposal** – Consider the following information related to device explant and
disposal:

- Interrogate the device and disable tachyarrhythmia detection before explanting,
  cleaning, or shipping the device. This prevents the device from delivering unwanted
  shocks.
- Explant the implantable device postmortem. In some countries, explanting
  battery-operated implantable devices is mandatory because of environmental
  concerns; check the local regulations. In addition, if subjected to incineration or
  cremation temperatures, the device may explode.
- Medtronic implantable devices are intended for single use only. Do not resterilize and
  reimplant explanted devices.
- Use the Tachyarrhythmia Product Information Report to return explanted devices to
  Medtronic for analysis and disposal.

**Inspecting the sterile package** – Carefully inspect the package before opening it:

- If the seal or package is damaged, contact a Medtronic representative.
- Do not use the product after the “Use by” date on the package label.
- For instructions on opening the sterile package, see the diagram inside the lid of the
  shelf box.

**Temperature limits** – Store and transport the package between –18 °C and +55 °C (0 °F
and 131 °F). Electrical reset may occur at temperatures below –18 °C (0 °F). Device
longevity may decrease and performance may be affected at temperatures above +55 °C
(131 °F).

**Use by date** – Do not implant the device after the “Use by” date on the package label.
Battery longevity may be reduced.
A.3 Lead evaluation and lead connection

Lead connection – Consider the following information when connecting the lead and the device:

- Cap abandoned leads to avoid transmitting electrical signals.
- Plug any unused lead ports to protect the device.
- Verify lead connections. Loose lead connections may result in inappropriate sensing and failure to deliver arrhythmia therapy.

Lead Impedance – Consider the following information about lead impedance when evaluating the lead system.

- Ensure that the defibrillation lead impedance is greater than 20 Ω. An impedance of less than 20 Ω may damage the device or prevent delivery of high-voltage therapy.
- Before taking electrical or defibrillation efficacy measurements, move objects made from conductive materials, such as guide wires, away from all electrodes. Metal objects, such as guide wires, can short circuit a device and lead, causing electrical current to bypass the heart and possibly damage the device and lead.
- Refer to the lead technical manuals for specific instructions and precautions about lead handling.

Epicardial leads – Do not fold, alter, or remove any portion of an epicardial lead. Doing so may compromise electrode function or longevity.

A.4 Device operation

Accessories – Use this device only with accessories, parts subject to wear, and disposable items that have been tested to technical standards and found safe by an approved testing agency.

Battery depletion – Carefully monitor battery longevity. Battery depletion will eventually cause the device to stop functioning. Cardioversion and defibrillation are high-energy therapies that shorten battery longevity. An excessive number of charging cycles will also shorten battery longevity.

Charge Circuit Timeout or Charge Circuit Inactive – Contact a Medtronic representative and replace the device immediately if the programmer displays a Charge Circuit Timeout or Charge Circuit Inactive message. If this message is displayed, high-voltage therapies are not available for the patient.

Concurrent pacemaker use – If a pacemaker is used concurrently with the ICD, verify that the ICD does not sense the pacemaker output pulses because this can affect the detection of tachyarrhythmias by the ICD. Program the pacemaker to deliver pacing pulses at intervals longer than the ICD tachyarrhythmia detection intervals.
End of Life (EOL) indicator – Replace the device immediately if the programmer displays an EOL indicator. The device may not perform adequately after the EOL indicator appears.

Follow-up testing – Consider this information when performing follow-up testing of the device.

- Keep external defibrillation equipment nearby for immediate use in case the patient requires external rescue.
- Changes in the patient’s condition, drug regimen, and other factors may change the defibrillation threshold (DFT), which may result in nonconversion of the arrhythmia postoperatively. Successful conversion of ventricular fibrillation or ventricular tachycardia during the implantation procedure is no assurance that conversion will occur postoperatively.

Higher than programmed energy – The device may deliver a therapy of higher than programmed energy if it was previously charged to a higher energy and that charge remains on the capacitors.

Magnets – Positioning a magnet over the device suspends detection and treatment but does not alter bradycardia therapy. The programming head contains a magnet that can suspend detection. However, detection is not suspended if telemetry between the device and programmer is established.

Pacemaker-dependent patients – Always program Ventricular Safety Pacing to On for pacemaker-dependent patients. Ventricular Safety Pacing prevents ventricular asystole due to inappropriate inhibition of ventricular pacing caused by oversensing.

Programmers – Use only Medtronic programmers and application software to communicate with the device. Programmers and software from other manufacturers are not compatible with Medtronic devices.

A.5 Warnings, precautions, and guidance for clinicians performing medical procedures on cardiac device patients

This section is intended for physicians and other health care professionals who perform medical procedures on patients with Medtronic implanted cardiac device systems and who consult with the patients’ cardiologists. This section provides warnings, precautions, and guidance related to medical therapies and diagnostic procedures that may cause serious injury to a patient, interfere with a Medtronic implanted cardiac device system, or permanently damage the system.

Note: Some common medical procedures that pose no risk are also listed in this section.
For additional guidance on medical procedures not addressed in this section, customers can contact the following resources:

- Customers in the United States can contact either of the following telephone numbers: for pacemakers, contact Medtronic Technical Services at +1 800 505 4636; for ICDs, contact Medtronic Technical Services at +1 800 723 4636. You may also submit questions to tshelp@Medtronic.com or your Medtronic representative.
- Customers outside of the United States can contact a Medtronic representative.

**Ablation (RF ablation or microwave ablation)** – Ablation is a surgical technique in which radio frequency (RF) or microwave energy is used to destroy cells by creating heat. Ablation used in cardiac device patients may result in, but is not limited to, induced ventricular tachyarrhythmias, oversensing, unintended tissue damage, device damage, or device malfunction.

Pulse-modulated ablation systems may pose higher risk for induced ventricular tachyarrhythmias. Medtronic cardiac devices are designed to withstand exposure to ablation energy. To mitigate risks, observe the following precautions:

- Ensure that temporary pacing and defibrillation equipment is available.
- Avoid direct contact between the ablation catheter and the implanted system.
- Position the return electrode patch so that the electrical current pathway does not pass through or near the device and leads.
- Always monitor the patient during ablation with at least two separate methods, such as arterial pressure display, ECG, manual monitoring of the patient’s rhythm (taking pulse) or monitor by some other means such as ear or finger pulse oximetry, or Doppler pulse detection.

To avoid or mitigate the effects of oversensing, if appropriate for the patient, initiate asynchronous pacing by implementing one of the following precautions:

- Suspend tachyarrhythmia detection by using a magnet or a programmer. If a programmer is used and ablation causes a device reset, the cardiac device resumes detection. After the ablation procedure, remove the magnet or restore device parameters.
- If appropriate for the patient, program the device to an asynchronous pacing mode (for example, DOO). After the ablation procedure, remove the magnet or restore device parameters.

**Capsule endoscopy, pH capsule procedures** – Capsule endoscopy is a procedure in which a capsule containing a tiny camera is swallowed by the patient to take pictures of the patient’s digestive tract. Capsule endoscopy and pH capsule procedures should pose no risk of electromagnetic interference.

**Dental procedures** – Dental equipment, such as ultrasonic scalers, drills, and pulp testers, poses no risk of electromagnetic interference. Keep a cardiac device at least 15 cm (6 in) away from magnets, such as magnets found in dental office pillow headrests.
Diagnostic radiology (CT scans, fluoroscopy, mammograms, x-rays) – Diagnostic radiology refers to the following medical procedures:

- Computed axial tomography (CT or CAT scan)
- Fluoroscopy (an x-ray procedure that makes it possible to see internal organs in motion by producing a video image)
- Mammograms
- X-rays (radiography, such as chest x-rays)

Normally, the accumulated dose from diagnostic radiology is not sufficient to damage the device. If the device is not directly exposed to the radiation beam, no risk of interference with device operation occurs. However, if the device is directly in a CT scan beam, see the following precautions in “CT scan”. Similar interference may be observed for some forms of high-intensity fluoroscopy.

CT scan – A CT scan is a computerized process in which two-dimensional x-ray images are used to create a three-dimensional x-ray image. If the device is not directly in the CT scan beam, the device is not affected. If the device is directly in the CT scan beam, oversensing may occur for the duration of time the device is in the beam. If the device will be in the beam for longer than 4 s, to avoid or mitigate the effects of oversensing, if appropriate for the patient, initiate asynchronous pacing by implementing one of the following precautions:

- Suspend tachyarrhythmia detection by using a magnet or a programmer. After completing the CT scan, remove the magnet or restore device parameters.
- If appropriate for the patient, program the device to an asynchronous pacing mode (for example, DOO). After completing the CT scan, restore device parameters.

Diagnostic ultrasound – Diagnostic ultrasound is an imaging technique that is used to visualize muscles and internal organs, their size, structures, and motion as well as any pathological lesions. It also is used for fetal monitoring and to detect and measure blood flow. Diagnostic ultrasound, such as echocardiogram, poses no risk of electromagnetic interference. For precautions about therapeutic ultrasound, see “Diathermy treatment (including therapeutic ultrasound)”.

Diathermy treatment (including therapeutic ultrasound) – Diathermy is a treatment that involves the therapeutic heating of body tissues. Diathermy treatments include high frequency, short wave, microwave, and therapeutic ultrasound. Except for therapeutic ultrasound, do not use diathermy treatments on cardiac device patients. Diathermy treatments may result in serious injury or damage to an implanted device and leads. Therapeutic ultrasound is the use of ultrasound at higher energies than diagnostic ultrasound to bring heat or agitation into the body. Therapeutic ultrasound is acceptable if treatment is performed with a minimum separation distance of 15 cm (6 in) between the applicator and the implanted device and leads.

Electrolysis – Electrolysis is the permanent removal of hair by using an electrified needle (AC or DC) that is inserted into the hair follicle. Electrolysis introduces electrical current into
the body, which may cause oversensing. Evaluate any possible risks associated with oversensing with the patient’s medical condition. To avoid or mitigate the effects of oversensing, if appropriate for the patient, initiate asynchronous pacing by implementing one of the following precautions:

- Suspend tachyarrhythmia detection by using a magnet or a programmer. After completing electrolysis, remove the magnet or restore device parameters.
- If appropriate for the patient, program the device to an asynchronous pacing mode (for example, DOO). After completing electrolysis, restore device parameters.

**Electrosurgery** – Electrosurgery (including electrocautery, electrosurgical cautery, and Medtronic Advanced Energy surgical incision technology) is a process in which an electric probe is used to control bleeding, to cut tissue, or to remove unwanted tissue. Electrosurgery used on cardiac device patients may result in, but is not limited to, oversensing, unintended tissue damage, tachyarrhythmias, device damage, or device malfunction. If electrosurgery cannot be avoided, consider the following precautions:

- Ensure that temporary pacing and defibrillation equipment is available.
- Use a bipolar electrosurgery system or Medtronic Advanced Energy surgical incision technology, if possible. If a unipolar electrosurgery system is used, position the return electrode patch so that the electrical current pathway does not pass through or within 15 cm (6 in) of the device and leads.
- Do not apply unipolar electrosurgery within 15 cm (6 in) of the device and leads.
- Use short, intermittent, and irregular bursts at the lowest clinically appropriate energy levels.
- Always monitor the patient during electrosurgery. If the ECG tracing is not clear due to interference, manually monitor the patient’s rhythm (take pulse); alternatively, monitor by some other means such as ear or finger pulse oximetry, Doppler pulse detection, or arterial pressure display.

To avoid or mitigate the effects of oversensing, consider the following precautions:

- Suspend tachyarrhythmia detection by using a magnet or a programmer. If a programmer is used and electrosurgery causes a device reset, the cardiac device resumes detection. After completing electrosurgery, remove the magnet or restore device parameters.
- If appropriate for the patient, program the device to an asynchronous pacing mode (for example, DOO). After completing electrosurgery, restore device parameters.

**External defibrillation and cardioversion** – External defibrillation and cardioversion are therapies that deliver an electrical shock to the heart to convert an abnormal heart rhythm to a normal rhythm.

Medtronic cardiac devices are designed to withstand exposure to external defibrillation and cardioversion. While damage to an implanted system from an external shock is rare, the probability increases with increased energy levels. These procedures may also temporarily or permanently elevate pacing thresholds or temporarily or permanently damage the
myocardium. If external defibrillation or cardioversion are required, consider the following precautions:

- Use the lowest clinically appropriate energy.
- Position the patches or paddles a minimum of 15 cm (6 in) away from the device.
- Position the patches or paddles perpendicular to the device and leads.
- If an external defibrillation or cardioversion is delivered within 15 cm (6 in) of the device, use a Medtronic programmer to evaluate the device and lead system.

Hyperbaric therapy (including hyperbaric oxygen therapy, or HBOT) – Hyperbaric therapy is the medical use of air or 100% oxygen at a higher pressure than atmospheric pressure. Hyperbaric therapies with pressures exceeding 2.5 ATA (approximately 15 m (50 ft) of seawater) may affect device function or cause device damage. To avoid or mitigate risks, do not expose implanted devices to pressures exceeding 2.5 ATA.

Lithotripsy – Lithotripsy is a medical procedure that uses mechanical shock waves to break up kidney or gallbladder stones. If the device is at the focal point of the lithotripter beam, lithotripsy may permanently damage the device. If lithotripsy is required, keep the focal point of the lithotripter beam a minimum of 2.5 cm (1 in) away from the device. To avoid or mitigate the effects of oversensing, consider the following precautions:

- Suspend tachyarrhythmia detection by using a magnet or a programmer. After completing lithotripsy treatment, remove the magnet or restore device parameters.
- If appropriate for the patient, program the device to an asynchronous pacing mode (for example, DOO). After completing lithotripsy treatment, restore device parameters.

Magnetic resonance imaging (MRI) – An MRI is a type of medical imaging that uses magnetic fields to create an internal view of the body. Do not conduct MRI scans on patients who have this device or lead implanted. MRI scans may result in serious injury, induction of tachyarrhythmias, or implanted system malfunction or damage.

Radiotherapy – Radiotherapy is a cancer treatment that uses radiation to control cell growth. When performing radiotherapy, take precautions to avoid oversensing, device damage, and device operational errors, as described in the following sections:

- Oversensing – If the patient undergoes radiotherapy treatment and the average dose rate at the device exceeds 1 cGy/min, the device may inappropriately sense direct or scattered radiation as cardiac activity for the duration of the procedure. To avoid or mitigate the effects of oversensing, consider these precautions:
  - Suspend tachyarrhythmia detection by using a magnet or a programmer. After completing radiotherapy treatment, remove the magnet or restore device parameters.
  - If appropriate for the patient, program the device to an asynchronous pacing mode (for example, DOO). After completing radiotherapy treatment, restore device parameters.
- **Device damage** – Exposing the device to high doses of direct or scattered radiation from any source that results in an accumulated dose greater than 500 cGy may damage the device. Damage may not be immediately apparent. If a patient requires radiation therapy from any source, do not expose the device to radiation that exceeds an accumulated dose of 500 cGy. To limit device exposure, use appropriate shielding or other measures. For patients who are undergoing multiple radiation treatments, consider the accumulated dose to the device from previous exposures.

**Note:** Normally, the accumulated dose from diagnostic radiology is not sufficient to damage the device. See “Diagnostic radiology” for precautions.

- **Device operational errors** – Exposing the device to scattered neutrons may cause electrical reset of the device, errors in device functionality, errors in diagnostic data, or loss of diagnostic data. To help reduce the chance of electrical reset due to neutron exposure, deliver radiotherapy treatment by using photon beam energies less than or equal to 10 MV. The use of conventional x-ray shielding during radiotherapy does not protect the device from the effects of neutrons. If photon beam energies exceed 10 MV, Medtronic recommends interrogating the device immediately after radiotherapy treatment. An electrical reset requires reprogramming of device parameters. Electron beam treatments that do not produce neutrons do not cause electrical reset of the device.

**Stereotaxis** – Stereotaxis is a catheter navigation platform that allows clinicians to steer catheter-based diagnostic and therapeutic devices throughout the body by using magnetic navigation. During a stereotaxis procedure, the magnetic field may activate the magnet detection sensor in the implanted device, which suspends tachyarrhythmia detection. The device resumes normal programmed operation after the procedure.

**Transcutaneous electrical nerve stimulation (TENS)** – TENS (including neuromuscular electrical stimulation or NMES) is a pain control technique that uses electrical impulses passed through the skin to stimulate nerves. A TENS device is not recommended for in-home use by cardiac device patients due to a potential for oversensing, inappropriate therapy, or inhibition of pacing. If a TENS device is determined to be medically necessary, contact a Medtronic representative for more information.

**Transurethral needle ablation (Medtronic TUNA therapy)** – Transurethral needle ablation is a surgical procedure used for benign prostatic hyperplasia (BPH) in which precisely focused, conducted radio frequency energy is used to ablate prostate tissue. Patients with implanted cardiac devices may conditionally undergo procedures that use the Medtronic TUNA system. To avoid affecting cardiac device function when performing the TUNA procedure, position the return electrode on the lower back or lower extremity at least 15 cm (6 in) away from the implanted device and leads.
A.6 Warnings, precautions, and guidance related to electromagnetic interference (EMI) for cardiac device patients

Many cardiac device patients resume their normal daily activities after full recovery from surgery. However, there may be certain situations that patients need to avoid. Because a cardiac device is designed to sense the electrical activity of the heart, the device may sense a strong electromagnetic energy field outside of the body and deliver a therapy that is not needed or withhold a therapy that is needed. The following sections provide important information to share with patients about electrical equipment or environments that may cause interference with their implanted cardiac device.

For additional guidance about EMI, customers can contact the following resources:

- Customers in the United States can contact either of the following telephone numbers: for pacemakers, contact Medtronic Technical Services at +1 800 505 4636; for ICDs, contact Medtronic Technical Services at +1 800 723 4636. You may also submit questions to tshelp@Medtronic.com or your Medtronic representative.
- Customers outside of the United States can contact a Medtronic representative.

General EMI guidelines for patients – Patients should observe the following general guidelines regarding EMI:

- Area restrictions – Before entering an area where signs are posted prohibiting persons with an implanted cardiac device, such as a pacemaker or ICD, consult with your doctor.
- Symptoms of EMI – If you become dizzy or feel rapid or irregular heartbeats while using an electrical item, release whatever you are touching or move away from the item. The cardiac device should immediately return to normal operation. If symptoms do not improve when you move away from the item, consult with your doctor. If you have an ICD and you receive a therapy shock while using an electrical item, release the item or move away from it, then consult with your doctor.
- Proper grounding of electrical items – To avoid interference from electrical current that may leak from improperly grounded electrical items and pass through the body, observe the following precautions:
  - Make sure that all electrical items are properly wired and grounded.
  - Make sure that electrical supply lines for swimming pools and hot tubs are properly installed and grounded according to local and national electrical code requirements.

Wireless communication devices – Wireless communication devices include transmitters that can affect cardiac devices. When using wireless communication devices, keep them at least 15 cm (6 in) away from your cardiac device. The following items are examples of such devices:

- Hand-held cellular, mobile, or cordless telephones (wireless telephones); two-way pagers; personal digital assistants (PDAs); smartphones; and mobile email devices
Wireless-enabled devices such as laptop, notebook, or tablet computers; network routers; MP3 players; e-readers; gaming consoles; televisions; DVD players; and headsets

Remote keyless entry and remote car starter devices

Household and hobby items with motors or magnets and other items that cause EMI – Household and hobby items that have motors or magnets or that generate electromagnetic energy fields could interfere with a cardiac device. Keep a cardiac device at least 15 cm (6 in) away from the following items:

- Hand-held kitchen appliances, such as electric mixers
- Sewing machines and sergers
- Personal care items, such as corded hand-held hair dryers, corded electric shavers, electric or ultrasonic toothbrushes (base charger), or back massagers
- Items that contain magnets, such as bingo wands, mechanic’s extractor wands, magnetic bracelets, magnetic clasps, magnetic chair pads, or stereo speakers
- Remote controller of radio-controlled toys
- Two-way walkie-talkies (less than 3 W)

The following household and hobby items require special precautions:

- Boat motors – Keep a cardiac device at least 30 cm (12 in) away from electric trolling motors or gasoline-powered boat motors.
- Electronic body fat scale – Using this type of scale is not recommended for cardiac device patients because it passes electricity through the body and can interfere with the device.
- Electronic pet fences or invisible fences – Keep a cardiac device at least 30 cm (12 in) away from the buried wire and the indoor antenna of electronic pet fences or invisible fences.
- Home-use electric kilns – Keep a cardiac device at least 60 cm (24 in) away from home-use electric kilns.
- Induction cook tops – An induction cook top uses an alternating magnetic field to generate heat. Keep a cardiac device at least 60 cm (24 in) away from the heating zone when the induction cook top is turned on.
- Magnetic mattress pads or pillows – Items containing magnets can interfere with the normal operation of a cardiac device if they are within 15 cm (6 in) of the device. Avoid using magnetic mattress pads or pillows because they cannot easily be kept away from the device.
- Portable electric generators up to 20 kW – Keep a cardiac device at least 30 cm (12 in) away from portable electric generators.
- UPS (uninterruptible power source) up to 200 A – Keep a cardiac device at least 30 cm (12 in) away from a UPS. If the UPS is operating by battery source, keep a cardiac device at least 45 cm (18 in) away.
Home power tools – Most home power tools should not affect cardiac devices. Consider the following common-sense guidelines:

- Keep all equipment in good working order to avoid electrical shock.
- Be certain that plug-in tools are properly grounded (or double insulated). Using a ground fault interrupter outlet is a good safety measure (this inexpensive device prevents a sustained electrical shock).

Some home power tools could affect cardiac device operation. Consider the following guidelines to reduce the possibility of interference:

- Electric yard and hand-held power tools (plug-in and cordless) – Keep a cardiac device at least 15 cm (6 in) away from such tools.
- Soldering guns and demagnetizers – Keep a cardiac device at least 30 cm (12 in) away from these tools.
- Gasoline-powered tools and gasoline-powered yard equipment – Keep a cardiac device at least 30 cm (12 in) away from components of the ignition system. Turn off the motor before making adjustments.
- Car engine repair – Turn off car engines before making any adjustments. When the engine is running, keep a cardiac device at least 30 cm (12 in) away from components of the ignition system.

Industrial equipment – After recovering from implant surgery, you likely will be able to return to work, school, or daily routine. However, if you will be using or working near high-voltage equipment, sources of high electrical current, magnetic fields, or other EMI sources that may affect device operation, consult with your doctor. You may need to avoid using, or working near, the following types of industrial equipment:

- Electric furnaces used in the manufacturing of steel
- Induction heating equipment and induction furnaces, such as kilns
- Industrial magnets or large magnets, such as those used in surface grinding and electromagnetic cranes
- Dielectric heaters used in industry to heat plastic and dry glue in furniture manufacturing
- Electric arc and resistance welding equipment
- Broadcasting antennas of AM, FM, shortwave radio, and TV stations
- Microwave transmitters. Note that microwave ovens are unlikely to affect cardiac devices.
- Power plants, large generators, and transmission lines. Note that lower voltage distribution lines for homes and businesses are unlikely to affect cardiac devices.

Radio transmitters – Determining a safe distance between the antenna of a radio transmitter and a cardiac device depends on many factors such as transmitter power, frequency, and the antenna type. If the transmitter power is high or if the antenna cannot be
directed away from a cardiac device, you may need to stay farther away from the antenna. Refer to the following guidelines for different types of radio transmitters:

- **Two-way radio transmitter (less than 3 W)** – Keep a cardiac device at least 15 cm (6 in) away from the antenna.
- **Portable transmitter (3 to 15 W)** – Keep a cardiac device at least 30 cm (12 in) away from the antenna.
- **Commercial and government vehicle-mounted transmitters (15 to 30 W)** – Keep a cardiac device at least 60 cm (24 in) away from the antenna.
- **Other transmitters (125 to 250 W)** – Keep a cardiac device at least 2.75 m (9 ft) away from the antenna.

For transmission power levels higher than 250 W, contact a Medtronic representative for more information.

**Security systems** – When passing through security systems, follow these precautions:

- **Electronic antitheft systems**, such as in a store or library, and point-of-entry control systems, such as gates or readers that include radio frequency identification equipment – These systems should not affect a cardiac device, but as a precaution, do not linger near or lean against such systems. Simply walk through these systems at a normal pace. If you are near an electronic antitheft or entry control system and experience symptoms, promptly move away from the equipment. After you move away from the equipment, the cardiac device resumes its previous state of operation.

- **Airport, courthouse, and jail security systems** – Given the short duration of security screening, it is unlikely that metal detectors (walk-through archways and hand-held wands) and full body imaging scanners (also called millimeter wave scanners and three-dimensional imaging scanners) in airports, courthouses, and jails will affect a cardiac device. When encountering these security systems, follow these guidelines:
  - Always carry your cardiac device ID card. If a cardiac device sets off a metal detector or security system, show your ID card to the security operator.
  - Minimize the risk of temporary interference with your cardiac device while going through the security screening process by not touching metal surfaces around any screening equipment.
  - Do not stop or linger in a walk-through archway; simply walk through the archway at a normal pace.
  - If a hand-held wand is used, ask the security operator not to hold it over or wave it back and forth over your cardiac device.
  - If you have concerns about security screening methods, show your cardiac device ID card to the security operator, request alternative screening, and then follow the security operator’s instructions.
B Device Parameters

B.1 Emergency settings

Table 80. Emergency settings and default values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defibrillation</strong></td>
<td></td>
</tr>
<tr>
<td>Energy(^a)</td>
<td>0.4; 0.6 … 1.8; 2; 3 … 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35(^\oplus) J</td>
</tr>
<tr>
<td>Pathway(^b)</td>
<td>B&gt;AX</td>
</tr>
<tr>
<td><strong>Cardioversion</strong></td>
<td></td>
</tr>
<tr>
<td>Energy(^a)</td>
<td>0.4; 0.6 … 1.8; 2; 3 … 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35(^\oplus) J</td>
</tr>
<tr>
<td>Pathway(^b)</td>
<td>B&gt;AX</td>
</tr>
<tr>
<td><strong>Fixed Burst</strong></td>
<td></td>
</tr>
<tr>
<td>Interval</td>
<td>100; 110 … 350(^\oplus) … 600 ms</td>
</tr>
<tr>
<td>RV Amplitude(^c)</td>
<td>8 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>1.5 ms</td>
</tr>
<tr>
<td><strong>VVI Pacing</strong></td>
<td></td>
</tr>
<tr>
<td>Pacing Mode</td>
<td>VVI</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>70 bpm</td>
</tr>
<tr>
<td>RV Amplitude(^c)</td>
<td>6 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>V. Blank Post VP</td>
<td>240 ms</td>
</tr>
<tr>
<td>Rate Hysteresis</td>
<td>Off</td>
</tr>
<tr>
<td>V. Rate Stabilization</td>
<td>Off</td>
</tr>
</tbody>
</table>

\(^a\)Delivered energy based on a biphasic pulse into a 75 \(\Omega\) load.
\(^b\)If Active Can is Off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.
\(^c\)Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude \(A\) depends upon the programmed amplitude \(A_p\) and programmed pulse width \(W_p\): \(A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})]\).
## B.2 Tachyarrhythmia detection parameters
### B.2.1 Tachyarrhythmia detection parameters, AT devices

Table 81. Tachyarrhythmia detection parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT/AF Detection</td>
<td>On; Monitor*</td>
<td>Monitor</td>
<td>Monitor</td>
</tr>
<tr>
<td>Zones</td>
<td>1*; 2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AT/AF Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>150; 160 ... 350* ... 450 ms</td>
<td>350 ms</td>
<td>350 ms</td>
</tr>
<tr>
<td>Fast AT/AF Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>150; 160 ... 200* ... 250 ms</td>
<td>200 ms</td>
<td>200 ms</td>
</tr>
<tr>
<td>VF Detection</td>
<td>On*; OFF</td>
<td>OFF</td>
<td>On</td>
</tr>
<tr>
<td>VF Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>240; 250 ... 320* ... 400 ms</td>
<td>320 ms</td>
<td>320 ms</td>
</tr>
<tr>
<td>VF Initial Beats</td>
<td>12/16; 18/24*; 24/32; 30/40; 45/60; 60/80; 75/100; 90/120; 105/140; 120/160</td>
<td>18/24</td>
<td>18/24</td>
</tr>
<tr>
<td>VF Redetect Beats</td>
<td>6/8; 9/12; 12/16*; 18/24; 21/28; 24/32; 27/36; 30/40</td>
<td>12/16</td>
<td>12/16</td>
</tr>
<tr>
<td>FVT Detection</td>
<td>OFF*; via VF; via VT</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>FVT Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>200; 210 ... 240* ... 600 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>VT Detection</td>
<td>On; OFF*</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>VT Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>280; 290 ... 400* ... 650 ms</td>
<td>400 ms</td>
<td>400 ms</td>
</tr>
<tr>
<td>VT Initial Beats</td>
<td>12; 16* ... 52; 76; 100</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>VT Redetect Beats</td>
<td>4; 8; 12* ... 52</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>VT Monitor</td>
<td>Monitor*; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>VT Monitor Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>280; 290 ... 450* ... 650 ms</td>
<td>450 ms</td>
<td>450 ms</td>
</tr>
<tr>
<td>VT Monitor Initial Beats</td>
<td>16; 20* ... 56; 80; 110; 130</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>AF/Afl&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>On*; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Sinus Tach&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>On*; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Other 1:1 SVTs&lt;sup&gt;b&lt;/sup&gt;</td>
<td>On; Off*</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>SVT V. Limit&lt;sup&gt;a&lt;/sup&gt;</td>
<td>240; 250 ... 320* ... 650 ms</td>
<td>320 ms</td>
<td>320 ms</td>
</tr>
<tr>
<td>Stability&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Off*; 30; 40 ... 100 ms</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Onset</td>
<td>Off*; On; Monitor</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Onset Percent</td>
<td>72; 75; 78; 81*; 84; 88; 91; 94; 97%</td>
<td>81%</td>
<td>81%</td>
</tr>
<tr>
<td>High Rate Timeout</td>
<td>Off*; 0.5; 1 ... 5; 6; 7; 8 ... 20; 22; 24; 26; 28; 30 min&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>High Rate Timeout Ther-</td>
<td>Zone Appropriate*; Skip to VF Therapy</td>
<td>Zone Appropriate</td>
<td></td>
</tr>
</tbody>
</table>
**Table 81. Tachyarrhythmia detection parameters (continued)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>Atrial Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2; 1.5; 2.1 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
</tbody>
</table>

- The measured intervals are truncated to a 10 ms multiple (for example, 457 ms becomes 450 ms). The device uses this truncated interval value when applying the programmed criteria and calculating interval averages.
- Double tachycardia detection is automatically enabled when any PR Logic criterion is enabled.
- The device is shipped with the Sinus Tach and AF/Afl criteria off. However, when VT Detection is set to On or VT Monitor is set to Monitor, these criteria are automatically set to On.
- Timer accuracy cannot be independently measured.
- With a 40 ms sine² waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.5 times the rated sine² sensing threshold.
- This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.
- With a 20 ms sine² waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.4 times the rated sine² sensing threshold.

**B.2.2 Tachyarrhythmia detection parameters, DR devices**

**Table 82. Tachyarrhythmia detection parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT/AF Detection</td>
<td>Monitor (fixed)</td>
<td>Monitor</td>
<td>Monitor</td>
</tr>
<tr>
<td>AT/AF Interval</td>
<td>150; 160 ... 350; ... 450 ms</td>
<td>350 ms</td>
<td>350 ms</td>
</tr>
<tr>
<td>VF Detection</td>
<td>On; OFF</td>
<td>OFF</td>
<td>On</td>
</tr>
<tr>
<td>VF Interval</td>
<td>240; 250 ... 320; ... 400 ms</td>
<td>320 ms</td>
<td>320 ms</td>
</tr>
<tr>
<td>VF Initial Beats</td>
<td>12/16; 18/24; 24/32; 30/40; 45/60; 60/80; 75/100; 90/120; 105/140; 120/160</td>
<td>18/24</td>
<td>18/24</td>
</tr>
<tr>
<td>VF Redetect Beats</td>
<td>6/8; 9/12; 12/16; ... 18/24; 21/28; 24/32; 27/36; 30/40</td>
<td>12/16</td>
<td>12/16</td>
</tr>
<tr>
<td>FVT Detection</td>
<td>OFF; via VF; via VT</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>FVT Interval</td>
<td>200; 210 ... 240; ... 600 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>VT Detection</td>
<td>On; OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>VT Interval</td>
<td>280; 290 ... 400; ... 650 ms</td>
<td>400 ms</td>
<td>400 ms</td>
</tr>
<tr>
<td>VT Initial Beats</td>
<td>12; 16; ... 52; 76; 100</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>VT Redetect Beats</td>
<td>4; 8; 12; ... 52</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>VT Monitor</td>
<td>Monitor; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>VT Monitor Interval</td>
<td>280; 290 ... 450; ... 650 ms</td>
<td>450 ms</td>
<td>450 ms</td>
</tr>
<tr>
<td>VT Monitor Initial Beats</td>
<td>16; 20; ... 56; 80; 110; 130</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>AF/Afl</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Sinus Tach</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Other 1:1 SVTs</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>

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Table 82. Tachyarrhythmia detection parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVT V. Limit&lt;sup&gt;a&lt;/sup&gt;</td>
<td>240; 250 … 320&lt;sup&gt;°&lt;/sup&gt; … 650 ms</td>
<td>320 ms</td>
<td>320 ms</td>
</tr>
<tr>
<td>Stability&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Off; 30; 40 … 100 ms</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Onset</td>
<td>Off; On; Monitor</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Onset Percent</td>
<td>72; 75; 78; 81&lt;sup&gt;°&lt;/sup&gt;; 84; 88; 91; 94; 97%</td>
<td>81%</td>
<td>81%</td>
</tr>
<tr>
<td>High Rate Timeout</td>
<td>Off; 0.5; 1 … 5; 6; 7; 8 … 20; 22; 24; 26; 28; 30 min&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>High Rate Timeout Therapy</td>
<td>Zone Appropriate&lt;sup&gt;°&lt;/sup&gt;; Skip to VF Therapy</td>
<td>Zone Appropriate</td>
<td></td>
</tr>
<tr>
<td>RV Sensitivity&lt;sup&gt;e,f&lt;/sup&gt;</td>
<td>0.15; 0.3&lt;sup&gt;°&lt;/sup&gt;; 0.45; 0.6; 0.9; 1.2 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>Atrial Sensitivity&lt;sup&gt;f,g&lt;/sup&gt;</td>
<td>0.15;0.3&lt;sup&gt;°&lt;/sup&gt;; 0.45; 0.6; 0.9; 1.2; 1.5; 2.1 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
</tbody>
</table>

<sup>a</sup>The measured intervals are truncated to a 10 ms multiple (for example, 457 ms becomes 450 ms). The device uses this truncated interval value when applying the programmed criteria and calculating interval averages.

<sup>b</sup>Double tachycardia detection is automatically enabled when any PR Logic criterion is enabled.

<sup>c</sup>The device is shipped with the Sinus Tach and AF/AFl criteria off. However, if you set VT Detection to On or set VT Monitor to Monitor, these criteria are automatically set to On.

<sup>d</sup>Timer accuracy cannot be independently measured.

<sup>e</sup>With a 40 ms sine<sup>2</sup> waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.5 times the rated sine<sup>2</sup> sensing threshold.

<sup>f</sup>This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.

<sup>g</sup>With a 20 ms sine<sup>2</sup> waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.4 times the rated sine<sup>2</sup> sensing threshold.

B.2.3 Tachyarrhythmia detection parameters, VR devices

Table 83. Tachyarrhythmia detection parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF Detection</td>
<td>On&lt;sup&gt;°&lt;/sup&gt;; OFF</td>
<td>OFF</td>
<td>On</td>
</tr>
<tr>
<td>VF Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>240; 250 … 320&lt;sup&gt;°&lt;/sup&gt; … 400 ms</td>
<td>320 ms</td>
<td>320 ms</td>
</tr>
<tr>
<td>VF Initial Beats</td>
<td>12/16; 18/24&lt;sup&gt;°&lt;/sup&gt;; 24/32; 30/40; 45/60; 60/80; 75/100; 90/120; 105/140; 120/160</td>
<td>18/24</td>
<td>18/24</td>
</tr>
<tr>
<td>VF Redetect Beats</td>
<td>6/8; 9/12; 12/16&lt;sup&gt;°&lt;/sup&gt;; 18/24; 21/28; 24/32; 27/36; 30/40</td>
<td>12/16</td>
<td>12/16</td>
</tr>
<tr>
<td>FVT Detection</td>
<td>OFF&lt;sup&gt;°&lt;/sup&gt;; via VF; via VT</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>FVT Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>200; 210 … 240&lt;sup&gt;°&lt;/sup&gt; … 600 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>VT Detection</td>
<td>On; OFF&lt;sup&gt;°&lt;/sup&gt;</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>VT Interval&lt;sup&gt;a&lt;/sup&gt;</td>
<td>280; 290 … 400&lt;sup&gt;°&lt;/sup&gt; … 650 ms</td>
<td>400 ms</td>
<td>400 ms</td>
</tr>
<tr>
<td>VT Initial Beats</td>
<td>12; 16&lt;sup&gt;°&lt;/sup&gt; … 52; 76; 100</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>VT Redetect Beats</td>
<td>4; 8; 12&lt;sup&gt;°&lt;/sup&gt; … 52</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
### Table 83. Tachyarrhythmia detection parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT Monitor</td>
<td>Monitor; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>VT Monitor Interval</td>
<td>280; 290 ... 450; ... 650 ms</td>
<td>450 ms</td>
<td>450 ms</td>
</tr>
<tr>
<td>VT Monitor Initial Beats</td>
<td>16; 20; ... 56; 80; 110; 130</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Wavelet</td>
<td>Off; On; Monitor</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Match Threshold</td>
<td>40; 43 ... 70 ... 97%</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Auto Collection</td>
<td>On; Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>SVT V. Limit</td>
<td>240; 250 ... 320; ... 650 ms</td>
<td>320 ms</td>
<td>320 ms</td>
</tr>
<tr>
<td>Stability</td>
<td>Off; 30; 40 ... 100 ms</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Onset</td>
<td>Off; On; Monitor</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Onset Percent</td>
<td>72; 75; 78; 81; 84; 88; 91; 94; 97%</td>
<td>81%</td>
<td>81%</td>
</tr>
<tr>
<td>High Rate Timeout</td>
<td>Off; 0.5; 1 ... 5; 6; 7; 8 ... 20; 22; 24; 26; 28; 30 min</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>High Rate Timeout Therapy</td>
<td>Zone Appropriate; Skip to VF Therapy</td>
<td>Zone Appropriate</td>
<td></td>
</tr>
<tr>
<td>RV Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
</tbody>
</table>

---

### Table 84. Atrial tachyarrhythmia therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT/AF Rx Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Therapy Type</td>
<td>50 Hz; Ramp; Burst+ Rx1: Ramp; Rx2: Burst+ Rx3: 50 Hz</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>AT/AF Automatic CV Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Fast AT/AF Rx Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Therapy Type</td>
<td>50 Hz; Ramp; Burst+ Rx1: Ramp; Rx2: Burst+ Rx3: 50 Hz</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

---

*a The measured intervals are truncated to a 10 ms multiple (for example, 457 ms becomes 450 ms). The device uses this truncated interval value when applying the programmed criteria and calculating interval averages.

*b The device is shipped with Wavelet off. However, when VT Detection is set to On, Wavelet is also set to Monitor.

*c Timer accuracy cannot be independently measured.

*d With a 40 ms sine^2 waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.5 times the rated sine^2 sensing threshold.

*e This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.

---

### B.3 Atrial tachyarrhythmia therapy parameters, AT devices
### Table 84. Atrial tachyarrhythmia therapy parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast AT/AF Automatic CV Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Patient Activated CV Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td><strong>Atrial cardioversion parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Pathway&lt;sup&gt;b&lt;/sup&gt;</td>
<td>AX&gt;B; B&gt;AX</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Minimum R-R Interval&lt;sup&gt;c&lt;/sup&gt;</td>
<td>400; 410 ... 500 ... 600 ms</td>
<td>500 ms</td>
<td>500 ms</td>
</tr>
<tr>
<td>Tilt</td>
<td>30; 40; 50; 65%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Active Can&lt;sup&gt;d&lt;/sup&gt;</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Delivery Window Start Time</td>
<td>00:00; 01:00; 02:00; 03:00 ... 23:00</td>
<td>03:00</td>
<td>03:00</td>
</tr>
<tr>
<td>Delivery Window Length</td>
<td>1; 2; 3; 4; 6; 8; 10; 12; 16; 20; 24 hr</td>
<td>1 hr</td>
<td>1 hr</td>
</tr>
<tr>
<td>Maximum shocks per day</td>
<td>1; 2; 3; 4; 5; No Limit</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Episode Duration before CV</td>
<td>0; 1; 2; 3; 4; 5; 7; 10; 15; 20; 25; 30; 40; 50 min; 1; 2; 3; 4; 5; 6; 12; 24; 48; 72 hr; 7 days</td>
<td>6 hr</td>
<td>6 hr</td>
</tr>
<tr>
<td><strong>50 Hz Burst parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 Hz Burst Duration</td>
<td>0.5; 1; 2; 3 s</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td># Sequences</td>
<td>1; 2 ... 10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Burst+ parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial # S1 Pulses</td>
<td>1; 2 ... 15; 20; 25</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>A-S1 Interval (%AA)</td>
<td>28; 31; 34; 38; 41 ... 59; 63; 66 ... 84; 88; 91; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>S1-S2 (%AA)</td>
<td>Off; 28; 31; 34; 38; 41 ... 59; 63; 66; 69 ... 84; 88; 91; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>S2-S3 Decrement</td>
<td>Off; 0; 10; 20 ... 80 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Interval Decrement</td>
<td>0; 10; 20; 30; 40 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td># Sequences</td>
<td>1; 2 ... 6 ... 10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Ramp parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial # S1 Pulses</td>
<td>1; 2 ... 6 ... 15; 20; 25</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>A-S1 Interval (% AA)</td>
<td>28; 31; 34; 38; 41 ... 59; 63; 66 ... 84; 88; 91; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Interval Decrement</td>
<td>0; 10 ... 40 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td># Sequences</td>
<td>1; 2 ... 8; 9; 10</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
### Table 84. Atrial tachyarrhythmia therapy parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shared atrial therapy parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration to stop</td>
<td>12; 24; 48; 72 hr; None</td>
<td>48 hr</td>
<td>48 hr</td>
</tr>
<tr>
<td>Disable all atrial therapies if atrial lead position is suspect?</td>
<td>Yes; No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Shared atrial ATP parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disable Atrial ATP if it accelerates V. rate?</td>
<td>Yes; No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Episode Duration Before ATP</td>
<td>0; 1; 2; 3; 4; 5; 7; 10; 15; 20; 25; 30; 40; 50 min; 1; 2; 3; 4; 5; 6; 12; 24 hr</td>
<td>1 min</td>
<td>1 min</td>
</tr>
<tr>
<td>Reactive ATP Rhythm Change</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Reactive ATP Time Interval</td>
<td>Off; 2; 4; 7; 12; 24; 36; 48 hr</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>A-A Minimum ATP Interval&lt;sup&gt;c&lt;/sup&gt;</td>
<td>100; 110; 120; 130 ... 400 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>A. Pacing Amplitude&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1; 2 ... 6; 8 V</td>
<td>6 V</td>
<td>6 V</td>
</tr>
<tr>
<td>A. Pacing Pulse Width</td>
<td>0.1; 0.2 ... 1.5 ms</td>
<td>1.5 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>VVI/VOO Backup Pacing</td>
<td>Off; On (Always); On (Auto-Enable)</td>
<td>On (Auto-Enable)</td>
<td>On (Auto-Enable)</td>
</tr>
<tr>
<td>VVI/VOO Backup Pacing Rate</td>
<td>60; 70 ... 120 bpm</td>
<td>70 bpm</td>
<td>70 bpm</td>
</tr>
</tbody>
</table>

<sup>a</sup> Delivered energy based on a biphasic pulse with a 50% Tilt value and a 75 Ω load.

<sup>b</sup> If Active Can is Off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.

<sup>c</sup> The measured intervals are truncated to a 10 ms multiple (for example, 457 ms becomes 450 ms). The device uses this truncated interval value when applying the programmed criteria and calculating interval averages.

<sup>d</sup> The Active Can parameter applies to all automatic, manual, and emergency high-voltage therapies. It also applies to T-Shock inductions.

<sup>e</sup> Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude A depends upon the programmed amplitude A<sub>p</sub> and programmed pulse width W<sub>p</sub>: \[ A = A_p \times 0.9 - (W_p \times 0.145 \text{ ms}^{-1}) \].

### B.4 Ventricular tachyarrhythmia therapy parameters

### Table 85. Ventricular tachyarrhythmia therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VF Therapy parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VF Therapy Status</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Energy&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J</td>
<td>35 J</td>
<td>35 J</td>
</tr>
</tbody>
</table>
### Table 85. Ventricular tachyarrhythmia therapy parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pathway</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td>AX&gt;B; B&gt;AX&lt;br&gt;Rx1–Rx4: B&gt;AX&lt;br&gt;Rx5–Rx6: AX&gt;B</td>
<td>B&gt;AX</td>
<td>B&gt;AX</td>
</tr>
<tr>
<td>ATP (Rx1 only)</td>
<td>During Charging; Before Charging; Off;</td>
<td>During Charging</td>
<td>Off</td>
</tr>
<tr>
<td>Deliver ATP if last 8 R-R &gt;=</td>
<td>200; 210; 240; 300 ms</td>
<td>240 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>Therapy Type</td>
<td>Burst; Ramp; Ramp+</td>
<td>Burst</td>
<td>Burst</td>
</tr>
<tr>
<td>ChargeSaver</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Switch when number of consecutive ATP successes equals</td>
<td>1; 2; 3; 4; 6; 8; 10</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Smart Mode</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
</tbody>
</table>

#### VT/FVT Therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT Therapy Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>FVT Therapy Status</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Therapy Type</td>
<td>CV; Burst; Ramp; Ramp+&lt;br&gt;Rx1: Burst&lt;br&gt;Rx2–Rx6: CV</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

#### Cardioversion parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.4; 0.6; 1.8; 2; 3; 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J&lt;br&gt;VT Rx1-Rx2: 20 J&lt;br&gt;VT Rx3–Rx6: 35 J&lt;br&gt;FVT Rx1–Rx6: 35 J</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Pathway&lt;sup&gt;c&lt;/sup&gt;</td>
<td>AX&gt;B; B&gt;AX&lt;br&gt;Rx1–Rx4: B&gt;AX&lt;br&gt;Rx5–Rx6: AX&gt;B</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

#### Burst therapy parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial # Pulses</td>
<td>1; 2; 8; 15</td>
<td>VF Rx1: 8</td>
<td>—</td>
</tr>
<tr>
<td>R-S1 Interval=(%RR)</td>
<td>50; 53; 56; 59; 63; 66; 84; 91; 94; 97%</td>
<td>VF Rx1: 88%</td>
<td>—</td>
</tr>
<tr>
<td>Interval Dec</td>
<td>0; 10; 40 ms</td>
<td>VF Rx1: 10 ms</td>
<td>—</td>
</tr>
<tr>
<td># Sequences</td>
<td>1; 2; 10</td>
<td>VF Rx1: 1</td>
<td>—</td>
</tr>
<tr>
<td>Smart Mode&lt;sup&gt;d&lt;/sup&gt;</td>
<td>On; Off</td>
<td>VF Rx1: On</td>
<td>—</td>
</tr>
</tbody>
</table>
Table 85. Ventricular tachyarrhythmia therapy parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ramp therapy parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial # Pulses</td>
<td>1; 2 ... 8* ... 15</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>R-S1 Interval=(%RR)</td>
<td>50; 53; 56; 59; 63; 66 ... 84; 88; 91*; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Interval Dec</td>
<td>0; 10* ... 40 ms</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td># Sequences</td>
<td>1; 2 ... 10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>VT Therapies: 3*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>FVT Therapies: 1*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Smart Mode&lt;sup&gt;d&lt;/sup&gt;</td>
<td>On; Off&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Ramp+ therapy parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial # Pulses</td>
<td>1; 2; 3* ... 15</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>R-S1 Interval=(%RR)</td>
<td>50; 53; 56; 59; 63; 66 ... 75* ... 84; 88; 91; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>S1S2(Ramp+)=(%RR)</td>
<td>50; 53; 56; 59; 63; 66; 69* ... 84; 88; 91; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>S2SN(Ramp+)=(%RR)</td>
<td>50; 53; 56; 59; 63; 66* ... 84; 88; 91; 94; 97%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td># Sequences</td>
<td>1; 2 ... 10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>VT Therapies: 3*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>FVT Therapies: 1*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Smart Mode&lt;sup&gt;d&lt;/sup&gt;</td>
<td>On; Off&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Shared therapy parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Auto Cap Formation Interval</td>
<td>Auto&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt;; 1; 2 ... 6 months</td>
<td>Auto</td>
<td>Auto</td>
</tr>
<tr>
<td>Progressive Episode Therapies</td>
<td>On; Off&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt;</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Active Can&lt;sup&gt;e&lt;/sup&gt;</td>
<td>On&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt;; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>V-V Minimum ATP Interval</td>
<td>150; 160 ... 200&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt; ... 400 ms</td>
<td>200 ms</td>
<td>200 ms</td>
</tr>
<tr>
<td>V. Pulse Width</td>
<td>0.1; 0.2 ... 1.5&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt; ms</td>
<td>1.5 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>V. Amplitude&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1; 2 ... 6; 8&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt; V</td>
<td>8 V</td>
<td>8 V</td>
</tr>
<tr>
<td>V. Pace Blanking</td>
<td>150; 160 ... 240&lt;sup&gt;*&lt;br&gt;*&lt;br&gt;*&lt;/sup&gt; ... 450 ms</td>
<td>240 ms</td>
<td>240 ms</td>
</tr>
</tbody>
</table>

<sup>a</sup> For automatic therapy 3, 4, 5, or 6, energy must be at least 10 J.
<sup>b</sup> Delivered energy based on a biphasic pulse into a 75 Ω load.
<sup>c</sup> If Active Can is Off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.
<sup>d</sup> Smart Mode is available only for Rx1 – Rx4.
<sup>e</sup> The Active Can parameter applies to all automatic, manual, and emergency high-voltage therapies. It also applies to T-Shock inductions.
<sup>f</sup> Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude A depends upon the programmed amplitude A<sub>p</sub> and programmed pulse width W<sub>p</sub>: A = A<sub>p</sub> x [0.9 - (W<sub>p</sub> x 0.145 ms<sup>–1</sup>)].
## B.5 Bradycardia pacing parameters

### B.5.1 Bradycardia pacing parameters, AT devices

**Table 86. Bradycardia pacing parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>AAIR&lt;=&gt;DDDR; AAI&lt;=&gt;DDD; DDR; DDD; DDIR; DDI; VVIR; VVI; AAIR; AAI; DOO; VOO; AOO; ODO</td>
<td>AAI&lt;=&gt;DDD</td>
<td>VVI</td>
</tr>
<tr>
<td>Mode Switch</td>
<td>On; Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 ... 60; 70; 75 ... 150 bpm</td>
<td>60 bpm</td>
<td>65 bpm</td>
</tr>
<tr>
<td>Upper Tracking Rate</td>
<td>80; 85 ... 130; 150 bpm</td>
<td>130 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Upper Sensor Rate</td>
<td>80; 85 ... 130; 150 bpm</td>
<td>130 bpm</td>
<td></td>
</tr>
<tr>
<td>Paced AV</td>
<td>30; 40 ... 180; 350 ms</td>
<td>180 ms</td>
<td>180 ms</td>
</tr>
<tr>
<td>Sensed AV</td>
<td>30; 40 ... 150; 350 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>PVARP</td>
<td>Varied; 150; 160; 310 ... 500 ms</td>
<td>310 ms</td>
<td>310 ms</td>
</tr>
<tr>
<td>A. Refractory Period</td>
<td>150; 160; 310 ... 500 ms</td>
<td>310 ms</td>
<td>310 ms</td>
</tr>
<tr>
<td>RV Amplitude(^a)</td>
<td>0.5; 1 ... 3; 3.5; 4; 5; 6 V</td>
<td>3 V</td>
<td>6 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4; 1.5 ms</td>
<td>0.4 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>RV Sensitivity(^b,c)</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>Atrial Amplitude(^a)</td>
<td>0.5; 1 ... 3; 3.5; 4; 5; 6 V</td>
<td>3 V</td>
<td>4 V</td>
</tr>
<tr>
<td>Atrial Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4; 1.5 ms</td>
<td>0.4 ms</td>
<td>0.4 ms</td>
</tr>
<tr>
<td>Atrial Sensitivity(^c,d)</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2; 1.5; 2.1 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>PVAB Interval</td>
<td>10; 20 ... 150; 300 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>PVAB Method</td>
<td>Partial; Partial+; Absolute</td>
<td>Partial</td>
<td>Partial</td>
</tr>
<tr>
<td>A. Blank Post AP</td>
<td>150; 160; 200; 250 ms</td>
<td>200 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>A. Blank Post AS</td>
<td>100; 110; 170 ms</td>
<td>100 ms</td>
<td>100 ms</td>
</tr>
<tr>
<td>V. Blank Post VP</td>
<td>150; 160; 200; 450 ms</td>
<td>200 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>V. Blank Post VS</td>
<td>120; 130; 170 ms</td>
<td>120 ms</td>
<td>120 ms</td>
</tr>
</tbody>
</table>

### Rate Response Pacing parameters

| Rate Response              | 1; 2; 7; 10                                                                     | 7                   | 7           |
| Activity Threshold         | Low; Medium Low; Medium High; High                                               | Medium Low          | Medium Low  |
| Activity Acceleration      | 15; 30; 60 s                                                                    | 30 s                | 30 s        |
| Activity Deceleration      | Exercise; 2.5; 5; 10 min                                                         | 5 min               | 5 min       |

### Rate Adaptive AV parameters

<p>| Rate Adaptive AV           | On; Off                                                                           | Off                 | On          |
| Start Rate                 | 50; 55; 80; 145 bpm                                                              | 80 bpm              | 60 bpm      |</p>
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop Rate</td>
<td>55; 60 ... 130 ... 150 bpm</td>
<td>130 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Minimum Paced AV</td>
<td>30; 40 ... 140 ... 200 ms</td>
<td>140 ms</td>
<td>140 ms</td>
</tr>
<tr>
<td>Minimum Sensed AV</td>
<td>30; 40 ... 110 ... 200 ms</td>
<td>110 ms</td>
<td>110 ms</td>
</tr>
</tbody>
</table>

**Arrhythmia/Post-Shock Pacing parameters**

A. Rate Stabilization

- On; Off
- Maximum Rate: 80; 85 ... 100 ... 150 bpm
- Interval Percentage Increment: 12.5; 25; 50%
- Maximum Rate: 100 bpm
- Interval Percentage Increment: 25%

A. Preference Pacing

- On; Off
- Maximum Rate: 80; 85 ... 100 ... 150 bpm
- Interval Decrement: 30; 40; 50 ... 100; 150 ms
- Search Beats: 5; 10 ... 25; 50
- Post Mode Switch: On; Off
- Overdrive Rate: 70; 75; 80 ... 120 bpm
- Overdrive Duration: 0.5; 1; 2; 3; 5; 10; 20; 30; 60; 90; 120 min
- Maximum Rate: 100 bpm
- Interval Decrement: 50 ms
- Search Beats: 10
- Post Mode Switch: Off
- Overdrive Rate: 80 bpm
- Overdrive Duration: 10 min

V. Rate Stabilization

- On; Off
- Maximum Rate: 80; 85 ... 120 bpm
- Interval Increment: 50; 60 ... 400 ms
- Maximum Rate: 120 bpm
- Interval Increment: 150 ms

Post VT/VF Shock Pac ing

- Overdrive Rate: 70; 75; 80 ... 120 bpm
- Overdrive Duration: 0.5; 1; 2; 3; 5; 10; 20; 30; 60; 90; 120 min
- Overdrive Rate: 80 bpm
- Overdrive Duration: 0.5 min

Post Shock A. Amplitude<sup>a</sup>

- 0.5; 1 ... 4; 5; 6; 8 V
- Post Shock A. Pulse Width
- 0.1; 0.2 ... 1.5 ms
- Post Shock RV Amplitude<sup>a</sup>
- 0.5; 1 ... 4; 5; 6; 8 V
- Post Shock RV Pulse Width
- 0.1; 0.2 ... 1.5 ms

**Additional pacing features**

- Non-Comp Atrial Pacing: On; Off
- NCAP Interval: 200; 250; 300; 350; 400 ms
- Rate Hysteresis: Off; 30; 40 ... 80 bpm
- PMT Intervention: On; Off

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Table 86. Bradycardia pacing parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC Response</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>V. Safety Pacing</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
</tbody>
</table>

a Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude $A$ depends upon the programmed amplitude $A_p$ and programmed pulse width $W_p$: $A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})]$.  
b With a $40 \text{ ms } \sin^2$ waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.5 times the rated $\sin^2$ sensing threshold.  
c This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.  
d With a $20 \text{ ms } \sin^2$ waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.4 times the rated $\sin^2$ sensing threshold.

B.5.2 Bradycardia pacing parameters, DR devices

Table 87. Bradycardia pacing parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>AAI&lt;=&gt;DDDR; AAI&lt;=&gt;DDD; DDRR; DDD; DDIR; DDI; VVIR; VVI; AAIR; AAI; DOO; VOO; AOO; ODO</td>
<td>AAI&lt;=&gt;DDD</td>
<td>VVI</td>
</tr>
<tr>
<td>Mode Switch</td>
<td>On; Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 ... 60; 70; 75 ... 150 bpm</td>
<td>60 bpm</td>
<td>65 bpm</td>
</tr>
<tr>
<td>Upper Tracking Rate</td>
<td>80; 85 ... 130 ... 150 bpm</td>
<td>130 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Upper Sensor Rate</td>
<td>80; 85 ... 130 ... 150 bpm</td>
<td>130 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Paced AV</td>
<td>30; 40 ... 180 ... 350 ms</td>
<td>180 ms</td>
<td>180 ms</td>
</tr>
<tr>
<td>Sensed AV</td>
<td>30; 40 ... 150 ... 350 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>PVARP</td>
<td>Varied; 150; 160 ... 310 ... 500 ms</td>
<td>310 ms</td>
<td>310 ms</td>
</tr>
<tr>
<td>A. Refractory Period</td>
<td>150; 160 ... 310 ... 500 ms</td>
<td>310 ms</td>
<td>310 ms</td>
</tr>
<tr>
<td>RV Amplitude</td>
<td>0.5; 1 ... 3; 3.5; 4; 5; 6 V</td>
<td>3 V</td>
<td>6 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4 ... 1.5 ms</td>
<td>0.4 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>RV Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>Atrial Amplitude</td>
<td>0.5; 1 ... 3; 3.5; 4; 5; 6 V</td>
<td>3 V</td>
<td>4 V</td>
</tr>
<tr>
<td>Atrial Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4 ... 1.5 ms</td>
<td>0.4 ms</td>
<td>0.4 ms</td>
</tr>
<tr>
<td>Atrial Sensitivity</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2; 1.5; 2.1 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>PVAB Interval</td>
<td>10; 20 ... 150 ... 300 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>PVAB Method</td>
<td>Partial; Partial+; Absolute</td>
<td>Partial</td>
<td>Partial</td>
</tr>
<tr>
<td>A. Blank Post AP</td>
<td>150; 160 ... 200 ... 250 ms</td>
<td>200 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>A. Blank Post AS</td>
<td>100; 110 ... 170 ms</td>
<td>100 ms</td>
<td>100 ms</td>
</tr>
<tr>
<td>V. Blank Post VP</td>
<td>150; 160 ... 200 ... 450 ms</td>
<td>200 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>V. Blank Post VS</td>
<td>120; 130 ... 170 ms</td>
<td>120 ms</td>
<td>120 ms</td>
</tr>
<tr>
<td>Parameter</td>
<td>Programmable values</td>
<td>Shipped</td>
<td>Reset</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Rate Response Pacing parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate Response</td>
<td>1; 2 … 7; … 10</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Activity Threshold</td>
<td>Low; Medium Low; Medium High; High</td>
<td>Medium Low</td>
<td>Medium Low</td>
</tr>
<tr>
<td>Activity Acceleration</td>
<td>15; 30; 60 s</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Activity Deceleration</td>
<td>Exercise; 2.5; 5; 10 min</td>
<td>5 min</td>
<td>5 min</td>
</tr>
<tr>
<td><strong>Rate Adaptive AV parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate Adaptive AV</td>
<td>On; Off</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>Start Rate</td>
<td>50; 55 … 80; 145 bpm</td>
<td>80 bpm</td>
<td>60 bpm</td>
</tr>
<tr>
<td>Stop Rate</td>
<td>55; 60 … 130; 150 bpm</td>
<td>130 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Minimum Paced AV</td>
<td>30; 40 … 140; 200 ms</td>
<td>140 ms</td>
<td>140 ms</td>
</tr>
<tr>
<td>Minimum Sensed AV</td>
<td>30; 40 … 110; 200 ms</td>
<td>110 ms</td>
<td>110 ms</td>
</tr>
<tr>
<td><strong>Arrhythmia/Post-Shock Pacing parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V. Rate Stabilization</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Maximum Rate</td>
<td>80; 85 … 120 bpm</td>
<td>120 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Interval Increment</td>
<td>50; 60 … 400 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>Post VT/VF Shock Pacing</td>
<td>Off; On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Overdrive Rate</td>
<td>70; 75; 80; 120 bpm</td>
<td>80 bpm</td>
<td>80 bpm</td>
</tr>
<tr>
<td>Overdrive Duration</td>
<td>0.5; 1; 2; 3; 5; 10; 20; 30; 60; 90; 120 min</td>
<td>0.5 min</td>
<td>0.5 min</td>
</tr>
<tr>
<td>Post Shock A. Amplitude(a)</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
<td>4 V</td>
<td>4 V</td>
</tr>
<tr>
<td>Post Shock A. Pulse Width</td>
<td>0.1; 0.2 … 1.5 ms</td>
<td>1.5 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>Post Shock RV Amplitude(a)</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
<td>6 V</td>
<td>6 V</td>
</tr>
<tr>
<td>Post Shock RV Pulse Width</td>
<td>0.1; 0.2 … 1.5 ms</td>
<td>1.5 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td><strong>Additional pacing features</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Comp Atrial Pacing</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>NCAP Interval</td>
<td>200; 250; 300; 350; 400 ms</td>
<td>300 ms</td>
<td>300 ms</td>
</tr>
<tr>
<td>Rate Hysteresis</td>
<td>Off; 30; 40 … 80 bpm</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>PMT Intervention</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>
### Table 87. Bradycardia pacing parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC Response</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>V. Safety Pacing</td>
<td>On; Off</td>
<td>On</td>
<td>On</td>
</tr>
</tbody>
</table>

1. Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude $A$ depends upon the programmed amplitude $A_p$ and programmed pulse width $W_p$: $A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})]$. 
2. With a 40 ms sine$^2$ waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.5 times the rated sine$^2$ sensing threshold.
3. This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.
4. With a 20 ms sine$^2$ waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.4 times the rated sine$^2$ sensing threshold.

### B.5.3 Bradycardia pacing parameters, VR devices

### Table 88. Bradycardia pacing parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>VVIR; VVI; VOO; OVO</td>
<td>VVI</td>
<td>VVI</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35; 40; ... 60; 70; 75 ... 150 bpm</td>
<td>40 bpm</td>
<td>65 bpm</td>
</tr>
<tr>
<td>Upper Sensor Rate</td>
<td>80; 85 ... 130; ... 150 bpm</td>
<td>130 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>RV Amplitude$^a$</td>
<td>0.5; 1 ... 3; 3.5; 4; 5; 6; 8 V</td>
<td>3 V</td>
<td>6 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2; 0.3; 0.4 ... 1.5 ms</td>
<td>0.4 ms</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>RV Sensitivity$^{b,c}$</td>
<td>0.15; 0.3; 0.45; 0.6; 0.9; 1.2 mV</td>
<td>0.3 mV</td>
<td>0.3 mV</td>
</tr>
<tr>
<td>V. Blank Post VP</td>
<td>150; 160 ... 200; ... 450 ms</td>
<td>200 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>V. Blank Post VS</td>
<td>120; 130 ... 170 ms</td>
<td>120 ms</td>
<td>120 ms</td>
</tr>
<tr>
<td>Rate Response Pacing parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate Response</td>
<td>1; 2 ... 7; ... 10</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Activity Threshold</td>
<td>Low; Medium Low; Medium High; High</td>
<td>Medium Low</td>
<td>Medium Low</td>
</tr>
<tr>
<td>Activity Acceleration</td>
<td>15; 30; 60 s</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Activity Deceleration</td>
<td>Exercise; 2.5; 5; 10 min</td>
<td>5 min</td>
<td>5 min</td>
</tr>
</tbody>
</table>

### Arrhythmia/Post-Shock Pacing parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Rate Stabilization</td>
<td>On; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Maximum Rate</td>
<td>80; 85 ... 120 bpm</td>
<td>120 bpm</td>
<td>120 bpm</td>
</tr>
<tr>
<td>Interval Increment</td>
<td>50; 60 ... 150; ... 400 ms</td>
<td>150 ms</td>
<td>150 ms</td>
</tr>
<tr>
<td>Post VT/VF Shock Pacing</td>
<td>Off; On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Overdrive Rate</td>
<td>70; 75; 80; ... 120 bpm</td>
<td>80 bpm</td>
<td>80 bpm</td>
</tr>
</tbody>
</table>

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Table 88. Bradycardia pacing parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overdrive Duration</td>
<td>0.5; 1; 2; 3; 5; 10; 20; 30; 60; 90; 120 min</td>
<td>0.5 min</td>
<td>0.5 min</td>
</tr>
<tr>
<td>Post Shock RV Amplitude&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
<td>6 V</td>
<td>6 V</td>
</tr>
<tr>
<td>Post Shock RV Pulse Width</td>
<td>0.1; 0.2 … 1.5 ms</td>
<td>1.5 ms</td>
<td>1.5 ms</td>
</tr>
</tbody>
</table>

Additional pacing features

| Rate Hysteresis            | Off; 30; 40 … 80 bpm                | Off     | Off   |

<sup>a</sup>Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude \( A \) depends upon the programmed amplitude \( A_p \) and programmed pulse width \( W_p \): \( A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})] \).

<sup>b</sup>With a 40 ms sine\(^2\) waveform. When using the CENELEC waveform, the rated sensing threshold value will be 1.5 times the rated sine\(^2\) sensing threshold.

<sup>c</sup>This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.

B.6 Patient Alert parameters

B.6.1 Patient Alert parameters, AT and DR devices

Table 89. Patient Alert parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert Time</td>
<td>00:00; 00:10 … 08:00; 23:50</td>
<td>08:00</td>
<td>08:00</td>
</tr>
</tbody>
</table>

Lead Impedance Out of Range Patient Alerts

A. Pacing lead impedance

| Less than                  | 200; 300; 400; 500 Ω                | 200 Ω   | 200 Ω |
| Greater than               | 1000; 1500; 2000; 3000 Ω            | 3000 Ω  | 3000 Ω |

RV Pacing lead impedance

| Less than                  | 200; 300; 400; 500 Ω                | 200 Ω   | 200 Ω |
| Greater than               | 1000; 1500; 2000; 3000 Ω            | 3000 Ω  | 3000 Ω |

RV Defibrillation lead impedance

| Less than                  | 20; 30; 40; 50 Ω                    | 20 Ω    | 20 Ω  |
| Greater than               | 100; 130; 160; 200 Ω                | 200 Ω   | 200 Ω |

SVC Defibrillation lead impedance

| Less than                  | 20; 30; 40; 50 Ω                    | 20 Ω    | 20 Ω  |
| Greater than               | 100; 130; 160; 200 Ω                | 200 Ω   | 200 Ω |

Lead impedance alert urgency

| Low; High                  | —                                   | —       | —     |
Table 89. Patient Alert parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Other Patient Alerts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Battery Voltage ERI</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Excessive Charge Time EOL</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Number of Shocks Delivered in an Episode</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Number of Shocks threshold</td>
<td>1; 2; 3; 4; 5; 6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>All Therapies in a Zone Exhausted for an Episode</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>VF Detection OFF, 3+ VF or 3+ FVT Rx Off(^a)</td>
<td>On-High; Off</td>
<td>On-High</td>
<td>On-High</td>
</tr>
</tbody>
</table>

\(^a\) If this is the only alert enabled, the device does not sound the Test tone when a magnet is applied.

B.6.2 Patient Alert parameters, VR devices

Table 90. Patient Alert parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert Time</td>
<td>00:00; 00:10 … 08:00; … 23:50</td>
<td>08:00</td>
<td>08:00</td>
</tr>
<tr>
<td><strong>Lead Impedance Out of Range Patient Alerts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RV Pacing lead impedance</td>
<td>On; Off(^\oplus)</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Less than</td>
<td>200(^\oplus); 300; 400; 500 (\Omega)</td>
<td>200 (\Omega)</td>
<td>200 (\Omega)</td>
</tr>
<tr>
<td>Greater than</td>
<td>1000; 1500; 2000; 3000 (\Omega)</td>
<td>3000 (\Omega)</td>
<td>3000 (\Omega)</td>
</tr>
<tr>
<td>RV Defibrillation lead impedance</td>
<td>On; Off(^\oplus)</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Less than</td>
<td>20(^\oplus); 30; 40; 50 (\Omega)</td>
<td>20 (\Omega)</td>
<td>20 (\Omega)</td>
</tr>
<tr>
<td>Greater than</td>
<td>100; 130; 160; 200(^\oplus) (\Omega)</td>
<td>200 (\Omega)</td>
<td>200 (\Omega)</td>
</tr>
<tr>
<td>SVC Defibrillation lead impedance</td>
<td>On; Off(^\oplus)</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Less than</td>
<td>20(^\oplus); 30; 40; 50 (\Omega)</td>
<td>20 (\Omega)</td>
<td>20 (\Omega)</td>
</tr>
<tr>
<td>Greater than</td>
<td>100; 130; 160; 200(^\oplus) (\Omega)</td>
<td>200 (\Omega)</td>
<td>200 (\Omega)</td>
</tr>
<tr>
<td>Lead impedance alert urgency</td>
<td>Low; High(^\oplus)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Other Patient Alerts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Battery Voltage ERI</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Excessive Charge Time EOL</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Number of Shocks Delivered in an Episode</td>
<td>On-Low; On-High; Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Number of Shocks threshold</td>
<td>1; 2; 3(^\oplus); 4; 5; 6</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 90. Patient Alert parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Therapies in a Zone Exhausted for an Episode</td>
<td>On-Low; On-High; Off&lt;sup&gt;φ&lt;/sup&gt;</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>VF Detection OFF, 3+ VF or 3+ FVT Rx Off&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Off</td>
<td>On-High</td>
<td>On-High</td>
</tr>
</tbody>
</table>

<sup>a</sup> If this is the only alert enabled, the device does not sound the Test tone when a magnet is applied.

B.7 Data collection parameters

B.7.1 Data collection parameters, AT and DR devices

Table 91. Data collection parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGM 1 Source</td>
<td>Can to HVB; Can to Vring; Can to Aring; Vtip to HVB; Vtip to Vring; Atip to Aring; Atip to Vring; Airing to HVB; Airing to SVC&lt;sup&gt;a&lt;/sup&gt;; Can to SVC&lt;sup&gt;a&lt;/sup&gt;; HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Atip to Aring</td>
<td>Atip to Aring</td>
</tr>
<tr>
<td>EGM 1 Range</td>
<td>±2; ±4; ±8&lt;sup&gt;φ&lt;/sup&gt;; ±16 mV</td>
<td>±8 mV</td>
<td>±8 mV</td>
</tr>
<tr>
<td>EGM 2 Source</td>
<td>Can to HVB; Can to Vring; Vtip to HVB; Vtip to Vring&lt;sup&gt;φ&lt;/sup&gt;; Can to SVC&lt;sup&gt;a&lt;/sup&gt;; HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Vtip to Vring</td>
<td>Vtip to Vring</td>
</tr>
<tr>
<td>EGM 2 Range</td>
<td>±2; ±4; ±8&lt;sup&gt;φ&lt;/sup&gt;; ±16 mV</td>
<td>±8 mV</td>
<td>±8 mV</td>
</tr>
<tr>
<td>Pre-arrhythmia EGM</td>
<td>Off&lt;sup&gt;φ&lt;/sup&gt;; On - 1 month; On - 3 months; On Continuous</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Device Date/Time&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(enter time and date)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Holter Telemetry</td>
<td>Off&lt;sup&gt;φ&lt;/sup&gt;; 0.5; 1; 2; 4; 8; 16; 24; 36; 46 hr</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>

<sup>a</sup> A lead must be connected to the SVC port for this configuration.

<sup>b</sup> The times and dates stored in episode records and other data are determined by the Device Date/Time clock.

B.7.2 Data collection parameters, VR devices

Table 92. Data collection parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGM 1 Source</td>
<td>Can to HVB; Can to Vring; Vtip to HVB; Vtip to Vring&lt;sup&gt;φ&lt;/sup&gt;; Can to SVC&lt;sup&gt;a&lt;/sup&gt;; HVB to SVC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Vtip to Vring</td>
<td>Vtip to Vring</td>
</tr>
<tr>
<td>EGM 1 Range</td>
<td>±2; ±4; ±8&lt;sup&gt;φ&lt;/sup&gt;; ±16 mV</td>
<td>±8 mV</td>
<td>±8 mV</td>
</tr>
</tbody>
</table>
### Table 92. Data collection parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Programmable values</th>
<th>Shipped</th>
<th>Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGM 2 Source</td>
<td>aCan to HVB; Can to Vring; Vtip to HVB; Vtip to Vring; Can to SVC; a HVB to SVC</td>
<td>Can to HVB</td>
<td>Can to HVB</td>
</tr>
<tr>
<td>EGM 2 Range</td>
<td>±2; ±4; ±8; ±16 mV</td>
<td>±8 mV</td>
<td>±8 mV</td>
</tr>
<tr>
<td>Pre-arrhythmia EGM</td>
<td>Off; On - 1 month; On - 3 months; On Continuous</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Device Date/Time</td>
<td>(enter time and date)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Holter Telemetry</td>
<td>Off; 0.5; 1; 2; 4; 8; 16; 24; 36; 46 hr</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>

a A lead must be connected to the SVC port for this configuration.

b The times and dates stored in episode records and other data are determined by the Device Date/Time clock.

### B.8 System test parameters

#### B.8.1 System test parameters, AT and DR devices

### Table 93. System test parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pacing threshold test parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Test Type</td>
<td>Amplitude; Pulse Width</td>
</tr>
<tr>
<td>Chamber</td>
<td>RV; Atrium</td>
</tr>
<tr>
<td>Decrement after</td>
<td>2; 3 ... 15 pulses</td>
</tr>
<tr>
<td>Mode&lt;sup&gt;a&lt;/sup&gt; (RV test)</td>
<td>VVI; VOO; DDI; DDD; DOO</td>
</tr>
<tr>
<td>Mode&lt;sup&gt;a&lt;/sup&gt; (Atrium test)</td>
<td>AAI; AOO; DDI; DDD; DOO</td>
</tr>
<tr>
<td>Lower Rate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30; 35 ... 60; 70; 75 ... 150 bpm</td>
</tr>
<tr>
<td>RV Amplitude&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2 ... 1.5 ms</td>
</tr>
<tr>
<td>A. Amplitude&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>A. Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2 ... 1.5 ms</td>
</tr>
<tr>
<td>AV Delay</td>
<td>30; 40 ... 350 ms</td>
</tr>
<tr>
<td>RV Pace Blanking</td>
<td>150; 160 ... 450 ms</td>
</tr>
<tr>
<td>A. Pace Blanking</td>
<td>150; 160 ... 250 ms</td>
</tr>
<tr>
<td>PVARP</td>
<td>150; 160 ... 500 ms</td>
</tr>
</tbody>
</table>
Table 93. System test parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensing test parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>AAI; DDD; DDI; VVI; ODO</td>
</tr>
<tr>
<td>AV Delay</td>
<td>30; 40 … 350 ms</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 … 60; 70; 75 … 120 bpm</td>
</tr>
</tbody>
</table>

a The selectable values for this parameter depend on the programmed pacing mode.

b The maximum Lower Rate value is 145 bpm if you perform the test in DDD mode.

c Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude \( A \) depends upon the programmed amplitude \( A_p \) and programmed pulse width \( W_p \): 
\[
A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})].
\]

B.8.2 System test parameters, VR devices

Table 94. System test parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pacing threshold test parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Test Type</td>
<td>Amplitude; Pulse Width</td>
</tr>
<tr>
<td>Decrement after</td>
<td>2; 3 … 15 pulses</td>
</tr>
<tr>
<td>Mode</td>
<td>VVI; VOO</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 … 60; 70; 75 … 150 bpm</td>
</tr>
<tr>
<td>RV Amplitude</td>
<td>0.5; 1 … 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>RV Pulse Width</td>
<td>0.03; 0.06; 0.1; 0.2 … 1.5 ms</td>
</tr>
<tr>
<td>V. Pace Blanking</td>
<td>150; 160 … 450 ms</td>
</tr>
<tr>
<td><strong>Sensing test parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>VVI; OVO</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 … 60; 70; 75 … 120 bpm</td>
</tr>
<tr>
<td><strong>Wavelet test parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>VVI; OVO</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>30; 35 … 60; 70; 75 … 120 bpm</td>
</tr>
</tbody>
</table>

a The selectable values for this parameter depend on the programmed pacing mode.

b Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude \( A \) depends upon the programmed amplitude \( A_p \) and programmed pulse width \( W_p \): 
\[
A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})].
\]
## B.9 EP study parameters

### B.9.1 EP Study parameters, AT and DR devices

Table 95. EP Study parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T-Shock induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Deliver</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>Enable</td>
<td>Enabled; Disabledφ</td>
</tr>
<tr>
<td>#S1</td>
<td>2; 3; 4; 5; 6; 7; 8</td>
</tr>
<tr>
<td>S1S1</td>
<td>300; 310 ... 400; ... 2000 ms</td>
</tr>
<tr>
<td>Delay</td>
<td>10; 20 ... 300; ... 600 ms</td>
</tr>
<tr>
<td>Energy(^a)</td>
<td>0.4; 0.6 ... 1; ... 2; 3; 4 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J</td>
</tr>
<tr>
<td>Waveform</td>
<td>Monophasic; Biphasic</td>
</tr>
<tr>
<td>Pathway(^b)</td>
<td>AX&gt;B; B&gt;AX</td>
</tr>
<tr>
<td><strong>50 Hz Burst induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Burst</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>Chamber</td>
<td>RV; Atrium</td>
</tr>
<tr>
<td>Amplitude(^c)</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 0.5; ... 1.5 ms</td>
</tr>
<tr>
<td>VOO Backup (for atrial 50 Hz Burst)</td>
<td>On; Offφ</td>
</tr>
<tr>
<td>Pacing Rate</td>
<td>60; 70 ... 120 bpm</td>
</tr>
<tr>
<td>RV Amplitude(^{c,d,e})</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>RV Pulse Width(^d)</td>
<td>0.1; 0.2 ... 1.5 ms</td>
</tr>
<tr>
<td><strong>Fixed Burst induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Burst</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>Chamber</td>
<td>RV; Atrium</td>
</tr>
<tr>
<td>Interval</td>
<td>100; 110 ... 600 ms</td>
</tr>
<tr>
<td>Amplitude(^c)</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 0.5; ... 1.5 ms</td>
</tr>
<tr>
<td>VVI Backup (for atrial Fixed Burst)</td>
<td>On; Offφ</td>
</tr>
<tr>
<td>Pacing Rate</td>
<td>60; 70 ... 120 bpm</td>
</tr>
<tr>
<td>RV Amplitude(^{c,d,e})</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>RV Pulse Width(^d)</td>
<td>0.1; 0.2 ... 1.5 ms</td>
</tr>
<tr>
<td><strong>PES induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Deliver</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>Chamber</td>
<td>RV; Atrium</td>
</tr>
<tr>
<td>#S1</td>
<td>1; 2 ... 8; ... 15</td>
</tr>
<tr>
<td>Parameter</td>
<td>Selectable values</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>S1S1</td>
<td>100; 110 ... 600; ... 2000 ms</td>
</tr>
<tr>
<td>S1S2</td>
<td>Off; 100; 110 ... 400; ... 600 ms</td>
</tr>
<tr>
<td>S2S3</td>
<td>Off; 100; 110 ... 600 ms</td>
</tr>
<tr>
<td>S3S4</td>
<td>Off; 100; 110 ... 600 ms</td>
</tr>
<tr>
<td>Amplitude&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 0.5; ... 1.5 ms</td>
</tr>
<tr>
<td>VVI Backup (for atrial PES)</td>
<td>On; Off</td>
</tr>
<tr>
<td>Pacing Rate</td>
<td>60; 70; ... 120 bpm</td>
</tr>
<tr>
<td>RV Amplitude&lt;sup&gt;c,d,e&lt;/sup&gt;</td>
<td>0.5; 1 ... 4; 5; 6; 8 V</td>
</tr>
<tr>
<td>RV Pulse Width&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.1; 0.2 ... 1.5 ms</td>
</tr>
</tbody>
</table>

**Manual defibrillation parameters**

| Energy<sup>a</sup>           | 0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J |
| Pathway<sup>b</sup>          | AX>B; B>AX                                            |

**Manual cardioversion parameters**

| Chamber                      | RV; Atrium                                           |
| Energy<sup>a</sup>           | 0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J |
| Pathway<sup>b</sup>          | AX>B; B>AX                                            |
| Minimum R-R (atrial CV only) | 400; 410 ... 500; ... 600 ms                        |
| Tilt (atrial CV only)        | 30; 40; 50; 65%                                      |

**General manual ATP therapy parameters**

| Minimum Interval (atrial ATP) | 100; 110; 120; 130; ... 400 ms                     |
| Minimum Interval (ventricular ATP) | 150; 160 ... 200; ... 400 ms                         |
| Amplitude<sup>c</sup>         | 0.5; 1 ... 4; 5; 6; 8; 8 V                           |
| Pulse Width                   | 0.1; 0.2 ... 1.5 ms                                  |
| VVI Backup (for atrial ATP therapy) | On; Off                                              |
| Pacing Rate                   | 60; 70; ... 120 bpm                                  |
| RV Amplitude<sup>c,d,e</sup>  | 0.5; 1 ... 4; 5; 6; 8 V                              |
| RV Pulse Width<sup>d</sup>    | 0.1; 0.2 ... 1.5 ms                                  |

**Manual Ramp therapy parameters**

| Chamber                      | RV; Atrium                                           |
| RV Ramp therapy parameters  | # Pulses 1; 2 ... 6; ... 15                           |
|                            | %RRR Interval 50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97% |
|                            | Dec/Pulse 0; 10; 20; 30; 40 ms                       |

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Table 95. EP Study parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial Ramp therapy parameters</td>
<td></td>
</tr>
<tr>
<td># Pulses</td>
<td>1; 2 ... 6; ... 15; 20; 30 ... 100</td>
</tr>
<tr>
<td>%AA Interval</td>
<td>28; 31; 34; 38; 41 ... 59; 63; 66 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>Dec/Pulse</td>
<td>0; 10; 20; 30; 40 ms</td>
</tr>
<tr>
<td>Manual Burst therapy parameters</td>
<td></td>
</tr>
<tr>
<td># Pulses</td>
<td>1; 2 ... 8; ... 15</td>
</tr>
<tr>
<td>%RR Interval</td>
<td>50; 53; 56; 63; 66 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>Manual Ramp+ therapy parameters</td>
<td></td>
</tr>
<tr>
<td># Pulses</td>
<td>1; 2; 3; ... 15</td>
</tr>
<tr>
<td>R-S1 (%RR)</td>
<td>50; 53; 56; 63; 66 ... 75; ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S1-S2 (%RR)</td>
<td>50; 53; 56; 63; 66; 69 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S2-SN (%RR)</td>
<td>50; 53; 56; 63; 66; 66 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>Manual Burst+ therapy parameters</td>
<td></td>
</tr>
<tr>
<td>#S1 Pulses</td>
<td>1; 2 ... 6; ... 15; 20; 30 ... 100</td>
</tr>
<tr>
<td>%AA Interval</td>
<td>28; 31; 34; 38; 41 ... 59; 63; 66 ... 84; 88; 91; 94; 97%</td>
</tr>
<tr>
<td>S1S2</td>
<td>Off; 28; 31; 34; 38; 41 ... 59; 63; 66 ... 84; 88; 91;</td>
</tr>
<tr>
<td></td>
<td>94; 97%</td>
</tr>
<tr>
<td>S2S3 Dec</td>
<td>Off; 0; 10; 20; ... 80 ms</td>
</tr>
</tbody>
</table>

a Delivered energy based on a biphasic pulse into a 75 Ω load.
b If Active Can is Off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.
c Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude A depends upon the programmed amplitude A_p and programmed pulse width W_p: A = A_p × [0.9 - (W_p × 0.145 ms⁻¹)]
d The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing.
e Crosstalk may occur when atrial pacing amplitude is greater than 6.0 V.

B.9.2 EP Study parameters, VR devices

Table 96. EP Study parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-Shock induction parameters</td>
<td></td>
</tr>
<tr>
<td>Resume at Deliver</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>Enable</td>
<td>Enabled; Disabled</td>
</tr>
<tr>
<td>#S1</td>
<td>2; 3; 4; 5; 6; 7; 8</td>
</tr>
<tr>
<td>S1S1</td>
<td>300; 310 ... 400 ... 2000 ms</td>
</tr>
<tr>
<td>Delay</td>
<td>20; 30 ... 300 ... 600 ms</td>
</tr>
<tr>
<td>Parameter</td>
<td>Selectable values</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Energy(^a)</td>
<td>0.4; 0.6 ... 1(^\circ); 2; 3; 4 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35 J</td>
</tr>
<tr>
<td>Waveform</td>
<td>Monophasic(^\circ); Biphasic</td>
</tr>
<tr>
<td>Pathway(^b)</td>
<td>AX&gt;B; B&gt;AX(^\circ)</td>
</tr>
<tr>
<td><strong>50 Hz Burst induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Burst</td>
<td>Enabled(^\circ); Disabled</td>
</tr>
<tr>
<td>Amplitude(^c)</td>
<td>0.5; 1 ... 4(^\circ); 5; 6; 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 0.5(^\circ) ... 1.5 ms</td>
</tr>
<tr>
<td><strong>Fixed Burst induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Burst</td>
<td>Enabled(^\circ); Disabled</td>
</tr>
<tr>
<td>Interval</td>
<td>100; 110 ... 600(^\circ) ms</td>
</tr>
<tr>
<td>Amplitude(^c)</td>
<td>0.5; 1 ... 4(^\circ); 5; 6; 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 0.5(^\circ) ... 1.5 ms</td>
</tr>
<tr>
<td><strong>PES induction parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Resume at Deliver</td>
<td>Enabled(^\circ); Disabled</td>
</tr>
<tr>
<td>#S1</td>
<td>1; 2 ... 8(^\circ) ... 15</td>
</tr>
<tr>
<td>S1S1</td>
<td>100; 110 ... 600(^\circ) ... 2000 ms</td>
</tr>
<tr>
<td>S1S2</td>
<td>Off; 100; 110 ... 400(^\circ) ... 600 ms</td>
</tr>
<tr>
<td>S2S3</td>
<td>Off(^\circ); 100; 110 ... 600 ms</td>
</tr>
<tr>
<td>S3S4</td>
<td>Off(^\circ); 100; 110 ... 600 ms</td>
</tr>
<tr>
<td>Amplitude(^c)</td>
<td>0.5; 1 ... 4(^\circ); 5; 6; 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 0.5(^\circ) ... 1.5 ms</td>
</tr>
<tr>
<td><strong>Manual defibrillation parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Energy(^a)</td>
<td>0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35(^\circ) J</td>
</tr>
<tr>
<td>Pathway(^b)</td>
<td>AX&gt;B; B&gt;AX(^\circ)</td>
</tr>
<tr>
<td><strong>Manual cardioversion parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Energy(^a)</td>
<td>0.4; 0.6 ... 1.8; 2; 3 ... 16; 18; 20; 22; 24; 25; 26; 28; 30; 32; 35(^\circ) J</td>
</tr>
<tr>
<td>Pathway(^b)</td>
<td>AX&gt;B; B&gt;AX(^\circ)</td>
</tr>
<tr>
<td><strong>Shared Manual ATP therapy parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Minimum Interval</td>
<td>150; 160 ... 200(^\circ) ... 400 ms</td>
</tr>
<tr>
<td>Amplitude(^c)</td>
<td>0.5; 1 ... 4; 5; 6(^\circ); 8 V</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.1; 0.2 ... 1.5(^\circ) ms</td>
</tr>
<tr>
<td><strong>Manual Ramp therapy parameters</strong></td>
<td></td>
</tr>
<tr>
<td># Pulses</td>
<td>1; 2 ... 6(^\circ) ... 15</td>
</tr>
<tr>
<td>%RR Interval</td>
<td>50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97(^\circ)%</td>
</tr>
</tbody>
</table>

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Table 96. EP Study parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selectable values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec/Pulse</td>
<td>0; 10; 20; 30; 40 ms</td>
</tr>
</tbody>
</table>

**Manual Burst therapy parameters**

| # Pulses                  | 1; 2 ... 8 ... 15                  |
| %RR Interval              | 50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97% |

**Manual Ramp+ therapy parameters**

| # Pulses                  | 1; 2; 3 ... 15                     |
| R-S1 (%RR)                | 50; 53; 56; 59; 63; 66 ... 75; ... 84; 88; 91; 94; 97% |
| S1-S2 (%RR)               | 50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97% |
| S2-SN (%RR)               | 50; 53; 56; 59; 63; 66 ... 84; 88; 91; 94; 97% |

aDelivered energy based on a biphasic pulse into a 75 Ω load.
bIf Active Can is Off, the HVA (Can) electrode is not used as part of the high-voltage delivery pathway.
cPeak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude A depends upon the programmed amplitude $A_p$ and programmed pulse width $W_p$: $A = A_p x [0.9 - (W_p x 0.145 ms^{-1})]$.

### B.10 Nonprogrammable parameters

#### B.10.1 Fixed parameters, AT devices

Table 97. Fixed parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature threshold</td>
<td>69%</td>
</tr>
<tr>
<td><strong>Fixed blanking periods</strong></td>
<td></td>
</tr>
<tr>
<td>Atrial blanking after a paced ventricular event</td>
<td>30 ms</td>
</tr>
<tr>
<td>Atrial blanking after high-voltage therapy</td>
<td>520 ms</td>
</tr>
<tr>
<td>Ventricular blanking after a paced atrial event</td>
<td>30 ms</td>
</tr>
<tr>
<td>Ventricular blanking on a high-voltage pulse delivery</td>
<td>520 ms</td>
</tr>
<tr>
<td><strong>Fixed bradycardia pacing parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Ventricular Safety Pacing intervals$^a$</td>
<td>110 ms</td>
</tr>
<tr>
<td></td>
<td>70 ms</td>
</tr>
<tr>
<td>PVC Response (PVARP extension)$^b$</td>
<td>Extended to 400 ms</td>
</tr>
<tr>
<td>PVC Response (NCAP extension)$^c$</td>
<td>Extended to 400 ms</td>
</tr>
<tr>
<td>PMT Intervention (PVARP extension)$^b$</td>
<td>Extended to 400 ms</td>
</tr>
<tr>
<td>PMT Intervention (NCAP extension)$^c$</td>
<td>Extended to 400 ms</td>
</tr>
<tr>
<td><strong>Fixed high-voltage therapy parameters</strong></td>
<td></td>
</tr>
<tr>
<td>VF confirmation for first enabled VF therapy</td>
<td>On</td>
</tr>
<tr>
<td>Maximum charging period</td>
<td>30 s</td>
</tr>
<tr>
<td>Waveform$^d$</td>
<td>Biphasic</td>
</tr>
</tbody>
</table>
### Table 97. Fixed parameters (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilt (ventricular therapy)</td>
<td>50%</td>
</tr>
<tr>
<td>Refractory period after V-sense during cardioversion synchronization</td>
<td>200 ms</td>
</tr>
<tr>
<td>Refractory period after paced event during charging or synchroni-</td>
<td>400 ms</td>
</tr>
<tr>
<td>zation(^e)</td>
<td></td>
</tr>
<tr>
<td>Refractory period after charge begins(^e)</td>
<td>400 ms</td>
</tr>
<tr>
<td>Atrial Vulnerable Period</td>
<td>250 ms</td>
</tr>
<tr>
<td>Escape interval after high-voltage therapy</td>
<td>1200 ms</td>
</tr>
<tr>
<td>Suspension of VT detection after defibrillation therapy</td>
<td>17 V. events</td>
</tr>
</tbody>
</table>

**Fixed automatic atrial ATP therapy parameters**

| VVI/VOO Backup Pacing amplitude\(^g\)                                     | 6 V           |
| VVI/VOO Backup Pacing pulse width                                         | 1.5 ms        |

**Fixed EP Study parameters**

| T-Shock pacing amplitude\(^g\)                                            | 8 V           |
| T-Shock pacing pulse width                                                | 1.5 ms        |
| 50 Hz burst pacing interval                                               | 20 ms         |

**Hardware parameters**

| Atrial rate limit\(^h\) (protective feature)                              | 171 bpm       |
| Ventricular rate limit\(^h\) (protective feature)                         | 171 bpm       |
| Input impedance                                                          | 150 kΩ minimum|

\(^a\) The shorter VSP interval takes effect when the pacing rate exceeds the results of the following formula: 60,000/2 x (Ventricular Pace Blanking + 110) per minute.

\(^b\) PVARP is extended to 400 ms only if the current PVARP (either the programmed PVARP value or the current Varied PVARP value) is less than 400 ms.

\(^c\) The NCAP extension applies only if NCAP is enabled.

\(^d\) The waveform for a T-Shock induction can be programmed to biphasic or monophasic.

\(^e\) Does not affect event classification during charging.

\(^f\) Timer accuracy cannot be independently measured.

\(^g\) Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude A depends upon the programmed amplitude A\(_p\) and programmed pulse width W\(_p\): A = A\(_p\) x \[0.9 - (W\(_p\) x 0.145 ms\(^{-1}\))]\).

\(^h\) Does not apply during therapies, programmed high rates, or ventricular safety pacing.
### B.10.2 Fixed parameters, DR devices

#### Table 98. Fixed parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature threshold</td>
<td>69%</td>
</tr>
<tr>
<td><strong>Fixed blanking periods</strong></td>
<td></td>
</tr>
<tr>
<td>Atrial blanking after a paced ventricular event</td>
<td>30 ms</td>
</tr>
<tr>
<td>Atrial blanking after high-voltage therapy</td>
<td>520 ms</td>
</tr>
<tr>
<td>Ventricular blanking after a paced atrial event</td>
<td>30 ms</td>
</tr>
<tr>
<td>Ventricular blanking on a high-voltage pulse delivery</td>
<td>520 ms</td>
</tr>
<tr>
<td><strong>Fixed bradycardia pacing parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Ventricular Safety Pacing intervals (^a)</td>
<td>110 ms</td>
</tr>
<tr>
<td>PVC Response (PVARP extension) (^b)</td>
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<tr>
<td>PVC Response (NCAP extension) (^c)</td>
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</tr>
<tr>
<td>PMT Intervention (NCAP extension) (^c)</td>
<td>Extended to 400 ms</td>
</tr>
<tr>
<td><strong>Fixed high-voltage therapy parameters</strong></td>
<td></td>
</tr>
<tr>
<td>VF confirmation for first enabled VF therapy</td>
<td>On</td>
</tr>
<tr>
<td>Maximum charging period</td>
<td>30 s</td>
</tr>
<tr>
<td>Waveform (^d)</td>
<td>Biphasic</td>
</tr>
<tr>
<td>Tilt (ventricular therapy)</td>
<td>50%</td>
</tr>
<tr>
<td>Refractory period after V-sense during cardioversion synchronization</td>
<td>200 ms</td>
</tr>
<tr>
<td>Refractory period after paced event during charging or synchronization (^e)</td>
<td>400 ms (^f)</td>
</tr>
<tr>
<td>Refractory period after charge begins (^e)</td>
<td>400 ms (^f)</td>
</tr>
<tr>
<td>Atrial Vulnerable Period</td>
<td>250 ms</td>
</tr>
<tr>
<td>Escape interval after high-voltage therapy</td>
<td>1200 ms</td>
</tr>
<tr>
<td>Suspension of VT detection after defibrillation therapy</td>
<td>17 V. events</td>
</tr>
<tr>
<td><strong>Fixed EP Study parameters</strong></td>
<td></td>
</tr>
<tr>
<td>T-Shock pacing amplitude (^g)</td>
<td>8 V</td>
</tr>
<tr>
<td>T-Shock pacing pulse width</td>
<td>1.5 ms</td>
</tr>
<tr>
<td>50 Hz burst pacing interval</td>
<td>20 ms</td>
</tr>
</tbody>
</table>
**Table 98. Fixed parameters (continued)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Atrial rate limit(^h) (protective feature)</td>
<td>171 bpm</td>
</tr>
<tr>
<td>Ventricular rate limit(^h) (protective feature)</td>
<td>171 bpm</td>
</tr>
<tr>
<td>Input impedance</td>
<td>150 kΩ minimum</td>
</tr>
</tbody>
</table>

\(^a\) The shorter VSP interval takes effect when the pacing rate exceeds the results of the following formula: 60,000/2 x (Ventricular Pace Blanking + 110) per minute.

\(^b\) PVARP is extended to 400 ms only if the current PVARP (either the programmed PVARP value or the current Varied PVARP value) is less than 400 ms.

\(^c\) The NCAP extension applies only if NCAP is enabled.

\(^d\) The waveform for a T-Shock induction can be programmed to biphasic or monophasic.

\(^e\) Does not affect event classification during charging.

\(^f\) Timer accuracy cannot be independently measured.

\(^g\) Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude \(A\) depends upon the programmed amplitude \(A_p\) and programmed pulse width \(W_p\): \(A = A_p x [0.9 - (W_p x 0.145 \text{ ms}^{-1})]\).

\(^h\) Does not apply during therapies, programmed high rates, or ventricular safety pacing.

**B.10.3 Fixed parameters, VR devices**

**Table 99. Fixed parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature threshold</td>
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</tr>
<tr>
<td><strong>Fixed blanking periods</strong></td>
<td></td>
</tr>
<tr>
<td>Ventricular blanking on a high-voltage pulse delivery</td>
<td>520 ms</td>
</tr>
<tr>
<td><strong>Fixed high-voltage therapy parameters</strong></td>
<td></td>
</tr>
<tr>
<td>VF confirmation for first enabled VF therapy</td>
<td>On</td>
</tr>
<tr>
<td>Maximum charging period</td>
<td>30 s</td>
</tr>
<tr>
<td>Waveform(^a)</td>
<td>Biphasic</td>
</tr>
<tr>
<td>Tilt</td>
<td>50%</td>
</tr>
<tr>
<td>Refractory period after V-sense during cardioversion synchronization</td>
<td>200 ms</td>
</tr>
<tr>
<td>Refractory period after paced event during charging or synchronization(^b)</td>
<td>400 ms(^c)</td>
</tr>
<tr>
<td>Refractory period after charge begins(^b)</td>
<td>400 ms(^c)</td>
</tr>
<tr>
<td>Escape interval after high-voltage therapy</td>
<td>1200 ms</td>
</tr>
<tr>
<td>Suspension of VT detection after defibrillation therapy</td>
<td>17 V. events</td>
</tr>
<tr>
<td><strong>Fixed EP Study parameters</strong></td>
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</tr>
<tr>
<td>T-Shock pacing amplitude(^d)</td>
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<td>50 Hz burst pacing interval</td>
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</tbody>
</table>
Table 99. Fixed parameters (continued)

<table>
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<tr>
<th>Parameter</th>
<th>Fixed value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware parameters</strong></td>
<td></td>
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<tr>
<td>Ventricular rate limit(^a) (protective feature)</td>
<td>171 bpm</td>
</tr>
<tr>
<td>Input impedance</td>
<td>150 kΩ minimum</td>
</tr>
</tbody>
</table>

\(^a\)The waveform for a T-Shock induction can be programmed to biphasic or monophasic.
\(^b\)Does not affect event classification during charging.
\(^c\)Timer accuracy cannot be independently measured.
\(^d\)Peak pacing amplitude. When tested per CENELEC standard prEN 45502-2-1:1998, the measured amplitude \(A\) depends upon the programmed amplitude \(A_p\) and programmed pulse width \(W_p\):
\[ A = A_p \times [0.9 - (W_p \times 0.145 \text{ ms}^{-1})] \]
\(^e\)Does not apply during therapies or programmed high rates.
Glossary

2:1 block rate – lowest atrial rate at which every second atrial event occurs during TARP. The operation results in a ventricular pacing rate one half as fast as the atrial rate.

50 Hz Burst – 1 VF induction protocol that delivers a train of pacing pulses into the ventricle at 20 ms intervals. 2 induction protocol that delivers a train of pacing pulses into the selected chamber (atrium or ventricle) at 20 ms intervals. It is also provided as an AT/AF therapy.

accelerated FVT – tachyarrhythmia episode redetected as VF that was initially detected as FVT.

accelerated VT – when the device redetects VT, it classifies the rhythm as accelerated by first averaging and comparing intervals prior to redetection with intervals prior to initial detection. VT acceleration occurs if the average drops by at least 60 ms. The device also identifies VT acceleration if the initial VT episode is redetected as FVT or VF.

Active Can – option to select the device case as an active electrode for delivering defibrillation and cardioversion therapies.

activity acceleration – programmable time that controls how quickly the device pacing rate responds to increased activity (in rate-responsive pacing modes).

activity deceleration – programmable time that controls how quickly the device pacing rate responds to decreased activity (in rate-responsive pacing modes).

activity sensor – accelerometer within the device that measures the patient’s body motion in rate responsive pacing modes.

activity threshold – programmable rate-responsive pacing parameter that defines the minimum level of patient body motion that evokes a rate change.

AF/Afl criterion – PR Logic criterion designed to discriminate between rapidly conducted atrial fibrillation or atrial flutter and ventricular tachyarrhythmia.

antitachycardia pacing (ATP) – therapies that deliver rapid sequences of pacing pulses to terminate tachyarrhythmias.

AT/AF Interval – programmable interval used to define the AT/AF detection zone. The median atrial interval must be shorter than this value for an AT/AF episode to be detected.

Atrial Lead Position Check – a feature that analyzes the atrial lead position every 24 hours. If the check fails, the device classifies the atrial lead position as incorrect and disables all atrial tachyarrhythmia therapies until they can be reenabled using the programmer.

Atrial Non-Sustained Tachycardia (AT-NS) – atrial rhythm that is fast enough to fall within the programmed AT/AF detection zones for at least 7 beats but does not meet the episode detection criteria.
Atrial Preference Pacing – atrial rhythm management feature that adapts the pacing rate to slightly higher than the intrinsic sinus rate.

Atrial Rate Stabilization – atrial rhythm management feature that eliminates a prolonged pause following a premature atrial contraction (PAC).

Atrial Refractory Period (ARP) – programmable refractory period that follows an atrial paced or sensed event. This period is applied when the device is programmed to a single chamber atrial pacing mode.

atrial tracking – dual chamber pacing operation that paces the ventricle in synchrony with atrial events.

Atrial Vulnerable Period (AVP) – 250 ms synchronization interval that starts 150 ms after a sensed atrial event. The device postpones a ventricular shock scheduled during this period for one ventricular event.

auto-adjusting sensitivity – after each sensed or paced event, the sensitivity thresholds briefly assume less sensitive settings to prevent sensing of T-waves and pacing artifacts.

auto resume – feature that automatically resumes tachyarrhythmia detection after the device delivers an EP Study induction.

biphasic – high-voltage therapy waveform in which most of the energy is delivered from anode to cathode, and the remaining energy is delivered from cathode to anode.

blanking, pace – programmable blanking periods. One parameter defines how long atrial sensing is disabled after atrial paced events. The other parameter defines how long ventricular sensing is disabled after ventricular paced events.

blanking period – time interval during which no sensing can occur. Blanking periods follow each pacing pulse, sensed event, or shock.

blanking, sense – programmable blanking periods. One parameter defines how long atrial sensing is disabled after atrial sensed events. The other parameter defines how long ventricular sensing is disabled after ventricular sensed events.

Burst pacing – ATP therapy that delivers sequences of ventricular pacing pulses with an interval that is a programmable percentage of the tachycardia cycle length. With each sequence of Burst pacing delivered, the device shortens the pacing interval by a programmable interval.

Burst+ pacing – ATP therapy that delivers sequences of atrial pacing pulses with an interval that is a programmable percentage of the tachycardia cycle length, followed by up to two premature stimuli delivered at programmable intervals. With each sequence of Burst+ pacing delivered, the device shortens the pacing interval by a programmable interval.

capacitor – component in the device that stores electrical energy so that high-voltage therapies can be delivered from a relatively small battery.
**capacitor formation** – any charge to maximum programmed energy that dissipates off the capacitors (is not dumped or delivered) for at least 10 min.

**Cardiac Compass report** – printed plot of up to 14 months of daily measurements that is used to identify and document long-term clinical trends.

**cardioversion** – 1 ventricular therapy designed to treat VT and FVT episodes with a programmable energy shock that must be synchronized to an arrhythmic ventricular event. 2 atrial therapy designed to treat AT/AF episodes with a programmable energy shock that must be synchronized with a ventricular event outside the ventricle’s vulnerable period.

**Charge Circuit Inactive** – indicates that three consecutive charging periods have each exceeded 30 s. The charge circuit is inactive, and all automatic therapy functions, EP Study functions, and manual system tests are disabled except for Emergency VVI pacing. Please inform your Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

**Charge Circuit Timeout** – indicates that the charging period has exceeded 30 s. The charge circuit is still active. Please inform your Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

**charging period** – time required for the device to store the programmed energy (charge) in its high-voltage capacitors.

**Checklist** – interactive list of programmer screens that helps users operate the programmer more efficiently. Clinicians can set up their own checklists or use a Medtronic standard checklist supplied with the programmer.

**Combined Beats to Detect** – number of events counted on both the VT and VF event counters required for Combined Count detection. If both VF detection and VT detection are enabled, the device calculates the Combined Beats to Detect by multiplying the VF Detection Beats by 7/6 and rounding down.

**counter data** – stored data including numbers of episodes, delivered therapies, and therapy outcomes.

**crosstalk** – sensing of a pacing stimulus delivered in the opposite chamber.

**current pathway** – electrical route between high-voltage electrodes across which defibrillation and cardioversion therapies are delivered.

**Decision Channel annotations** – annotations to stored and telemetered EGMs that document details about tachyarrhythmia detection operations.

**Decision Channel telemetry** – annotations displayed on stored EGMs and telemetered waveforms that document certain details of tachyarrhythmia detection.

**defibrillation** – therapy designed to treat VF episodes with a programmable energy shock. Unless VF confirmation is active, the device delivers a defibrillation therapy even if it cannot synchronize to a ventricular event.
**detection** – condition occurring when the device identifies the presence of a tachyarrhythmia episode.

**device status indicators** – programmer messages that describe problems with device memory or operation.

**double tachycardia** – ventricular tachyarrhythmia episode that occurs simultaneously with an unrelated supraventricular tachycardia (SVT).

**EGM range** – maximum magnitude of EGM amplifier signal, in millivolts. Smaller settings result in a higher resolution for displayed and recorded EGM waveforms.

**EGM source** – the pair of implanted electrodes that are selected as the sensing pathway for stored and telemetered EGM signals.

**EGM strip** – stored recording of the intracardiac waveforms from a detected arrhythmia episode.

**Elective Replacement Indicator** – see “ERI”.

**electrical reset** – automatic device operation to recover from a disruption in device memory and control circuitry. Programmed parameters may be set to electrical reset values. This operation triggers a device status indicator and an automatic Patient Alert tone.

**electromagnetic interference (EMI)** – energy transmitted by radiation, conduction, or induction that can interfere with device operations (such as sensing) or can potentially damage device circuitry.

**EOL (End of Life)** – battery status indicator for when immediate replacement of the device is recommended. The programmer displays the EOL symbol to indicate that the device is at End of Life and may not operate per specifications.

**episode** – period of time between tachyarrhythmia detection and termination.

**episode record** – stored information about the cardiac rhythm and device behavior during a detected tachyarrhythmia episode.

**ERI (Elective Replacement Indicator)** – battery status indicator for when replacement of the device is recommended.

**escape interval** – scheduled time, in milliseconds, between a sensed or paced event and the subsequent pacing output.

**event** – a sensed or paced beat.

**far-field EGM** – the EGM signal sensed between distant electrodes. An example is the EGM sensed between the device can and the ventricular lead ring.

**Fast AT/AF Interval** – Programmable interval used to define the Fast AT/AF detection zone. The A-A Median Interval must be shorter than this value for a Fast AT/AF episode to be detected.
**Fixed Burst** – tachyarrhythmia induction protocol that delivers a train of pacing pulses at a uniform, programmed interval.

**Flashback memory** – programmer display of the intervals that preceded recent episodes or that preceded the last interrogation of the device.

**FVT detection via VF** – condition that occurs when the device identifies the presence of a fast ventricular tachycardia using the VF event counter and an FVT Interval less than the VF interval.

**FVT detection via VT** – condition that occurs when the device identifies the presence of a fast ventricular tachycardia using the VT event counter and an FVT Interval greater than the VF interval.

**FVT episode** – period of time between FVT detection and termination.

**FVT event** – a sensed beat that falls within the FVT detection zone between the programmed FVT Interval and VF Interval.

**FVT Interval** – programmable interval used to define the FVT detection zone. FVT via VF detection requires that the FVT Interval be shorter than the VF Interval. FVT via VT detection requires that the FVT Interval be longer than the VF Interval, but not greater than the VT Interval.

**FVT plus SVT** – see “double tachycardia”.

**High Rate Timeout** – feature that ensures that sustained high ventricular rates are treated with tachyarrhythmia therapy by limiting the time that SVT detection criteria can withhold detection. Episodes that are detected after the High Rate Timeout timer expires can be treated with zone-appropriate therapies or with VF therapies.

**Holter Telemetry** – telemetry feature that transmits EGM and Marker Channel data continuously for a programmable number of hours, regardless of whether the programming head is positioned over the device.

**HVA/HVB/HVX** – high-voltage electrode identifiers. In a standard lead configuration, HVA is the titanium body of the device; HVB is the RV electrode; and HVX is the SVC electrode.

**impedance** – total opposition that a circuit presents to electrical current flow; the device lead impedances can be measured to assess the lead system’s integrity.

**Inhibit** – temporary function that prevents pacing output pulses.

**interlock** – safety restriction in the programmer software that aids in the choice of proper parameter values, usually by displaying a screen message.

**Interrogate** – command to transmit the device parameters and stored data to the programmer.

**Last Session** – most recent time the device was successfully interrogated. A session ends 8 hours after the last interrogation.
Lead Performance Trends – long-term trend graphs of lead impedance and sensing amplitude measurements.

Live Rhythm Monitor – configurable programmer window that displays ECG, Leadless ECG, Marker Channel with marker annotations, and telemetered EGM waveform traces. It also displays the patient heart rate and interval in the upper left corner of the window.

Longevity – number of years before the device battery is depleted.

Marker Channel telemetry – telemetered symbols that annotate the device sensing, pacing, detection, and therapy operations.

Median atrial interval – the seventh in a numerically ordered list of the 12 most recent A-A intervals.

Median ventricular interval – the seventh in a numerically ordered list of the 12 most recent V-V intervals.

MVP (Managed Ventricular Pacing) – promotes intrinsic conduction by reducing unnecessary right ventricular pacing. MVP operates when the programmed mode is either AAIR<=>DDDR or AAI<=>DDD.

Near-field EGM – the EGM signal that is sensed across two closely spaced electrodes, for example, the EGM sensed between the tip and ring of a ventricular lead. Sometimes referred to as a bipolar EGM.

Nominal – parameter value that is suggested by Medtronic and is expected to be acceptable for the majority of patients.

Non-Competitive Atrial Pacing (NCAP) – programmable pacing feature that prohibits atrial pacing within a programmable interval after a refractory atrial event.

Observations – programmer messages in the Quick Look screen that identify possible issues of concern in the programming, the status of the device, or in the patient’s condition.

Onset criterion – programmable VT detection criterion that requires a sudden increase in ventricular rate to enable VT event classification. This helps prevent sinus tachycardias from being detected as VT episodes, since sinus tachycardias tend to exhibit gradual rate increases.

Other 1:1 SVTs criterion – PR Logic criterion designed to withhold ventricular detection for supraventricular tachycardias that exhibit nearly simultaneous atrial and ventricular activation.

Paced AV (PAV) interval – programmable delay following an atrial pace that schedules a corresponding ventricular pace.

Paced events – output pulses delivered at pacing energy levels from the device.
Pacemaker-Mediated Tachycardia (PMT) – paced rhythm that results when the device senses and tracks retrograde P-waves in DDD or DDDR mode. This retrograde conduction and atrial tracking repeats itself to produce an inappropriately rapid paced rhythm.

pacemaker Wenckebach – see “Wenckebach operation”.

pacing threshold – minimum programmable pacing output that consistently captures the heart.

patient-activated CV – cardioversion therapy that is initiated by a telemetered command from an external Patient Assistant device. Patient-activated CV is only delivered if a detected AT/AF episode is in progress.

Patient Alert monitoring system – audible alerts that notify the patient when any of the programmable alert conditions have occurred so that the patient can schedule an appointment.

PMOP (Post Mode Switch Overdrive Pacing) – atrial rhythm management feature that applies an elevated DDIR rate for a programmable period following AT/AF reversion.

Post Shock Pacing – feature that provides pacing after an atrial or ventricular high-voltage therapy. Post Shock Pacing pulses have programmable amplitudes and pulse widths.

Post VT/VF Shock Pacing – feature that provides pacing after a ventricular high-voltage therapy at a programmed overdrive pacing rate for a programmed duration.

Pre-arrhythmia EGM storage – (also called EGM pre-storage) programmable option to record EGM from before the onset or detection of a tachyarrhythmia. While this feature is operating, the device records EGM continuously. If a tachyarrhythmia episode occurs, the most recently collected EGM is added to the episode record to document the rhythm at onset.

PR Logic criteria – detection criteria that analyze both atrial and ventricular rhythms to discriminate between ventricular and supraventricular arrhythmias.

Programmed Electrical Stimulation (PES) – tachyarrhythmia induction protocol that paces the patient’s heart during vulnerable periods in the cardiac cycle to induce atrial or ventricular tachyarrhythmias.

Progressive Episode Therapies – feature that causes the device to skip therapies or modify high-voltage energy levels to ensure that each therapy delivered during an episode is at least as aggressive as the previous therapy.

PVAB (Post-Ventricular Atrial Blanking) – sets the interval after ventricular events during which sensed atrial events are ignored by bradycardia pacing features. If the programmed PVAB method is Absolute, the device ignores atrial events during the PVAB for all features, including tachyarrhythmia detection.

PVARP (Post-ventricular Atrial Refractory Period) – programmable refractory period used to prevent inappropriate inhibition or PMTs in dual chamber pacing modes.
PVC (premature ventricular contraction) – a sensed ventricular event that directly follows any other ventricular event with no atrial event between them.

PVC Response – dual chamber pacing feature that detects a PVC and responds by extending the PVARP to 400 ms (if the current PVARP is less than 400 ms).

QuickLink software design – navigation feature that provides easy, direct access between related programmer screens.

Quick Look software display – programmer screen that provides a summary of device status, notable events since the last interrogation, counters, and programming observations.

Ramp pacing – ATP therapy that delivers ventricular pacing pulses with progressively shorter pacing intervals per pulse. Each sequence of Ramp pacing that is delivered during a therapy includes an additional pacing pulse.

Ramp+ pacing – ATP therapy that delivers ventricular pacing pulses at programmable intervals that are based on percentages of the tachycardia cycle length. Each sequence of Ramp+ pacing delivered during a therapy includes an additional pacing pulse.

Rate Adaptive AV – dual chamber pacing feature that shortens the AV interval as the heart rate increases.

Rate Hysteresis – device feature that enables tracking of the patient’s intrinsic rhythm below the programmed Lower Rate to prevent pacing during extended periods of inactivity, such as when a patient is sleeping.

Reactive ATP – feature that allows the device to repeat programmed atrial antitachycardia pacing (ATP) therapies during long AT/AF episodes. Therapies are repeated after a programmed time interval or when the atrial rhythm changes in regularity or cycle length.

redetection – condition that occurs when the device identifies the continued presence of a tachyarrhythmia after therapy.

refractory period – time interval during which the device senses events, but marks them as refractory, and responds to them in a limited way. Refractory periods do not affect tachyarrhythmia detection.

Resume – programming command that reinstates automatic tachyarrhythmia detection.

retrograde – electrical conduction from the ventricles to the atria.

Sensed AV (SAV) interval – programmable delay following an atrial sensed event that schedules a corresponding ventricular pace.

sensed event – electrical activity across the sensing electrodes that exceeds the programmed sensitivity threshold.
Sensing Integrity Counter – diagnostic counter that records the number of short ventricular intervals that occur between patient sessions. A large number of short intervals may indicate that the ventricular sensing lead is damaged.

sensitivity – degree to which the sensing circuitry is responsive to intracardiac signals.

sensor-indicated rate – pacing rate that is determined by the patient’s level of physical activity and the rate response parameters.

sequence – one programmable set of antitachycardia pacing (ATP) pulses.

Sinus Tach criterion – PR Logic criterion designed to discriminate between high rate sinus tachycardia and ventricular tachyarrhythmia.

Smart Mode – disables an ATP therapy that has been unsuccessful in 4 consecutive episodes so that the device can treat subsequent episodes more quickly with therapies that have been effective.

Stability criterion – VT detection criterion that allows the device to screen out irregular ventricular rhythms or unstable VTs (for example, those caused by the conduction of atrial fibrillation or flutter).

successful – therapy counter that indicates how many times the therapy’s outcome was episode termination.

Suspend – programming command that temporarily deactivates the tachyarrhythmia detection functions.

SVT V. Limit – programmable interval value used by SVT discrimination criteria. If the median ventricular interval is less than the programmed SVT V. Limit, SVT discrimination criteria are not applied to ventricular detection.

synchronization – period during defibrillation and cardioversion therapies when the device attempts to deliver the therapy shock simultaneously with a sensed ventricular event.

synchrony – coordinated contraction of the atria and ventricles for most effective cardiac output.

TARP (Total Atrial Refractory Period) – sum of SAV and PVARP in dual chamber pacing modes. When the atrial cycle length is shorter than TARP, every other atrial event occurs in the PVARP and is not tracked.

telemetry – transmission of data between the device and the programmer by radio waves.

termination – condition that occurs when the criteria for identifying the end of a tachyarrhythmia episode are met.

test values – temporary parameters that are used during system test and EP study operations.

therapy – electrical stimulation provided to treat a tachyarrhythmia.
tilt – percentage by which the amplitude of a high-voltage pulse is decreased before the output is truncated.

tracking – see “atrial tracking”.

T-Shock induction – VF induction protocol that delivers a shock synchronized with the ventricular repolarization or T-wave. The device delivers a rapid series of paced beats to entrain the heart rhythm, followed by a programmable shock.

undersensing – failure to sense the P-wave or R-wave. Undersensing can cause inappropriate bradycardia pacing or a failure to detect tachyarrhythmia.

varied PVARP – a setting for PVARP that is based on the sensor-indicated rate.

Ventricular Non-Sustained Tachycardia (VT-NS) – ventricular rhythm that is fast enough to fall within the programmed VT or VF detection zones for at least 5 beats but does not meet any episode detection criteria.

Ventricular Rate Stabilization – ventricular rhythm management feature that eliminates a prolonged pause in the ventricular cycle following a premature ventricular contraction (PVC).

VF confirmation – device operation that confirms the presence of VF after initial detection but before a defibrillation therapy is delivered. This feature applies only to the first programmed VF therapy.

VF detection – condition occurring when the device identifies the presence of ventricular fibrillation.

VF episode – period of time between VF detection and termination.

VF event – a sensed beat that is shorter than the programmed VF Interval.

VF Initial Beats – programmable number of VF events required for initial VF detection to occur.

VF Interval – programmable interval that is used to define the VF detection zone. V-V intervals shorter than the VF Interval are counted as VF events.

VF plus SVT – see “double tachycardia”.

VF Redetect Beats – number of VF events required for a VF episode to be redetected after therapy.

VT acceleration – redetection in the VT zone with an average cycle length at least 60 ms shorter than at initial detection.

VT detection – condition in which the device identifies the presence of ventricular tachycardia.

VT episode – period of time between VT detection and termination.
**VT event** – a sensed beat that falls within the VT detection zone. That is, an interval that is shorter than the programmed VT Interval, but greater than or equal to the programmed VF Interval and/or FVT Interval.

**VT Initial Beats** – programmable number of consecutive VT events required for initial VT detection to occur.

**VT Interval** – programmable interval that is used to define the VT detection zone. V-V intervals shorter than the VT Interval but greater than or equal to the VF or FVT Interval are counted as VT events.

**VT monitoring** – programmable option that allows the device to detect fast rhythms as VT and record episode data without delivering VT therapy.

**VT plus SVT** – see "double tachycardia".

**VT Redetect Beats** – number of VT events required for a VT episode to be redetected after therapy.

**waveform** – graphic plot of electrical activity, for example, intracardiac EGM or surface ECG trace.

**Wavelet Dynamic Discrimination criterion** – programmable detection criterion designed to prevent detection of rapidly conducted SVTs as ventricular tachyarrhythmias by comparing the shape of each QRS complex during a fast ventricular rate to the stored template.

**Wenckebach operation** – a dual chamber pacing operation that exhibits dynamic variations in the Sensed AV interval and A:V synchrony. When the atrial rate exceeds the programmed Upper Tracking Rate, it is too fast to be tracked 1:1. The device applies increasing Sensed AV intervals on each atrial cycle until an atrial event occurs in the PVARP and is not tracked. See also 2:1 block rate.

**zone merging** – feature that merges an FVT detection zone with its parent detection zone after detection (for example, a FVT via VF detection zone merges into the VF zone). The merged zone uses the event counting and therapies designated for the faster arrhythmia.
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