

REFERENCE GUIDE

**VISIONIST™**

**VISIONIST™ X4**

**REF** U225, U226, U228

**VALITUDE™**

**VALITUDE™ X4**

**REF** U125, U128

**INLIVEN™**

**REF** W274, W275

**INTUA™**

**REF** W272, W273

**INVIVE™**

**REF** W172, W173

CARDIAC RESYNCHRONIZATION THERAPY  
PACEMAKER

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# ABOUT THIS MANUAL

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## INTENDED AUDIENCE

This literature is intended for use by professionals trained or experienced in device implant and/or follow-up procedures.

This family of cardiac resynchronization therapy pacemakers (CRT-Ps) provides atrial and/or ventricular pacing and sensing, cardiac resynchronization therapy (CRT), and a variety of diagnostic tools.

The Physician Technical Manual, used in conjunction with the ZOOMVIEW software, is intended to provide information most relevant for implanting the pulse generator. This Reference Guide provides further descriptions of programmable features and diagnostics.

To view and download any of these documents, go to [www.bostonscientific-international.com/manuals](http://www.bostonscientific-international.com/manuals).

## NEW OR ENHANCED FEATURES

These pulse generator systems include additional or enhanced features as compared to previous Boston Scientific cardiac resynchronization therapy pacemaker devices.

The list below is intended to highlight some of these features; it is not a comprehensive list. Please refer to the feature-specific content elsewhere in this manual for detailed descriptions of these features.

**The following new or enhanced features apply to VISIONIST and/or VALITUDE devices.**

### User Experience

- EasyView header with port identifiers: increased header transparency is designed to provide enhanced visibility of the lead ports and ease of individual port identification.
- MICS Telemetry: RF telemetry band utilized is MICS (Medical Implant Communication Service).

### Brady Therapy

- PaceSafe LV Automatic Threshold: automatically performs left ventricular threshold testing every 24 hours and sets an output safety margin. Additionally, Maximum Amplitude and Safety Margin are programmable.
- LV Quadripolar Devices: provides 17 pacing configurations and 8 sensing configurations for devices compatible with IS4 left ventricular leads.

### Patient Diagnostics

- Programmable Lead Impedance Limits for daily measurements: the High Impedance Limit is programmable between 2000 and 3000  $\Omega$  and the Low Impedance Limit is programmable between 200 and 500  $\Omega$ .
- Snapshot: up to 6 unique traces of the ECG/EGM display can be stored at any time by pressing the Snapshot button. The traces are 10 seconds pre-activation and 2 seconds post-activation. A 10 second trace will automatically be stored at the end of Pace Threshold tests, which counts as one of the 6 snapshots.

The following are trademarks of Boston Scientific or its affiliates: EASYVIEW, INLIVEN, INTUA, INVIVE, LATITUDE, PaceSafe, QUICK NOTES, RightRate, Safety Core, Smart Blanking, SmartDelay, VALITUDE, VISIONIST, ZIP, ZOOM, ZOOMVIEW.

- Atrial Arrhythmia Report: AT/AF % and Total Time in AT/AF Counters are provided. AT/AF Burden, RV Rate during AT/AF, Pacing Percent, Heart Rate, Activity Level and Respiratory Rate Trends are provided. Histograms are provided for RV Rate during AT/AF. A timeline history of interrogations, programming, and counter resets for one year is collected. The Longest AT/AF, Fastest RVS rate in AT/AF, and most recent episode information is also collected.
- POST (Post-Operative System Test): provides an automatic device/lead check at a pre-determined time post-implant to help document proper system functionality without requiring manual system testing.

**The following new or enhanced features apply to INLIVEN, INTUA, and/or INVIVE devices.**

### **User Experience**

- Hardware: the number of setscrews has been reduced to one setscrew per port.
- ZIP Telemetry: provides wandless, two-way RF communication with the pulse generator.
- ZOOMVIEW Programmer Software: the new user interface is consistent across Boston Scientific brady, tachy, and heart failure devices.
- Indications-Based Programming (IBP): allows you to set up programming parameters based on the patient's clinical needs and indications.
- USB storage devices are supported: pulse generator data can be saved and transferred to a USB pen drive.
- PDF versions of reports are available.

### **Tachy Detection**

- Ventricular Tachy EGM Storage utilizes the strengths of an ICD-based tachycardia detection strategy including a V > A detection enhancement.

### **Brady Therapy**

- New brady modes available include permanent asynchronous pacing modes.
- PaceSafe RV Automatic Threshold: automatically performs ventricular threshold testing every 21 hours and sets a 2:1 output safety margin.
- PaceSafe RA Automatic Threshold: automatically performs atrial threshold testing every 21 hours and sets a 2:1 output safety margin.
- RightRate Pacing: utilizes minute ventilation to provide rate adaptive pacing based on physiologic changes along with automatic calibration, a simplified user interface, and filtering designed to mitigate MV interactions.
- SmartDelay: provides customized recommended AV Delay settings based on measurements of intrinsic AV intervals.
- Safety Core: safety architecture is utilized to provide basic pacing if non-recoverable or repeated fault conditions occur.
- Electrocautery Protection: provides asynchronous pacing operation at the LRL.

### **Sensing**

- Automatic gain control (AGC): dynamically adjusts sensitivity in both the atrium and ventricle.

- Smart Blanking: used in conjunction with AGC sensing to promote appropriate cross-chamber sensing capabilities.

### Patient Diagnostics

- Programmable Lead Impedance Limits for daily measurements: the Low Impedance Limit is programmable between 200 and 500  $\Omega$ .
- Snapshot: up to 6 unique traces of the ECG/EGM display can be stored at any time by pressing the Snapshot button. The traces are 10 seconds pre-activation and 2 seconds post-activation. A 10 second trace will automatically be stored at the end of Pace Threshold tests, which counts as one of the 6 snapshots.
- A counter for Total Time in AT/AF is provided.
- Trends: expanded set of trends is provided including:
  - Respiratory Rate
  - AP Scan
  - AT/AF Burden (including total number of episodes)
  - Events
- Average V Rate in ATR: provides the average ventricular rate during ATR episodes.
- Arrhythmia Logbook: memory is allocated between numerous episode types with increased data storage available.
- Lead Safety Switch: diagnostic information is provided to show the date and impedance value which caused the LSS.

This guide may contain reference information for model numbers that are not currently approved for sale in all geographies. For a complete list of model numbers approved in your geography, consult with your local sales representative. Some model numbers may contain fewer features; for those devices, disregard descriptions of the unavailable features. Descriptions found within this manual apply to all device tiers unless otherwise noted. References to names of non-quadripolar devices also apply to the corresponding quadripolar devices. References to "ICD" include all types of ICDs (e.g., ICD, CRT-D, S-ICD).

The screen illustrations used in this manual are intended to familiarize you with the general screen layout. The actual screens you see when interrogating or programming the pulse generator will vary based on the model and programmed parameters.

LATITUDE NXT is a remote monitoring system that provides pulse generator data for clinicians. These pulse generators are designed to be LATITUDE NXT enabled; availability varies by region.

LATITUDE NXT is available for the following devices: VISIONIST, VALITUDE, INLIVEN, INTUA, INVIVE.

A complete list of programmable options is provided in the appendix ("Programmable Options" on page A-1). The actual values you see when interrogating or programming the pulse generator will vary based on the model and programmed parameters.

The text conventions discussed below are used throughout this manual.

- PRM KEYS                    The names of Programmer/Recorder/Monitor (PRM) keys appear in capital letters (e.g., PROGRAM, INTERROGATE).
- 1., 2., 3.                    Numbered lists are used for instructions that should be followed in the order given.
- Bulleted lists are used when the information is not sequential.

The following acronyms may be used in this Reference Guide:

<b>A</b>	Atrial
<b>ABM</b>	Autonomic Balance Monitor
<b>AF</b>	Atrial Fibrillation
<b>AFR</b>	Atrial Flutter Response
<b>AGC</b>	Automatic Gain Control
<b>APP</b>	Atrial Pacing Preference
<b>AT</b>	Atrial Tachycardia
<b>ATP</b>	Antitachycardia Pacing
<b>ATR</b>	Atrial Tachy Response
<b>AV</b>	Atrioventricular
<b>BiV</b>	Biventricular
<b>BPEG</b>	British Pacing and Electrophysiology Group
<b>BTR</b>	Brady Tachy Response
<b>CHF</b>	Congestive Heart Failure
<b>CPR</b>	Cardiopulmonary Resuscitation
<b>CRT</b>	Cardiac Resynchronization Therapy
<b>CRT-D</b>	Cardiac Resynchronization Therapy Defibrillator
<b>CRT-P</b>	Cardiac Resynchronization Therapy Pacemaker
<b>EAS</b>	Electronic Article Surveillance
<b>ECG</b>	Electrocardiogram
<b>EF</b>	Ejection Fraction
<b>EGM</b>	Electrogram
<b>EMI</b>	Electromagnetic Interference
<b>EP</b>	Electrophysiology; Electrophysiologic
<b>HRV</b>	Heart Rate Variability
<b>IBP</b>	Indications-Based Programming
<b>IC</b>	Industry Canada
<b>ICD</b>	Implantable Cardioverter Defibrillator
<b>LRL</b>	Lower Rate Limit
<b>LV</b>	Left Ventricular
<b>LVAT</b>	Left Ventricular Automatic Threshold
<b>LVPP</b>	Left Ventricular Protection Period
<b>LVRP</b>	Left Ventricular Refractory Period
<b>MI</b>	Myocardial Infarction
<b>MICS</b>	Medical Implant Communication Service
<b>MPR</b>	Maximum Pacing Rate
<b>MRI</b>	Magnetic Resonance Imaging
<b>MSR</b>	Maximum Sensor Rate
<b>MTR</b>	Maximum Tracking Rate
<b>MV</b>	Minute Ventilation
<b>NASPE</b>	North American Society of Pacing and Electrophysiology
<b>NSR</b>	Normal Sinus Rhythm
<b>NSVT</b>	Nonsustained Ventricular Tachycardia
<b>PAC</b>	Premature Atrial Contraction
<b>PAT</b>	Paroxysmal Atrial Tachycardia
<b>PES</b>	Programmed Electrical Stimulation
<b>PMT</b>	Pacemaker-Mediated Tachycardia
<b>POST</b>	Post-Operative System Test
<b>PRM</b>	Programmer/Recorder/Monitor
<b>PSA</b>	Pacing System Analyzer
<b>PTM</b>	Patient Triggered Monitor
<b>PVARP</b>	Post-Ventricular Atrial Refractory Period
<b>PVC</b>	Premature Ventricular Contraction

<b>RAAT</b>	Right Atrial Automatic Threshold
<b>RADAR</b>	Radio Detection and Ranging
<b>RF</b>	Radio Frequency
<b>RRT</b>	Respiratory Rate Trend
<b>RTTE</b>	Radio and Telecommunications Terminal Equipment
<b>RV</b>	Right Ventricular
<b>RVAT</b>	Right Ventricular Automatic Threshold
<b>RVRP</b>	Right Ventricular Refractory Period
<b>SBR</b>	Sudden Bradycardia Response
<b>SCD</b>	Sudden Cardiac Death
<b>SDANN</b>	Standard Deviation of Averaged Normal-to-Normal R-R intervals
<b>S-ICD</b>	Subcutaneous Implantable Cardioverter Defibrillator
<b>SVT</b>	Supraventricular Tachycardia
<b>TARP</b>	Total Atrial Refractory Period
<b>TENS</b>	Transcutaneous Electrical Nerve Stimulation
<b>V</b>	Ventricular
<b>VF</b>	Ventricular Fibrillation
<b>VRP</b>	Ventricular Refractory Period
<b>VRR</b>	Ventricular Rate Regulation
<b>VT</b>	Ventricular Tachycardia

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# USING THE PROGRAMMER/RECORDER/MONITOR

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## CHAPTER 1

This chapter contains the following topics:

- "ZOOM LATITUDE Programming System" on page 1-2
- "Software Terminology and Navigation" on page 1-2
- "Demonstration Mode" on page 1-7
- "Communicating with the Pulse Generator" on page 1-8
- "Indications-Based Programming (IBP)" on page 1-13
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- "DIVERT THERAPY" on page 1-15
- "STAT PACE" on page 1-16
- "Data Management" on page 1-16
- "Safety Mode" on page 1-18

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## ZOOM LATITUDE PROGRAMMING SYSTEM

The ZOOM LATITUDE Programming System is the external portion of the pulse generator system and includes:

- Model 3120 Programmer/Recorder/Monitor (PRM)
- Model 3140 ZOOM Wireless Transmitter
- Model 2869 ZOOMVIEW Software Application
- Model 6577 Accessory Telemetry Wand

The ZOOMVIEW software provides advanced device programming and patient monitoring technology. It was designed with the intent to:

- Enhance device programming capability
- Improve patient and device monitoring performance
- Simplify and expedite programming and monitoring tasks

You can use the PRM system to do the following:

- Interrogate the pulse generator
- Program the pulse generator to provide a variety of therapy options
- Access the pulse generator's diagnostic features
- Perform noninvasive diagnostic testing
- Access therapy history data
- Store a 12 second trace of the ECG/EGM display from any screen
- Access an interactive Demonstration Mode or Patient Data Mode without the presence of a pulse generator
- Print patient data including pulse generator therapy options and therapy history data
- Save patient data

You can program the pulse generator using two methods: automatically using IBP or manually.

For more detailed information about using the PRM or ZOOM Wireless Transmitter, refer to the PRM Operator's Manual or ZOOM Wireless Transmitter Reference Guide.

## SOFTWARE TERMINOLOGY AND NAVIGATION

This section provides an overview of the PRM system.

### Main Screen

The main PRM screen is shown below, followed by a description of the components (Figure 1-1 on page 1-3).

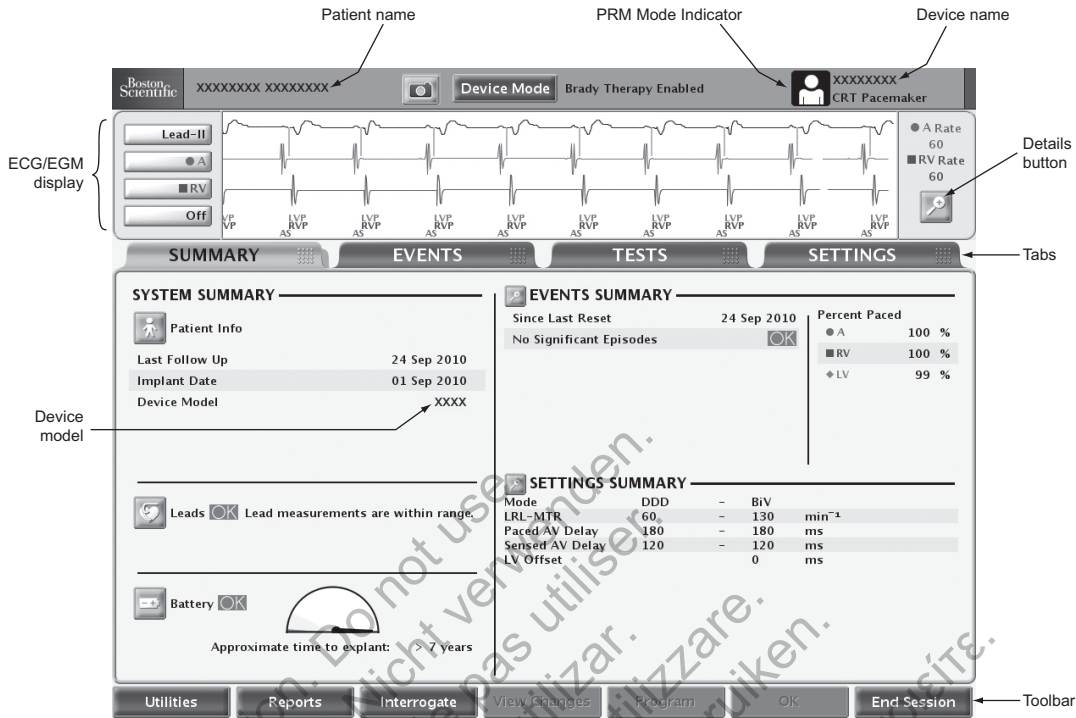


Figure 1-1. Main Screen

## PRM Mode Indicator

The PRM Mode Indicator displays at the top of the screen to identify the current PRM operational mode.



**Patient**—indicates that the PRM is displaying data obtained by communicating with a device.



**Patient Data**—indicates that the PRM is displaying stored patient data.



**Demo Mode**—indicates that the PRM is displaying sample data and operating in demonstration mode.

## ECG/EGM Display

The ECG area of the screen shows real-time status information about the patient and the pulse generator that can be useful in evaluating system performance. The following types of traces can be selected:

- Surface ECGs are transmitted from body surface lead electrodes that are connected to the PRM, and can be displayed without interrogating the pulse generator.

- Real-time EGMs are transmitted from the pace/sense electrodes, and are often used to evaluate lead system integrity and help identify faults such as lead fractures, insulation breaks, or dislodgments.

Real-time EGMs can only be displayed upon interrogation of the pulse generator. Because they rely on ZIP or wanded telemetry, they are susceptible to radio frequency interference. Significant interference may cause a break or drop-out of real-time EGMs ("ZIP Telemetry Security" on page 1-9).

- At any time, a 12 second trace of the ECG/EGM display can be stored by pressing the Snapshot button from any screen.

**NOTE:** If the PRM is left idle for 15 minutes (or 28 minutes if the pulse generator was in Storage Mode at interrogation) real-time EGMs are shut off. The PRM provides a dialog box allowing real-time EGMs to be restored.

**NOTE:** Real-time LV EGMs are available on all LV sense configurations.

**NOTE:** In the presence of telemetry interference, the real-time intracardiac EGM traces and markers may become misaligned from the real-time surface ECG traces. When the telemetry link has improved, re-select any of the intracardiac EGM traces to cause re-initialization.

You can select the Details button to enlarge the ECG/EGM screen. The following options are available:

- Show Device Markers—displays annotated event markers, which identify certain intrinsic cardiac and device-related events, and provide information such as sensed/paced events
- Enable Surface Filter—minimizes noise on the surface ECG
- Display Pacing Spikes—shows detected pacing spikes, annotated by a marker on the surface ECG waveform
- Trace Speed—adjusts the speed of the trace (0, 25, or 50 mm/s). As the speed is increased, the time/horizontal scale is expanded
- Gain—adjusts the amplitude/vertical scale (AUTO, 1, 2, 5, 10, or 20 mm/mV) for each channel. As the gain is increased, the amplitude of the signal is enlarged

You can print real-time EGMs, which include annotated event markers, by performing the following steps:

1. Press one of the print speed keys on the PRM (e.g., speed key 25) to begin printing.
2. Press the 0 (zero) speed key to stop printing.
3. Press the paper-feed key to fully eject the last printed sheet.

You can print definitions of the annotated markers by pressing the calibration key while the EGM is printing. Alternatively you can print a full report containing the definitions of all of the annotated markers by performing the following steps:

1. From the toolbar, click the Reports button. The Reports window displays.
2. Select the Marker Legend checkbox.
3. Click the Print button. The Marker Legend Report is sent to the printer.

## Toolbar

The toolbar allows you to perform the following tasks:

- Select system utilities



- Generate reports
- Interrogate and program the pulse generator
- View pending or programmed changes
- View attentions and warnings
- End your PRM session

## Tabs

Tabs allow you to select PRM tasks, such as viewing summary data or programming device settings. Selecting a tab displays the associated screen. Many screens contain additional tabs, which allow you to access more detailed settings and information.

## Buttons

Buttons are located on screens and dialogs throughout the application. Buttons allow you to perform various tasks, including:

- Obtain detailed information
- View setting details
- Set programmable values
- Load initial values

When a button selection opens a window in front of the Main Screen, a Close button displays in the upper-right corner of the window to allow you to close the window and return to the Main Screen.

## Icons

Icons are graphic elements that, when selected, may initiate an activity, display lists or options, or change the information displayed.



Details—opens a window containing detailed information.



Patient—opens a window with patient information details.



Leads—opens a window with details on leads.



Battery—opens a window with details on the pulse generator battery.



Check—indicates that an option is selected.



Event—indicates that an event has occurred. When you view the Trends timeline on the Events tab, event icons display wherever events have occurred. Selecting an events icon displays details about the event.



Information—indicates information that is provided for reference.

### Action Icons



Run—causes the programmer to perform an action.



Hold—causes the programmer to pause an action.



Continue—causes the programmer to continue an action.



Snapshot—causes the programmer to store a 12 second trace of the ECG/EGM display from any screen.



POST Complete—opens the Reports window to print POST information on the Quick Notes or Follow-Up Reports.

### Slider Icons



Horizontal Slider—indicates that a slider object can be clicked and dragged left or right.



Vertical Slider—indicates that a slider object can be clicked and dragged up or down.

### Sort Icons



Sort Ascending—indicates that Ascending sort is currently selected on a table column sort button. (e.g., 1, 2, 3, 4, 5)



Sort Descending—indicates that Descending sort is currently selected on a table column sort button. (e.g., 5, 4, 3, 2, 1)

### Increment and Decrement Icons



Increment—indicates that an associated value can be incremented.



Decrement—indicates that an associated value can be decremented.

### Scroll Icons



Scroll Left—indicates that an associated item can be scrolled left.



Scroll Right—indicates that an associated item can be scrolled right.



Scroll Up—indicates that an associated item can be scrolled up.



Scroll Down—indicates that an associated item can be scrolled down.

## Common Objects

Common objects such as status bars, scroll bars, menus, and dialogs are used throughout the application. These operate similarly to the objects found in web browsers and other computer applications.

## Use of Color

Colors and symbols are used to highlight buttons, icons, and other objects, as well as certain types of information. The use of specific color conventions and symbols is intended to provide a more consistent user experience and simplify programming. Refer to the table below to understand how colors and symbols are used on the PRM screens (Table 1-1 on page 1-7).

Table 1-1. PRM color conventions

Color	Meaning	Examples	Symbol
Red	Indicates warning conditions	The selected parameter value is not allowed; click the red warning button to open the Parameter Interactions screen, which provides information about corrective action.	
		Device and patient diagnostic information that requires serious consideration.	
Yellow	Indicates conditions requiring your attention	The selected parameter value is allowed, but not recommended; click the yellow attention button to open the Parameter Interactions screen, which provides information about corrective action.	
		Device and patient diagnostic information that should be addressed.	
Green	Indicates acceptable changes or conditions	The selected parameter value is allowed, but is still pending.	
		There is no device or patient diagnostic information requiring your specific attention.	
White	Indicates the value that is currently programmed		

## DEMONSTRATION MODE

The PRM includes a Demonstration Mode feature, which enables the PRM to be used as a self-teaching tool. When selected, this mode allows you to practice PRM screen navigation without interrogating a pulse generator. You can use Demonstration Mode to familiarize yourself with many of the specific screen sequences that will display when interrogating or programming a specific pulse generator. You can also use Demonstration Mode to examine available features, parameters, and information.

To access Demonstration Mode, select the appropriate PG from the Select PG screen, and then select Demo from the Select PG Mode dialog. When the PRM is operating in Demonstration

Mode, the PRM Mode Indicator displays the Demo Mode icon. The pulse generator cannot be programmed when the PRM is operating in Demonstration Mode. Exit the Demonstration Mode before attempting to interrogate or program the pulse generator.

## COMMUNICATING WITH THE PULSE GENERATOR

The PRM communicates with the pulse generator using a telemetry wand.

After initiating communication with the wand, the PRM can use wandless ZIP telemetry (two-way RF communication) to interface with some pulse generator models.

Telemetry is required to:

- Direct commands from the PRM system, such as:
  - INTERROGATE
  - PROGRAM
  - STAT PACE
  - DIVERT THERAPY
- Modify device parameter settings
- Conduct EP testing
- Conduct diagnostic tests including the following:
  - Pacing impedance tests
  - Pacing threshold tests
  - Intrinsic amplitude tests

### ZIP Telemetry

ZIP telemetry is available in VISIONIST and VALITUDE devices and operates with a transmit frequency of 402 to 405 MHz. ZIP telemetry is available in INLIVEN, INTUA and INVIVE devices and operates with a transmit frequency of 869.85 MHz.

ZIP telemetry is a wandless, two-way RF communication option that allows the PRM system to communicate with these RF capable pulse generators.

- For VISIONIST and VALITUDE devices, RF communication is enabled by the ZOOM Wireless Transmitter unit connected to the PRM. When initiating communication, wanded telemetry is needed. When ZIP telemetry is ready for use, a message will display on the PRM screen indicating that the wand can be removed. Otherwise, the session will continue with wanded telemetry.
- For INLIVEN, INTUA and INVIVE devices, when a wanded telemetry session is initiated, the PRM checks the pulse generator's telemetry capability. If the PRM detects a pulse generator with ZIP telemetry capability, a message will display indicating that ZIP telemetry is available and the wand can be removed. Otherwise, the session will continue with wanded telemetry.

ZIP telemetry offers the following advantages over traditional wanded telemetry:

- The faster data transmission speed means less time is required for device interrogation
- Data transmission over a longer distance (within 3 m [10 ft]) minimizes the need to keep the wand in the sterile field during implant, which may reduce the risk of infection

- Continuous telemetry is possible during the entire implant procedure, allowing monitoring of pulse generator performance and lead integrity during implant
- Allows the physician to continue with the operating procedure while the device is being programmed for the patient

Regardless of whether ZIP telemetry is being used, wanded communication is still available.

## Starting a Wanded Telemetry Session

Follow this procedure to begin a wanded telemetry communication session:

1. Make sure the telemetry wand is connected to the PRM system and is available throughout the session.
2. Position the wand over the pulse generator at a distance not greater than 6 cm (2.4 inches).
3. Use the PRM to Interrogate the pulse generator.
4. Retain the wand position whenever communication is required.

## Starting a ZIP Telemetry Session

Follow this procedure to begin a ZIP telemetry communication session:

1. For VISIONIST and VALITUDE devices, verify that the ZOOM Wireless Transmitter is connected to the PRM via the USB cable and that the green light on top of the transmitter is illuminated (indicating the transmitter is ready for use).
2. Start a wanded telemetry session. Verify that the wand cord is within reach of the pulse generator to enable the use of wanded telemetry should it become necessary.
3. Keep the telemetry wand in position until either a message appears, indicating that the telemetry wand may be removed from proximity of the pulse generator, or the ZIP telemetry light illuminates on the PRM system.

## Ending a Telemetry Session

Select the End Session button to quit a telemetry session and return to the startup screen. You can choose to end the session or return to the current session. Upon ending a session, the PRM system terminates all communication with the pulse generator.

## ZIP Telemetry Security

**The following ZIP Telemetry Security information applies to devices operating with a transmit frequency of 402 to 405 MHz.**

The pulse generator contains a compliant low-power transceiver. The pulse generator can only be interrogated or programmed by RF signals that employ the proprietary ZIP telemetry protocol. The pulse generator verifies that it is communicating with a ZOOMVIEW system before responding to any RF signals. The pulse generator stores, transmits, and receives individually identifiable health information in an encrypted format.

ZIP telemetry is possible when all of the following conditions are met:

- ZIP telemetry for the PRM is enabled
- The ZOOM Wireless Transmitter is connected to the PRM via the USB cable
- The indicator light on top of the ZOOM Wireless Transmitter is green; indicating the transmitter is ready for use

- The pulse generator is within range of the PRM system
- The pulse generator has not reached Explant; note that a total of 1.5 hours of ZIP telemetry will be available after the pulse generator reaches Explant
- The pulse generator battery capacity is not depleted

In order to meet local communications rules and regulations, ZIP telemetry should not be used when the pulse generator is outside its normal operating temperature of 20°C–45°C (68°F–113°F).

Communication can be supported between multiple PRMs and pulse generators at a time, as independent sessions. Signals from other sessions using RF communication or interference from other RF sources may interfere with or prevent ZIP telemetry communication.

**CAUTION:** RF signals from devices that operate at frequencies near that of the pulse generator may interrupt ZIP telemetry while interrogating or programming the pulse generator. This RF interference can be reduced by increasing the distance between the interfering device and the PRM and pulse generator. Examples of devices that may cause interference in the 869.85 MHz frequency band include:

- Cordless phone handsets or base stations
- Certain patient monitoring systems

Radio frequency interference may temporarily disrupt ZIP telemetry communication. The PRM will normally reestablish ZIP communication when the RF interference ends or subsides. Because continued RF interference may prevent ZIP telemetry communication, the system is designed to use wanded telemetry when ZIP telemetry is not available.

If ZIP telemetry is not available due to interference or if the ZOOM Wireless Transmitter is unplugged or not functioning properly, wanded telemetry communication with the PRM can be established. The system provides the following feedback to indicate that ZIP telemetry is not available:

- The ZIP telemetry indicator light on the PRM turns off
- The green indicator light on the ZOOM Wireless Transmitter is off
- If event markers and/or EGMs are activated, transmission of the event markers and/or EGMs will be interrupted
- If a command or other action has been requested, the PRM displays a notification indicating the wand should be placed in range of the pulse generator

ZIP telemetry operates consistently with wanded telemetry—no programming step can be completed unless the entire programming command has been received and confirmed by the pulse generator.

The pulse generator cannot be misprogrammed as a result of interrupted ZIP telemetry. Interruptions of ZIP telemetry may be caused by RF signals that operate at frequencies near that of the pulse generator and are strong enough to compete with the ZIP telemetry link between the pulse generator and the PRM. Significant interference may result in a break or drop-outs of real-time EGMs. If commands are interrupted, the PRM displays a message to place the wand on the pulse generator. Repeated displays of this message may indicate the presence of intermittent interference. These situations can be resolved by repositioning the ZOOM Wireless Transmitter attached to the PRM or by using standard wanded telemetry. There will be no interruption of device functionality or therapy during this period.

**NOTE:** When both ZIP and wanded telemetry are being used (for example, switching from ZIP to wanded because of the presence of interference), the pulse generator will communicate with the programmer by ZIP telemetry when possible. If wanded telemetry only is desired, set the Communication Mode (accessed via the Utilities button) to use the wand for all telemetry.

**NOTE:** To conserve battery longevity, a ZIP telemetry session will be terminated if the pulse generator completely loses communication with the PRM for a continuous period of one hour (or 73 minutes if the device was in Storage Mode at interrogation). Wanded telemetry must be used to re-establish communication with the pulse generator after this period has elapsed.

### Considerations for Reducing Interference

Increasing the distance from the source of interfering signals may enable the use of the ZIP telemetry channel.

Repositioning the ZOOM Wireless Transmitter may improve ZIP telemetry performance. If ZIP telemetry performance is not satisfactory, the option of using wanded telemetry is available.

Depending on the environment and PRM orientation relative to the pulse generator, the system is capable of maintaining ZIP telemetry communication at distances up to 3 m (10 ft). For optimum ZIP telemetry communication, position the ZOOM Wireless Transmitter within 3 m (10 ft) of the pulse generator and remove any obstruction between the ZOOM Wireless Transmitter and the pulse generator.

Positioning the ZOOM Wireless Transmitter at least 1 m (3 ft) away from walls or metal objects and ensuring the pulse generator (prior to implant) is not in direct contact with any metal objects may reduce signal reflection and/or signal blocking.

Avoid placing the ZOOM Wireless Transmitter in close proximity to monitors, high-frequency electrosurgical equipment, or strong magnetic fields since the telemetry link may be impaired.

Ensuring there are no obstructions (e.g., equipment, metal furniture, people, or walls) between the ZOOM Wireless Transmitter and pulse generator may improve signal quality. Personnel or objects that momentarily move between the ZOOM Wireless Transmitter and pulse generator during ZIP telemetry may temporarily interrupt communication, but will not affect device functionality or therapy.

Checking the time required to complete an interrogation after ZIP telemetry is established can provide an indication of whether interference is present. If an interrogation using ZIP telemetry takes less than 20 seconds, the current environment is likely free of interference. Interrogation times longer than 20 seconds (or short intervals of EGM drop-outs) indicate that interference may be present.

## ZIP Telemetry Security

**The following ZIP Telemetry Security information applies to devices operating with a transmit frequency of 869.85 MHz.**

The pulse generator contains a compliant low-power transceiver. The pulse generator can only be interrogated or programmed by RF signals that employ the proprietary ZIP telemetry protocol. The pulse generator verifies that it is communicating with a ZOOMVIEW system before responding to any RF signals. The pulse generator stores, transmits, and receives individually identifiable health information in an encrypted format.

ZIP telemetry is possible when all of the following conditions are met:

- ZIP telemetry for the PRM is enabled
- The pulse generator has RF communication capabilities

- The ZIP telemetry channel is available for use
- The pulse generator is within range of the PRM system
- The pulse generator has not reached Explant; note that a total of 1.5 hours of ZIP telemetry will be available after the pulse generator reaches Explant
- The pulse generator battery capacity is not depleted

In order to meet local communications rules and regulations, ZIP telemetry should not be used when the pulse generator is outside its normal operating temperature of 20°C–43°C (68°F–109°F).

Communication is supported between one PRM and one pulse generator at a time. If there is a PRM–pulse generator communication session already occurring in the vicinity, a second session will not be allowed to start; wanded communication will be necessary in this case.

The PRM notifies you if ZIP telemetry is unavailable because of other sessions already in progress.

RF signals in the same frequency band used by the system may interfere with ZIP telemetry communication. These interfering signals include:

- Signals from other pulse generator/PRM system RF communication sessions after the maximum number of independent sessions has been reached. Other nearby pulse generators and PRMs using ZIP telemetry may prevent ZIP telemetry communication.
- Interference from other RF sources.

**CAUTION:** RF signals from devices that operate at frequencies near that of the pulse generator may interrupt ZIP telemetry while interrogating or programming the pulse generator. This RF interference can be reduced by increasing the distance between the interfering device and the PRM and pulse generator. Examples of devices that may cause interference in the 869.85 MHz frequency band include:

- Cordless phone handsets or base stations
- Certain patient monitoring systems

Radio frequency interference may temporarily disrupt ZIP telemetry communication. The PRM will normally reestablish ZIP communication when the RF interference ends or subsides. Because continued RF interference may prevent ZIP telemetry communication, the system is designed to use wanded telemetry when ZIP telemetry is not available.

If ZIP telemetry is not available, wanded telemetry communication with the PRM can be established. The system provides the following feedback to indicate that ZIP telemetry is not available:

- The ZIP telemetry indicator light on the PRM turns off
- If event markers and/or EGMs are activated, transmission of the event markers and/or EGMs is interrupted
- If a command or other action has been requested, the PRM displays a notification indicating the wand should be placed in range of the pulse generator

ZIP telemetry operates consistently with wanded telemetry—no programming step can be completed unless the entire programming command has been received and confirmed by the pulse generator.



The pulse generator cannot be misprogrammed as a result of interrupted ZIP telemetry. Interruptions of ZIP telemetry may be caused by RF signals that operate at frequencies near that of the pulse generator and are strong enough to compete with the ZIP telemetry link between the pulse generator and the PRM. Significant interference may result in a break or drop-outs of real-time EGMs. If commands are interrupted, the PRM displays a message to place the wand on the pulse generator. Repeated displays of this message may indicate the presence of intermittent interference. These situations can be resolved by repositioning the PRM or using standard wanded telemetry. There will be no interruption of device functionality or therapy during this period.

**NOTE:** *When both ZIP and wanded telemetry are being used (for example, switching from ZIP to wanded because of the presence of interference), the pulse generator will communicate with the programmer by ZIP telemetry when possible. If wanded telemetry only is desired, set the Communication Mode (accessed via the Utilities button) to use the wand for all telemetry.*

**NOTE:** *To conserve battery longevity, a ZIP telemetry session will be terminated if the pulse generator completely loses communication with the PRM for a continuous period of one hour (or 73 minutes if the device was in Storage Mode at interrogation). Wanded telemetry must be used to re-establish communication with the pulse generator after this period has elapsed.*

**NOTE:** *The PRM operates on a country-specific frequency range. The PRM determines the ZIP frequency range that the pulse generator uses based on the specific device model. If the PRM and pulse generator ZIP frequency ranges do not match, it indicates that the patient has traveled outside the country in which the pulse generator was implanted. The PRM will display a message indicating that ZIP telemetry cannot be used; however, the patient's pulse generator can be interrogated by using the wand. If out-of-country interrogation is needed, contact Boston Scientific using the information on the back cover of this manual.*

### Considerations for Reducing Interference

Increasing the distance from the source of interfering signals may enable the use of the ZIP telemetry channel. A minimum distance of 14 m (45 ft) is recommended between the source of interference (having an average output of 50 mW or less) and both the pulse generator and PRM.

Repositioning the PRM antenna or repositioning the PRM may improve ZIP telemetry performance. If ZIP telemetry performance is not satisfactory, the option of using wanded telemetry is available.

Positioning the PRM at least 1 m (3 ft) away from walls or metal objects and ensuring the pulse generator (prior to implant) is not in direct contact with any metal objects may reduce signal reflection and/or signal blocking.

Ensuring there are no obstructions (e.g., equipment, metal furniture, people, or walls) between the PRM and pulse generator may improve signal quality. Personnel or objects that momentarily move between the PRM and pulse generator during ZIP telemetry may temporarily interrupt communication, but will not affect device functionality or therapy.

Checking the time required to complete an interrogation after ZIP telemetry is established can provide an indication of whether interference is present. If an interrogation using ZIP telemetry takes less than 20 seconds, the current environment is likely free of interference. Interrogation times longer than 20 seconds (or short intervals of EGM drop-outs) indicate that interference may be present.

## INDICATIONS-BASED PROGRAMMING (IBP)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

IBP is a tool that provides specific programming recommendations based on the patient's clinical needs and primary indications.

IBP is a clinical approach to programming that was developed based on physician consultation and case studies. The intent of IBP is to enhance patient outcomes and save time by providing base programming recommendations that you can customize as needed. IBP systematically presents the specific features intended for use with the clinical conditions you identify in the IBP user interface, and allows you to take maximum advantage of the pulse generator's capabilities.

IBP can be accessed from the Settings tab on the main application screen (Figure 1-2 on page 1-14).

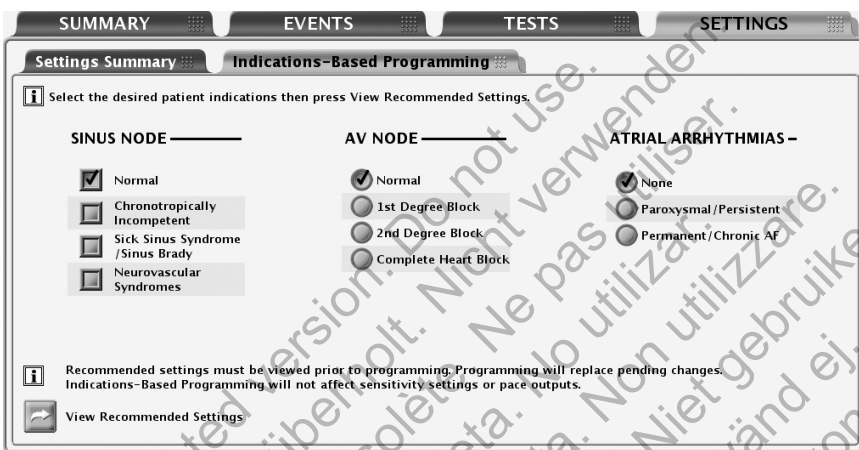


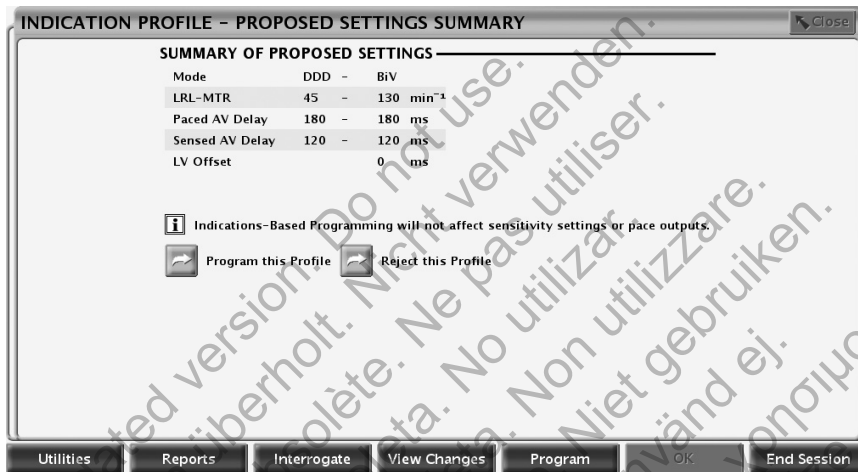
Figure 1-2. Indications-based Programming screen

Indications are clustered in general categories as illustrated above. The intent for each category of indications is described below:

- Sinus Node
    - If Normal is selected, the intent is to allow intrinsic atrial events and provide CRT pacing.
    - If Chronotropically Incompetent is selected, the intent is to provide rate-adaptive CRT pacing.
    - If Sick Sinus Syndrome is selected, the intent is to provide atrial pacing support and CRT pacing.
    - If Neurovascular Syndromes is selected, the intent is to provide Sudden Brady Response.
  - AV Node
    - The intent is to use nominal Paced AV Delay and Sensed AV Delay settings. The SmartDelay optimization feature may be used to adjust the AV delay.
- NOTE:** The selected settings for AF and Sinus Node may affect the suggested value for the setting of AV Node.
- Atrial Arrhythmias
    - If Paroxysmal/Persistent is selected, the intent is to avoid tracking atrial arrhythmias by using ATR Mode Switch when a dual-chamber pacing mode is suggested.
    - If Permanent/Chronic AF is selected, the intent is to provide rate-adaptive CRT pacing and set atrial sensing to Off.

After choosing appropriate patient indications, select the View Recommended Settings button to view a summary of the programming recommendations (Figure 1-3 on page 1-15).

**NOTE:** You must view the recommended settings before you can program them. Selecting the View Recommended Settings button allows you to view the settings that are recommended based on the indications that you selected. Viewing the recommended settings does not overwrite any pending (i.e., not yet programmed) parameter changes. You must choose to program or reject the recommended settings after viewing them. If you choose to reject the recommended settings, all of your pending settings will be restored. If you choose to program the recommended settings, any pending parameter changes will be overwritten, with the exception of sensitivity and therapy outputs, which are independent of IBP.



**Figure 1-3. Proposed Settings Summary screen**

The Proposed Settings Summary screen displays the primary programming recommendations. Additional details about all changed parameters are available by selecting the View Changes button from the toolbar. You have the option to program the proposed settings or reject them, as long as telemetry is still engaged:

- Program—select the Program this Profile button to accept the proposed settings.
- Reject—select the Reject this Profile button to reject the proposed settings; this action will return you to the main IBP screen with no changes made.

**MANUAL PROGRAMMING**

Manual programming controls such as sliders and menus are available to allow you to individually adjust pulse generator program settings.

Manual programming controls are located on the Settings Summary tab, which can be accessed from the Settings tab or by selecting the Settings Summary button on the Summary tab. Refer to other feature descriptions in this manual for specific manual programming information and instructions. Refer to "Programmable Options" on page A-1 for detailed listings of available settings.

**DIVERT THERAPY**

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The DIVERT THERAPY key can be used to terminate any diagnostic test in progress, as well as Electrocautery Protection Mode (if using wanded telemetry, maintain the telemetry wand position until the divert function is complete to avoid interruption to the divert command).

## STAT PACE

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Emergency bradycardia pacing using the STAT PACE command sets the bradycardia operation to parameters intended to ensure capture.

1. If you are not already in a session, position the telemetry wand within range of the pulse generator.
2. Press the STAT PACE key. A message window displays the STAT PACE values.
3. Press the STAT PACE key a second time. A message indicates that STAT PACE is being performed, followed by the STAT PACE values.
4. Select the Close button on the message window.
5. To stop STAT PACE, reprogram the pulse generator.

**NOTE:** STAT PACE will terminate Electrocautery Protection Mode.

**CAUTION:** When a pulse generator is programmed to STAT PACE settings, it will continue to pace at the high-energy STAT PACE values if it is not reprogrammed. The use of STAT PACE parameters will likely decrease device longevity.

The STAT PACE parameter values are listed below (Table 1-2 on page 1-16).

**Table 1-2. STAT PACE Parameter Values**

Parameter	Values
Mode	VVI
Lower Rate Limit	60 min <sup>-1</sup>
Interval	1000 ms
Pacing Chamber	BIV
Amplitude	7.5 V
Pulse Width	1.0 ms
Paced Refractory	250 ms
Lead Configuration (Pace/Sense)	Unipolar

## DATA MANAGEMENT

The PRM system allows you to view, print, store, or retrieve patient and pulse generator data. This section describes the PRM data management capabilities.

### Patient Information

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Information about the patient can be stored in pulse generator memory. The information is accessible from the Summary screen by selecting the Patient icon. This information includes, but is not limited to, the following:

- Patient and physician data
- Pulse generator serial number
- Implant date

- Lead configurations
- Implant test measurements

The information can be retrieved at any time by interrogating the pulse generator and viewing it on the PRM screen or printing it as a report.

**NOTE:** *If the data for patient date of birth, gender, or fitness level are changed within Patient Information, the corresponding value in Minute Ventilation will automatically change. Likewise, if the data for fitness level is changed within Minute Ventilation, the corresponding value in Patient Information will automatically change.*

**NOTE:** *The data entered for patient Sleep Schedule is used for the AP Scan trend.*

## Data Storage

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The PRM system allows you to save pulse generator data to the PRM hard drive or a removable floppy data disk. Data saved to the PRM can also be transferred to a removable USB pen drive.

Saved pulse generator data includes, but is not limited to, the following:

- Therapy history
- Programmed parameter values
- Trending values
- HRV
- Histogram paced/sensed counters

Select the Utilities button, and then select the Data Storage tab to access the following options:

- Read Disk—allows you to retrieve saved pulse generator data from a floppy disk.
- Save All—allows you to save pulse generator data to either a floppy disk (disk must be inserted) or the PRM hard drive (if no floppy disk is detected). Data saved to a floppy disk can be retrieved using the Read Disk option described above. Data saved to the PRM can be read, deleted, or exported to a USB pen drive from the PRM startup screen. Reports are available in PDF format. Refer to the PRM Operator's Manual for more information.

**NOTE:** *While the data is being saved, a message on the right-hand side of the System Status screen indicates where the data is being saved.*

Consider the following when storing and retrieving pulse generator data:

- No more than 400 unique patient records may be saved to the PRM. When a pulse generator is interrogated, the PRM evaluates if there is already a record on file for this pulse generator, or if a new record will need to be created. If a new record is needed, and the PRM is at the 400 record capacity, the oldest record on file will be deleted to create space for the new patient record.
- When performing multiple patient checkups, be sure to start a new session for each patient.
- Be sure to save all pulse generator data to either a floppy disk or USB pen drive before returning a PRM to Boston Scientific, as all patient and pulse generator data will be erased from the PRM when it is returned.
- To protect patient privacy, pulse generator data can be encrypted before it is transferred to a USB pen drive.

## Device Memory

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Device Memory utility allows you to retrieve, save, and print pulse generator memory data, which is intended for use by a Boston Scientific representative for clinical and troubleshooting purposes. This utility should only be used when directed by a Boston Scientific representative. Digital media with device memory data contains protected health information and therefore should be handled in accordance with applicable privacy and security policies and regulations.

**NOTE:** Use the Data Storage tab to access pulse generator data for clinician use ("Data Storage" on page 1-17).

## Print

You can print PRM reports by using the internal printer, or by connecting to an external printer. To print a report, select the Reports button. Then select the report you wish to print from the following categories:

- Follow-up reports
- Episode reports
- Other reports (includes device settings, patient data, and other information)

## SAFETY MODE

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The pulse generator is equipped with dedicated Safety Core hardware that is intended to provide life-sustaining therapy if certain nonrecoverable or repeat fault conditions occur and cause a system reset. These types of faults indicate a loss of component integrity in the pulse generator's central processing unit (CPU), including the microprocessor, program code, and system memory. Using minimal hardware (i.e., unipolar lead configuration), Safety Core operates independently and acts as a backup to these components.

Safety Core also monitors the device during normal pacing; if normal pacing does not occur, Safety Core delivers an escape pace, and a system reset is initiated.

If the pulse generator experiences three resets within approximately 48 hours, the device reverts to Safety Mode and device replacement should be considered. The following will also occur:

- ZIP telemetry is unavailable for communicating with the PRM when Safety Mode is active; wanded telemetry must be used instead.
- LATITUDE NXT will alert that Safety Mode has been activated.
- Upon interrogation, a warning screen is displayed indicating that the pulse generator is in Safety Mode, and directing you to contact Boston Scientific.

## Backup Pacemaker

Safety Mode provides biventricular pacing, with the following parameters:

- Brady Mode—VVI
- LRL—72.5 min<sup>-1</sup>
- Pulse Amplitude—5.0 V
- Pulse Width—1.0 ms

- RV Refractory Period (RVRP)—250 ms
- RV Sensitivity—AGC 0.25 mV
- RV lead configuration—Unipolar
- Ventricular Pacing Chamber—BiV
- LV Offset—0 ms
- LV lead configuration—Unipolar (LV tip to Can)
- Noise Response—VOO

**NOTE:** Safety Mode also disables Magnet Response.

Outdated version. Do not use.  
 Version überholt. Nicht verwenden.  
 Version obsolete. Ne pas utiliser.  
 Versión obsoleta. No utilizar.  
 Verouderde versie. Niet gebruiken.  
 Föråldrad version. Använd ej.  
 Παλιά έκδοση. Μην την χρησιμοποιείτε.  
 Versão obsoleta. Não utilize.  
 Forældet version. Må ikke anvendes.  
 Zastaralá verzia. Nepoužívať.  
 Utdatert versjon. Skal ikke brukes.  
 Zastaraná verzia. Nepoužívať.  
 Elavult verzió. Ne használja!  
 Wersja nieaktualna. Nie używać.

Outdated version. Do not use.  
Version überholt. Nicht verwenden.  
Version obsolète. Ne pas utiliser.  
Versión obsoleta. No utilizar.  
Versione obsoleta. Non utilizzare.  
Verouderde versie. Niet gebruiken.  
Föråldrad version. Använd ej.  
Παλιά έκδοση. Μην την χρησιμοποιείτε.  
Versão obsoleta. Não utilize.  
Forældet version. Må ikke anvendes.  
Zastaralá verze. Nepoužívat.  
Utdatert versjon. Skal ikke brukes.  
Zastaraná verzia. Nepoužívať.  
Elavult verzió. Ne használja!  
Wersja nieaktualna. Nie używać.



## PACING THERAPIES

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### CHAPTER 2

This chapter contains the following topics:

- "Pacing Therapies" on page 2-2
- "Device Modes" on page 2-2
- "Device Programming Recommendations" on page 2-3
- "Maintaining CRT" on page 2-5
- "Basic Parameters" on page 2-6
- "Temporary Brady Pacing" on page 2-30
- "Rate Adaptive Pacing and Sensor Trending" on page 2-31
- "Atrial Tachy Response" on page 2-46
- "Rate Enhancements" on page 2-54
- "Lead Configuration" on page 2-61
- "AV Delay" on page 2-67
- "Refractory" on page 2-72
- "Noise Response" on page 2-82

## PACING THERAPIES

CRT-Ps provide both atrial and biventricular sensing and pacing, including adaptive-rate modes.

The bradycardia pacing function is independent of the tachycardia detection function of the device, with the exception of interval-to-interval sensing.

The pulse generator provides the following types of therapies:

### CRT

- When the patient's intrinsic atrial rate is below the MTR and the programmed AV Delay is less than the intrinsic intracardiac AV interval, the device delivers pacing pulses to the ventricles at the programmed settings in order to synchronize ventricular contractions.
- Independent programmability of the RV and LV leads allows therapeutic flexibility for restoring mechanical coordination.

**NOTE:** For CRT and bradycardia therapy decisions, the cardiac cycle is determined by RV sensed and paced events or LV paced events when the pacing chamber is programmed to LV Only. It is necessary that an RV lead be implanted even when programmed to LV-only pacing because all of the device timing cycles rely on the RV. LV sensed events inhibit inappropriate LV pacing and do not modify the timing cycle.

**CAUTION:** To ensure a high percentage of biventricular pacing, the programmed AV Delay setting must be less than the patient's intrinsic PR interval.

### Normal Bradycardia Pacing

- If the intrinsic heart rate falls below the programmed pacing rate (i.e., LRL), the device delivers pacing pulses at the programmed settings.
- Adaptive-rate pacing allows the pulse generator to adapt the pacing rate to the patient's changing activity levels and/or physiologic needs.

### Additional Options

- Temporary Bradycardia Pacing—allows the clinician to examine alternate therapies while maintaining the previously programmed normal pacing settings in the pulse generator memory ("Temporary Brady Pacing" on page 2-30).
- STAT PACE—initiates emergency ventricular pacing at high output settings when commanded via the PRM using telemetry communication ("STAT PACE" on page 1-16).
- Electrocautery Protection—provides asynchronous pacing at the programmed outputs and LRL when commanded by the programmer ("Electrocautery Protection Mode" on page 2-3).

## DEVICE MODES

Once the pulse generator has been programmed out of Storage Mode, the following device modes are available:

- Brady Therapy Enabled—indicates that the pulse generator is providing normal pacing therapy. This mode is not selectable; it is set automatically so long as Brady Mode is programmed to anything except Off.
- Brady Therapy Off—indicates that the pulse generator is not providing any therapy. This mode is not selectable; it is set automatically when the Brady Mode is programmed to Off.

- Electrocautery Protection Mode—provides asynchronous pacing at the programmed outputs and LRL when commanded by the programmer. This mode is enabled via the Device Mode button.
- Safety Mode—automatically activated by the pulse generator when it experiences a nonrecoverable fault. This mode is not selectable ("Safety Mode" on page 1-18).

## Electrocautery Protection Mode

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Electrocautery Protection Mode provides asynchronous pacing at the programmed outputs and LRL. Tachyarrhythmia detection is deactivated.

When Electrocautery Protection is enabled, the Brady Mode switches to an XOO mode (where X is determined by the programmed Brady Mode). Other pacing parameters remain at the programmed settings (including pacing output). If Brady Mode is Off prior to enabling Electrocautery Protection, it will remain Off during Electrocautery Protection. Once enabled, Electrocautery Protection does not require constant telemetry to remain active.

After cancelling Electrocautery Protection, the Brady Mode will revert to the previously programmed setting.

After attempting to enable Electrocautery Protection Mode, refer to the message on the PRM screen confirming that Electrocautery Protection is active.

Except for STAT PACE, no commanded therapies, diagnostic tests, or printing of reports will be allowed while Electrocautery Protection is enabled.

Application of a magnet while the device is in Electrocautery Protection has no effect on pacing rate.

Biventricular pacing with LV Offset programmed to zero will be delivered while Electrocautery Protection Mode is enabled if the programmed mode is a ventricular pacing mode.

To enable and disable Electrocautery Protection Mode, perform the following steps:

1. Select the Device Mode button from the top of the PRM screen.
2. Select the check box to Enable Electrocautery Protection.
3. Select the Apply Changes button to enable Electrocautery Protection Mode. A dialog window will appear, indicating that Electrocautery Protection is active.
4. Select the Cancel Electrocautery Protection button on the dialog window to return the device to the previously programmed mode. Electrocautery Protection can also be cancelled by pressing the STAT PACE or DIVERT THERAPY key on the PRM.

## DEVICE PROGRAMMING RECOMMENDATIONS

It is important to program device parameters to the appropriate settings to ensure optimal CRT delivery. Please consider the following guidelines in conjunction with the patient's specific condition and therapy needs.

**NOTE:** Also consider using *Indications-Based Programming (IBP)*, a tool that provides specific programming recommendations based on the patient's clinical needs and primary indications ("*Indications-Based Programming (IBP)*" on page 1-13).

**CAUTION:** This device is intended to provide biventricular or left ventricular pacing therapy. Programming the device to provide RV-only pacing is not intended for the treatment of heart failure. The clinical effects of RV-only pacing for the treatment of heart failure have not been established.

**Pacing mode**—Program a dual-chamber tracking mode [VDD(R) or DDD(R)]. Adaptive-rate pacing modes are intended for patients who exhibit chronotropic incompetence and who would benefit by increased pacing rates concurrent with physical activity ("Brady Mode" on page 2-7).

**Pacing chamber**—Program to BiV (nominal) unless medical discretion dictates the selection of a different pacing chamber ("Ventricular Pacing Chamber" on page 2-13).

**BiV Trigger**—Program to On to provide biventricular pacing up to the applicable upper rate limit.

**LRL**—Program below a sinus rate normally reached while still providing an appropriate rate for bradycardia support ("Lower Rate Limit (LRL)" on page 2-10). If the pulse generator is programmed to VVI(R) mode and the patient has AV conduction during atrial tachyarrhythmias, resulting in inhibition of biventricular pacing (loss of CRT), consider programming an elevated LRL to increase the delivery of biventricular pacing.

**MTR**—Program high enough to ensure 1:1 AV synchrony. A MTR at  $130 \text{ min}^{-1}$  is recommended unless medical discretion dictates otherwise ("Maximum Tracking Rate (MTR)" on page 2-10).

**Pacing Output**—Typically program for a minimum 2x voltage safety margin for each chamber based on the capture thresholds. PaceSafe may be used to automatically measure thresholds and adjust pacing output ("PaceSafe" on page 2-15).

**Paced AV Delay**—The Paced AV Delay setting should be individualized for each patient to ensure consistent CRT delivery. Several methods are available to determine the Paced AV Delay setting, including:

- Intrinsic QRS duration assessment
- Echocardiogram
- Pulse pressure monitoring
- SmartDelay optimization, which will recommend AV Delay settings ("SmartDelay Optimization" on page 2-70)

Since optimizing the Paced AV Delay can significantly influence CRT effectiveness, consider using methods that demonstrate the hemodynamic impact of different Paced AV Delay settings, such as echocardiography or pulse pressure monitoring.

Atrial pacing may prolong the interatrial delay; therefore, it may be necessary to program different Paced AV Delay settings to optimize CRT during normal sinus rhythm and atrial pacing.

**Sensed AV Delay**—Sensed AV Delay is used to achieve a shorter AV Delay following sensed atrial events while the longer, programmed Paced AV Delay is used following paced atrial events. When programmed to the DDD(R) mode, it is recommended that the patient be tested to determine the optimal Sensed AV Delay during atrial sensing and pacing.

**Dynamic AV Delay**—Dynamic AV Delay is set automatically based on the following ("Paced AV Delay" on page 2-68):

- If the minimum and maximum Paced AV Delays are equal, then AV Delay is fixed.
- If the minimum Paced AV Delay is less than the maximum, then AV Delay is set to Dynamic.

**PVARP**—Program PVARP to 280 ms. For heart failure patients with intact AV conduction, a long intrinsic intracardiac AV interval and a long programmed PVARP can cause a loss of atrial

tracking below the MTR, resulting in a loss of BiV stimulation (CRT). If loss of atrial tracking below the MTR is occurring, program Tracking Preference to On (nominal) ("A-Refractory - PVARP" on page 2-73).

PVARP after PVC—Program PVARP after PVC to 400 ms (nominal) to potentially reduce the number of PMTs at high rates. The occurrence of PMTs may also be due to other factors ("PVARP after PVC" on page 2-74).

ATR—If ATR is used, Entry and Exit Counts should be programmed to ensure appropriate and timely mode switching ("Atrial Tachy Response" on page 2-46).

Note that VRR and BiV Trigger have the potential to increase CRT delivery during atrial tachyarrhythmias. BiV Trigger should be programmed to On, and VRR should be programmed to On at the maximum setting to increase the percent of ventricular pacing and maximize consistent CRT delivery during conducted atrial tachyarrhythmias.

PMT Termination—Program to On (nominal) to terminate PMTs at high rates ("PMT Termination" on page 2-51).

LVPP—Program to 400 ms (nominal) to prevent the device from pacing in the LV vulnerable period ("Left Ventricular Protection Period (LVPP)" on page 2-76).

Tracking Preference—Program to On (nominal) to support CRT delivery for atrial rates below, but near, the MTR. Use this feature when PVARP and the patient's intrinsic intracardiac AV interval are longer than the programmed MTR interval ("Tracking Preference" on page 2-54).

LV Lead Configuration—For devices with an IS-1 or LV-1 left ventricular lead port, program in accordance with the number of electrodes on the LV lead ("Left Ventricular Electrode Configuration" on page 2-63).

## MAINTAINING CRT

Certain conditions may cause the temporary loss of CRT or AV synchrony due to Wenckebach-like behavior, and heart failure patients may become symptomatic if CRT is compromised. Please consider the following when you are programming the device.

### MTR

Rapid atrial rates with a fast ventricular response above MTR can cause:

- Temporary inhibition of CRT if AV conduction is intact
- Wenckebach-like behavior if second- or third-degree AV block is present

CRT delivery and programmed AV synchrony return when normal sinus rates are restored.

MTR should be programmed sufficiently high to maintain CRT at fast atrial rates. In addition, please consider the following for maintaining CRT:

- Rate Smoothing may be used to prevent sudden changes in rate
- SBR may be used to provide therapy for sudden drops in rate
- VRR may help promote CRT by increasing the percent of ventricular pacing during conducted atrial arrhythmias
- SVTs may require medical management to preserve CRT as well as protect the patient from the potential hemodynamic compromise associated with fast rates

- Medical management of fast atrial rates can maximize the amount of time that the patient remains below MTR and help ensure consistent CRT delivery

### AFR

AFR may delay or inhibit an atrial paced event and prevent pacing into the atrial vulnerable period and provide immediate cessation of tracking of atrial rates higher than the AFR programmable rate. This changes the AV Delay and may impact CRT effectiveness if the AFR rate is programmed slower than the patient's sinus rate.

### Rate Smoothing

When Rate Smoothing Up is programmed to On, CRT is compromised during episodes of atrial rate increases exceeding the programmed Rate Smoothing Up percentage. For patients with AV block, this occurs because Rate Smoothing Up prolongs AV Delay from the optimal setting (controls the biventricular pacing rate while the atrial rate increases).

### Features that Switch to VVI or VVI-like Behavior

ATR may result in Wenckebach-like behavior or the temporary loss of CRT. CRT delivery with programmed AV synchrony will return when the SVT event is resolved and a normal sinus rhythm is restored.

For patients programmed to VDD(R) with sinus rates below LRL, CRT will not be synchronized with atrial events and loss of AV synchrony will result. Consider programming a lower LRL or enabling a pacing mode that provides atrial pacing with synchronous ventricular pacing [e.g., DDD(R)], as medically appropriate.

STAT PACE delivers CRT in VVI mode with a loss of AV synchrony. The permanent, programmed settings resume when the pulse generator is programmed out of STAT PACE.

## BASIC PARAMETERS

By programming device parameters, the pulse generator provides CRT for the intent of providing mechanical synchronization. The programming options used for CRT include those used for bradycardia pacing therapy.

LV stimulation is delivered using a unipolar or bipolar LV lead. The device uses atrial pacing and sensing to coordinate AV contractions with CRT.

Normal Settings include the following:

- Pacing parameters, which are independently programmable from temporary pacing parameters
- Pacing and Sensing
- Leads
- Rate Adaptive Pacing and Sensor Trending

### Interactive Limits

Because many features with programmable parameters interact, programmed values must be compatible across such features. When values requested by the user are incompatible with existing parameters, the programmer screen displays an alert describing the incompatibility and either prohibits the selection or instructs the user to proceed with caution ("Use of Color" on page 1-7).

## Brady Mode

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Brady modes provide programmable options to help individualize patient therapy.

### CRT Modes

The objective of CRT is to deliver continuous pacing to the ventricles. CRT can only be delivered in modes that provide ventricular pacing.

The maximal CRT benefit can be achieved when biventricular stimulation is delivered. Atrial pacing and adaptive-rate modes may be appropriate for patients who also experience bradycardia.

**WARNING:** Do not use atrial-only modes in patients with heart failure because such modes do not provide CRT.

**NOTE:** *The safety and effectiveness of CRT was evaluated in clinical studies using the VDD mode. Use medical discretion when programming the pulse generator to pacing modes other than VDD.*

**NOTE:** *Atrial pacing may prolong interatrial conduction, desynchronizing right and left atrial contractions. The effect of atrial pacing on CRT has not been studied.*

### DDD and DDDR

In the absence of sensed P- and R-waves, pacing pulses will be delivered to the atrium and the ventricle at the LRL (DDD) or the sensor-indicated rate (DDDR), separated by the AV Delay. A sensed P-wave will inhibit an atrial pace and start the AV Delay. At the end of the AV Delay, a ventricular pace will be delivered unless inhibited by a sensed R-wave.

- Could be appropriate for heart failure patients with sinus bradycardia since DDD(R) can provide atrial-synchronous biventricular pacing at rates above the LRL and AV-sequential biventricular pacing at the LRL or sensor-indicated rate—DDDR
- DDD mode may be preferred over VDD mode for patients with sinus bradycardia or atrial rates below the LRL to preserve AV synchrony with CRT delivery

### DDI and DDIR

In the absence of sensed P- and R-waves, pacing pulses will be delivered to the atrium and the ventricle at the LRL (DDI) or the sensor-indicated rate (DDIR), separated by the AV Delay. A sensed P-wave will inhibit an atrial pace but will not start the AV Delay.

- May not be appropriate for heart failure patients with normal sinus activity
- Could be appropriate for heart failure patients who have no underlying intrinsic sinus rhythm but might experience episodes of atrial tachyarrhythmias such as brady-tachy syndrome
- Provide AV-sequential biventricular pacing only at the LRL (DDI) or sensor-indicated rate (DDIR) in the absence of sinus activity
- During periods of intrinsic atrial activity above the LRL and in the absence of sensed R-waves, non-atrial-synchronous biventricular pacing is delivered at the LRL or sensor-indicated rate

**VDD and VDDR**

In the absence of sensed P- and R-waves, pacing pulses will be delivered to the ventricle at the LRL (VDD) or the sensor-indicated rate (VDDR). A sensed P-wave will start the AV Delay. At the end of the AV Delay, a ventricular pace will be delivered unless inhibited by a sensed R-wave. A sensed R-wave or a paced ventricular event will determine the timing of the next ventricular pace.

- VDD is appropriate for heart failure patients with normal sinus activity, since VDD delivers atrial-synchronous biventricular pacing but no atrial pacing
- VDDR may not be appropriate for heart failure patients with normal sinus activity due to the increased potential for loss of AV synchrony
- While VDDR can provide atrial-synchronous biventricular pacing during normal sinus activity, sensor-driven ventricular pacing will result in the loss of AV synchrony if the sensor-indicated rate exceeds the sinus rate
- Consider programming a low LRL for bradycardia support since loss of AV synchrony is likely to occur during LRL ventricular pacing
- If frequent pacing at the LRL is anticipated or observed, consider programming a DDD(R) mode to maintain AV synchrony during LRL pacing

**VVI and VVIR**

In VVI(R) mode, sensing and pacing occur only in the ventricle. In the absence of sensed events, pacing pulses will be delivered to the ventricle at the LRL (VVI) or the sensor-indicated rate (VVIR). A sensed R-wave or a paced ventricular event will determine the timing of the next ventricular pace.

- May be detrimental for heart failure patients with normal sinus activity
- Could be appropriate for heart failure patients with chronic atrial tachyarrhythmias or during episodes of atrial tachyarrhythmia since they provide biventricular pacing at the LRL or sensor-indicated rate—VVI(R)
- If patients have AV conduction during atrial tachyarrhythmias that results in inhibition of biventricular pacing (loss of CRT), consider programming an elevated LRL in an attempt to increase the delivery of biventricular pacing and/or to VVI(R), if not already programmed

**AAI and AAIR**

In AAI(R) mode, sensing and pacing occur only in the atrium. In the absence of sensed events, pacing pulses will be delivered to the atrium at the LRL (AAI) or the sensor-indicated rate (AAIR). A sensed P-wave or a paced atrial event will determine the timing of the next atrial pace.

**DOO**

Pacing pulses will be delivered asynchronously to the atrium and the ventricle at the LRL, separated by the AV Delay. Intrinsic events will neither inhibit nor trigger pacing in either chamber.

**NOTE:** DOO mode is the magnet mode of DDD(R) and DDI(R) modes.

- May be used intraoperatively to reduce the likelihood of inhibition when sources of conducted electrical current are present

**NOTE:** Electrocautery Protection Mode is the preferred option if available.

- May not be appropriate for heart failure patients with normal sinus activity



- Provide AV-sequential biventricular pacing only at the LRL
- During periods of intrinsic atrial activity above the LRL, non-atrial-synchronous biventricular pacing is delivered at the LRL

### VOO

Pacing pulses will be delivered asynchronously to the ventricle at the LRL. Intrinsic events will neither inhibit nor trigger pacing in the ventricle.

**NOTE:** VOO mode is the magnet mode of VVI(R) and VDD(R) modes.

- May be used intraoperatively to reduce the likelihood of inhibition when sources of conducted electrical current are present

**NOTE:** Electrocautery Protection Mode is the preferred option if available.

- Provides biventricular pacing only at the LRL
- May not be appropriate for heart failure patients with intrinsic activity due to the increased potential for loss of AV synchrony and competitive pacing

### AOO

Pacing pulses will be delivered asynchronously to the atrium at the LRL. Intrinsic events will neither inhibit nor trigger pacing in the atrium.

**NOTE:** AOO mode is the magnet mode of AAI(R) mode.

- May be used intraoperatively to reduce the likelihood of inhibition when sources of conducted electrical current are present

**NOTE:** Electrocautery Protection Mode is the preferred option if available.

- May be detrimental for heart failure patients with normal sinus activity

### Dual-Chamber Modes

Do not use DDD(R) and VDD(R) modes in the following situations:

- In patients with chronic refractory atrial tachyarrhythmias (atrial fibrillation or flutter), which may trigger ventricular pacing
- In the presence of slow retrograde conduction that induces PMT, which cannot be controlled by reprogramming selective parameter values

### Atrial Pacing Modes

In DDD(R), DDI(R), AAI(R), DOO, and AOO modes, atrial pacing may be ineffective in the presence of chronic atrial fibrillation or flutter or in an atrium that does not respond to electrical stimulation. In addition, the presence of clinically significant conduction disturbances may contraindicate the use of atrial pacing.

**WARNING:** Do not use atrial tracking modes in patients with chronic refractory atrial tachyarrhythmias. Tracking of atrial arrhythmias could result in ventricular tachyarrhythmias.

**CAUTION:** If a dual-chamber device is programmed to AAI(R), ensure that a functional RV lead is present. In the absence of a functional RV lead, programming to AAI(R) may result in undersensing or oversensing.

If you have any questions regarding the individualization of patient therapy, contact Boston Scientific using the information on the back cover.

## Lower Rate Limit (LRL)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

LRL is the number of pulses per minute at which the pulse generator paces in the absence of sensed intrinsic activity.

As long as the ventricle is being paced (or if a PVC occurs), the interval is timed from one ventricular event to the next. Whenever an event is sensed in the ventricle (e.g., intrinsic AV conduction occurs before the AV Delay elapses), the timing base switches from ventricular-based timing to modified atrial-based timing (Figure 2-1 on page 2-10). This switching of timing base ensures accurate pacing rates since the difference between the intrinsic AV conduction and programmed AV Delay is applied to the next V–A interval.

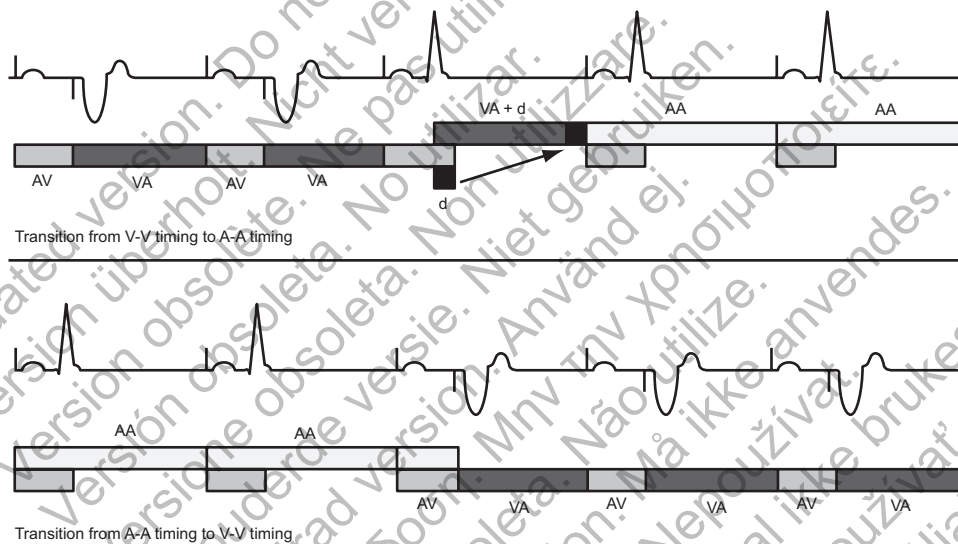


Illustration of timing transitions ( $d$  = the difference between AV Delay and the AV interval in the first cycle during which intrinsic conduction occurs. The value of  $d$  is applied to the next V–A interval to provide a smooth transition without affecting A–A intervals).

**Figure 2-1. LRL timing transitions**

## Maximum Tracking Rate (MTR)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The MTR is the maximum rate at which the paced ventricular rate tracks 1:1 with nonrefractory sensed atrial events in the absence of a sensed ventricular event within the programmed AV Delay. MTR applies to atrial synchronous pacing modes, namely DDD(R) and VDD(R).

Consider the following when programming MTR:

- The patient's condition, age, and general health
- The patient's sinus node function
- A high MTR may be inappropriate for patients who experience angina or other symptoms of myocardial ischemia at higher rates

**NOTE:** If the pulse generator is operating in DDDR or VDDR mode, the MSR and MTR may be programmed independently to different values.

### Upper Rate Behavior

For heart failure patients with normal AV conduction, biventricular stimulation (CRT) may not be delivered when the atrial rate exceeds the MTR. This can occur if the AV Delay lengthens beyond the patient's intrinsic intracardiac AV interval and AV conduction occurs, which inhibits ventricular pacing. In both situations (AV block and AV conduction) CRT is compromised when the atrial rate exceeds the MTR, either because of the suboptimal, prolonged AV Delay or a loss of biventricular pacing, or both.

If the patient's normal atrial rate exceeds the MTR, consider programming a higher MTR to ensure 1:1 atrial synchronous, biventricular pacing at the programmed AV Delay. If reprogramming a higher MTR is limited by the current TARP ( $AV\ Delay + PVARP = TARP$ ), attempt to shorten the PVARP before shortening the AV Delay in order to avoid a suboptimal AV Delay for CRT.

When the sensed atrial rate is between the programmed LRL and MTR, 1:1 ventricular pacing will occur in the absence of a sensed ventricular event within the programmed AV Delay. If the sensed atrial rate exceeds the MTR, the pulse generator begins a Wenckebach-like behavior to prevent the paced ventricular rate from exceeding the MTR. This Wenckebach-like behavior is characterized by a progressive lengthening of the AV Delay until an occasional P-wave is not tracked because it falls into the PVARP. This results in an occasional loss of 1:1 tracking as the pulse generator synchronizes its paced ventricular rate to the next sensed P-wave. Should the sensed atrial rate continue to increase further above the MTR, the ratio of sensed atrial events to sequentially paced ventricular events becomes lower until, eventually, 2:1 block results (e.g., 5:4, 4:3, 3:2, and finally 2:1).

The sensing window should be maximized by programming the appropriate AV Delay and PVARP. At rates close to the MTR, the sensing window can be maximized by programming Dynamic AV Delay and Dynamic PVARP, and Wenckebach behavior will be minimized.

High rate atrial tracking is limited by the programmed MTR and the total atrial refractory period (TARP) ( $AV\ Delay + PVARP = TARP$ ). In order to avoid complete closure of the sensing window at MTR, the PRM will not allow a TARP interval that is longer (lower pacing rate) than the programmed MTR interval.

If the TARP interval is shorter (higher pacing rate) than the interval of the programmed MTR, then the pulse generator's Wenckebach-like behavior limits the ventricular pacing rate to the MTR. If the TARP interval is equal to the interval of the programmed MTR, 2:1 block may occur with atrial rates above the MTR.

Rapid changes in the paced ventricular rate (e.g., Wenckebach-like, 2:1 block) caused by sensed atrial rates above the MTR may be dampened or eliminated by the implementation of any of the following:

- AFR
- ATR
- APP/ProACT
- Rate Smoothing parameters and sensor input

**NOTE:** For the purpose of atrial tachycardia detection and histogram updates, atrial events are detected throughout the cardiac cycle (except during atrial blanking), including AV Delay and PVARP.

### Examples

If the atrial rate exceeds the MTR, the AV Delay will be progressively lengthened (AV') until an occasional P-wave is not tracked because it falls into the atrial refractory period (Figure 2-2 on page 2-12). This results in occasional loss of 1:1 tracking as the pulse generator synchronizes its paced ventricular rate to the next tracked P-wave (pacemaker Wenckebach).

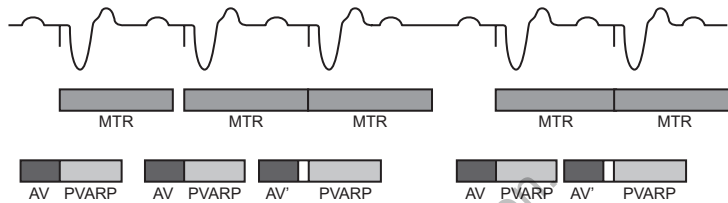


Figure 2-2. Wenckebach behavior at MTR

Another type of pulse generator upper rate behavior (2:1 block) can occur when tracking high atrial rates. In this type of behavior, every other intrinsic atrial event occurs during PVARP and, thus, is not tracked (Figure 2-3 on page 2-12). This results in a 2:1 ratio of atrial-to-ventricular events or a sudden drop in the ventricular paced rate to half of the atrial rate. At faster atrial rates, several atrial events can fall in the TARP period, resulting in the pulse generator tracking only every third or fourth P-wave. The block then occurs at rates such as 3:1 or 4:1.

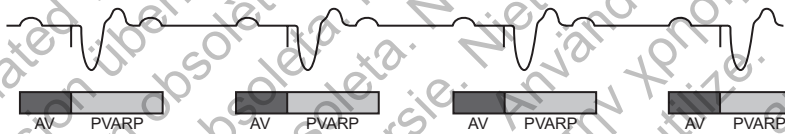


Illustration of pacemaker 2:1 block, in which every other P-wave falls inside the PVARP interval.

Figure 2-3. Pacemaker 2:1 block

### Maximum Sensor Rate (MSR)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

MSR is the maximum pacing rate allowed as a result of rate-adaptive sensor control.

Consider the following when programming MSR:

- Patient's condition, age, and general health.
  - Adaptive-rate pacing at higher rates may be inappropriate for patients who experience angina or other symptoms of myocardial ischemia at these higher rates
  - An appropriate MSR should be selected based on an assessment of the highest pacing rate that the patient can tolerate well

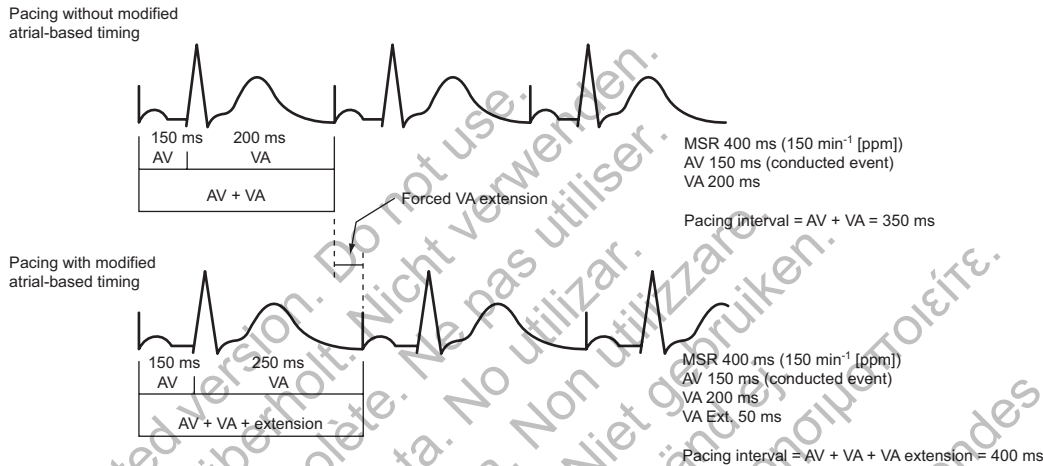
**NOTE:** If the pulse generator is operating in DDDR or VDDR mode, the MSR and MTR may be programmed independently to different values.

MSR is independently programmable at, above, or below the MTR. If the MSR setting is higher than the MTR, pacing above the MTR may occur if the sensor rate exceeds the MTR.

Pacing above the MSR (when programmed lower than the MTR) can only occur in response to sensed intrinsic atrial activity.

**CAUTION:** Adaptive-rate pacing is not limited by refractory periods. A long refractory period programmed in combination with a high MSR can result in asynchronous pacing during refractory periods since the combination can cause a very small sensing window or none at all. Use Dynamic AV Delay or Dynamic PVARP to optimize sensing windows. If you are programming a fixed AV Delay, consider the sensing outcomes.

With intrinsic conduction, the pulse generator maintains the A–A pacing rate by extending the V–A interval. This extension is determined by the degree of difference between the AV Delay and the intrinsic ventricular conduction—often referred to as modified atrial-based timing (Figure 2-4 on page 2-13).



The pulse generator's timing algorithm provides effective pacing at the MSR with intrinsic ventricular conduction. Extending the VA interval prevents the A pace from exceeding the MSR at high rates.

**Figure 2-4. VA interval extension and MSR**

## Runaway Protection

Runaway protection is designed to prevent pacing rate accelerations above the MTR/MSR for most single-component failures. This feature is not programmable and operates independently from the pulse generator's main pacing circuitry.

Runaway protection prevents the pacing rate from increasing above 205 min<sup>-1</sup>.

**NOTE:** Runaway protection is not an absolute assurance that runaways will not occur.

During PES and Manual Burst Pacing, runaway protection is temporarily suspended to allow for high-rate pacing.

## Ventricular Pacing Chamber

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

With the Ventricular Pacing Chamber option, you can choose which chamber(s) will receive pacing pulses.

The following options are available:

- RV Only
- LV Only
- BiV (both RV and LV)—when selected, LV Offset becomes available

**NOTE:** It is necessary that an RV lead be implanted even when programmed to LV-only pacing because all of the device timing cycles rely on the RV.

For devices with an IS-1 or LV-1 left ventricular lead port, the nominal LV Electrode Configuration is None. This results in a parameter interaction when combined with the nominal Ventricular Pacing Chamber setting of BiV. This is intended to ensure that an appropriate LV Electrode Configuration (dual or single) is chosen based on the implanted LV lead.

For devices with an IS4 left ventricular lead port, the LV Electrode Configuration is automatically set to Quadripolar.

**CAUTION:** This device is intended to provide biventricular or left ventricular pacing therapy. Programming the device to provide RV-only pacing is not intended for the treatment of heart failure. The clinical effects of RV-only pacing for the treatment of heart failure have not been established.

### LV Offset

When the Pacing Chamber is set to BiV, the LV Offset feature is available and allows you to adjust the delay between delivery of the left ventricular pacing pulse and the right ventricular pacing pulse. LV Offset is designed to enhance programming flexibility to coordinate the mechanical response of the ventricles.

The device automatically accommodates the LV Offset for high pacing rates (VISIONIST and VALITUDE devices) and the programmed ventricular tachy detection threshold when biventricular pacing occurs near the upper rate limit.

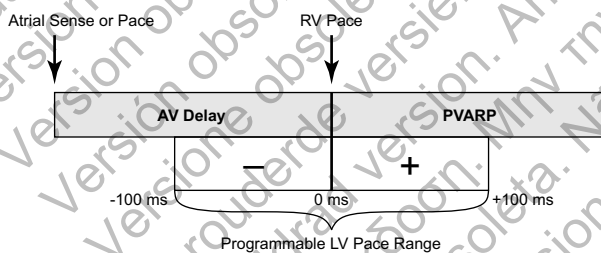


Figure 2-5. Programmable LV pace range

**NOTE:** The programmed AV Delay is based on RV timing; therefore, it is not affected by LV Offset.

### Pulse Width

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Pulse Width, also referred to as pulse duration, determines how long the output pulse will be applied between the pacing electrodes.

Consider the following when programming Pulse Width:

- Pulse Widths are independently programmable for each chamber.
- If a Pulse Width Threshold Test is performed, a minimum 3X pulse width safety margin is recommended.

- The energy delivered to the heart is directly proportional to the Pulse Width; doubling the Pulse Width doubles the energy delivered. Therefore, programming a shorter Pulse Width while maintaining an adequate safety margin may increase battery longevity. To prevent loss of capture, exercise caution when you are programming permanent Pulse Width values of less than 0.3 ms (Figure 2-6 on page 2-15).

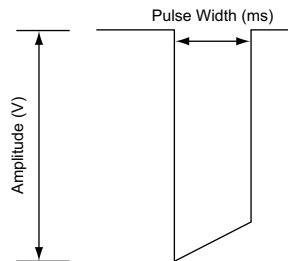


Figure 2-6. Pulse waveform

## Amplitude

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The pulse amplitude, or voltage of the output pulse, is measured at the leading edge of the output pulse (Figure 2-6 on page 2-15).

Consider the following when programming Amplitude:

- Amplitudes are independently programmable for each chamber.
- Brady Mode may be programmed to Off via permanent or temporary programming. In effect, this turns Amplitude Off to monitor the patient's underlying rhythm.
- A minimum 2X voltage safety margin is recommended for each chamber based on the capture thresholds. If PaceSafe is programmed On, it will automatically provide an adequate safety margin and may help extend battery longevity.
- The energy delivered to the heart is directly proportional to the square of the amplitude: doubling the amplitude quadruples the energy delivered. Therefore, programming to a lower Amplitude while maintaining an adequate safety margin may increase battery longevity.

## PaceSafe

### PaceSafe Right Atrial Automatic Threshold (RAAT)

This feature is available in VISIONIST, VALITUDE, INLIVEN, and INTUA devices.

PaceSafe RAAT is designed to dynamically adjust the atrial pacing output to ensure capture of the atrium by optimizing the output voltage to a 2X safety margin (for thresholds less than or equal to 2.5V). RAAT will measure pacing thresholds between 0.2 V and 4.0 V at 0.4 ms and the output will be a minimum of 2.0 V and a maximum of 5.0 V with a fixed pulse width of 0.4 ms.

**NOTE:** To function properly, RAAT requires a functional RV lead and a bipolar atrial lead. It is important to indicate on the Patient Information screen that a bipolar lead is present, particularly if the Atrial Pace and Sense Lead Configurations are programmed to Unipolar.

**NOTE:** RAAT is only available in pulse generators programmed to DDD(R) and DDI(R) modes as well as DDI(R) Fallback Mode.

RAAT can be programmed on by selecting Auto from the Atrial Amplitude parameter options. Programming the atrial output to Auto will automatically adjust the Pulse Width to 0.4 ms and set the atrial voltage output to an initial value of 5.0 V unless there is a successful test result within the last 24 hours.

**NOTE:** Prior to programming RAAT on, consider performing a Commanded Atrial Automatic Threshold Measurement to verify that the feature functions as expected. RAAT testing is performed in a unipolar configuration and there may be a discrepancy between unipolar and bipolar thresholds. If the bipolar threshold is greater than the unipolar threshold by more than 0.5 V, consider programming a fixed Atrial Amplitude or programming the Atrial Pace Lead Configuration to Unipolar.

RAAT is designed to work with typical lead implant criteria and an atrial threshold between 0.2 V and 4.0 V at 0.4 ms.

The RAAT algorithm then measures the atrial pacing threshold each day and adjusts the voltage output. During testing, RAAT measures an evoked response signal to confirm that each atrial pacing output captures the atrium. If the device is unable to repeatedly measure an evoked response signal of sufficient amplitude, a “Low ER” or “Noise” message may be displayed and the algorithm will default to 5.0 V pacing amplitude. Consider programming a fixed atrial pacing amplitude in these situations and re-check with a Commanded RAAT test at a later follow-up; maturation of the lead-tissue interface may improve the performance of RAAT.

If testing is successful, the Atrial Amplitude is adjusted to 2X the highest measured threshold of the last 7 successful ambulatory tests (output Amplitude between 2.0 V and 5.0 V). Seven tests are used to account for circadian cycle effects on threshold and ensure an adequate safety margin. This also allows for a rapid increase in output due to a sudden rise in threshold while requiring consistently lower threshold measurements to decrease output (i.e., one low threshold measurement will not cause a decrease in output) (Figure 2-7 on page 2-16).

**NOTE:** Since output is set to a 2X safety margin and RV pacing occurs shortly after atrial pacing, there is no beat-to-beat capture verification or backup atrial pacing at any time.

When Daily Trend is selected along with a fixed Amplitude, automatic atrial threshold measurements will occur every 21 hours with no change to programmed output.

The RAAT feature is designed to operate with a large range of pacing leads (e.g., high impedance, low impedance, tined fixation, or positive fixation).

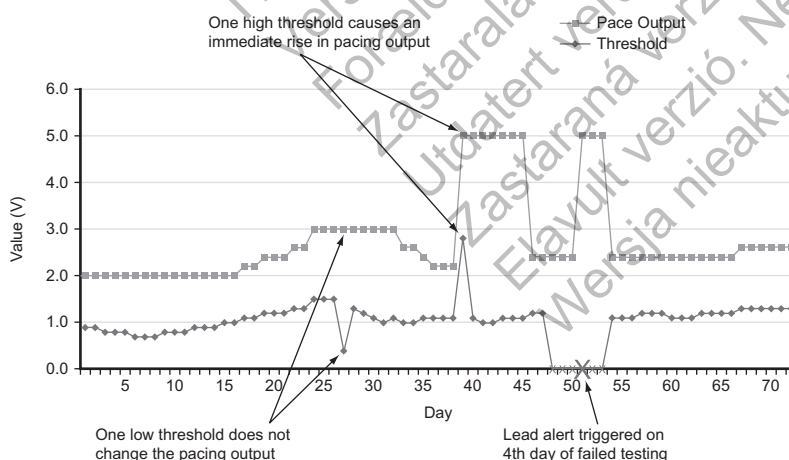


Figure 2-7. Effect of threshold change on RAAT pacing output



### Ambulatory Atrial Automatic Threshold Measurement

Testing uses an RA tip >> can (unipolar) pacing vector and an RA ring >> can (unipolar) sensing vector whether the lead is programmed to Unipolar or Bipolar Pace/Sense.

When RAAT is set to Auto or Daily Trend, ambulatory atrial automatic threshold measurements are conducted every 21 hours and the following parameters are adjusted to ensure a valid measurement is obtained:

- Starting atrial pacing amplitude is the output that RAAT is currently using. If that Amplitude value fails or if no previous results are available, the starting Amplitude is 4.0 V.
- The pacing amplitude will decrement in 0.5 V steps above 3.5 V and in 0.1 V steps at or below 3.5 V.
- Paced AV Delay is fixed at 85 ms.
- Sensed AV Delay is fixed at 55 ms.
- Initial pacing rate is set to the average atrial rate, the LRL or sensor-indicated rate, whichever is faster.
- If there are an insufficient number of atrial paces or if fusion occurs, the atrial pacing rate will be increased by 10 min<sup>-1</sup> (it may be increased a second time), but will not exceed the lowest of the MTR, MSR, MPR, 110 min<sup>-1</sup>, or 5 min<sup>-1</sup> below the VT Detection Rate.
- If LV Offset is negative, it will be set to zero during testing.

Following initialization paces, the pulse generator will decrement the atrial output every 3 paces until a threshold is determined. If loss of capture occurs twice at a particular output level, threshold is declared as the previous output level that demonstrated consistent capture. If 3 captured beats occur at any particular output level, output decrements to the next level.

**NOTE:** To ensure that loss of capture during RAAT does not encourage PMT (and also end the test prematurely due to too many atrial senses), the pulse generator uses a PMT algorithm. Following the loss of capture of any atrial beat, the PVARP following that ventricular event is extended to 500 ms to prevent tracking of a subsequent P-wave.

If daily testing is unsuccessful, RAAT will return to the previously determined output and the pulse generator will perform up to 3 re-attempts at hourly intervals. If a successful test does not occur for 4 days, a Lead Alert will be triggered and RAAT will enter Suspension.

### Right Atrial Automatic Threshold Suspension

If ambulatory testing fails in Auto mode for 4 consecutive days, RAAT will go into a Suspension mode and the pacing output will operate at 5.0 V and 0.4 ms. Testing will continue each day with up to 3 re-attempts to evaluate thresholds and the pulse generator will adjust to a lower output setting when indicated by a successful test.

Although RAAT is designed to work with a wide range of leads, in some patients the lead signals may hinder successful determination of the atrial threshold. In these instances, RAAT will continually operate in the Suspension mode at 5.0 V. In situations where Suspension mode persists for an extended period of time, it is recommended to turn RAAT off by programming a fixed atrial output.

### Commanded Atrial Automatic Threshold Measurement

An automatic threshold measurement can be commanded via the Threshold Tests screen by selecting Auto Amplitude as the Test Type. If testing completes successfully and RAAT

is programmed on, the output will automatically be set to 2X that test's measured threshold (between 2.0 V and 5.0 V). The last 7 successful daily measurements are cleared and the current commanded test result is used as the first successful test of a new 7 test cycle. This is to ensure that there will be an immediate output adjustment based on the current commanded test result rather than on older ambulatory test data. This can be confirmed by observing the output voltage on the Brady Settings screen, which will show the actual operating voltage of the RAAT algorithm.

If testing is unsuccessful, the Threshold Tests screen will display a failure code indicating the reason the test was not successful, and the output will return to the previously set level (Table 2-1 on page 2-18).

**NOTE:** For the initial Atrial Threshold test after the pulse generator is implanted, the Test Type field is seeded to Auto. Choose the desired test type from the Test Type field options, and adjust any other programmable values as appropriate.

**NOTE:** Commanded testing requires a functional bipolar atrial lead and may be performed in AAI mode.

### Test Results and Lead Alerts

A stored EGM for the most recent successful ambulatory test will be stored in the Arrhythmia Logbook ("Arrhythmia Logbook" on page 4-2). Refer to the Daily Measurements screen for the resulting threshold value. If desired, the stored EGM can be reviewed to determine where loss of capture occurred.

Up to 12 months of Ambulatory Threshold Test results, as well as test failure codes and lead alerts, can be found within the Daily Measurement and Trends screens. To provide further information on the reason for test failure, a failure code is provided for each day in which testing fails. Additionally, failure codes are provided on the Threshold Test screen if a commanded automatic threshold test does not complete successfully. Threshold Test Failure Codes are listed below (Table 2-1 on page 2-18).

The following scenarios will trigger the Check Atrial Lead alert:

- Threshold > Programmed Amplitude will be displayed if RAAT is in Daily Trend mode and the ambulatory test results of the last 4 consecutive days exceed the manually programmed fixed output.
- Automatic Threshold Suspension will be displayed if no successful tests are performed for 4 consecutive days in Auto or Daily Trend mode.

Table 2-1. Threshold Test Codes

Code	Reason
N/R: device telem.	Telemetry started during an ambulatory test
N/R: comm. lost	Telemetry was lost during a commanded test
N/R: no capture	Capture was not obtained at the starting amplitude for a commanded test or capture is > 4.0 V for an ambulatory test
N/R: mode switch	ATR mode switch either started or stopped
N/R: fusion events	Too many consecutive or too many total fusion events occurred
No data collected	Minimum pacing amplitude was reached without losing capture for an ambulatory test, or neither Auto nor Daily Trend is turned on to obtain an ambulatory result
N/R: battery low	Test was skipped due to Battery Capacity Depleted
N/R: noise	Too many consecutive sense channel noise or Evoked Response noise cycles occurred

**Table 2-1. Threshold Test Codes** (continued)

Code	Reason
N/R: incompat. mode	Incompatible Brady mode was present (e.g. VDI Fallback Mode, Magnet Mode) or a Lead Safety Switch occurred
N/R: rate too high	Rate was too high at the start of the test, a rate increase would raise the rate too high or more than 2 rate increases were required
N/R: user cancelled	Commanded test was stopped by the user
N/R: intrinsic beats	Too many cardiac cycles occurred during the test
N/R: test delayed	Test was delayed due to telemetry being active, VT episode already in progress, Electrocautery mode, or RAAT was turned on while the device remained in Storage mode
N/R: respiration	Respiratory artifact was too high
N/R: low ER	The Evoked Response signal could not be assessed adequately
Auto N/R	Minimum pacing amplitude was reached without losing capture for a commanded test, or telemetry is manually cancelled during a commanded test
Invalid Failure Code	Unexpected Failure

### PaceSafe Right Ventricular Automatic Threshold (RVAT)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

PaceSafe RVAT is designed to dynamically adjust the right ventricular pacing output to ensure capture of the ventricle by optimizing the output voltage to a 2X safety margin (for thresholds less than or equal to 2.5 V). RVAT will measure pacing thresholds between 0.2 V and 3.0 V at 0.4 ms, and the output will be a minimum of 2.0 V and a maximum of 5.0 V with a fixed Pulse Width of 0.4 ms.

**NOTE:** RVAT is available in DDD(R), DDI(R), VDD(R), and VVI(R) modes, as well as during VDI(R) and DDI(R) Fallback Modes.

RVAT can be programmed on by selecting Auto from the Ventricular Amplitude parameter options. If starting from a fixed amplitude greater than 3.5 V, program a fixed amplitude of 3.5 V prior to selecting Auto. Programming the ventricular output to Auto will automatically adjust the Pulse Width to 0.4 ms and set the ventricular voltage output to an initial value of 5.0 V unless there is a successful test result within the last 24 hours.

**NOTE:** Prior to programming RVAT on, consider performing a Commanded Ventricular Automatic Threshold Measurement to verify that the feature functions as expected.

RVAT is designed to work with typical lead implant criteria and measure a ventricular threshold between 0.2 V and 3.0 V at 0.4 ms.

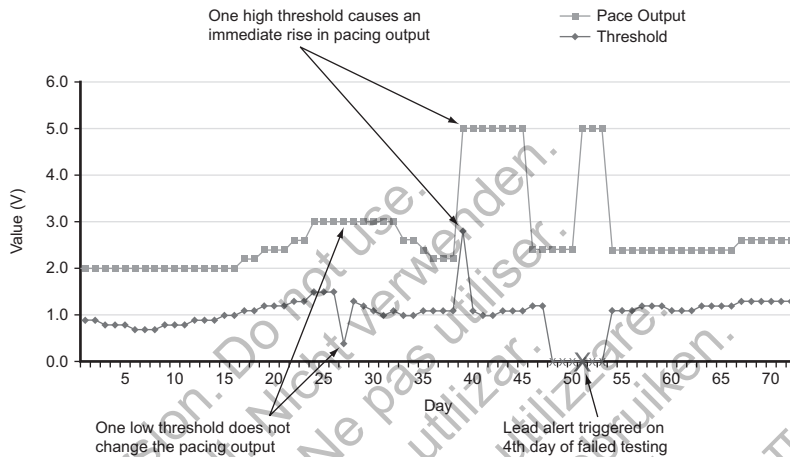
The RVAT algorithm then measures the ventricular pacing threshold each day and adjusts the voltage output. During testing, RVAT uses an evoked response signal to confirm that each ventricular pacing output captures the ventricle.

If testing is successful, the Ventricular Amplitude is adjusted to 2X the highest measured threshold of the last 7 successful ambulatory tests between 2.0 V and 5.0 V. Seven tests are used to account for circadian cycle effects on threshold and ensure an adequate safety margin. This also allows for a rapid increase in output due to a sudden rise in threshold while requiring consistently lower threshold measurements to decrease output (i.e. one low threshold measurement will not cause a decrease in output) (Figure 2-8 on page 2-20).

**NOTE:** Since output is set to a 2X safety margin, there is no beat-to-beat capture verification.

When Daily Trend is selected along with a fixed Amplitude, automatic ventricular threshold measurements will occur every 21 hours with no change to programmed output.

The RVAT feature is designed to operate with a large range of pacing leads (e.g., high impedance, low impedance, tined fixation, or positive fixation). Also, RVAT is independent of pacing and sensing lead polarity; the Ventricular Pace and Sense Lead Configurations can be programmed to Unipolar or Bipolar.



**Figure 2-8.** Effect of threshold changes on RVAT pacing output

### Ambulatory Right Ventricular Automatic Threshold Measurement

When RVAT is set to Auto or Daily Trend, ambulatory ventricular automatic threshold measurements are conducted every 21 hours.

In atrial tracking modes, the automatic threshold measurement adjusts the following parameters to help ensure a valid measurement is obtained:

- Paced AV Delay is fixed at 60 ms.
- Sensed AV Delay is fixed at 30 ms.
- LV pacing is temporarily suspended in order to evaluate an RV-only evoked response.
- Starting ventricular pacing output amplitude is 3.5 V.
- The pacing amplitude will decrement in 0.1 V steps.
- A backup pulse at 5.0 V is delivered approximately 70 ms after every primary pacing pulse.

In nontracking modes, the automatic threshold measurement adjusts the following parameters to help ensure a valid measurement is obtained.

- Paced AV Delay is fixed at 60 ms.
- LV pacing is temporarily suspended in order to evaluate an RV-only evoked response.
- Starting ventricular pacing output amplitude is 3.5 V.
- The pacing amplitude will decrement in 0.1 V steps.
- A backup pulse at 5.0 V is delivered approximately 70 ms after every primary pacing pulse.

- The ventricular pacing rate will be increased by  $10 \text{ min}^{-1}$  above the current rate (paced or intrinsic) and is capped at the lowest of the MPR, MSR,  $110 \text{ min}^{-1}$ , or  $5 \text{ min}^{-1}$  below the VT Detection Rate.

**NOTE:** If fusion (which could potentially be a noise beat) is detected, the AV interval and/or V–V interval may be extended on the next cardiac cycle in an attempt to distinguish the fusion beat from ventricular capture.

Following initialization paces, the pulse generator will decrement the ventricular output every 3 paces until a threshold is determined. Additional pacing pulses will be issued if there is fusion or intermittent loss of capture. Threshold is declared as the previous output level that demonstrated consistent capture.

If daily testing is unsuccessful, RVAT will return to the previously determined output and the device will perform up to 3 re-attempts at hourly intervals. If a successful test does not occur for 4 days, a Lead Alert will be triggered and RVAT will enter Suspension.

### Right Ventricular Automatic Threshold Suspension

If ambulatory testing fails in Auto mode for 4 consecutive days, RVAT will go into a Suspension mode and the pacing output will operate at 5.0 V and 0.4 ms. Testing will continue each day with up to 3 re-attempts to evaluate thresholds and the pulse generator will adjust to a lower output setting when indicated by a successful test.

Although RVAT is designed to work with a wide range of leads, in some patients the lead signals may hinder successful determination of the ventricular threshold. In these instances, RVAT will continually operate in the Suspension mode at 5.0 V. In situations where Suspension mode persists for an extended period of time, it is recommended to turn RVAT off by programming a fixed ventricular output.

### Commanded Right Ventricular Automatic Threshold Measurement

An automatic threshold measurement can be commanded via the Threshold Tests screen by selecting Auto Amplitude as the Test Type. If testing completes successfully in the currently programmed pacing lead configuration and RVAT is programmed on, the output will automatically be set to 2X that test's measured threshold (between 2.0 V and 5.0 V). The last 7 successful daily measurements are cleared and the current commanded test result is used as the first successful test of a new 7 test cycle (if the test is performed in the currently programmed pacing lead configuration). This is to ensure that there will be an immediate output adjustment based on the current commanded test result rather than on older ambulatory test data. This can be confirmed by observing the output voltage on the Brady Settings screen, which will show the actual operating voltage of the RVAT algorithm.

Backup pacing is delivered at 5.0 V approximately 70 ms after the primary pace for every loss of capture beat during commanded testing.

If testing is unsuccessful, the Threshold Tests screen will display the reason the test was not successful, and the output will return to the previously set level (Table 2-2 on page 2-22).

**NOTE:** For the initial Ventricular Threshold Test after the pulse generator is implanted, the Test Type field is seeded to Auto. Choose the desired test type from the Test Type field options, and adjust any other programmable values as appropriate.

### Test Results and Lead Alerts

A stored EGM for the most recent successful ambulatory test will be stored in the Arrhythmia Logbook ("Arrhythmia Logbook" on page 4-2). Refer to the Daily Measurements screen for the resulting threshold value. If desired, the stored EGM can be reviewed to determine where loss of capture occurred.

Up to 12 months of Ambulatory Threshold Test results, as well as test failure codes and lead alerts, can be found within the Daily Measurement and Trends screens. To provide further information on the reason for test failure, a failure code is provided for each day in which testing fails. Additionally, failure codes are provided on the Threshold Test screen if a commanded automatic threshold test does not complete successfully. Threshold Test Failure Codes are listed below (Table 2-2 on page 2-22).

The following scenarios will trigger the Check RV Lead alert:

- Threshold > Programmed Amplitude will be displayed if RVAT is in Daily Trend mode and the ambulatory test results of the last 4 consecutive days exceed the manually programmed fixed output.
- Automatic Threshold Suspension will be displayed if no successful tests are performed for 4 consecutive days in Auto or Daily Trend mode.

Table 2-2. Threshold Test Failure Codes

Code	Reason
N/R: device telem.	Telemetry started during an ambulatory test
N/R: comm. lost	Telemetry was lost during a commanded test
> 3.0 V	Threshold was measured between 3.5 V and 3.1 V for commanded or ambulatory tests
N/R: no capture	Capture was not obtained at the starting amplitude for commanded or ambulatory tests
N/R: mode switch	ATR either started or stopped (testing will not fail if ATR is already active and stays active during testing)
No data collected	Minimum pacing amplitude was reached without losing capture for an ambulatory test, or neither Auto nor Daily Trend is turned on to obtain an ambulatory test result
N/R: battery low	Test was skipped due to Battery Capacity Depleted
N/R: noise	Too many consecutive sense channel noise or Evoked Response noise cycles occurred
N/R: incompat. mode	Test failed due to being in an incompatible Brady mode (Magnet Mode)
N/R: rate too high	Rate was too high at the start of the test, or during testing
N/R: user cancelled	Commanded test was stopped by the user
N/R: intrinsic beats	Too many cardiac cycles occurred during the test
N/R: test delayed	Test was delayed due to telemetry being active, VT episode already in progress, Electrocautery mode, or RVAT was turned on while the device remained in Storage mode
N/R: respiration	Respiratory artifact was too high
N/R: low ER	The Evoked Response signal could not be assessed adequately
Auto N/R	Minimum pacing amplitude was reached without losing capture for a commanded test or telemetry is manually cancelled during a commanded test
Invalid Failure Code	Unexpected Failure

### PaceSafe Left Ventricular Automatic Threshold (LVAT)

This feature is available in VISIONIST devices.

PaceSafe LVAT is designed to dynamically adjust the left ventricular pacing output to ensure capture of the left ventricle using a programmable Safety Margin. LVAT will measure pacing thresholds from 0.2 V up to the programmable Maximum Amplitude (7.5 V maximum). The

output will be at a minimum amplitude of 1.0 V up to the programmable Maximum Amplitude of 7.5 V (with a programmable pulse width).

**NOTE:** LVAT is available in DDD(R), DDI(R), VDD(R), and VVI(R) modes, as well as during VDI(R) and DDI(R) Fallback Modes.

**NOTE:** LVAT is available in all bipolar and unipolar LV pacing configurations, but is not available in Quadripolar devices.

LVAT can be programmed on by selecting Auto from the Left Ventricular Amplitude parameter options. The Maximum Amplitude and Safety Margin can be programmed via the Pacing and Sensing Details button. The programmable Maximum Amplitude and Safety Margin are intended to allow the clinician to optimize the safety margin while also avoiding diaphragmatic stimulation. To determine an appropriate combination, it is recommended that testing be performed in multiple LV pacing configurations.

If starting from a fixed amplitude greater than the programmable maximum, program a lower amplitude prior to selecting Auto. Programming the left ventricular output to Auto will automatically set the left ventricular voltage output to the programmable Maximum Amplitude unless there is a successful test result within the last 24 hours.

**NOTE:** Prior to programming LVAT on, consider performing a Commanded Left Ventricular Automatic Threshold Measurement to verify that the feature functions as expected.

LVAT is designed to work with typical lead implant criteria and a left ventricular threshold between 0.2 V and the programmable Maximum Amplitude.

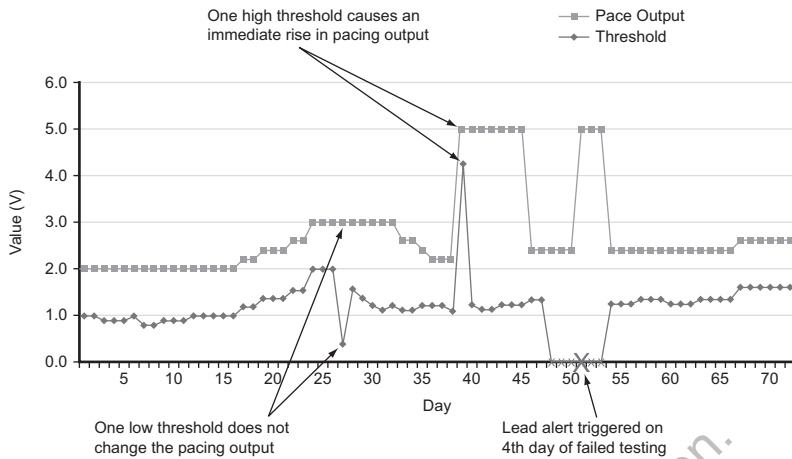
The LVAT algorithm then measures the left ventricular pacing threshold each day and adjusts the voltage output. During testing, LVAT uses an evoked response signal to confirm that each left ventricular pacing output captures the left ventricle. If the device is unable to repeatedly measure an evoked response signal of sufficient quality, an "Intrinsic Beats" or "Fusion Events" message may be displayed and the algorithm will default to the programmed Maximum Amplitude. Consider programming a fixed pacing amplitude in these situations and re-check with a Commanded LVAT test at a later follow-up; maturation of the lead-tissue interface may improve the performance of LVAT.

If testing is successful, the Left Ventricular Amplitude is adjusted by adding the programmable Safety Margin to the highest measured threshold of the last 7 successful ambulatory tests (between 1.0 V and the programmable Maximum Amplitude). Seven tests are used to account for circadian cycle effects on threshold and ensure an adequate safety margin. This also allows for a rapid increase in output due to a sudden rise in threshold while requiring consistently lower threshold measurements to decrease output (i.e. one low threshold measurement will not cause a decrease in output) (Figure 2-9 on page 2-24).

**NOTE:** Since output is set with a programmable Safety Margin, there is no beat-to-beat capture verification.

When Daily Trend is selected along with a fixed Amplitude, automatic left ventricular threshold measurements will occur every 21 hours with no change to programmed output.

The LVAT feature is designed to operate with a large range of pacing leads (e.g., high impedance, low impedance) and is independent of the Pace and Sense lead configuration. If a Lead Safety Switch occurs, the last 7 successful daily measurements are cleared and LVAT will operate in a Unipolar configuration.



**Figure 2-9. Effect of threshold changes on LVAT pacing output (with a programmable Maximum Amplitude of 5.0 V and Safety Margin of 1.0 V)**

### Ambulatory Left Ventricular Automatic Threshold Measurement

When LVAT is set to Auto or Daily Trend, ambulatory left ventricular automatic threshold measurements are conducted every 21 hours.

In atrial tracking modes, the automatic threshold measurement adjusts the following parameters to help ensure a valid measurement is obtained:

- Paced AV Delay is fixed at 140 ms.
- Sensed AV Delay is fixed at 110 ms.
- RV pacing is provided as backup throughout LV testing with an applied LV Offset of -80 ms.
- Starting left ventricular pacing output amplitude is the programmable Maximum Amplitude.
- The pacing amplitude will decrement in 0.5 V steps above 3.5 V and in 0.1 V steps at or below 3.5 V.

In nontracking modes, the automatic threshold measurement adjusts the following parameters to help ensure a valid measurement is obtained:

- Paced AV Delay is fixed at 140 ms.
- RV pacing is provided as backup throughout LV testing with an applied LV Offset of -80 ms.
- Starting left ventricular pacing output amplitude is the programmable Maximum Amplitude.
- The pacing amplitude will decrement in 0.5 V steps above 3.5 V and in 0.1 V steps at or below 3.5 V.
- The ventricular pacing rate will be increased by 10 min<sup>-1</sup> above the current rate (paced or intrinsic) and is capped at the lowest of the MPR, MSR, 110 min<sup>-1</sup>, or 5 min<sup>-1</sup> below the lowest VT Detection Rate.

Following initialization paces, the pulse generator will decrement the left ventricular output every 3 paces until a threshold is determined. Additional pacing pulses will be issued if there is fusion or intermittent loss of capture. Threshold is declared as the previous output level that demonstrated consistent capture.



If daily testing is unsuccessful, LVAT will return to the previously determined output and the device will perform up to 3 re-attempts at hourly intervals. If a successful test does not occur for 4 days, a Lead Alert will be triggered and LVAT will enter Suspension.

### Left Ventricular Automatic Threshold Suspension

If ambulatory testing fails in Auto mode for 4 consecutive days, LVAT will go into a Suspension mode and the pacing output will operate at the programmable pulse width and Maximum Amplitude. Testing will continue each day with up to 3 re-attempts to evaluate thresholds and the pulse generator will adjust to a lower output setting when indicated by a successful test.

Although LVAT is designed to work with a wide range of leads, in some patients the lead signals may hinder successful determination of the left ventricular threshold. In these instances, LVAT will continually operate in the Suspension mode at the programmable Maximum Amplitude. In situations where Suspension mode persists for an extended period of time, it is recommended to turn LVAT off by programming a fixed left ventricular output.

### Commanded Left Ventricular Automatic Threshold Measurement

An automatic threshold measurement can be commanded via the Threshold Tests screen by selecting Auto Amplitude as the Test Type. If testing completes successfully in the currently programmed pacing lead configuration and LVAT is programmed on, the output will automatically be set by adding the programmable Safety Margin to that test's measured threshold (between 1.0 V and the programmable Maximum Amplitude). The last 7 successful daily measurements are cleared and the current commanded test result is used as the first successful test of a new 7 test cycle (if the test is performed in the currently programmed pacing lead configuration). This is to ensure that there will be an immediate output adjustment based on the current commanded test result rather than on older ambulatory test data. This can be confirmed by observing the output voltage on the Brady Settings screen, which will show the actual operating voltage of the LVAT algorithm.

RV pacing is provided as backup throughout LV testing with an applied LV Offset of -80 ms.

If testing is unsuccessful, the Threshold Tests screen will display the reason the test was not successful, and the output will return to the previously set level (Table 2-3 on page 2-26).

**NOTE:** For the initial Ventricular Threshold Test after the pulse generator is implanted, the Test Type field is seeded to Auto. Choose the desired test type from the Test Type field options, and adjust any other programmable values as appropriate.

### Test Results and Lead Alerts

A stored EGM for the most recent successful ambulatory test will be stored in the Arrhythmia Logbook ("Arrhythmia Logbook" on page 4-2). Refer to the Daily Measurements screen for the resulting threshold value. If desired, the stored EGM can be reviewed to determine where loss of capture occurred.

Up to 12 months of Ambulatory Threshold Test results, as well as test failure codes and lead alerts, can be found within the Daily Measurement and Trends screens. To provide further information on the reason for test failure, a failure code is provided for each day in which testing fails. Additionally, failure codes are provided on the Threshold Test screen if a commanded automatic threshold test does not complete successfully. Threshold Test Failure Codes are listed below (Table 2-3 on page 2-26).

The following scenarios will trigger the Check LV Lead alert:

- Threshold > Programmed Amplitude will be displayed if LVAT is in Daily Trend mode and the ambulatory test results of the last 4 consecutive days exceed the manually programmed fixed output.

- Automatic Threshold Suspension will be displayed if no successful tests are performed for 4 consecutive days in Auto or Daily Trend mode.

Table 2-3. Threshold Test Failure Codes

Code	Reason
N/R: device telem.	Telemetry started during an ambulatory test
N/R: comm. lost	Telemetry was lost during a commanded test
N/R: no capture	Capture was not obtained at the starting amplitude
N/R: mode switch	ATR either started or stopped (testing will not fail if ATR is already active and stays active during testing)
No data collected	Minimum pacing amplitude was reached without losing capture, neither Auto nor Daily Trend is turned on to obtain an ambulatory test result, or an inadequate number of initialization paces occurred
N/R: battery low	Test was skipped due to Battery Capacity Depleted
N/R: noise	Too many consecutive sense channel noise cycles occurred
N/R: incompat. mode	Test failed due to being in an incompatible Brady mode (Magnet Mode)
N/R: rate too high	Rate was too high at the start of the test, or during testing
N/R: user cancelled	Commanded test was stopped by the user
N/R: intrinsic beats	Too many cardiac cycles occurred during the test or initialization restarted too many times
N/R: test delayed	Test was delayed due to telemetry being active, VT episode already in progress, Electrocautery mode, or LVAT was turned on while the device remained in Storage mode
Auto N/R	Minimum pacing amplitude was reached without losing capture for a commanded test or telemetry is manually cancelled during a commanded test
N/R: fusion events	Test failed due to too many consecutive fusion beats

## Sensitivity

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Sensitivity feature can be programmed to either AGC or Fixed Sensing. The Sensitivity feature allows the pulse generator to detect intrinsic cardiac signals that exceed the programmed Fixed Sensitivity value or the dynamically increasing sensitivity of AGC. Adjusting the Sensitivity value shifts the atrial and/or ventricular sensing range to higher or lower sensitivity. Detection and timing decisions are based on the sensed cardiac signals. Although the atrial and ventricular Sensitivity values are independently programmable, the type of sensing method used (AGC or Fixed) must be the same for all chambers.

- High Sensitivity (low programmed value)—when Sensitivity is programmed to a very sensitive setting, the pulse generator may detect signals unrelated to cardiac depolarization (oversensing, such as sensing of myopotentials)
- Low Sensitivity (high programmed value)—when Sensitivity is programmed to a less sensitive setting, the pulse generator may not detect the cardiac depolarization signal (undersensing)

**CAUTION:** When a single pass VDD lead is used with a dual-chamber device, the atrial electrodes may not be in contact with the atrial wall. In this case, the measured depolarization signal has a relatively low Amplitude and could require a more sensitive setting.

**WARNING:** Left ventricular lead dislodgement to a position near the atria can result in atrial oversensing and left ventricular pacing inhibition.

Should it become necessary to adjust the Sensitivity parameter in a chamber, always choose the setting that provides appropriate sensing of intrinsic activity and best resolves oversensing/undersensing.

If proper sensing cannot be restored with an adjustment or if any undersensing or oversensing is observed after making a change, consider any of the following (taking into account individual patient characteristics):

- Reprogram the Sensing Method from Fixed to AGC or from AGC to Fixed

**NOTE:** *The Sensing Method selected applies to all chambers. When changing the Sensing Method, verify appropriate sensing in all chambers.*

- Reprogram the AGC or Fixed sensitivity value
- Evaluate the sensing lead configuration (Unipolar versus Bipolar or Bipolar versus Unipolar)
- Reprogram the Refractory or cross-chamber blanking period appropriately to address the observed undersensing or oversensing
- Reposition the lead
- Implant a new sensing lead

After any change to Sensitivity, evaluate the pulse generator for appropriate sensing and pacing.

**CAUTION:** Following any Sensitivity parameter adjustment or any modification of the sensing lead, always verify appropriate sensing. Programming Sensitivity to the highest value (lowest sensitivity) may result in undersensing of cardiac activity. Likewise, programming to the lowest value (highest sensitivity) may result in oversensing of non-cardiac signals.

### Unipolar Sensing

When the unipolar sensing configuration is programmed, the cardiac signals are detected between the lead tip and the pulse generator case. In the unipolar sensing configuration, the pacemaker can generally discern smaller intrinsic cardiac signals than in the bipolar configuration. However, the unipolar configuration is also more sensitive to myopotentials. In bipolar configurations, due to the relatively short distance between the tip and ring electrodes, sensitivity is highest for signals originating in the proximity of the lead tip and ring. As a result, the pulse generator is less likely to sense myopotentials and other signals unrelated to cardiac depolarization.

**NOTE:** *Consider using Fixed Sensing instead of AGC for patients who are pacemaker-dependent or have leads programmed to unipolar.*

**NOTE:** *Blanking Period behavior will vary depending on which Lead Configuration is selected. Refer to cross-chamber blanking for more details ("Cross-Chamber Blanking" on page 2-77).*

**CAUTION:** The amplitude and prevalence of myopotential noise is increased in unipolar lead configurations, as compared to bipolar lead configurations. For patients with a unipolar lead configuration and myopotential oversensing during activity involving the pectoral muscles, the programming of Fixed Sensitivity is recommended.

### Automatic Gain Control

The pulse generator has the option to use digital Automatic Gain Control (AGC) to dynamically adjust the sensitivity in both the atrium and the ventricle. The pulse generator has independent AGC circuits for each chamber. Selection of the AGC Sensing Method applies that method to all chambers.

Cardiac signals can vary widely in size and rate; therefore the pulse generator needs the ability to:

- Sense an intrinsic beat, regardless of rate or size
- Adjust to sense varying amplitude signals, but not overreact to aberrant beats
- Sense any intrinsic activity after a paced beat
- Ignore T-waves
- Ignore noise

The programmable AGC value is the minimum sensitivity value (floor) that could be reached between one beat and the next beat. This programmable value is not a fixed value present throughout the cardiac cycle; rather, the sensitivity level begins at a higher value (based on the peak of a sensed event or a fixed value for a paced event) and decrements towards the programmed floor (Figure 2-10 on page 2-29).

With Fixed Sensing, signal amplitudes below the Fixed Sensitivity setting will not be sensed, whether during pacing or sensing. In contrast, AGC will typically reach the programmable floor during pacing (or with low amplitude signals). But when moderate or high amplitude signals are sensed, AGC will typically be less sensitive and not reach the programmable floor.

The AGC circuit in each respective chamber processes an electrogram signal via a two step process to optimize sensing of potentially rapidly changing cardiac signals. The process is illustrated in the figure below (Figure 2-10 on page 2-29):

- First step
  1. AGC uses a rolling average of previous signal peaks to calculate a search area where the next peak will likely occur.
    - If the previous beat is sensed, it is incorporated into the rolling peak average.
    - If the previous beat is paced, the peak average is calculated using the rolling average and a paced peak value. The paced peak value depends on the settings:
      - For nominal or more sensitive settings, it is a fixed value (initial value 4.8 mV in the RV, 8 mV in the LV, 2.4 mV in the RA).
      - For less sensitive settings, it is a higher value calculated using the programmed AGC floor value (for example, if RV sensitivity is programmed to the least sensitive setting or the highest value of 1.5 mV, the paced peak value = 12 mV).

The peak average is then used to bound an area with MAX (maximum) and MIN (minimum) limits.

- Second step
  2. AGC senses the peak of the intrinsic beat (or uses the calculated peak for a paced beat as described above).
  3. It holds the sensitivity level at the peak (or MAX) through the absolute refractory period + 15 ms.
  4. It drops to 75% of the sensed peak or calculated peak average for paced events (ventricular paced events only).
  5. AGC becomes more sensitive by 7/8 of the previous step.
  6. Sensed beat steps are 35 ms for the RV and LV and 25 ms for the atrium. Paced beat steps are adjusted based on the pacing interval to ensure an approximately 50 ms sensing window at the MIN level.
  7. It reaches the MIN (or programmed AGC floor).
  - The programmed AGC floor will not be reached if the MIN value is higher.
  8. The AGC remains at the MIN (or programmed AGC floor) until a new beat is sensed, or the pacing interval times out and a pace is delivered.

**NOTE:** If a new beat is sensed as the sensitivity level steps down, AGC starts over at Step 1.

**NOTE:** If the amplitude of a signal is below the sensitivity threshold in effect at the time the signal occurs, it will not be sensed.

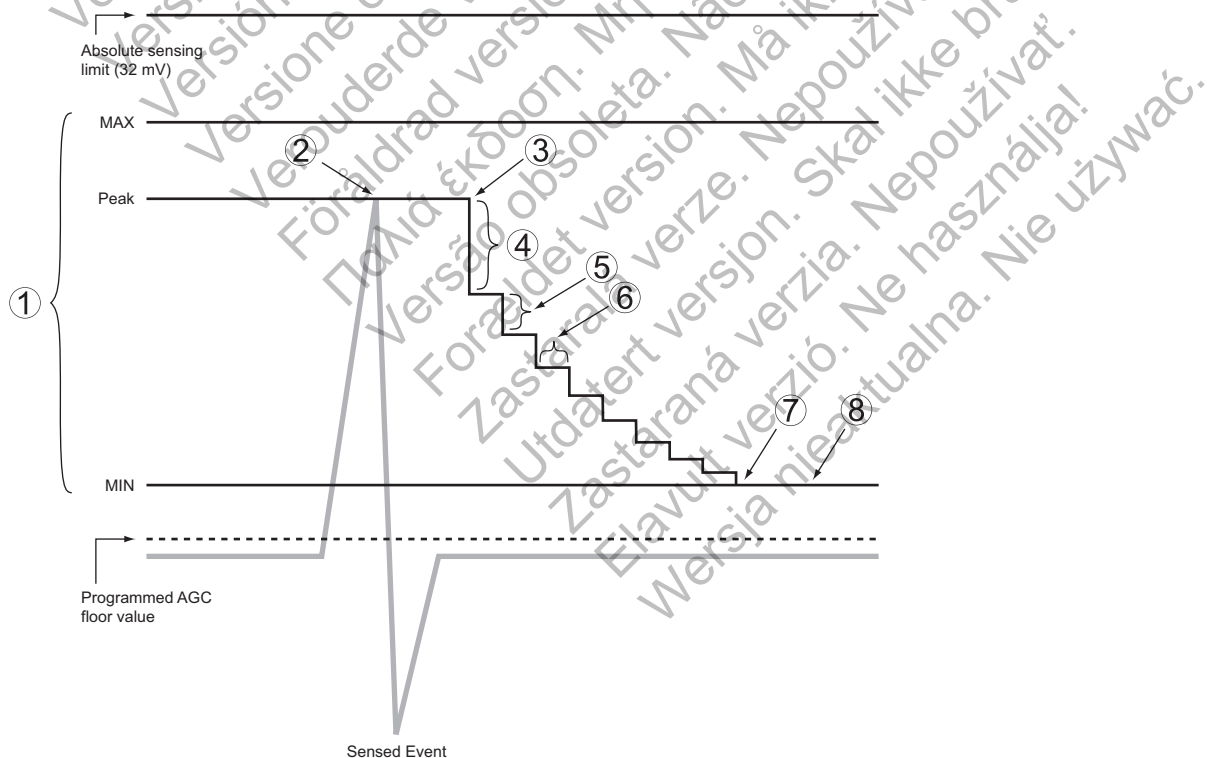


Figure 2-10. AGC sensing

A nonprogrammable Dynamic Noise Algorithm is active in rate channels where AGC sensing is used. The Dynamic Noise Algorithm is intended to help filter out persistent noise. The Dynamic Noise Algorithm is a separate noise channel for each chamber that continuously measures the baseline signal that is present and is designed to adjust the sensitivity floor to minimize the effects of noise.

The algorithm uses the characteristics of a signal (frequency and energy) to classify it as noise. When persistent noise is present, the algorithm is designed to minimize its impact, which may help to prevent oversensing myopotentials and the associated inhibition of pacing. Noise that affects the sensing floor may be visible on the intracardiac EGMs, but would not be marked as sensed beats. However, if the noise is significant, the floor may rise to a level above the intrinsic electrogram and the programmed Noise Response behavior (asynchronous pacing or Inhibit Pacing) will occur ("Noise Response" on page 2-82).

**NOTE:** *The Dynamic Noise Algorithm does not ensure that AGC will always accurately distinguish intrinsic activity from noise.*

### Fixed Sensing

With Fixed Sensing, the Sensitivity value will not dynamically adjust as in AGC, and the Dynamic Noise Algorithm is not utilized. Presence of persistent noise will result in the programmed Noise Response behavior: asynchronous pacing or Inhibit Pacing ("Noise Response" on page 2-82). For manual programming, Sensitivity must be programmed to a value that prevents sensing of extraneous signals, but ensures accurate sensing of intrinsic cardiac signals. Signals with an amplitude below the Fixed Sensitivity setting will not be sensed.

**WARNING:** If programmed to a fixed atrial Sensitivity value of 0.15 mV, or a fixed sensitivity value of 2.0 mV or less in a unipolar lead configuration in any chamber, the pulse generator may be more susceptible to electromagnetic interference. This increased susceptibility should be taken into consideration when determining the follow-up schedule for patients requiring such a setting.

## TEMPORARY BRADY PACING

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The pulse generator can be programmed with temporary pacing parameter values that differ from the programmed Normal Settings. This allows you to examine alternate pacing therapies while maintaining the previously programmed Normal Settings in the pulse generator memory. During the Temporary function, all other bradycardia features not listed on the screen are disabled.

To use this function, follow these steps:

1. From the Tests tab, select the Temp Brady tab to display the temporary parameters.
2. Select the desired values; these values are independent from other pacing functions.

**NOTE:** *Temporary Brady interactive limits must be corrected before Temporary pacing can occur.*

**NOTE:** *If Off is selected as the Temporary Brady Mode, the pulse generator will not sense or pace while Temporary pacing mode is in effect.*

3. Establish telemetry communication, then select the Start button. Pacing begins at the temporary values. A dialog box indicates that temporary parameters are being used, and a Stop button is provided.

**NOTE:** *Temporary pacing cannot be started while a tachyarrhythmia episode is in progress.*

**NOTE:** Emergency therapy is the only function that can be initiated until the Temporary function is stopped.

4. To stop the Temporary pacing mode, select the Stop button. The Temporary pacing mode also stops when you command emergency therapy from the PRM, when you press the DIVERT THERAPY key, or if telemetry is lost.

Once Temporary pacing mode is stopped, pacing reverts to the previously programmed Normal settings.

## RATE ADAPTIVE PACING AND SENSOR TRENDING

### Rate Adaptive Pacing

In rate adaptive pacing modes (i.e., any mode ending with R), sensors are used to detect changes in the patient's activity level and/or physiologic demand and increase the pacing rate accordingly. Rate adaptive pacing is intended for patients who exhibit chronotropic incompetence and who would benefit from increased pacing rates that are concurrent with increased activity level and/or physiologic need.

The device can be programmed to use the Accelerometer, Minute Ventilation, or a blend of both. The clinical benefit of rate adaptive pacing using either of these sensors has been shown in previous clinical studies.

**CAUTION:** Rate Adaptive Pacing should be used with care in patients who are unable to tolerate increased pacing rates.

When rate adaptive parameters are programmed, the pacing rate increases in response to increased activity level and/or physiologic need, then decreases as appropriate.

**NOTE:** Activity involving minimal upper body motion, such as bicycling, may result in only a moderate pacing response from the accelerometer.

**CAUTION:** The clinical benefit of Rate Adaptive Pacing in heart failure patients has not been studied. Rate Adaptive Pacing should be used with medical discretion if the patient develops an indication such as chronotropic incompetence. Patients with heart failure may have hemodynamic compromise at rapid sensor-driven rates, and the physician may wish to program less aggressive rate adaptive parameters in accordance with patient condition. Rate Adaptive Pacing may be helpful for heart failure patients with coexisting bradyarrhythmic conditions. It is not recommended for patients who exhibit only heart failure-induced chronotropic incompetency.

### Accelerometer

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Motion-Based Pacing uses an accelerometer to detect motion that is associated with a patient's physical activity and generates an electronic signal that is proportional to the amount of body motion. Based on accelerometer input, the pulse generator estimates the patient's energy expenditure as a result of exercise, then translates it into a rate increase.

The pulse generator senses body motion by means of an integrated circuit accelerometer. The accelerometer sensor responds to activity in the frequency range of typical physiologic activity (1–10 Hz). The accelerometer evaluates both the frequency and the amplitude of the sensor signal.

- Frequency reflects how often an activity occurs (e.g., the number of steps taken per minute during a brisk walk)

- Amplitude reflects the force of motion (e.g., the more deliberate steps taken while walking)

Once detected, an algorithm translates the measured acceleration into a rate increase above the LRL.

Because the accelerometer is not in contact with the pulse generator case, it does not respond to simple static pressure on the device case.

There are three Accelerometer settings: On, Passive, and ATR Only. If the pulse generator is permanently programmed to a non-rate adaptive mode, it is possible to program the ATR Fallback mode to an adaptive-rate mode using the accelerometer sensor. In this case, the Accelerometer field will display ATR Only. If Passive is selected, the Accelerometer will not provide rate response but will continue to collect data for Sensor Trending.

The following programmable parameters control the pulse generator’s response to the sensor values generated by the Accelerometer:

- Response Factor
- Activity Threshold
- Reaction Time
- Recovery Time

**Response Factor (Accelerometer)**

Response Factor (accelerometer) determines the pacing rate increase that will occur above the LRL at various levels of patient activity (Figure 2-11 on page 2-32).

- High Response Factor—results in less activity required for the pacing rate to reach the MSR
- Low Response Factor—results in more activity required for the pacing rate to reach the MSR

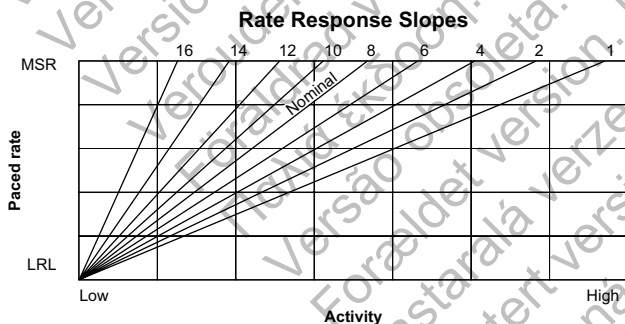
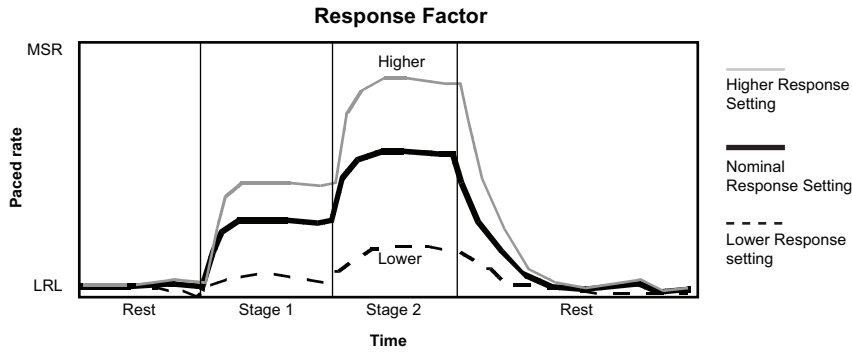


Figure 2-11. Response Factor and paced rate

The pacing rate achieved can be limited either by the detected activity level or the programmed MSR. If the detected activity level results in a steady-state rate below the MSR, the pacing rate can still increase when the detected activity levels increase (Figure 2-12 on page 2-33). The steady-state response is independent of the programmed reaction and recovery times.





This figure shows the effect of higher and lower settings during a theoretical two-stage exercise test.

**Figure 2-12. Response Factor in exercise test**

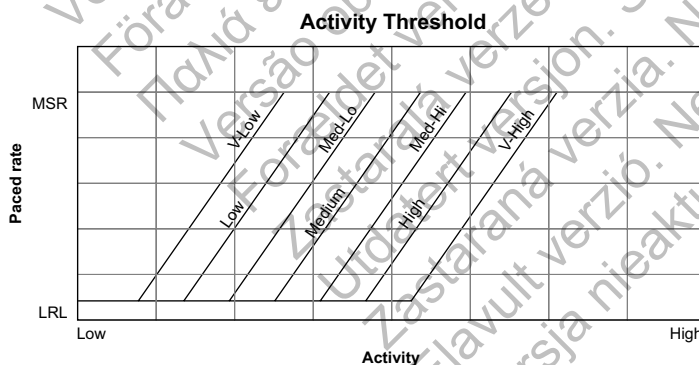
Programming the LRL up or down moves the entire response up or down without changing its shape.

**Activity Threshold**

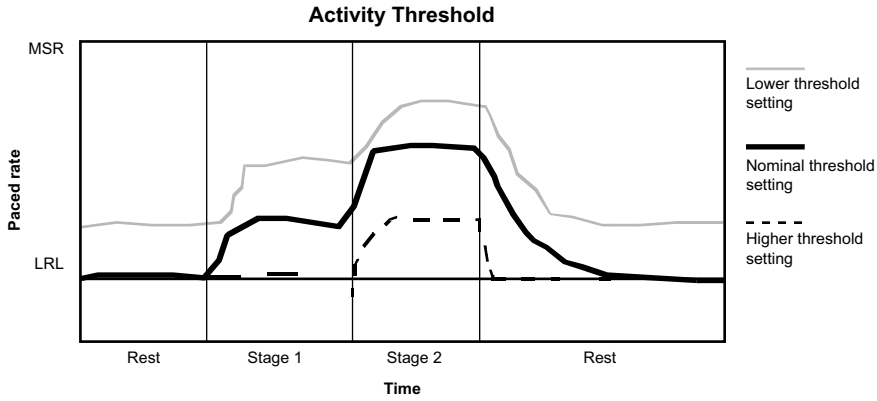
Activity Threshold prevents rate increases due to low-intensity, extraneous motion (e.g., motion caused by respiration, heart beat, or in some cases tremor associated with Parkinson’s disease).

Activity Threshold represents the activity level that must be exceeded before the sensor-driven pacing rate will increase. The pulse generator will not increase the paced rate above the LRL until the activity signal increases above the Activity Threshold. An Activity Threshold setting should allow a rate increase with minor activity, such as walking, but be high enough so the pacing rate will not increase inappropriately when the patient is inactive (Figure 2-13 on page 2-33 and Figure 2-14 on page 2-34).

- Lower setting—less motion is required to increase the pacing rate
- Higher setting—more motion is required to increase the pacing rate



**Figure 2-13. Activity Threshold and rate response**



This figure demonstrates the effect of increased or decreased Activity Threshold settings in response to a theoretical two-stage exercise test.

Figure 2-14. Activity Threshold in exercise test

**Reaction Time**

Reaction Time determines how quickly the pacing rate will rise to a new level once an increase in activity level is detected.

Reaction Time affects only the time required for a rate increase to occur. The value selected determines the time required for the paced rate to move from the LRL to the MSR for a maximum level of activity (Figure 2-15 on page 2-34 and Figure 2-16 on page 2-34).

- Short Reaction Time: results in a rapid increase in the pacing rate
- Long Reaction Time: results in a slower increase in the pacing rate

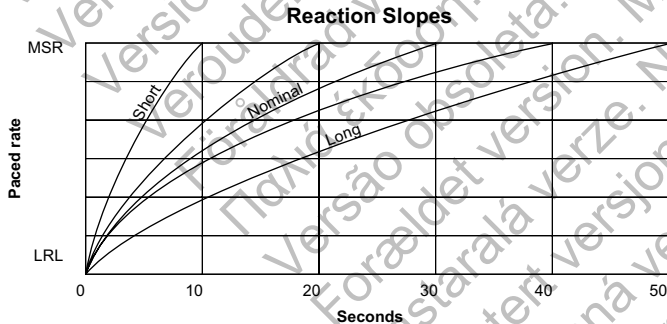


Figure 2-15. Reaction Time and paced rate

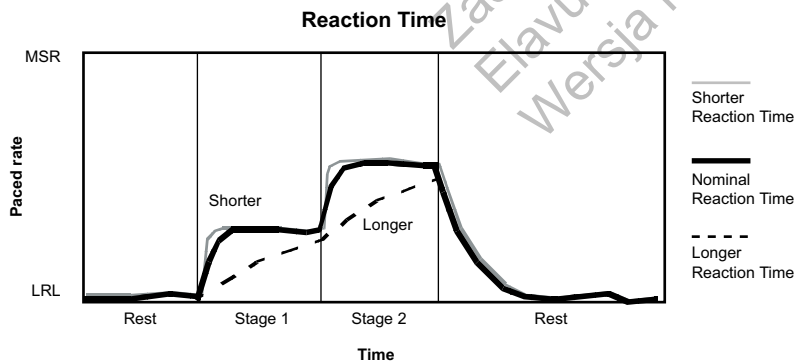
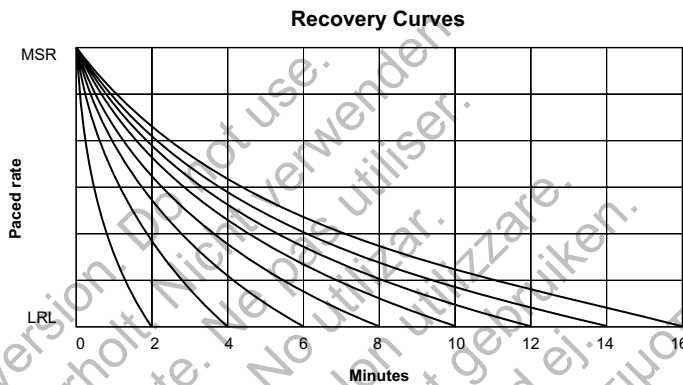


Figure 2-16. Reaction Time in exercise test

### Recovery Time

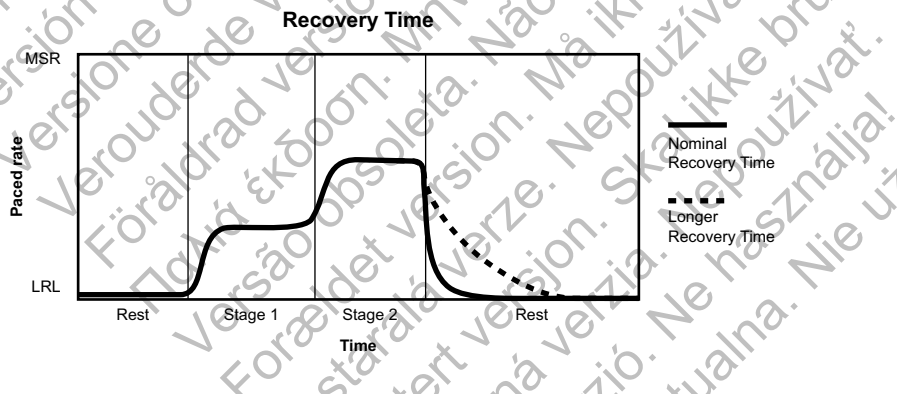
Recovery Time determines the time required for the paced rate to decrease from the MSR to the LRL in the absence of activity. When patient activity concludes, Recovery Time is used to prevent an abrupt decrease in pacing rate (Figure 2-17 on page 2-35 and Figure 2-18 on page 2-35).

- Short Recovery Time—results in a faster decrease in pacing rate after patient activity lowers or stops
- Long Recovery Time—results in a slower decrease in pacing rate after patient activity lowers or stops



There are 15 settings available; only the even-numbered settings are shown.

Figure 2-17. Recovery Time and paced rate



The figure shows the effect of higher and lower settings during a theoretical two-stage exercise test.

Figure 2-18. Recovery Time in exercise test

### Minute Ventilation (MV)

This feature is available in VISIONIST and INLIVEN devices.

The pulse generator uses transthoracic impedance to measure minute ventilation (MV), which is the product of respiration rate and tidal volume. Based on the MV measurement, the pulse generator calculates the sensor-indicated rate.

**CAUTION:** Do not program the MV sensor to On until after the pulse generator has been implanted and system integrity has been tested and verified.

Approximately every 50 ms (20 Hz), the device will deliver a current excitation waveform between the RA Ring electrode and Can (primary vector) or the RV Ring electrode and Can (secondary vector). Since either lead may be used to measure MV, at least one of the implanted leads must have normal bipolar lead impedances.

**NOTE:** *If an RA lead is not used, only the secondary vector is available.*

**NOTE:** *Leads may be programmed Unipolar or Bipolar, but either Lead Configuration or Patient Information must indicate that a bipolar lead is present.*

Inductive (wanded) telemetry may temporarily interfere with the pulse generator's MV sensor function. MV driven rates may hold at the current rate for approximately one minute immediately following any interrogation or programming command. This period will be indicated by a Sensor Status of Rate Hold: Telemetry (Table 2-4 on page 2-39). If a significant amount of data (for example, Arrhythmia Logbook episodes) is being retrieved from the device, the MV driven rate may then decrease to the LRL and further rate changes may not occur for several additional minutes. This time period will be indicated by a Sensor Status of Suspended: Telemetry (Table 2-4 on page 2-39).

If MV driven rate changes are desired prior to the rate hold or suspension periods, allow the MV driven rate to reach the desired rate prior to using inductive telemetry, or use RF telemetry to communicate with the device.

**CAUTION:** Any medical equipment, treatment, therapy, or diagnostic test that introduces electrical current into the patient has the potential to interfere with pulse generator function.

- External patient monitors (e.g., respiratory monitors, surface ECG monitors, hemodynamic monitors) may interfere with the pulse generator's impedance-based diagnostics (e.g., Respiratory Rate trend). This interference may also result in accelerated pacing, possibly up to the maximum sensor-driven rate, when MV is programmed to On. To resolve suspected interactions with the MV sensor, deactivate the sensor either by programming it to Off (no MV rate driving or MV sensor-based trending will occur), or Passive (no MV rate driving will occur). Alternatively, program the Brady Mode to a non-rate responsive mode (no MV rate driving will occur). If a PRM is not available and the pulse generator is pacing at the sensor-driven rate, apply a magnet to the pulse generator to initiate temporary asynchronous, non-rate responsive pacing.

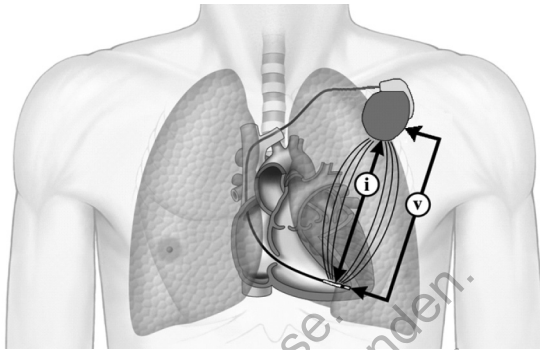
To resolve suspected interactions with Respiratory Sensor-based diagnostics, deactivate the pulse generator's Respiratory Sensor by programming it to Off.

During MV function, the active vector may be the primary vector (RA Ring electrode to Can) or secondary vector (RV Ring electrode to Can). Lead impedances for the active vector are evaluated each hour to assess lead integrity. If the active vector values are out of range, impedances for the alternate vector are evaluated to determine if that vector can be utilized for MV. If both the primary and secondary vectors are out of range, the sensor is suspended for the next one hour. Lead integrity will continue to be tested every hour to evaluate if the MV signal will use the primary vector, the secondary vector, or remain suspended. Acceptable lead impedance values are 200–2000  $\Omega$  for the tip to can vector and 100–1500  $\Omega$  for the ring to can vector.

If a vector switch occurs, an automatic 6-hour calibration will occur (no MV-driven rate response occurs during the 6-hour calibration period).

The application of current between the ring electrode and the can will create an electrical field across the thorax, modulated by respiration. During inspiration the transthoracic impedance is high, and during expiration it is low. The device will measure the resulting voltage modulations between the lead tip electrode and the can.

**CAUTION:** If MV/Respiratory Sensor signal artifacts are observed on EGMs, and the leads are otherwise shown to be performing appropriately, consider programming the sensor to Off to prevent oversensing.

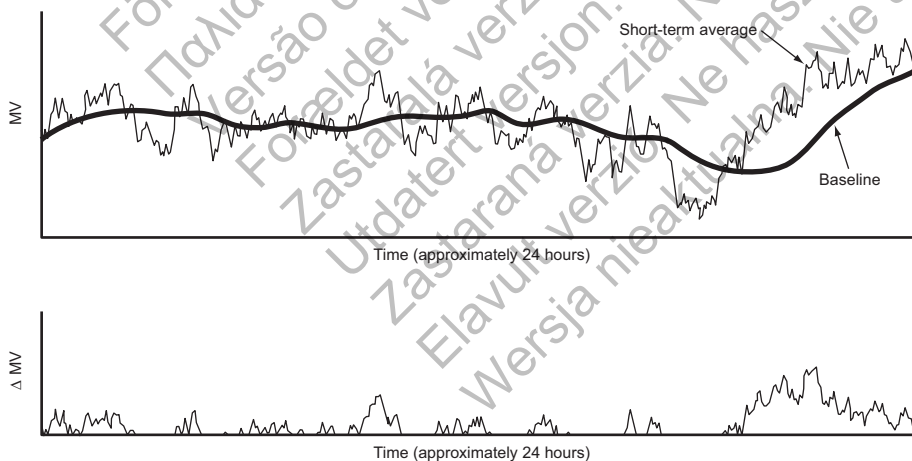


i = current, V = volts

**Figure 2-19. Measurement of the MV signal from the RV lead**

Due to advanced filtering, the algorithm supports breathing rates up to 72 breaths per minute. The filtered waveform is then processed to obtain the total volume measurement. The average excitation current that is delivered to the tissue is 320  $\mu\text{A}$ . If the noise becomes excessive, the MV sensor will be suspended until the noise level decreases. The excitation waveform is a balanced low amplitude signal that will not distort surface ECG recordings. On some ECG monitoring equipment, the waveforms may be detected and displayed. These waveforms are present only when the MV sensor is used.

The pulse generator keeps a long-term moving average (baseline) of these measurements (updated every 4 minutes) as well as a short-term (approximately 30-second) moving average, which is updated every 7.5 seconds. The magnitude of the difference between the short-term average and long-term baseline determines the magnitude of the rate increase over the LRL, or decrease down to the LRL. The increase or decrease in the sensor-indicated rate occurs at a maximum of 2  $\text{min}^{-1}$  per cycle (Figure 2-20 on page 2-37).



Top: The baseline (long-term average) follows the drift of the short-term average. Bottom: The difference between the short- and long-term average is used for increasing the sensor-driven rate upon exertion.

**Figure 2-20. Difference between MV short-term average and MV baseline**

**NOTE:** Whenever a magnet is applied and the Magnet Response has been programmed to Pace Async, the pacemaker will pace asynchronously at the magnet rate and will not respond to MV data.

**CAUTION:** Program the MV/Respiratory Sensor to Off during mechanical ventilation. Otherwise, the following may occur:

- Inappropriate MV sensor-driven rate
- Misleading respiration-based trending

For optimal rate response, a variety of Minute Ventilation parameters can be programmed via the RightRate Pacing area on the Rate Adaptive Pacing Settings screen.

To activate the MV sensor, the system needs a measure of the baseline or resting MV. Methods for calibration include:

- **Automatic Calibration.** An automatic, 6-hour calibration will occur whenever MV is programmed to On or Passive. No MV-driven rate response or hourly lead integrity checks will occur during the 6-hour calibration time.
  - For VISIONIST devices, if MV is programmed to On at implant, the first hourly lead check with acceptable lead impedance values will begin a 2-hour wait period followed by the 6-hour calibration. This 2-hour period will be indicated by a sensor status of Initializing and is intended to allow the implantation procedure to be completed.
  - For INLIVEN devices, if MV is programmed to On at implant there is a 2-hour wait period after lead attachment, followed by the 6-hour calibration. This 2-hour period will be indicated by a sensor status of Suspended and is intended to allow the implantation procedure to be completed.
- **Manual Calibration.** Whenever MV is programmed On, (including during the 2-hour period following lead attachment) the sensor can be calibrated manually. From the RightRate Pacing Details screen, select the Start Sensor Calibration button to initiate the manual calibration process. If the calibration is successful, MV-driven rate response takes effect within one minute. Manual calibration may take as little as 2 minutes or as much as 5 minutes to complete, depending on whether noise is encountered during data collection. The patient should be resting quietly and breathing normally for a few minutes prior to and during the manual calibration. If the manual calibration fails due to noise, it will be indicated by a Suspended: Noise Detected sensor status and the 6-hour automatic calibration will automatically begin.
  - For VISIONIST devices, if the manual calibration fails due to no valid MV lead vector (indicated by a sensor status of Suspended: No Valid Lead) the pulse generator will continue to check for a valid vector every hour and will start the 6-hour calibration once a valid vector is detected.
  - For INLIVEN devices, if the manual calibration fails due to no valid MV lead vector (indicated by a sensor status of Suspended) the pulse generator will continue to check for a valid vector every hour and will start the 6-hour calibration once a valid vector is detected.

**NOTE:** The Manual Calibration method will not be available upon initial interrogation while information such as Arrhythmia Logbook episodes are retrieved from the device. This will be indicated by a dimmed Start Sensor Calibration icon and may occur for seconds to minutes depending on the amount of data being retrieved.

There is no clinical difference between the Automatic and the Manual calibration methods. A successful Manual calibration simply allows a baseline to be obtained and MV-driven

rate response to begin immediately. Neither calibration method requires that telemetry communication be maintained for the duration of the calibration.

**CAUTION:** To obtain an accurate MV baseline, the MV sensor will be calibrated automatically or can be calibrated manually. A new, manual calibration should be performed if the pulse generator is removed from the pocket following implant, such as during a lead repositioning procedure, or in cases where the MV baseline may have been affected by factors such as lead maturation, air entrapment in the pocket, pulse generator motion due to inadequate suturing, external defibrillation or cardioversion, or other patient complications (e.g., pneumothorax).

The PRM will display one of the messages below to indicate the current MV Sensor Status on the RightRate Pacing Details screen (Figure 2-23 on page 2-40).

The messages are all updated in real-time for VISIONIST devices. The messages of Suspended: Noise Detected, Suspended: Telemetry and Rate Hold: Telemetry are updated real-time while the remainder are updated upon interrogation for INLIVEN devices.

Table 2-4. MV Sensor Status Messages

Sensor Status	MV Sensor Driven Pacing	MV Sensor Data Collection <sup>a</sup>
Off	No	No
Initializing (VISIONIST devices)	No	No
Manual Calibration in Progress	No	Yes
Auto Calibration in Progress	No	Yes
Calibrated	Yes <sup>b</sup>	Yes
Suspended	No	No
Suspended: No Valid Lead (VISIONIST devices)	No	No
Suspended: Noise Detected	No	Yes
Suspended: Telemetry	No	Yes
Rate Hold: Telemetry	No <sup>c</sup>	Yes

- a. Individual Trends determine if data collected during Suspension is valid and incorporated into Trend results.
- b. If the MV Sensor is programmed to Passive, MV sensor driven pacing will not occur.
- c. Rate will hold at the current MV indicated value for up to one minute; further MV based rate changes will not occur with this sensor status.

There are four Minute Ventilation settings: On, Off, Passive, and ATR Only. If the pulse generator is permanently programmed to a non-rate adaptive mode, but a rate adaptive ATR fallback mode is selected, the MV field will display ATR Only. If programmed to a non-rate adaptive mode, the 'On' setting is not available. If Passive is selected, the MV sensor will not provide rate response but will continue to collect data for use by other features (e.g., Sensor Trending).

**Response Factor (Minute Ventilation)**

An increase in MV over baseline due to an increase in metabolic demand will be detected by the pulse generator and converted by its algorithm into an increased pacing rate. The relationship between the detected increase in MV and the resulting increase in the sensor-indicated rate is established by the MV Response Factor.

The Response Factor parameter determines the pacing rate that will occur above the LRL at various elevated levels of MV. Larger response factor values will result in higher sensor rates for a given MV level (Figure 2-21 on page 2-40). The effects of higher and lower Response Factor settings on sensor-driven pacing rate during a theoretical two-stage exercise test are illustrated below (Figure 2-22 on page 2-40).

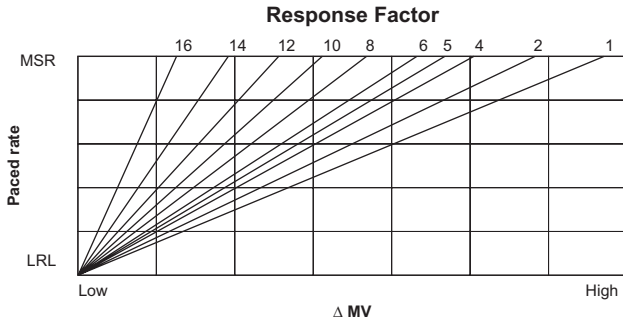


Figure 2-21. Relationship between the programmed Response Factor setting and rate response

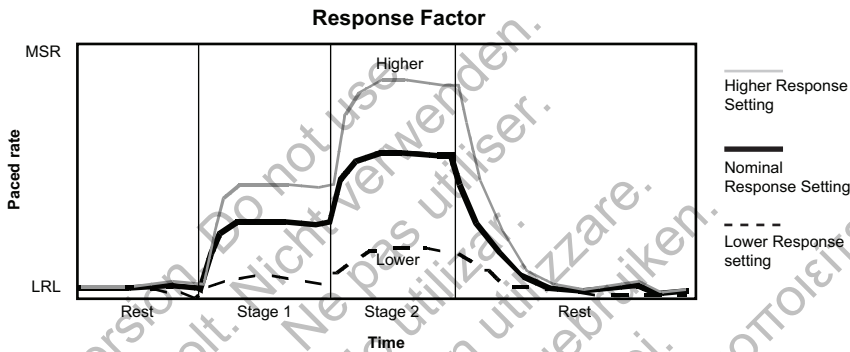


Figure 2-22. Effects of Response Factor settings in a two-stage exercise test

### Ventilatory Threshold and Ventilatory Threshold Response

The Ventilatory Threshold and Ventilatory Threshold Response can be either manually programmed or automatically derived from patient information. The clinician can select Derive from Patient Attributes from the RightRate Pacing Details screen to obtain settings based on the patient's age and gender (and Fitness Level, see below). As parameters are changed, the graph will likewise adjust to demonstrate the effect of the new programming on overall rate response (Figure 2-23 on page 2-40). If the Date of Birth or Gender is adjusted on the Patient Information screen, the new values will also be reflected on the RightRate Pacing Details screen.

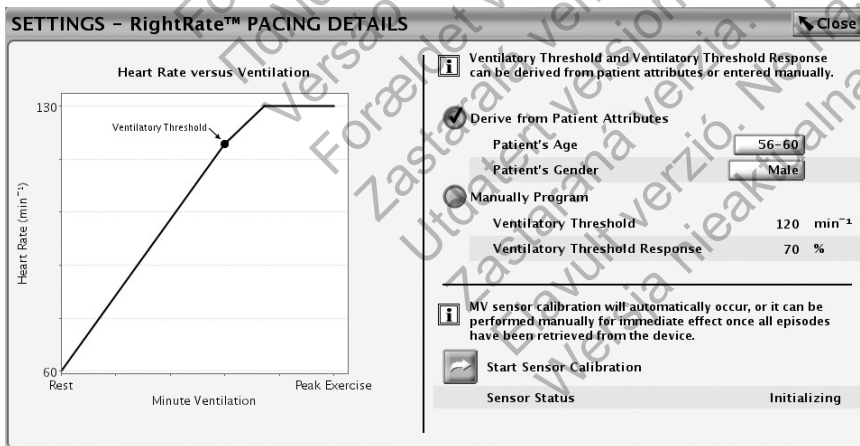


Figure 2-23. Ventilatory Threshold and Ventilatory Threshold Response



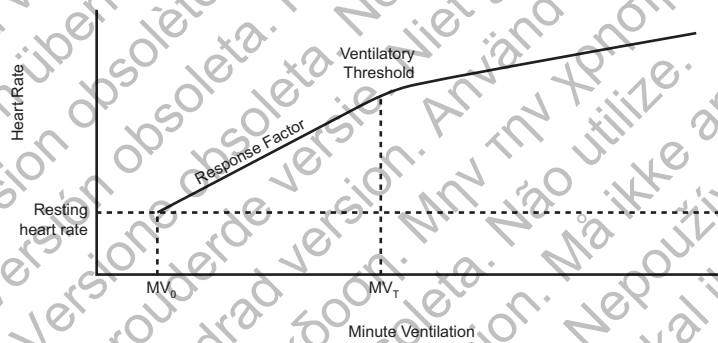
### Ventilatory Threshold

Ventilatory Threshold is a physiologic term describing the point during exercise when the breathing rate increases faster than the heart rate (sometimes referred to as Anaerobic or Lactate Threshold).

The Response Factor controls the MV rate response for sensor rates between the LRL and the Ventilatory Threshold. The Ventilatory Threshold Response controls the MV rate response when the sensor rate is above the Ventilatory Threshold.

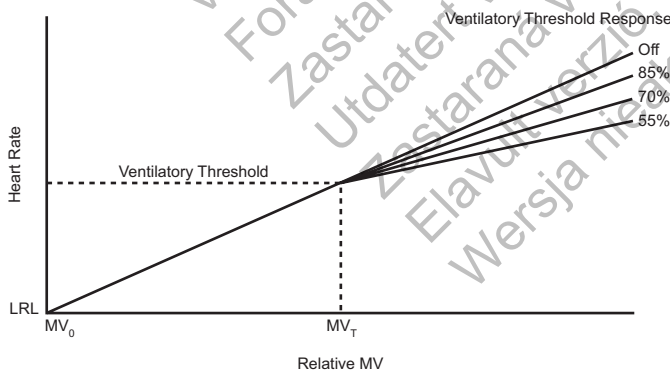
### Ventilatory Threshold Response

The physiologic relationship between MV and rate is approximately bilinear as shown (Figure 2-24 on page 2-41). During exercise levels up to the Ventilatory Threshold, this relationship can be approximated by a linear relationship. At exertion levels above the Ventilatory Threshold, the relationship is still approximately linear, but at a reduced slope. The relationship between the two slopes varies from person to person and depends on several factors such as gender, age, and exercise frequency and intensity. The pulse generators allow programming of a slope above the Ventilatory Threshold that is less steep and thus designed to mimic the physiologic relationship between respiration rate and heart rate. The Ventilatory Threshold Response is programmed as a percentage of the Response Factor. Ventilatory Threshold Response is in effect at rates above the Ventilatory Threshold and will result in a less aggressive response to MV at higher rates (Figure 2-25 on page 2-41).



MV<sub>0</sub> = resting MV; MV<sub>T</sub> = MV at the Ventilatory Threshold

Figure 2-24. Typical physiologic relationship between MV and heart rate



The Response Factor is linear from the resting state up to the Ventilatory Threshold (MV<sub>0</sub> = resting MV; MV<sub>T</sub> = MV at the Ventilatory Threshold).

Figure 2-25. Ventilatory Threshold Response

### Fitness Level

The selected Fitness Level will automatically determine an appropriate Ventilatory Threshold Response factor and rate at which the MV baseline will be fixed.

Table 2-5. Recommended Fitness Level settings

Recommended Fitness Level setting	Patient activity level
Sedentary	Little to no physical activity
Active	Regular walking and low impact activities
Athletic	Moderate intensity, non-competitive jogging/biking
Endurance Sports	Strenuous, competitive activities such as marathons

The baseline (long-term average) is fixed for up to 4.5 hours. This allows active patients who exercise for a long duration (e.g., long-distance runners) to maintain an adequate sensor-driven rate throughout the exercise period. The baseline will be fixed when the sensor indicated rate is above 110 min<sup>-1</sup> for the Fitness Level setting of Endurance Sports or 90 min<sup>-1</sup> for the other three Fitness Level settings. After 4.5 hours, or when the sensor rate falls below 90 min<sup>-1</sup> or 110 min<sup>-1</sup> as defined above, baseline adaptation will be re-enabled.

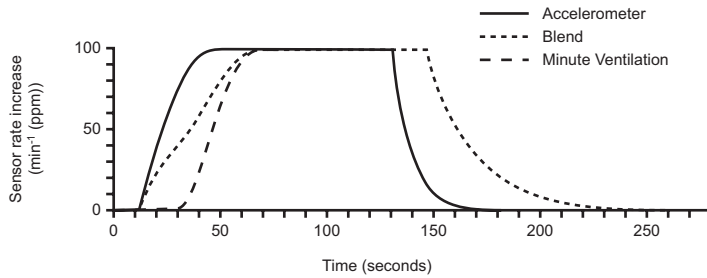
### Dual-Sensor Blending

Whenever both the Accelerometer and the MV sensor are programmed On for rate adaptive pacing, the two sensor-indicated rates are blended to produce a rate-dependent, weighted average response. As a result, the blended response will always be equal to one of the rates or between the two rates. Whenever the Accelerometer response is less than the MV response, the sensor blending will be 100% MV-based. If the Accelerometer response is greater than the MV response, the blending will range from approximately 80% Accelerometer and 20% MV when the Accelerometer rate is at LRL, to approximately 40% Accelerometer and 60% MV when the Accelerometer rate is at MSR.

The following examples illustrate the blending algorithm operation.

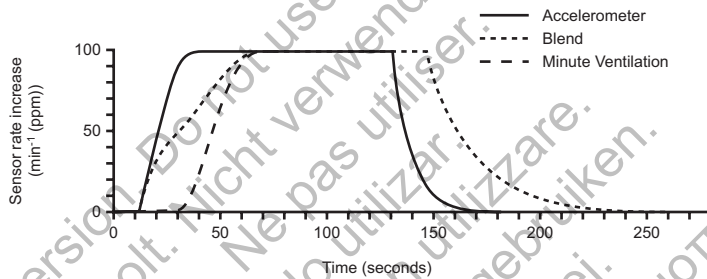
#### Example 1

The Accelerometer detects motion with a simultaneous MV increase (Figure 2-26 on page 2-43). Upon exercise, the blended response will promptly (within 4 seconds) increase the rate based on the Accelerometer response. As the rate continues to increase, the blended response will be moving toward the MV response, but will always remain between the Accelerometer and MV responses. At higher rates, the changes in Accelerometer input will have a lesser effect on the blended response (only 40% at MSR), whereas changes in MV will have a more significant effect. At cessation of exercise, the Accelerometer rate will decrease as prescribed by the Recovery Time parameter and, in this example, will drop below the MV response. As a result, the algorithm will switch over to a 100% MV blend during the recovery phase for as long as the Accelerometer response remains below the MV response. When using dual-sensor blending, retain the nominal Accelerometer value of 2 minutes. This allows the physiologic MV signal to control rate adaptive pacing in the exercise recovery phase.



**Figure 2-26. Blended response with an Accelerometer Reaction Time of 30 seconds**

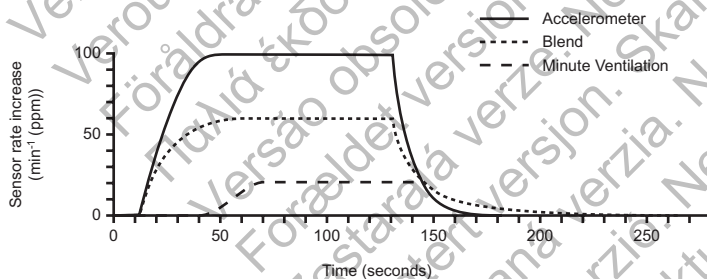
The aggressiveness of response at the onset of exercise can be controlled by programming a shorter Accelerometer Reaction Time (Figure 2-27 on page 2-43).



**Figure 2-27. Blended response with an Accelerometer Reaction Time of 20 seconds**

**Example 2**

The Accelerometer detects motion with little MV increase (Figure 2-28 on page 2-43). The response of the blended sensor will be limited to approximately 60% of the Accelerometer response. Once the Accelerometer response drops below the MV response during recovery, the blended response will be 100% MV-driven.



**Figure 2-28. Blended response: Accelerometer detects motion with little or no increase in MV**

**Example 3**

MV increases with little Accelerometer rate increase (Figure 2-29 on page 2-44). The blended response will initially increase with the Accelerometer response, but as the MV response increases over the Accelerometer response, the blended response will be 100% MV-driven. This provides adequate response during increases in metabolic demand under conditions of little or no upper body movement.

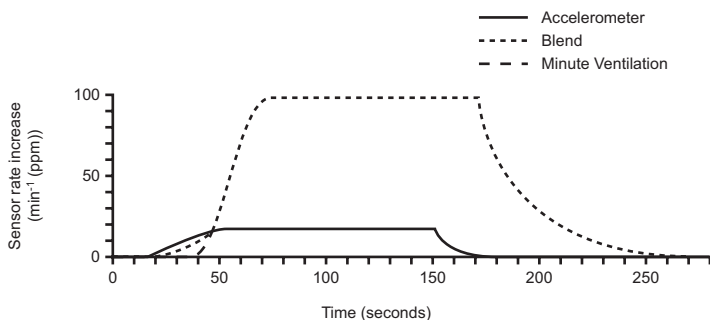


Figure 2-29. Blended response: MV increase with little or no motion detected by the Accelerometer

## Sensor Trending

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Sensor Trending provides a graphical display of the pulse generator’s rate response to the patient’s detected activity level and/or physiologic need and provides useful information during exercise testing. This allows the clinician to adapt the sensor-driven pacing rate to correspond to the patient’s actual need.

The Sensor Trending graph and Sensor Trending Setup parameters are viewable via the Rate Adaptive Pacing screen.

The Sensor Trending graph (Figure 2-30 on page 2-44) identifies a fixed range of heart rates (80–100 min<sup>-1</sup>) for Light to Moderate Exertion. This range can be used as a guide for target heart rates corresponding to regular walking and other low impact activities and may help identify patients with chronotropic incompetence.<sup>1 2</sup> This range may vary due to factors such as patient age and the type of exercise.<sup>2</sup>

The up and down buttons (Figure 2-30 on page 2-44) for More MV Pacing and Less MV Pacing are an alternate method to manually selecting the RightRate Response Factor. Each press of the button changes the RightRate Response Factor by one. The up button increases the Response Factor, and the down button decreases the Response Factor. For further information about sensor optimization, refer to the section about working with trending data below.

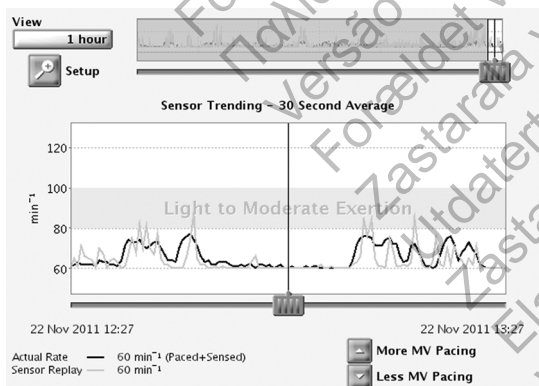


Figure 2-30. Sensor Trending graph with exertion range

1. Scherr, J. et al., Associations between Borg’s rating of perceived exertion and physiologic measures of exercise intensity. Eur J. Appl Physiol, Vol. 113 (1): 147-155, 2013.
2. Newman et al., Walking Performance and Cardiovascular Response: Associations with Age and Morbidity—The Health Aging and Body Composition Study. J. of Gerontology, Vol. 58A (8): 715-720, 2003.

Setup includes the following options:

- Recording Method—programmable:
    - 30-Second Average—records and plots the average rate every 30 seconds.
    - Beat to Beat—records and plots the rate of every beat.
- NOTE:** *Beat to Beat is recommended when using hall walks or shorter periods of activity to manually optimize sensor rates.*
- Off—no trending data is gathered.
- Duration—non-programmable and based on the selected Recording Method:
    - When Recording Method is set to Off or 30-Second Average—Duration is approximately 25 hours.
    - When Recording Method is set to Beat to Beat—Duration is approximately 40 minutes at 75 min<sup>-1</sup>.
  - Data Storage—programmable:
    - Continuous—contains the most recent data available. Storage starts when setup is confirmed and continuously records the latest information, overwriting the oldest data until the information is retrieved. This option allows you to view data for the recording duration immediately prior to data retrieval.
    - Fixed—storage starts when setup is confirmed and continues until device memory storage is full. This allows you to view data from initial setup for a fixed amount of time.

The pulse generator collects and stores rate and sensor data which is then displayed on the PRM in a graphical format as the patient's Actual Rate and Sensor Replay during the recording time.

The Actual Rate (black line) indicates the patient's heart rate during activity (whether paced or sensed). The Sensor Replay (orange line) depicts the sensor-driven heart rate response with the current sensor parameter settings. As the slider along the horizontal axis of the graph is moved, actual and sensor-indicated heart rates are displayed for particular data points. Additionally, the atrial events represented by a particular data point (single beat or 30-second average) are classified and displayed next to the Actual Rate. Events are classified and displayed as one or more of the following: Paced, Sensed, Sensed in ATR. This event type will reflect ventricular events in VVI(R) modes.

Current sensor parameters can be adjusted to view the resulting change to sensor rate behavior without having to repeat an exercise test.

The pulse generator can collect and store data in rate adaptive and non-rate adaptive modes. In non-rate adaptive modes, the trending is collected via the Passive sensor setting. Passive allows for sensor data collection that can be used to optimize the sensors in the absence of the sensor-driven rate response. However, when the sensor setting is Passive, Sensor Replay data will not be displayed on the graph until a rate responsive mode is selected.

The pulse generator will record Sensor Trending data while wandled or RF telemetry is active.

When the heart rate is completely sensor-driven, small differences between the Actual Rate and Sensor Replay may still be observed because they are calculated independently by slightly different methods.

## Working with Trending Data

To use the Sensor Trending function, follow these steps:

1. Following an exercise session, navigate to the Sensor Trending graph and press Interrogate to update trending information. Trending data is retrieved on initial interrogation. If a session remains active while the patient performs a hall walk, press Interrogate again to update the trending information.
2. Select the View button to expand or compress the amount of data viewed at one time. The start and end dates and times at the bottom of the graph will change to reflect the time period represented on the graph. The 30 Second Average Recording Method has options for 1 to 25 hours, and the Beat to Beat Recording Method has options for 5 to 40 minutes.
3. To adjust which data is displayed on the graph or to view particular data points, move the sliders along the horizontal axes at the bottom of the display windows.
4. Adjust the sensor parameters to the right of the graph to see how adjustments in the rate adaptive pacing parameters will affect the sensor response (orange line). As these parameters and/or the MSR and LRL are changed on the screen, the application will modify the graph to illustrate the resulting effects. If the patient's heart rate is appropriate for the activity performed, no sensor optimization is necessary.
5. When a patient's heart rate is within the desired range for the activity performed, select Program.

**NOTE:** Sensor Trending results may be printed via the Reports tab. Both the Present (currently programmed) and Replay (clinician adjusted) parameters are provided in addition to the current graph as represented on the programmer screen.

**NOTE:** Sensor adjustments should not be based on data which is collected during the MV calibration time period.

## ATRIAL TACHY RESPONSE

### ATR Mode Switch

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

ATR is designed to limit the amount of time that the ventricular paced rate is at the MTR or exhibits upper-rate behavior (2:1 block or Wenckebach) in response to a pathological atrial arrhythmia.

ATR also limits the amount of time that CRT is inhibited due to pathological atrial tachycardia.

In the presence of detected atrial activity that exceeds the ATR Trigger Rate, the pulse generator switches the pacing mode from a tracking mode to a nontracking mode as follows:

- From DDD(R) to DDI(R) or VDI(R)
- From VDD(R) to VDI(R)

An example of ATR behavior is shown (Figure 2-31 on page 2-47).

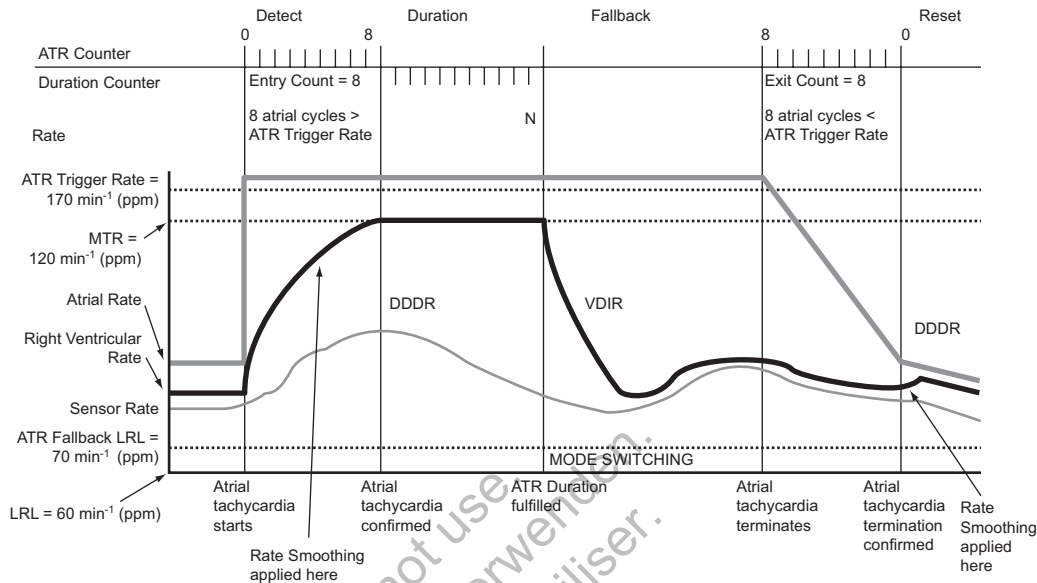


Figure 2-31. ATR behavior

**CAUTION:** ATR should be programmed to On if the patient has a history of atrial tachyarrhythmias. The delivery of CRT is compromised because AV synchrony is disrupted if the ATR mode switch occurs.

When a heart failure patient has an atrial tachyarrhythmia episode, the effectiveness of CRT is compromised because AV synchrony is disrupted. While ATR cannot resolve AV asynchrony, it can quickly bring the biventricular paced rate from the MTR to the ATR Fallback LRL, VRR rate or sensor-indicated rate (DDIR or VDIR). Programming a short ATR Duration and ATR Fallback Time allows a quicker mode switch and faster decrease in the biventricular pacing rate.

Patients with intact AV conduction may have conducted ventricular rates during ATR episodes. If the intrinsic ventricular rate exceeds the biventricular pacing rate during the ATR episode, biventricular pacing will be inhibited. For these patients, consider programming the VRR and BiV Trigger features to On.

**NOTE:** In ATR, the pacing chamber is always biventricular, regardless of the permanently programmed Ventricular Pacing Chamber.

**NOTE:** Parameter settings that reduce the atrial sensing window may inhibit ATR therapy.

### ATR Trigger Rate

The ATR Trigger Rate determines the rate at which the pulse generator begins to detect atrial tachycardias.

The pulse generator monitors atrial events throughout the pacing cycle, except during the atrial blanking period and the noise rejection intervals. Atrial events faster than the Trigger Rate increase the ATR detection counter; atrial events slower than the Trigger Rate decrease the counter.

When the ATR detection counter reaches the programmed entry count, the ATR Duration begins. When the ATR detection counter counts down from the programmed Exit Count value to zero at any point in time, ATR Duration and/or fallback are terminated, and the ATR algorithm is reset. An event marker is generated whenever the ATR detection counter is incremented or decremented.

## ATR Duration

ATR Duration is a programmable value that determines the number of ventricular cycles during which the atrial events continue to be evaluated after initial detection (entry count) is met. This feature is intended to avoid mode switching due to short, nonsustained episodes of atrial tachycardia. If the ATR counter reaches zero during ATR Duration, the ATR algorithm will be reset, and no mode switch will occur.

If the atrial tachycardia persists for the programmed ATR Duration, then mode switching occurs and the Fallback Mode and Fallback Time begin.

## Entry Count

The Entry Count determines how quickly an atrial arrhythmia is initially detected.

The lower the programmable value, the fewer the fast atrial events required to fulfill initial detection. Once the number of fast atrial events detected equals the programmable Entry Count, ATR Duration begins, and the Exit Count is enabled.

**CAUTION:** Exercise care when programming the Entry Count to low values in conjunction with a short ATR Duration. This combination allows mode switching with very few fast atrial beats. For example, if the Entry Count was programmed to 2 and the ATR Duration to 0, ATR mode switching could occur on 2 fast atrial intervals. In these instances, a short series of premature atrial events could cause the device to mode switch.

## Exit Count

The Exit Count determines how quickly the ATR algorithm is terminated once the atrial arrhythmia is no longer detected.

The lower the programmed value, the more quickly the pulse generator will return to an atrial tracking mode once an atrial arrhythmia terminates. Once the number of slow atrial events detected equals the programmable Exit Count, ATR Duration and/or Fallback will be terminated, and the ATR algorithm will be reset. The ATR Exit Count is decremented by atrial events slower than the ATR Trigger Rate or by any ventricular event that occurs more than two seconds after the last atrial event.

**CAUTION:** Exercise care when programming the Exit Count to low values. For example, if the Exit Count was programmed to 2, a few cycles of atrial undersensing could cause termination of mode switching.

## Fallback Mode

Fallback Mode is the nontracking pacing mode that the pulse generator automatically switches to when ATR Duration is fulfilled.

After switching modes, the pulse generator gradually decreases the ventricular paced rate. This decrease is controlled by the Fallback Time parameter.

**NOTE:** *Dual-chamber pacing fallback mode values are only available when the Normal pacing mode is also set to dual-chamber.*

**NOTE:** *ATR Fallback mode may be programmed rate responsive even if the permanent brady mode is non-rate responsive. In this scenario, the sensor parameters will indicate "ATR Only".*



### Fallback Time

Fallback Time controls how quickly the paced rate will decrease from the MTR to the ATR Fallback LRL during fallback. The paced rate will decrease to the highest of the sensor-indicated rate, VRR rate, or the ATR Fallback LRL.

During fallback, the following features are disabled:

- Rate Smoothing—disabled until fallback reaches the ATR Fallback LRL or the sensor-indicated rate. If VRR is enabled, then Rate Smoothing is disabled throughout the mode switch
- Rate Hysteresis
- APP/ProACT
- PVARP Extension

### Fallback LRL

The ATR Fallback LRL is the programmed lower rate to which the rate decreases during mode switching. The ATR Fallback LRL may be programmed higher or lower than the permanent brady LRL.

The rate will decrease to the highest among the sensor-indicated rate (when applicable), the VRR rate (if enabled), and the ATR Fallback LRL.

### End of ATR Episode

The End of ATR Episode identifies the point when the pulse generator reverts to AV-synchronous operation because the atrial arrhythmia is no longer detected.

With the termination of the arrhythmia, the ATR Exit Count decrements from its programmed value until it reaches 0. When the ATR Exit Count reaches 0, the pacing mode automatically switches to the programmed tracking mode, and AV-synchronous operation is restored.

## Ventricular Rate Regulation (VRR)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

VRR is designed to reduce the V–V cycle length variability during partially conducted atrial arrhythmias by modestly increasing the ventricular pacing rate. In addition, VRR preserves CRT delivery during conducted atrial arrhythmias.

The VRR algorithm calculates a VRR-indicated pacing interval based on a weighted sum of the current V–V cycle length and the previous VRR-indicated pacing intervals.

- Paced intervals have more influence than sensed intervals such that paced events cause a decrease in the VRR-indicated rate.
- For sensed intervals, the VRR-indicated rate may be increased; however, the influence is tempered by the previous history.
- The VRR-indicated rate is further bound by the LRL and the VRR MPR.

The programmable values for VRR are Min (Minimum), Med (Medium), and Max (Maximum). The programmed value will affect the degree of rate regulation as follows:

- A higher setting will increase CRT pacing more than a lower setting (i.e., Max vs. Med).
- A higher setting will decrease V–V variability more than a lower setting.
- A lower setting will result in a wider range of V–V variability and less ventricular CRT pacing.

**NOTE:** VRR has the potential to increase CRT delivery during atrial tachyarrhythmias and should be programmed on at the maximum setting to increase the ventricular pacing percent and maximize CRT delivery during conducted atrial tachyarrhythmias.

When VRR is programmed on in tracking modes, it is only active when an ATR mode switch has occurred. Once the tracking mode operation resumes at the termination of the atrial arrhythmia, VRR becomes inactive. In tracking modes where both Rate Smoothing and VRR are programmed on, Rate Smoothing is disabled when VRR is active during ATR and re-enabled once the ATR terminates.

When programmed on in nontracking modes, VRR is continually active and updates the VRR-indicated pacing rate and the smoothed average on each cardiac cycle.

#### **Ventricular Rate Regulation Maximum Pacing Rate (VRR MPR)**

The VRR MPR limits the maximum pacing rate for VRR.

VRR operates between the LRL and the MPR.

### **Biventricular Trigger**

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Biventricular Trigger (BiV Trigger) is designed to promote synchronized RV and LV contractions in the presence of RV sensed events. It does this by pacing the left and right ventricles immediately after any sensed RV event, including any PVCs. When used in conjunction with VRR, BiV Trigger is designed to provide additional CRT support during atrial tachycardias.

Biventricular Trigger operates between the LRL and the MPR. Paces that occur as a result of BiV Trigger are marked as RVP-Tr and LVP-Tr with no LV Offset applied. These triggered events are counted toward RVS and LVP counters.

Biventricular Trigger is separately programmable for normal pacing and ATR Fallback.

**NOTE:** If the pulse generator is programmed to RV or LV only, pacing in both chambers will occur if BiV Trigger is enabled.

#### **Biventricular Trigger Maximum Pacing Rate (MPR)**

The Biventricular Trigger MPR limits the maximum pacing rate that Biventricular Trigger can reach.

### **Atrial Flutter Response (AFR)**

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Atrial Flutter Response is designed to:

- Prevent pacing into the vulnerable period following an atrial sense. Pacing into the vulnerable period could occur if an atrial pace is scheduled soon after a refractory atrial sense.
- Provide immediate nontracking of atrial rates higher than the AFR Trigger Rate.

The nontracking behavior is maintained for as long as atrial events continually exceed the AFR Trigger Rate.

*Example:* When AFR is programmed to 170 min<sup>-1</sup>, a detected atrial event inside the PVARP or a previously triggered AFR interval starts an AFR window of 353 ms (170 min<sup>-1</sup>). Atrial detection inside the AFR is classified as a sense within the refractory period and is not tracked. Atrial tracking may only occur after both PVARP and the AFR window expire. Paced atrial events scheduled inside an AFR window are delayed until the AFR window expires. If there are fewer than 50 ms remaining before the subsequent ventricular pace, the atrial pace is inhibited for the cycle.

**NOTE:** *This feature may override the programmed AV Delay and temporarily alter the effectiveness of CRT due to the effect on AV synchrony.*

Ventricular pacing is not affected by AFR and will take place as scheduled. The wide programmable range for AFR Trigger rates allows for appropriate sensing of slow atrial flutters. High-rate atrial sensing may continuously retrigger the AFR window, effectively resulting in behavior similar to the VDI(R) fallback mode.

**NOTE:** *For atrial arrhythmias that meet the programmed AFR rate criteria, using the AFR feature will result in slower ventricular pacing rates.*

**NOTE:** *When both AFR and ATR are active in the presence of atrial arrhythmias, nontracking ventricular paced behavior may occur sooner, but the ATR Mode Switch may take longer. This is because the ATR Duration feature counts ventricular cycles for meeting duration and the AFR feature slows the ventricular paced response to fast atrial arrhythmias.*

## PMT Termination

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

PMT Termination detects and attempts to interrupt pacemaker-mediated tachycardia (PMT) conditions.

AV synchrony may be lost for many reasons, including atrial fibrillation, PVCs, PACs, atrial oversensing, or loss of atrial capture. If the patient has an intact retrograde conduction pathway when AV synchrony is lost, the unsynchronized beat may conduct retrograde to the atrium, resulting in premature atrial depolarization. In DDD(R) and VDD(R) pacing modes, the device may detect and track retrograde conducted P-waves that fall outside of PVARP. The repeated cycle of sensing and tracking retrograde conduction is known as PMT, which can result in triggered ventricular pacing rates as high as the MTR. Programming certain refractory periods (e.g., PVARP after PVC) can reduce the likelihood of tracking retrograde events. Rate Smoothing can also be useful in controlling the pulse generator's response to retrograde conduction.

When the pulse generator's response to retrograde conduction has not been controlled by device programming, PMT Termination (when programmed to On) is used to detect and terminate PMT within 16 cycles of onset when the following conditions have been met:

- 16 successive ventricular paces are counted at the MTR following atrial sensed events

- All 16 V–A intervals are within 32 ms (preceding or following) of the second V–A interval measured at MTR during the 16 ventricular paced events (to distinguish Wenckebach behavior from PMT)

When both conditions are met, the pulse generator sets the PVARP to a fixed setting of 500 ms for one cardiac cycle in an attempt to break the PMT. If both conditions are not met, the pulse generator continues to monitor successive ventricular paces for the presence of a PMT.

When PMT Termination is programmed to On, the pulse generator stores PMT episodes in the Arrhythmia Logbook.

**NOTE:** Although the V–A interval evaluation helps discriminate true PMT (stable V–A intervals) from upper rate behavior due to sinus tachycardia or normal exercise response (typically unstable V–A intervals), it is possible that a patient's intrinsic atrial rate can meet PMT detection criteria. In such cases, if PMT Termination is programmed On, the algorithm will declare the rhythm a PMT and extend PVARP on the 16th cycle.

**NOTE:** Because retrograde conduction times may vary over a patient's lifetime due to their changing medical condition, occasional programming changes may be necessary.

If retrograde conduction is evident in a stored EGM, you can evaluate the electrogram and/or perform a threshold test to confirm appropriate atrial pacing and sensing. If stored EGMs are not available for review, follow these steps to use the PRM to assist in V–A interval evaluation:

1. From the Tests screen, select the Temp Brady tab.
2. Program an appropriate atrial sensing mode that provides atrial markers (VDD, DDD, or DDI).
3. Program the maximum PVARP to a value shorter than the average retrograde conduction time.

**NOTE:** Scientific literature suggests that the average retrograde conduction time is  $235 \pm 50$  ms (with a range of 110–450 ms).<sup>3</sup>

4. Program the LRL to ensure pacing above the intrinsic atrial rate (e.g., 90, 100, 110...).
5. Begin printing the real-time ECG.
6. Select the Start button to activate the temporary parameters.
7. When testing is complete for the specified LRL value, select the Stop button.
8. Stop printing the real-time ECG.
9. Evaluate the ECG strip for V–A conduction (VP followed by an AS). Look for stable and consistent intervals suggestive of retrograde conduction.
  - If retrograde conduction was identified, compare the retrograde V–A interval time to the programmed refractory period. Consider programming PVARP to the appropriate value so that the retrograde event is not tracked.
  - If retrograde conduction was not identified, the PMT episode may be a result of normal upper rate behavior. Review Histograms to see how often the rate is at the MTR, and consider raising the MTR (if clinically appropriate).

3. Furman S, Hayes D.L., Holmes D.R., A Practice of Cardiac Pacing. 3rd ed. Mount Kisco, New York: Futura Publishing Co.; 1993:74-75.

10. If necessary, repeat this procedure with different LRL values, as retrograde conduction may occur at different rates.

## Atrial Pacing Preference (APP) and ProACT

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Atrial Pacing Preference (APP) and ProACT features are designed to promote atrial pacing by increasing the pacing rate. APP and ProACT use algorithms that function similarly, but the ProACT algorithm reacts to premature atrial contractions (PACs) while the APP algorithm reacts to non-PAC atrial senses.

APP and ProACT are designed to decrease the number of atrial arrhythmic episodes.

### PAC Determination

The pulse generator determines a PAC occurrence by calculating the average of 4 A–A intervals prior to an atrial sensed event. Both atrial paced and atrial sensed events are used in determining the A–A intervals (Figure 2-32 on page 2-53). When an atrial sensed event occurs, it is classified as a PAC if the previous A–A interval is less than 75% of the average interval (calculated on the previous 4 intervals) and is less than 600 ms. An atrial paced event is not classified as a PAC.

**NOTE:** PACs are not detected if an ATR Mode Switch is in progress.

**NOTE:** If any of the A–A intervals used in the average interval computation are longer than 2000 ms, the interval length used in the computation is 2000 ms.

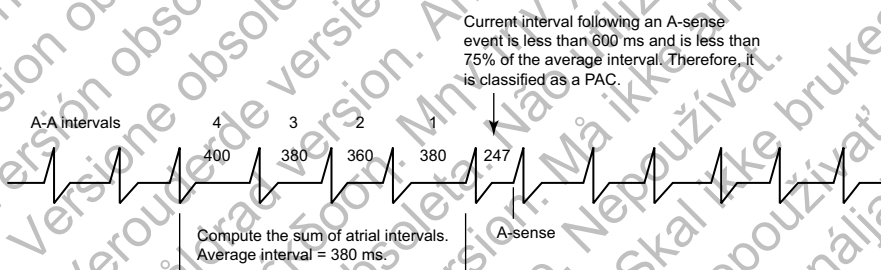


Figure 2-32. PAC detection

### Atrial Pacing Preference (APP)

Atrial Pacing Preference is an algorithm designed to promote atrial pacing by increasing the atrial pacing rate when non-PAC, nonrefractory atrial sensed events occur.

When an AS–VS event occurs, APP shortens the A–A interval for the next cycle by 10 ms to help ensure atrial pacing. When an AS–VP event occurs, APP shortens the V–V interval for the next cycle by 10 ms.

Additionally, the pacing rate is gradually decreased back down to the LRL by lengthening the V–A interval by 10 ms if 4 consecutive cardiac cycles occur where each cycle falls into one of the following categories:

- A refractory atrial sense as the only atrial event
- No atrial event
- A PAC

- An atrial pace
- Multiple atrial events where the last atrial event is a nonrefractory atrial sense preceded by at least one PAC

This new V–A interval is used until either an intrinsic atrial sensed event occurs and the algorithm shortens the A–A or V–V interval or the V–A interval is again lengthened by 10 ms as described.

When APP/ProACT is active, SBR and Rate Hysteresis are not allowed. In addition, Rate Smoothing Up will be ignored at pacing rates less than the APP/ProACT Max Pacing Rate. An example of the APP/ProACT operation is shown below (Figure 2-33 on page 2-54).

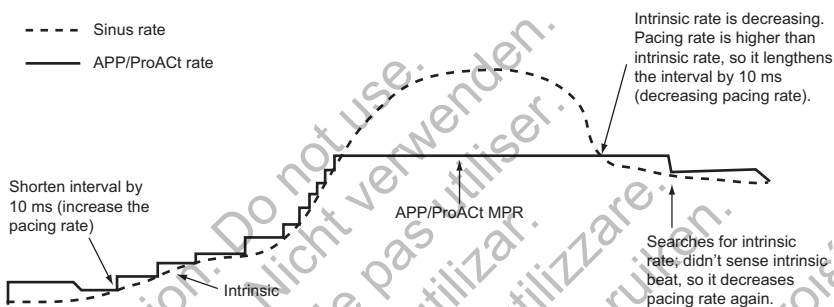


Figure 2-33. Atrial Pacing Preference

APP is available in DDI(R) and DDD(R) modes. The APP/ProACT pacing rate is limited by the programmable APP/ProACT MPR.

### ProACT

ProACT increases the pacing rate in the presence of PACs in order to increase the likelihood of atrial pacing.

If the previous atrial event was a PAC, the ProACT algorithm calculates 75% of the V–V interval prior to the PAC and applies this calculated V–V interval to the next cycle to promote atrial pacing. The pacing rate is gradually decreased back down to the LRL by lengthening the V–V interval by 10 ms if 4 consecutive cycles occur with a non-PAC sense, no atrial event, or an atrial pace. This new V–V interval is used until either a PAC occurs and the algorithm shortens the V–V interval or the V–V interval is again lengthened by 10 ms as described.

### APP/ProACT Maximum Pacing Rate (MPR)

The APP/ProACT indicated rate is limited by the programmable APP/ProACT Max Pacing Rate (MPR) value.

## RATE ENHANCEMENTS

### Tracking Preference

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Tracking Preference is designed to maintain atrial-tracked ventricular pacing in DDD(R) and VDD(R) modes by identifying atrial events for tracking that should be tracked but fall within PVARP. This feature supports CRT delivery for atrial rates below but near the MTR; otherwise, therapy might be inhibited.

Atrial events can fall within PVARP when a patient has a combination of a long intrinsic intracardiac AV interval and a long PVARP. If two successive cycles occur in which a sensed RV event is preceded by an atrial sensed event in PVARP, the pulse generator shortens PVARP until normal atrial-tracked ventricular pacing is established. The PVARP is shortened enough for tracking to occur on any atrial event that occurs after the A-Blank after RV-Sense cross-chamber blanking period ends. When atrial tracking is re-established, the AV Delay may be extended to prevent violation of the MTR. The shortened PVARP remains in effect until a ventricular pace occurs at the programmed AV Delay. By programming Tracking Preference to On, continuous CRT is delivered at rates below MTR-rates which otherwise might be inhibited when the sum of PVARP and the intrinsic intracardiac AV interval is longer than the MTR interval.

The effect of Tracking Preference on atrial rates is illustrated below (Figure 2-34 on page 2-55).

**NOTE:** *Tracking Preference is inhibited if the atrial rate interval is greater than or equal to the MTR interval. This prevents the tracking of potentially pathological atrial rates and PMT.*

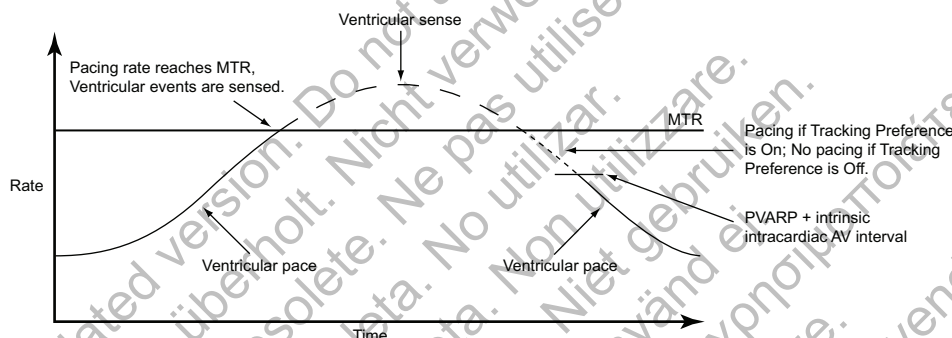


Figure 2-34. Tracking Preference on atrial events that should be tracked but fall within PVARP

## Rate Hysteresis

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Rate Hysteresis can improve device longevity by reducing the number of pacing stimuli. This feature is available in DDD and AAI modes and is activated by a single nonrefractory, atrial sensed event.

In DDD and AAI modes, Hysteresis is deactivated by a single atrial pace at the Hysteresis Rate. In DDD mode, Hysteresis is deactivated by an atrial rate above the MTR.

When Rate Smoothing Down is enabled, Rate Hysteresis remains in effect until pacing occurs at the Hysteresis Rate. This allows Rate Smoothing to control the transition to the Hysteresis Rate.

### Hysteresis Offset

Hysteresis Offset is used to lower the escape rate below the LRL when the pulse generator senses intrinsic atrial activity.

If intrinsic activity below the LRL occurs, then Hysteresis Offset allows inhibition of pacing until the LRL minus Hysteresis Offset is reached. As a result, the patient might benefit from longer periods of sinus rhythm.

### Search Hysteresis

When Search Hysteresis is enabled, the pulse generator periodically lowers the escape rate by the programmed Hysteresis Offset in order to reveal potential intrinsic atrial activity below

the LRL. The programmed number of search cycles must be consecutively atrial paced for a search to occur.

*Example:* At a rate of 70 min<sup>-1</sup> and a search interval of 256 cycles, a search for intrinsic atrial activity would occur approximately every 3.7 minutes (256 ÷ 70 = 3.7).

During Search Hysteresis, the pacing rate is lowered by the Hysteresis Offset for up to 8 cardiac cycles. If intrinsic activity is sensed during the search period, Hysteresis will remain active until an atrial pace occurs at the hysteresis offset rate.

Rate Smoothing is disabled during the search cycles. If no intrinsic atrial activity is detected during the 8-cycle search, the pacing rate is brought up to the LRL. Rate Smoothing Up, if enabled, controls the pacing rate increase.

## Rate Smoothing

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Rate Smoothing controls the pulse generator's response to atrial and/or ventricular rate fluctuations that cause sudden changes in pacing intervals. Rate Smoothing is an important enhancement to ATR because it can significantly reduce the rate fluctuations associated with the onset and cessation of atrial arrhythmias.

Without Rate Smoothing, a sudden, large atrial rate increase will cause a simultaneous sudden increase in the paced ventricular rate as high as the programmed MTR. Patients who experience large variations in their ventricular paced rate can feel symptomatic during these episodes. Rate Smoothing can prevent these sudden rate changes and the accompanying symptoms (such as palpitations, dyspnea, and dizziness).

In a normal conduction system, limited cycle-to-cycle rate variations occur. However, the paced rate can change dramatically from one beat to the next in the presence of any of the following:

- Sinatrial disease such as sinus pause or arrest, sinoatrial block, and brady-tachy syndrome
- PACs and/or PVCs
- Pacemaker Wenckebach
- Intermittent, brief, self-terminating SVTs, and atrial flutter/fibrillation
- Retrograde P-waves
- Pulse generator sensing of myopotential signals, EMI, crosstalk, etc.

In single-chamber modes, Rate Smoothing operates between:

- The LRL and the MPR when programmed VVI or AAI
- The LRL and the MSR when programmed VVIR or AAIR

In dual-chamber modes, Rate Smoothing operates between:

- The LRL and the greater of the MSR or MTR when programmed DDD(R) or VDD(R)
- The LRL and MPR when programmed to DDI
- The LRL and MSR when programmed to DDIR

Rate Smoothing is also applicable between the Hysteresis Rate and LRL when Hysteresis is active, except during Search Hysteresis.



When Rate Smoothing is programmed to On, it is functional except:

- During the 8 cycles of rate Search Hysteresis
- During ATR Fallback until fallback reaches the ATR LRL, the sensor-indicated rate, or the VRR interval
- During VRR when active
- Upon triggering PMT Termination
- Immediately following programmed LRL increases
- When the intrinsic rate is above the MTR
- When Tracking Preference is active
- When APP/ProACT is active, Rate Smoothing Up is not applied for pacing rates below the APP/ProACT Maximum Pacing Rate

**NOTE:** Rate Smoothing cannot be programmed to On when Sudden Brady Response is programmed to On.

#### Programmable Values

Rate Smoothing values are a percentage of the RV R–R interval (3% to 25% in 3% increments) and can be independently programmed for:

- Increase—Rate Smoothing Up
- Decrease—Rate Smoothing Down
- Off

The pulse generator stores the most recent R–R interval in memory. R-waves may be either intrinsic or paced. Based on this R–R interval and the programmed Rate Smoothing value, the device limits the variation in paced rate on a beat to beat basis.

It is important to ascertain the patient's physiologic cycle-to-cycle variation and program the Rate Smoothing parameter to a value that protects against pathologic interval changes, yet allows physiologic interval changes in response to increases in activity or exercise.

#### Rate Smoothing Up

Rate Smoothing Up controls the largest pacing rate increase allowed when the intrinsic or sensor rate is increasing.

**NOTE:** Rate Smoothing Up will transiently modify the programmed AV Delay. This could change the effectiveness of the AV Delay recommended with SmartDelay optimization.

When Rate Smoothing Up is programmed On, CRT is compromised during episodes of atrial rate increases that exceed the programmed value.

- For patients with AV block, this occurs because Rate Smoothing prolongs the AV Delay from the optimal setting as it controls the biventricular pacing rate while the atrial rate increases.
- For patients with normal AV conduction, biventricular stimulation (CRT) may be inhibited in one or more cycles during the Rate Smoothing operation because intrinsic AV conduction may occur during the prolonged AV Delay and inhibit ventricular pacing.

While the effect of the Rate Smoothing Up operation may only be transient and its impact on CRT minimal, consider the following recommendations when programming this parameter On:

- Address only patient-specific, sudden atrial rate increases
- Use the highest value that can achieve the desired control because the higher the value, the less the impact on the AV Delay extension

### Rate Smoothing Down

Rate Smoothing Down controls the largest pacing rate decrease allowed when the intrinsic or sensor rate is decreasing.

CRT delivery is not altered by programming Rate Smoothing Down On. However, it is important to consider that when Rate Smoothing Down is On in DDD(R) mode, atrial pacing will occur during the downward Rate Smoothing operation. The AV Delay for optimal CRT may be different during atrial pacing than during intrinsic sinus rhythm.

**NOTE:** When Rate Smoothing Down is programmed On and Rate Smoothing Up is programmed Off, the pulse generator will automatically prevent fast intrinsic beats (e.g., PVCs) from resetting the Rate Smoothing Down escape rate any faster than 12% per cycle.

### Rate Smoothing Maximum Pacing Rate (MPR)

The Rate Smoothing Maximum Pacing Rate places a limit on the maximum pacing rate that Rate Smoothing can reach.

The Rate Smoothing Down parameter requires a programmed MPR when in AAI, VVI, or DDI. Rate Smoothing will then be used only between the MPR and the LRL or the Hysteresis Rate (if applicable).

When both VRR and Rate Smoothing are programmed on in the VVI(R) or DDI(R) mode, VRR will have priority.

### Rate Smoothing Example Based on a Dual-Chamber Tracking Mode

Based on the most recent R–R interval stored in memory and the programmed Rate Smoothing value, the pulse generator sets up the two synchronization windows for the next cycle: one for the atrium and one for the ventricle. The synchronization windows are defined below:

Ventricular synchronization window: previous R–R interval  $\pm$  Rate Smoothing value

Atrial synchronization window: (previous R–R interval  $\pm$  Rate Smoothing value) - AV Delay

The following example explains how these windows are calculated (Figure 2-35 on page 2-59):

- Previous R–R interval = 800 ms
- AV Delay = 150 ms
- Rate Smoothing Up = 9%
- Rate Smoothing Down = 6%

The windows would be calculated as follows:

Ventricular Synchronization Window = 800 - 9% to 800 + 6% = 800 ms - 72 ms to 800 ms + 48 ms = 728 ms to 848 ms

Atrial Synchronization Window = Ventricular Synchronization Window - AV Delay =  
728 ms - 150 ms to 848 ms - 150 ms = 578 ms to 698 ms

The timing for both windows is initiated at the end of every R-R interval (RV event or LV paces when the Pacing Chamber is programmed to LV Only).

If paced activity is to occur, it must occur within the appropriate synchronization window.

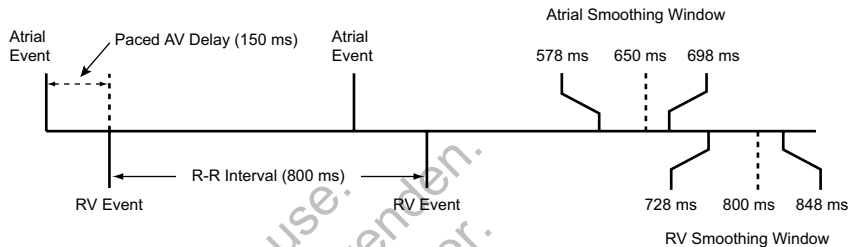


Figure 2-35. Rate smoothing synchronization window

## Sudden Brady Response (SBR)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Sudden Brady Response (SBR) is designed to respond to sudden decreases in intrinsic atrial rates by applying pacing at an elevated rate.

SBR is available in DDD(R) modes. SBR is declared when the atrial chamber has been continuously sensed for one minute (nonprogrammable), followed by a sudden decrease in atrial rate such that atrial pacing occurs at the LRL or the sensor-indicated rate for a programmable number of cycles. The decrease in atrial rate preceding the paced events must exceed  $10 \text{ min}^{-1}$  (nonprogrammable).

The SBR algorithm continually monitors the average of the atrial rate and this average is updated each cardiac cycle. This average rate is used both to determine if the atrial rate has decreased more than  $10 \text{ min}^{-1}$  and to determine the rate of SBR therapy.

**NOTE:** Sudden Brady Response is not available when Rate Smoothing and/or APP/ProACT are enabled.

**NOTE:** Sudden Brady Response will not be activated based on an atrial rate decrease during ATR Fallback.

### SBR Atrial Paces Before Therapy

The SBR Atrial Paces Before Therapy criteria are applied once the decrease in atrial rate has been detected and LRL or sensor-indicated rate pacing begins. Atrial pacing must occur for the programmable number of consecutive intervals before the SBR criteria are met. This parameter is used to ensure that the rate stays at the LRL or sensor-indicated rate prior to delivering therapy. If atrial senses occur during these intervals, the algorithm is reset and SBR therapy is not applied.

### SBR Atrial Pacing Rate Increase

SBR Atrial Pacing Rate Increase is calculated by using the patient's average atrial rate before the drop in rate and adding a programmable positive offset (Figure 2-36 on page 2-60).

Pacing is applied in the DDD(R) mode at whichever of the following rates is higher:

- The previous average atrial rate plus the SBR Atrial Pacing Rate Increase (not to exceed the MTR), or
- The sensor-indicated rate (DDDR mode only)

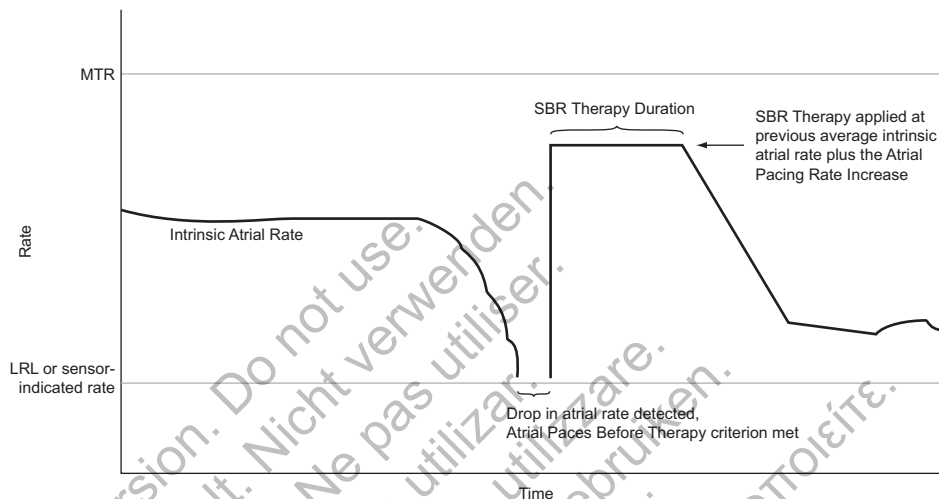


Figure 2-36. Sudden Brady Response

### SBR Therapy Duration

SBR Therapy Duration is the programmable time interval during which the SBR pacing therapy rate will be applied. Once pacing therapy has been delivered, the atrial pacing rate will be decreased using a 12% Rate Smoothing Down factor (nonprogrammable) until the LRL or sensor-indicated rate is reached.

**NOTE:** Rate Hysteresis is not active during SBR Therapy Duration.

**NOTE:** SBR Therapy Duration will end if a manual or PaceSafe Threshold Test is performed.

### SBR Inhibit During Rest

SBR Inhibit During Rest is designed to distinguish between a natural drop in rate (sleep) and a pathologic drop. It provides the ability to inhibit SBR therapy when the SBR rate and duration criteria are met, but the patient's current MV/Respiratory Sensor measurement is lower than an MV/Respiratory Sensor comparison value. The MV/Respiratory Sensor must be set to On (or Passive for the MV Sensor) for the SBR Inhibit During Rest to be programmed On. When the MV/Respiratory Sensor is activated, the pulse generator determines the lowest measured baseline value for each day over a 1-week period (rolling 7-day window). The MV/Respiratory Sensor comparison value is then set to 50% above that lowest weekly baseline. Each day, this MV/Respiratory Sensor comparison value is updated so that the algorithm adjusts to long-term changes in the patient's baseline. In the event the SBR atrial rate and duration criteria are met, the current MV/Respiratory Sensor measurement is compared to the comparison value. If the current MV/Respiratory Sensor measurement is less than the comparison value, SBR therapy is inhibited (Figure 2-37 on page 2-61). If the present MV/Respiratory Sensor measurement is greater than or equal to the comparison value, SBR therapy is initiated (Figure 2-38 on page 2-61).

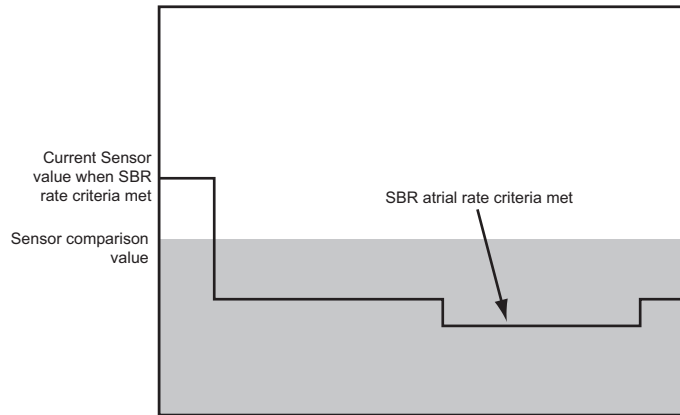


Figure 2-37. SBR Therapy Inhibited by Sensor Comparison

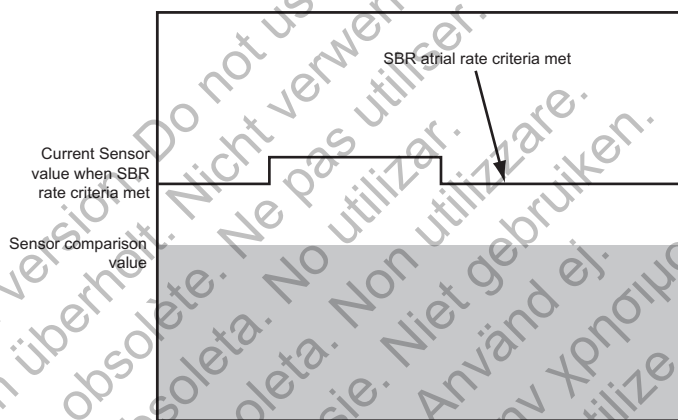


Figure 2-38. SBR Therapy Delivered after Sensor Comparison

## LEAD CONFIGURATION

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The pulse generator has independently programmable lead configurations for the following:

- Atrium
- Right Ventricle
- Left Ventricle

The atrial, RV, and LV leads may be set to Unipolar and/or Bipolar pacing and sensing. Additionally, the atrial lead can be programmed to a Bipolar or Unipolar pacing lead configuration with the atrial sensing lead configuration Off.

The input impedance is > 100 KΩ for each sense/pace electrode pair.

In dual-chamber devices programmed to AAI(R), the ventricular sensing lead configuration is available to facilitate VT detection. This parameter will be available unless the Ventricular Tachy EGM Storage parameter is set to Off.

If the atrial or ventricular lead type is specified as Unipolar on the Patient Information screen, programming to Bipolar configuration for either pacing or sensing is not allowed. Certain features and programming options require a bipolar lead to be identified either in Patient Information or with a bipolar lead configuration. Therefore, if Patient Information is not entered, Unipolar programming may result in a parameter interaction.

**NOTE:** If a unipolar pacing configuration is required at implant, ensure that the configuration is programmed to Unipolar before implant.

**CAUTION:** If the Lead Configuration is programmed to Bipolar when a unipolar lead is implanted, pacing will not occur.

**NOTE:** If a separate ICD is present, programming the pacemaker Lead Configuration to Unipolar is contraindicated.

When the pacing configuration is programmed to Unipolar, the pacing stimulus will be applied between the lead tip and the pacemaker case. When the pacing configuration is programmed to Bipolar, the stimulus will be applied between the lead tip and the lead ring. In the Unipolar pacing configuration, the pacing artifact should be clearly visible on the surface ECG, which will assist in its interpretation. However, unipolar pacing at high outputs is more likely than bipolar pacing to cause muscle stimulation.

When the sensing configuration is programmed to Unipolar, cardiac signals are detected between the lead tip and the pacemaker case. In the Unipolar sensing configuration, the pacemaker can generally discern smaller intrinsic cardiac signals than in the Bipolar configuration. However, the Unipolar configuration is also more sensitive to myopotentials which can cause pacemaker inhibition. When the sensing configuration is programmed to Bipolar, because of the relatively short distance between the tip and ring electrodes, sensitivity is highest for signals originating in the proximity of the lead tip and ring. As a result, the pacemaker is less likely to sense myopotentials and other signals unrelated to cardiac depolarization.

**NOTE:** Blanking Period behavior will vary slightly depending on which Lead Configuration is selected ("Cross-Chamber Blanking" on page 2-77).

## Use of Atrial Information

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Atrial sensing can be programmed to On or Off in any dual or single chamber Brady Mode. The pulse generator will respond to atrial sensing regardless of whether an atrial lead is implanted.

There may be clinical situations in which atrial lead information is not useful (e.g., chronic atrial fibrillation, faulty or dislodged atrial lead, plugged atrial port).

**CAUTION:** If an atrial lead is not implanted (port is plugged instead), or an atrial lead is abandoned but remains connected to the header, device programming should be consistent with the number and type of leads actually in use.

If an atrial lead will not be used, use the following programming recommendations to ensure appropriate device behavior:

- Program the Brady Mode to VVI or VVI(R), to prevent atrial pacing and ensure that atrial information is not used to drive brady pacing.
- Program the atrial sensing Lead Configuration to Off to prevent atrial sensing and minimize accrual of atrial counters. This will also disable the V>A detection enhancement [all tachy events will be labeled as VT (V>A)].

**CAUTION:** Sensing high atrial rates may impact device longevity. Therefore, the Atrial Sense lead configuration will be seeded to Off when programming from an atrial sensing mode to a non-atrial sensing mode.

**CAUTION:** When atrial sensing is programmed to Off in a DDI(R) or DDD(R) mode, any atrial pacing that occurs will be asynchronous. Additionally, features that require atrial sensing may not function as expected.

**NOTE:** An atrial EP Test should not be performed if the atrial sensing Lead Configuration is programmed to Off.

- Program the Atrial Intrinsic Amplitude and Atrial Pace Impedance daily lead measurements to Off to disable atrial diagnostics (e.g., Atrial Amplitude and Impedance).
- During follow-up visits, consider deselecting the atrial real-time EGM.

If an atrial lead is used in the future, these programming adjustments should be reevaluated, and the pulse generator should be programmed appropriately for use with an atrial lead.

## Left Ventricular Electrode Configuration

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The LV Electrode Configuration provides programmable options for LV lead pacing and sensing via the Lead Settings screen (accessible from the Normal Settings screen).

**CAUTION:** Proper programming of the LV coronary venous Lead Configuration is essential for proper LV lead function. Program the Lead Configuration in accordance with the number of electrodes on the LV lead; otherwise, erratic LV sensing, loss of LV pacing, or ineffective LV pacing might occur.

The following programming options are available for devices with an IS-1 or LV-1 left ventricular lead port:

- Dual—used when an LV lead with two electrodes is implanted
- Single—used when an LV lead with only one electrode is implanted
- None—used when an LV lead is not implanted

**NOTE:** The nominal LV Electrode Configuration is None, which, along with the nominal Ventricular Pacing Chamber of BiV, results in a parameter interaction. This is intended behavior to ensure the clinician selects an appropriate LV Electrode Configuration (dual or single) for the implanted LV lead.

For devices with an IS4 left ventricular lead port, the LV Electrode Configuration is automatically set to Quadripolar.

These pulse generators are intended for use with an LV lead; however, there may be clinical situations such as those described below in which an LV lead is not used:

- The LV lead cannot be positioned, and a decision is made to temporarily use the pulse generator without an LV lead (plug the unused LV port).
- The LV lead dislodges to a suboptimal position, and a decision is made to leave the lead implanted and connected but not use it.

The pulse generator cannot detect whether an LV lead is present or absent. Therefore, if an LV lead is not used, consider the following programming adjustments, which can help to prevent reporting of irrelevant LV diagnostic information, minimize storage of LV information (e.g., counters, EGMs, markers, intervals), minimize diaphragm stimulation, and improve device longevity:

**NOTE:** *If these steps are performed in a different sequence, the PRM may display warning messages and certain steps may not be available.*

1. Program BiV Trigger to Off under both the ATR section and the Ventricular Regulation section of the Atrial Tachy Therapy Settings screen.
2. Program LV Amplitude and LV Pulse Width to the minimum value.
3. Program the Ventricular Pacing Chamber to RV Only.
4. Turn off LV sensing:
  - a. For devices with an IS-1 or LV-1 left ventricular lead port:
    - i. Change the LV Electrode Configuration to Single or Dual.
    - ii. Program LV Sense to Off.
    - iii. Program the LV Electrode Configuration to None.
  - b. For devices with an IS4 left ventricular lead port:
    - i. Select the Disable Sensing checkbox on the LV Sense selection screen.
    - ii. Select the Accept button.
    - iii. Program the device.
5. Program the daily lead measurements for LV Intrinsic Amplitude and LV Pace Impedance to Off.

When this programming sequence is followed, LV pacing and sensing are turned Off, and the following are unavailable:

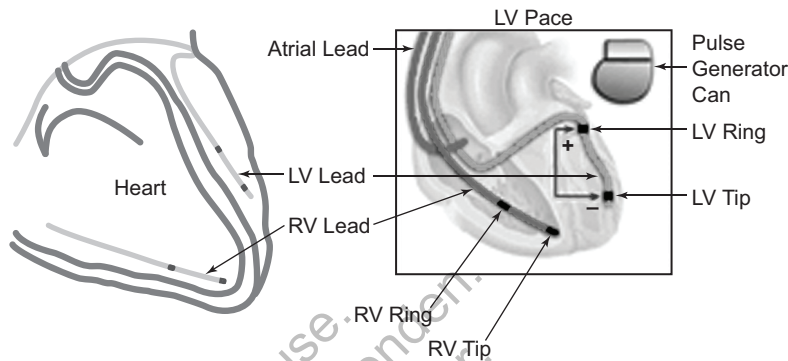
- LV electrograms
- LV markers
- LV intervals
- LV Offset
- LV-Blank after A-Pace cross-chamber blanking period
- SmartDelay optimization (non-Quadripolar devices)
- LV daily measurements

**NOTE:** *Some features (e.g., ATR Mode Switch and Electrocautery Protection Mode) temporarily use BiV pacing (regardless of LV Lead Configuration), which will add LV data to the counters, electrograms, markers, and intervals.*

Any time a change is made to the Electrode Configuration, it is important to verify lead system baseline measurements to ensure optimal functioning.



The programmed selections are reflected in the Electrode Configuration illustration on the programmer Leads Setting screen (Figure 2-39 on page 2-65). Illustrations will dynamically adjust on the programmer screen to reflect the currently selected LV Pace and LV Sense configurations.



Left illustration: heart with LV and RV leads. Right illustration: leads on the programmer screen.

**Figure 2-39. Heart LV, and RV lead in situ**

### LV Pace and Sense Configurations

Multiple LV pace and sense configurations are available for the lead, allowing you to change the pacing or sensing vectors for increased signal selection. For devices with an IS-1 or LV-1 left ventricular lead port, additional programming options are available when a dual-electrode LV lead is implanted and the corresponding Electrode Configuration is programmed to Dual. Additionally, LV sensing can be disabled by selecting Off as the LV Sense configuration.

Illustrations of pace and sense configurations are shown on the programmer Leads Setting screen.

**NOTE:** It is necessary to have an RV bipolar lead indicated in Patient Information or the RV Lead Configuration when programming the LV Lead Configuration to LV tip to RV or LV ring to RV.

### Quadripolar Devices

For VISIONIST X4 and VALITUDE X4 devices, 17 pacing configurations and 8 sensing configurations are available. A table of programmable options is provided within the LV Sense and LV Pace selections.

For the LV Pace configuration, the pacing stimulus travels between the cathode (negative [-] electrode) and the anode (positive [+] electrode). Follow these steps to program the LV Pace configuration:

1. Determine the desired Cathode (-) which is listed on the left-hand side of the table.
2. Determine the desired Anode (+) which is listed at the top of the table.
3. Select the option in the table which corresponds to the desired Cathode and Anode combination.

**CAUTION:** When an LVRing4>>RV pacing configuration is programmed with an IS4-LLLL lead, the LV tip may be used as the anode rather than the RV ring. When programming to this configuration, evaluate the pacing threshold and ensure no extracardiac stimulation is present.

The illustration to the right of the table will dynamically adjust to reflect the currently selected LV configuration. For example, if LVTip1 is selected as the Cathode and LVRing2 is selected

as the Anode, this configuration will be reflected in the associated illustration to the right of the table (Figure 2-40 on page 2-66).

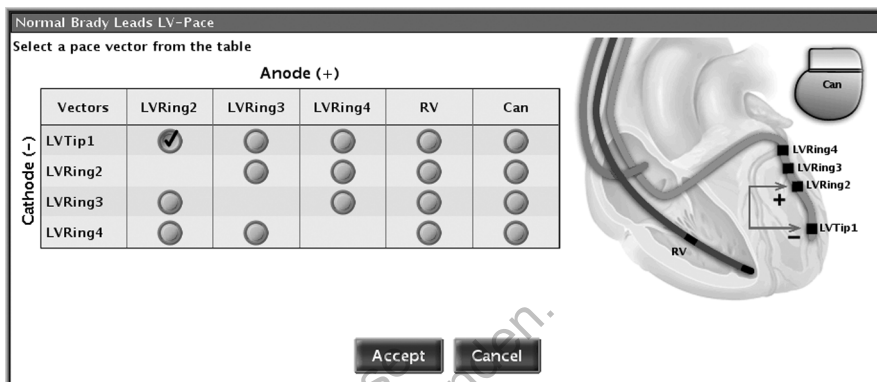


Figure 2-40. Pacing lead configuration screen for Quadripolar devices

For the LV Sense configuration, the patient's intrinsic cardiac signals will be sensed between Electrode 1 and Electrode 2. Select the option in the table which corresponds to the desired Electrode 1 and Electrode 2 combination. The illustration to the right of the table will dynamically adjust to reflect the currently selected LV configuration. For example, if LVTip1 is selected as Electrode 1 and LVRing2 is selected as Electrode 2, this configuration will be reflected in the associated illustration to the right of the table (Figure 2-41 on page 2-66). Additionally, LV sensing can be turned off by selecting the Disable Sensing checkbox.

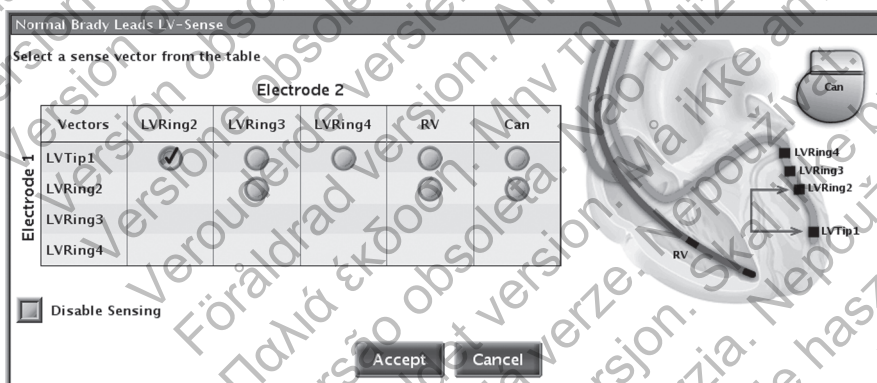


Figure 2-41. Sensing lead configuration screen for Quadripolar devices

### LV Electrograms

Real-time LV EGMs can be used to assess LV lead performance and to assist in optimizing some programmable parameters (e.g., AV Delay, LV Offset).

LV EGMs and associated LV event markers are available for display or printing in all sense configurations.

### Lead Safety Switch

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Lead Safety Switch feature allows the pacemaker to monitor lead integrity and to switch the pacing and sensing Lead Configuration from Bipolar to Unipolar if the impedance criteria indicate unacceptably high or low lead impedances.

Lead integrity is monitored once per day by measuring lead impedance. The Safety Switch feature may be programmed On in either the Atrium, Right Ventricle, or Left Ventricle.

When the measured Impedance is less than or equal to the programmed Low Impedance Limit or greater than or equal to 2000  $\Omega$  (or the programmed High Impedance Limit) for any Daily Measurement, both pacing and sensing configurations will automatically be switched to Unipolar or LV tip to Can for that chamber. Once the configuration has switched, it will remain Unipolar until it is manually reprogrammed back to Bipolar.

**NOTE:** *Reprogramming back to Bipolar may result in unexpected behavior due to the lead integrity issue that triggered the Safety Switch.*

If a Safety Switch has occurred, information is presented in the following locations on the programmer:

- Summary dialog on initial interrogation
- Leads section of the summary tab
- Daily Measurement graph regardless of the horizontal cursor position
- Safety Switch Details button from the Leads Setting screen

The date on which the Safety Switch occurred as well as the out of range lead impedance value measured are provided. Additionally, an attention symbol is displayed next to the Pace and Sense Lead Configuration for the affected lead, with Unipolar displayed as the currently programmed parameter for that lead.

The Safety Switch lead alert messages will remain on the PRM screen until the session is ended and will not be present on subsequent sessions unless an additional Safety Switch occurs.

Further testing of lead integrity and performance may be carried out via the Lead Tests screen. Testing will be performed in Unipolar until the Lead Configuration is manually reprogrammed back to Bipolar.

**CAUTION:** If properly functioning leads with stable measured impedance values near the programmed impedance limits are used, consider programming Lead Safety Switch Off or changing the impedance limits to avoid undesirable switching to a Unipolar Lead Configuration.

**NOTE:** *Disabling daily lead impedance measurements in a given chamber also disables the Lead Safety Switch feature in that chamber.*

**WARNING:** Lead Safety Switch should be programmed Off for patients with an ICD. Unipolar pacing due to Lead Safety Switch is contraindicated for patients with an ICD.

## AV DELAY

AV Delay is the programmable time period from the occurrence of either a paced or sensed right atrial event to a paced RV event when the Ventricular Pacing Chamber is programmed to BiV or RV Only.

When the Pacing Chamber is programmed to LV Only, AV Delay is the period from a paced or sensed atrial event to a paced LV event.

AV Delay is designed to help preserve the heart's AV synchrony. If a sensed right ventricular event does not occur during the AV Delay following an atrial event, the pulse generator delivers a ventricular pacing pulse when the AV Delay expires.

AV Delay can be programmed to one or both of the following operations:

- Paced AV Delay
- Sensed AV Delay

**CAUTION:** To ensure a high percentage of biventricular pacing, the programmed AV Delay setting must be less than the patient's intrinsic PR interval.

AV Delay is applicable in DDD(R), DDI(R), DOO or VDD(R) modes.

## Paced AV Delay

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Paced AV Delay corresponds to the AV Delay following an atrial pace.

The Paced AV Delay setting should be individualized for each patient to ensure consistent CRT delivery. Several methods are available to determine the Paced AV Delay setting, including:

- Intrinsic QRS duration assessment
- Echocardiogram evaluation
- Pulse pressure monitoring
- SmartDelay optimization

Since optimization of the Paced AV Delay can significantly influence CRT effectiveness, consider using methods that demonstrate the hemodynamic impact of different Paced AV Delay settings, such as echocardiography or pulse pressure monitoring.

When the minimum AV Delay value is less than the maximum AV Delay value, then the Paced AV Delay is scaled dynamically according to the current pacing rate. Dynamic AV Delay provides a more physiologic response to rate changes by automatically shortening the Paced AV Delay or Sensed AV Delay with each interval during an increase in atrial rate. This helps minimize the occurrence of large rate changes at the upper rate limit and allows one-to-one tracking at higher rates.

When using Dynamic AV Delay, consider evaluating the Paced AV Delay in effect when the patient has an elevated heart rate to ensure that CRT is still effective.

The pulse generator automatically calculates a linear relationship based on the interval length of the previous A–A or V–V cycle (depending on the previous event type) and the programmed values for the following:

- Minimum AV Delay
- Maximum AV Delay
- LRL
- MTR
- MSR
- MPR

The Dynamic AV Delay is not adjusted following a PVC or when the previous cardiac cycle was limited by the MTR.

If the atrial rate is at or below the LRL (e.g., hysteresis), the maximum AV Delay is used. If the atrial rate is at or above the higher of the MTR, MSR, or MPR, the programmed minimum AV Delay is used.

When the atrial rate is between the LRL and the higher of the MTR, MSR, and MPR, the pulse generator calculates the linear relationship to determine the Dynamic AV Delay.

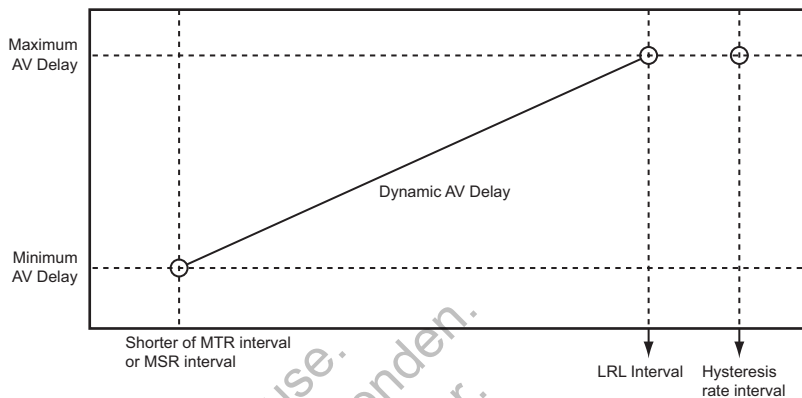


Figure 2-42. Dynamic AV Delay

The AV Delay may be programmed to either a fixed or dynamic value as follows:

- Fixed AV Delay—occurs when Paced AV Delay minimum and maximum values are equal
- Dynamic AV Delay—occurs when Paced AV Delay minimum and maximum values are not equal

### Sensed AV Delay

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Sensed AV Delay corresponds to the AV Delay after a sensed atrial event.

Sensed AV Delay may be programmed to a value shorter than or equal to the Paced AV Delay. A shorter value is intended to compensate for the difference in timing between paced atrial events and sensed atrial events (Figure 2-43 on page 2-69).

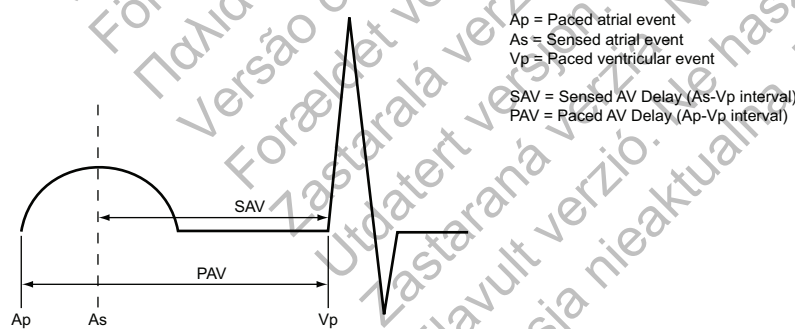


Figure 2-43. Sensed AV Delay

The hemodynamic impact of the Sensed AV Delay depends on the appropriateness of the timing between the atrial and ventricular contractions. Atrial pacing initiates atrial electrical excitation, whereas atrial sensing can only occur after the onset of spontaneous atrial excitation. The delay between initiation and sensing depends on the lead location and conduction. As a result, when Sensed AV Delay is programmed to the same value as Paced AV Delay, the hemodynamic AV interval will differ between paced and sensed atrial events.

When the DDD(R) mode is used to deliver biventricular stimulation (CRT), it may be necessary to program different Paced and Sensed AV Delay settings to optimize CRT during normal sinus rhythm and during atrial pacing because atrial pacing may prolong the interatrial delay. The prolonged interatrial delay may require a longer Paced AV Delay to achieve an optimal timing relationship between left atrial activation and biventricular pacing. The interatrial delay may be estimated by the longest P-wave duration.

When the device is programmed to DDD(R), it is recommended that the patient be tested to determine the optimal AV Delay during atrial sensing and atrial pacing. If the optimal AV Delays are different, this can be reflected by programming different Paced AV Delay and Sensed AV Delay parameter settings.

### Using Sensed AV Delay with Paced AV Delay—Fixed

When Paced AV Delay is programmed to a fixed value, then the Sensed AV Delay will be fixed at the programmed Sensed AV Delay value.

### Using Sensed AV Delay with Paced AV Delay—Dynamic

When Paced AV Delay is programmed as dynamic, then the Sensed AV Delay will also be dynamic.

Dynamic Sensed AV Delay and Paced AV Delay are based on the atrial rate. To reflect the shortening of the PR interval during periods of increased metabolic demand, the AV Delay shortens linearly from the programmed (maximum) value at the LRL (or hysteresis rate) to a value determined by the ratio of minimum and maximum AV Delay at the higher of the MTR, MSR, or MPR (Figure 2-44 on page 2-70). When Dynamic AV Delay is used, if the maximum Sensed AV Delay value is programmed as shorter than the maximum Paced AV Delay value, then the minimum Sensed AV Delay value will also be shorter than the minimum Paced AV Delay value.

**NOTE:** The minimum Sensed AV Delay value is programmable only in VDD(R) mode.

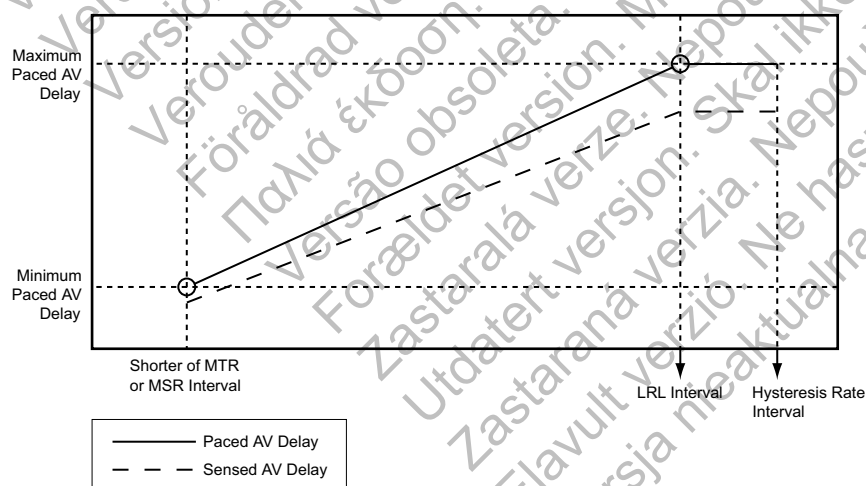


Figure 2-44. Dynamic and Sensed AV Delay function

## SmartDelay Optimization

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The SmartDelay optimization feature quickly (< 2.5 minutes) provides recommended settings for programming paced and sensed AV Delay based on the measurement of intrinsic AV intervals.

The objective of the feature is to recommend AV delays that provide optimally timed CRT, which maximizes contractile function.

Clinical data regarding hemodynamic performance of this feature relative to other AV Delay optimization methods shows that the SmartDelay optimization algorithm recommended AV delays that maximized global contractile function as measured independently by LV  $dP/dt_{max}$ . LV  $dP/dt_{max}$  is considered an index for global ventricular contractile function and pumping efficiency.

The SmartDelay optimization test evaluates right and left ventricular response to both atrial sensed and paced events to determine suggested settings for the following:

- Paced AV Delay
- Sensed AV Delay
- Pacing Chamber

These suggested settings can be used when programming the pulse generator for CRT. In addition to the parameters suggested by SmartDelay, the following parameters are also displayed on the PRM:

- LV Offset (when applicable), which is a separately programmable feature that you can enter manually. If you manually adjust LV Offset after running SmartDelay optimization, you will need to adjust the AV Delay either by running SmartDelay optimization again or manually reprogramming the AV Delay. SmartDelay takes the LV Offset into account as follows:
  - SmartDelay uses simple arithmetic to account for the programmed LV Offset in the Paced and Sensed AV Delay recommendations it provides. For example, if the SmartDelay suggested AV Delay (which starts at the atrial event and ends at the left ventricular pace) is 150 ms and the programmed LV Offset is -20 ms, then the SmartDelay feature will adjust its recommendation to 170 ms, since the AV Delay feature is programmed from the atrial event to the right ventricular pace.
  - SmartDelay maintains the currently programmed LV Offset with the following exceptions:
    - (1) If SmartDelay cannot collect sufficient intrinsic events, nominal settings that include an LV Offset of zero are suggested.
    - (2) If SmartDelay recommends an AV Delay and LV Offset that together exceed the maximum programmable AV Delay of 300 ms, SmartDelay will suggest a reduced LV Offset.
    - (3) If the currently programmed LV Offset is greater than 0 ms, an LV Offset of zero is suggested.

**NOTE:** Before making a programming change, it is important to assess whether the suggested settings are appropriate for the patient.

The SmartDelay optimization screen is shown below (Figure 2-45 on page 2-71).

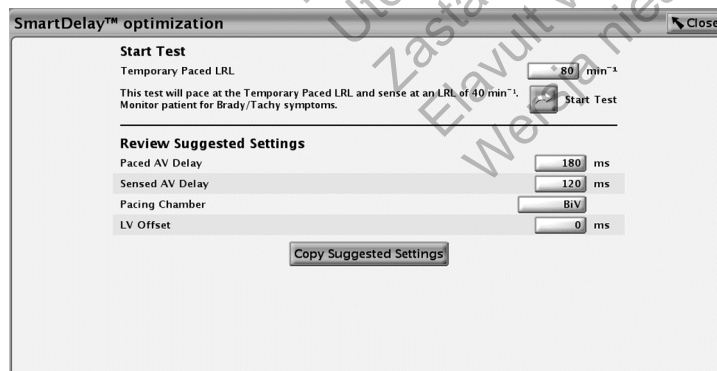


Figure 2-45. SmartDelay optimization screen

SmartDelay optimization automatically switches to a unipolar sensing configuration for the duration of the test. The test runs automatically when Start Test is pressed. The SmartDelay optimization test will not run under the following conditions:

- When the LV Electrode Configuration is programmed to None for devices with an IS-1 or LV-1 left ventricular lead port
- During an ATR Mode Switch
- During a tachycardia episode as determined by the pulse generator detection criteria

**NOTE:** When collecting atrial sensed events during the test, backup DDD pacing is provided at 40 min<sup>-1</sup>.

**NOTE:** When collecting atrial paced events, backup DDD pacing is provided at the temporary LRL, which can be selected from the SmartDelay optimization screen. This temporary LRL is nominally set to 80 min<sup>-1</sup>.

**NOTE:** It is necessary to increase temporary paced LRL 10 to 15 min<sup>-1</sup> higher than the intrinsic atrial rate to achieve paced AV interval measurements.

Follow these steps to run the SmartDelay optimization test.

1. From the Normal Settings screen, select the Mode.
  - In DDD(R) mode, the recommendation is for both Paced AV Delay and Sensed AV Delay.
  - In VDD(R) mode, the recommended AV Delay is the Sensed AV Delay; the Paced AV Delay does not apply.

When changing modes from DDD(R) to VDD(R) or vice versa, it is important to rerun the SmartDelay optimization test.

2. Select the SmartDelay optimization button.
3. Enter the temporary paced LRL value or use the default value of 80 min<sup>-1</sup>.
4. Maintain telemetry throughout the test.
5. Before beginning the test, advise the patient to remain still and to avoid talking during the test.
6. Press the Start Test button. A notification window indicates that the test is in progress. If it is necessary to cancel the test, select the Cancel Test button.

**NOTE:** The test is automatically cancelled if a STAT PACE or DIVERT THERAPY command is selected.

7. When the test is complete, the suggested settings appear. For ease in programming, select the Copy Suggested Settings button to transfer the suggested settings to the Normal Brady and CRT Settings screen.

**NOTE:** If testing fails, the reason for test failure will be provided.

## REFRACTORY

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Refractory periods are the intervals following paced or sensed events during which the pulse generator is not inhibited or triggered by detected electrical activity. They suppress (or prevent) oversensing of pulse generator artifacts and evoked responses following a pacing pulse. They



also promote appropriate sensing of a single, wide, intrinsic complex and prevent the sensing of other intrinsic signal artifacts (e.g., a T-wave or far-field R-wave).

**NOTE:** Rate Adaptive Pacing is not inhibited during refractory periods.

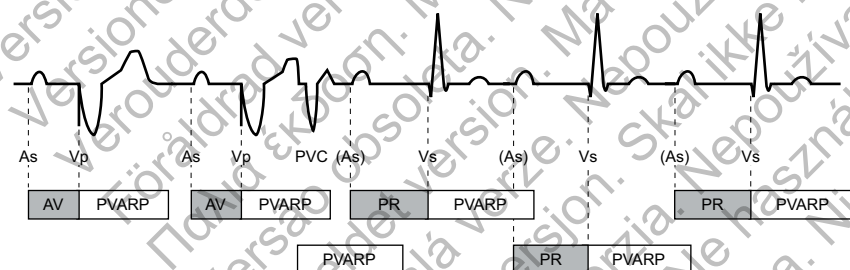
## A-Refractory - PVARP

PVARP is defined according to the pacing mode:

- Dual-chamber device programmed AAI(R)—the time period after a sensed or paced atrial event when an atrial sense event does not inhibit an atrial pace.
- Dual-chamber modes: DDD(R), DDI(R), VDD(R)—the time period after a sensed or paced RV event (or LV pace when the Pacing Chamber is programmed to LV Only) when an atrial event does not inhibit an atrial pace or trigger a ventricular pace. The Atrial Refractory period prevents the tracking of retrograde atrial activity initiated in the ventricle.

PVARP can be programmed to a fixed value or to a dynamic value calculated based on the previous cardiac cycles. To program a fixed PVARP, set the minimum and maximum to the same value. PVARP will automatically be dynamic if the minimum value is less than the maximum value.

For heart failure patients with intact AV conduction, a long intrinsic intracardiac AV interval and a long programmed PVARP can cause the loss of atrial tracking below the MTR, resulting in the loss of biventricular stimulation (CRT). If an atrial event, such as a PAC or a P-wave that immediately follows a PVC, falls into PVARP, it will not be tracked. This allows for AV conduction of an intrinsic ventricular event, which restarts PVARP. Unless the next atrial event occurs outside of PVARP, it too will not be tracked, and another intrinsic AV-conducted ventricular event will occur, again restarting PVARP. This pattern can continue until an atrial event is finally sensed outside of PVARP (Figure 2-46 on page 2-73).



**Figure 2-46.** Atrial sensed event in PVARP

If you believe a loss of atrial tracking below the MTR is occurring, program Tracking Preference to On. If the loss of CRT below MTR continues to be a problem or if Tracking Preference is not used, consider reprogramming a shorter PVARP.

For heart failure patients with second- and third-degree AV block, programming long Atrial Refractory periods in combination with certain AV Delay periods can cause 2:1 block to occur abruptly at the programmed MTR.

In DDD(R) and VDD(R) pacing modes, the pulse generator may detect retrograde conduction in the atrium, causing triggered ventricular pacing rates as high as the MTR (i.e., PMT). Retrograde conduction times may vary over a patient's lifetime as a function of changing autonomic tone. If testing does not reveal retrograde conduction at implantation, it may still occur at a later time. This problem can usually be avoided by increasing the atrial refractory period to a value that exceeds the retrograde conduction time.

In controlling the pulse generator's response to retrograde conduction, it may also be useful to program the following:

- PVARP after PVC
- PMT Termination
- Rate Smoothing

### Dynamic PVARP

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Programming of Dynamic PVARP and Dynamic AV Delay optimizes the sensing window at higher rates, allowing upper rate behavior (e.g., 2:1 block and pacemaker Wenckebach) in DDD(R) and VDD(R) modes to be significantly reduced, even at higher MTR settings. At the same time, Dynamic PVARP reduces the likelihood of PMTs at lower rates. Dynamic PVARP also reduces the likelihood of competitive atrial pacing.

The pulse generator automatically calculates the Dynamic PVARP using a weighted average of the previous cardiac cycles. This results in a shortening of the PVARP in a linear fashion as the rate increases. When the average rate is between the LRL and the MTR or applicable upper rate limit, the pulse generator calculates the Dynamic PVARP according to the linear relationship shown (Figure 2-47 on page 2-74). This relationship is determined by the programmed values for Minimum PVARP, Maximum PVARP, the LRL, and the MTR or applicable upper rate limit.

**CAUTION:** Programming minimum PVARP less than retrograde V–A conduction may increase the likelihood of a PMT.

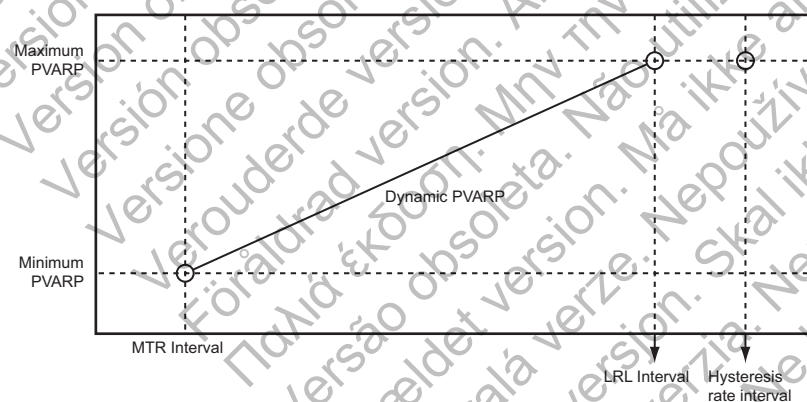


Figure 2-47. Dynamic PVARP

### Maximum PVARP

If the average rate is equal to or lower than the LRL (e.g., hysteresis), the Maximum PVARP is used.

### Minimum PVARP

If the average rate is equal to or higher than the MTR interval, the programmed Minimum PVARP is used.

### PVARP after PVC

PVARP after PVC is designed to help prevent PMT due to retrograde conduction, which can occur due to a PVC.

When the pulse generator detects a sensed RV event without detecting a preceding atrial sensed event (refractory or non-refractory) or delivering an atrial pace, the Atrial Refractory period automatically extends to the programmed PVARP after PVC value for one cardiac cycle. After a PVC is detected, the timing cycles reset automatically. PVARP extends no more frequently than every other cardiac cycle.

The pulse generator automatically extends the PVARP to the PVARP after PVC value for one cardiac cycle in these additional situations:

- If an atrial pace is inhibited due to Atrial Flutter Response
- After a ventricular escape pace that is not preceded by an atrial sense in VDD(R) mode
- When the device transitions from a non-atrial tracking mode to an atrial tracking mode (e.g., exits ATR Fallback, transitions from temporary non-atrial tracking mode to permanent atrial tracking mode)
- When the device returns from magnet operation to an atrial tracking mode
- When the device returns from Electrocautery Protection to an atrial tracking mode

For heart failure patients with intact AV conduction, PVARP after PVC has the potential to cause inhibition of CRT if the atrial cycle length is shorter than the intrinsic intracardiac AV interval (PR interval) + PVARP. If this occurs, program Tracking Preference to On in conjunction with the PVARP after PVC feature.

## A Refractory - same chamber

### Dual-chamber Modes

Atrial Refractory provides an interval following an atrial paced or sensed event when additional atrial sensed events do not impact the timing of pacing delivery.

The following are nonprogrammable intervals for dual-chamber modes:

- 85 ms Atrial Refractory following an atrial sensed event
- 150 ms Atrial Refractory following an atrial pace in DDD(R) and DDI(R) modes

## RV-Refractory (RVRP)

The programmable RVRP provides an interval following an RV pace event, or leading ventricular pace event when LV Offset is not programmed to zero, during which RV sensed events do not impact the timing of pacing delivery.

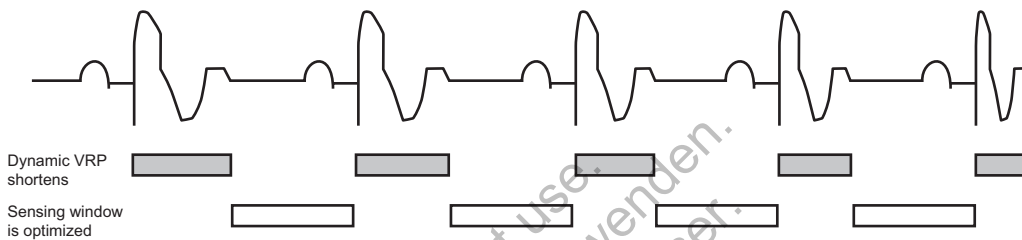
Additionally, a 135 ms nonprogrammable refractory period provides an interval following an RV sensed event during which further RV sensed events do not impact the timing of pacing delivery.

Any event which falls into VRP is not detected or marked (unless it occurs within the noise window), and does not impact timing cycles.

RVRP is available in any mode where ventricular sensing is enabled, and RVRP can be programmed to a fixed or dynamic interval (Figure 2-48 on page 2-76):

- Fixed—RVRP remains at the programmed, fixed RVRP value between the LRL and the applicable upper rate limit (MPR, MTR or MSR).

- Dynamic—RVRP shortens as ventricular pacing increases from the LRL to the applicable upper rate limit, allowing adequate time for RV sensing.
  - Maximum—if the pacing rate is less than or equal to the LRL (i.e., hysteresis), the programmed Maximum VRP is used as the RVRP.
  - Minimum—if the pacing rate is equal to the applicable upper rate limit, the programmed Minimum VRP is used as the RVRP.



**Figure 2-48.** Relationship between ventricular rate and refractory interval

To provide an adequate sensing window, the following Refractory value (fixed or dynamic) programming is recommended:

- Single-chamber modes—less than or equal to one-half the LRL in ms
- Dual-chamber modes—less than or equal to one-half the applicable upper rate limit in ms

The use of a long RVRP shortens the ventricular sensing window.

Programming the Ventricular Refractory Period to a value greater than PVARP can lead to competitive pacing. For example, if the Ventricular Refractory is longer than PVARP, an atrial event can be appropriately sensed following PVARP and intrinsic conduction to the ventricle falls into the Ventricular Refractory Period. In this case, the device will not sense the ventricular depolarization and will pace at the end of the AV Delay, resulting in competitive pacing.

### LV-Refractory (LVRP)

The LVRP prevents sensed electrical events from causing an inappropriate loss of CRT following a sensed or paced event, such as a left-sided T-wave. Proper programming of this feature will help maximize CRT delivery while reducing the risk of accelerating the patient's rhythm to a ventricular tachyarrhythmia.

CRT should be delivered continuously to maximize the patient benefit; however, there are circumstances when it may be appropriate to inhibit therapy delivery. LVRP provides an interval following an LV sense or pace event, or leading ventricular pace event when LV Offset is not programmed to zero, during which LV sensed events do not impact the timing of therapy delivery. Use of a long LVRP shortens the LV sensing window.

LVRP is available in any mode where LV sensing is enabled. The LV interval remains at the programmed fixed value between the LRL and the applicable upper rate limit.

LV oversensing of a T-wave may inhibit LV pacing. To prevent inappropriate inhibition of LV pacing, program LVRP to a duration sufficiently long to include the T-wave.

### Left Ventricular Protection Period (LVPP)

The LVPP prevents the pulse generator from inadvertently delivering a pacing stimulus during the LV vulnerable period if, for example, a left-sided PVC occurs. Proper programming of this

feature will help maximize CRT delivery while reducing the risk of accelerating the patient's rhythm to a ventricular tachyarrhythmia.

CRT should be delivered continuously to maximize the patient benefit; however, there are circumstances when it may be appropriate to inhibit therapy delivery. LVPP is the period after a paced or sensed LV event when the pulse generator will not pace the left ventricle. LVPP prevents the pulse generator from pacing into the LV vulnerable period.

**CAUTION:** Use of a long LVPP reduces the maximum LV pacing rate and may inhibit CRT at higher pacing rates.

**NOTE:** *If LVPP inhibits in LV Only, the pulse generator will issue an RV pace for bradycardia support.*

LVPP is available in any mode where ventricular sensing and LV pacing are enabled.

## Cross-Chamber Blanking

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Cross-chamber blanking periods are designed to promote appropriate sensing of in-chamber events and prevent oversensing of activity in another chamber (e.g., cross-talk, far-field sensing).

Cross-chamber blanking periods are initiated by paced and/or sensed events in an adjacent chamber. For example, a blanking period is initiated in the right ventricle each time a pacing pulse is delivered to the right atrium; this prevents the device from detecting the atrial paced event in the right ventricle.

Cross-chamber Blanking can be programmed to Smart (when available) or a fixed value. Smart Blanking is designed to promote appropriate sensing of in-chamber events by shortening the cross-chamber blanking period (37.5 ms following paced events and 15 ms following sensed events) and prevent oversensing of cross-chamber events by automatically raising the AGC threshold for sensing at the expiration of the Smart Blanking period.

Smart Blanking does not change the programmed AGC or Fixed Sensitivity settings.

**NOTE:** *Smart Blanking periods will be lengthened to 85 ms if a same-chamber blanking period or a retriggerable noise window is active when the Smart Blanking period begins. For example, if an RV sense occurs within the atrial refractory period, the A-Blank after RV-Sense cross chamber blank will be 85 ms.*

**CAUTION:** Sensitivity adjustments associated with Smart Blanking may not be sufficient to inhibit detection of cross-chamber artifacts if the cross-chamber artifacts are too large. Consider other factors that impact the size/amplitude of cross-chamber artifacts including lead-placement, pacing output, and programmed Sensitivity settings.

Blanking period nominals and programmable options will automatically change in certain situations in order to ensure that cross-chamber artifacts are not detected:

- If the AGC Sensing Method is selected, Smart Blanking is the nominal setting (except for V-Blank after A-Pace) and Fixed Blanking is also available.

**NOTE:** *If AGC is used with a Unipolar Atrial Sense Lead Configuration, Fixed atrial blanking is the nominal setting but Smart Blanking is available.*

- If the Fixed Sensing Method is selected, Fixed Blanking is the nominal setting and Smart Blanking is not available for any chamber.

- When a change to the Sensing Method occurs, blanking periods will automatically revert to the nominal value associated with that Sensing Method unless the blanking period was previously reprogrammed. If the blanking period was previously reprogrammed for a Sensing Method, the period will revert to the last programmed value.

### **RV-Blank after A-Pace**

RV-Blank after A-Pace is a cross-chamber blanking period designed to promote the appropriate sensing of RV events and prevent oversensing of cross-chamber events following an atrial pace.

The pulse generator will not respond to RV events for the duration selected following an atrial pace.

**NOTE:** *Smart Blanking is not available for the RV-Blank after A-Pace parameter.*

When adjusting Blanking, consider the following:

- To promote continuous pacing for pacemaker-dependent patients, it may be preferable to lessen the potential for ventricular oversensing of atrial paced artifacts by programming a longer blanking period. However, programming a longer blanking period may increase the likelihood of undersensing R-waves (e.g., PVCs, should they occur within the RV-Blank after A-Pace cross-chamber blanking period).
- For patients with a high percentage of atrial pacing and frequent PVCs who are not pacemaker-dependent, it may be preferable to shorten the blanking period to lessen the potential for undersensing a PVC (should it occur in the cross-chamber blanking period following an atrial paced event). However, a shorter blanking period may increase the likelihood for ventricular oversensing of an atrial paced event.

Certain programmed combinations of dual-chamber pacing parameters may interfere with ventricular tachy detection. For example, when dual-chamber pacing occurs, RV undersensing due to the refractory period caused by an atrial pace (RV-Blank after A-Pace) could occur. In certain usage scenarios, if a pattern of atrial pacing and VT beats is detected, the Brady Tachy Response (BTR) feature will automatically adjust the AV Delay to facilitate confirmation of a suspected VT. If no VT is present, the AV Delay is returned to the programmed value. For programming scenarios where the automatic AV Delay adjustment may occur, a specific Parameter Interaction Attention will not be displayed. For discussion of details, please contact Boston Scientific using the information on the back cover.

### **LV-Blank after A-Pace**

LV-Blank after A-Pace is a cross-chamber blanking period designed to promote the appropriate sensing of LV events and prevent oversensing of cross-chamber events following an atrial pace. The pulse generator will not respond to LV events for the duration selected following an atrial pace.

LV-Blank after A-Pace may be programmed to a Fixed or Smart (available with the AGC Sensing Method) value.

If the value is programmed to Smart, the pulse generator automatically raises the AGC threshold for sensing at the expiration of the Smart Blanking period in order to aid rejection of cross-chamber atrial events. This promotes sensing of LV events that may have otherwise fallen in the cross-chamber blanking period. Smart Blanking does not change the programmed Sensitivity settings.

**A-Blank after V-Pace**

A-Blank after V-Pace is a cross-chamber blanking period designed to promote the appropriate sensing of P-waves and prevent oversensing of cross-chamber events following either an RV or LV pace.

A-Blank after V-Pace may be programmed to a Fixed or Smart (available with the AGC Sensing Method) value.

If the value is programmed to Smart, the pulse generator automatically raises the AGC threshold for sensing at the expiration of the Smart Blanking period in order to aid rejection of cross-chamber ventricular events. This promotes sensing of P-waves that may have otherwise fallen in the cross-chamber blanking period. Smart Blanking does not change the programmed Sensitivity settings.

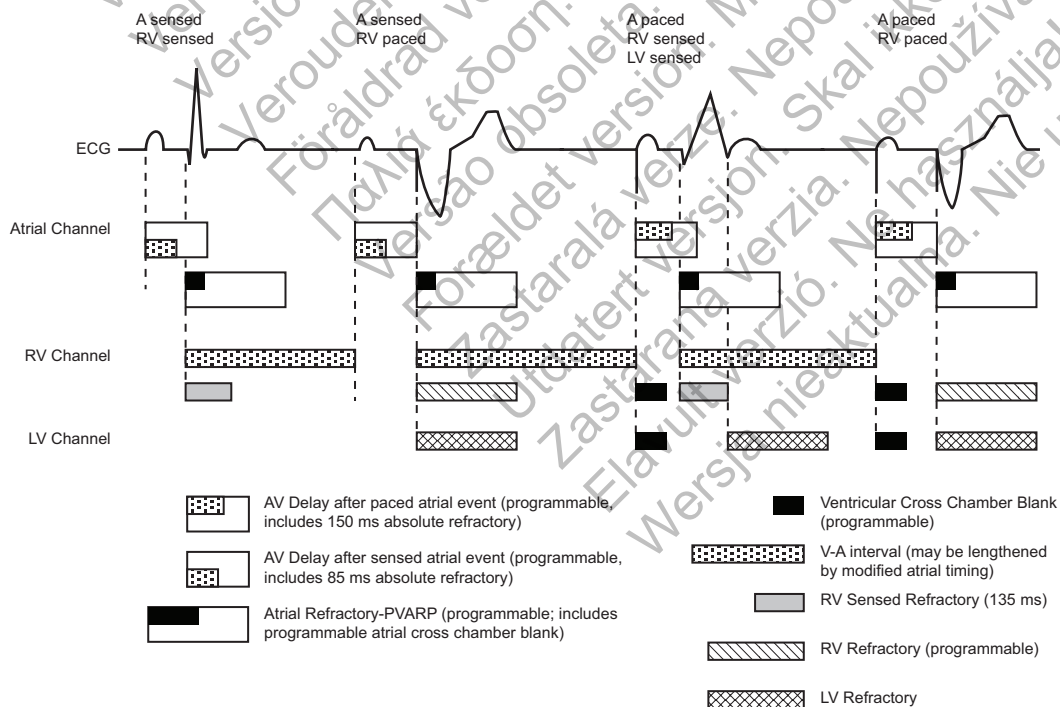
**A-Blank after RV-Sense**

A-Blank after RV-Sense is a cross-chamber blanking period designed to promote appropriate sensing of P-waves and prevent oversensing of cross-chamber events following an RV-sensed event.

A-Blank after RV-Sense may be programmed to a Fixed or Smart (available with the AGC Sensing Method) value.

If the value is programmed to Smart, the pulse generator automatically raises the AGC threshold for sensing at the expiration of the Smart Blanking period in order to aid rejection of cross-chamber RV events. This promotes sensing of P-waves that may have otherwise fallen in the cross-chamber blanking period. Smart Blanking does not change the programmed Sensitivity settings.

Refer to the following illustrations:



**Figure 2-49. Refractory periods, dual-chamber pacing modes; RV only**

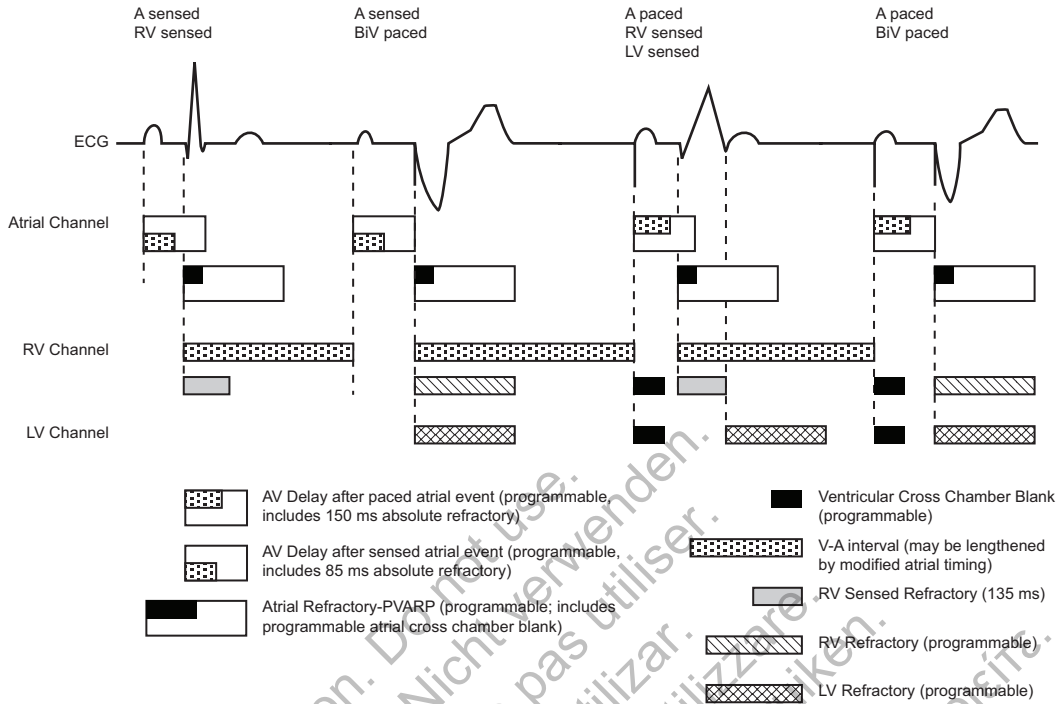


Figure 2-50. Refractory periods, dual-chamber pacing modes; BiV

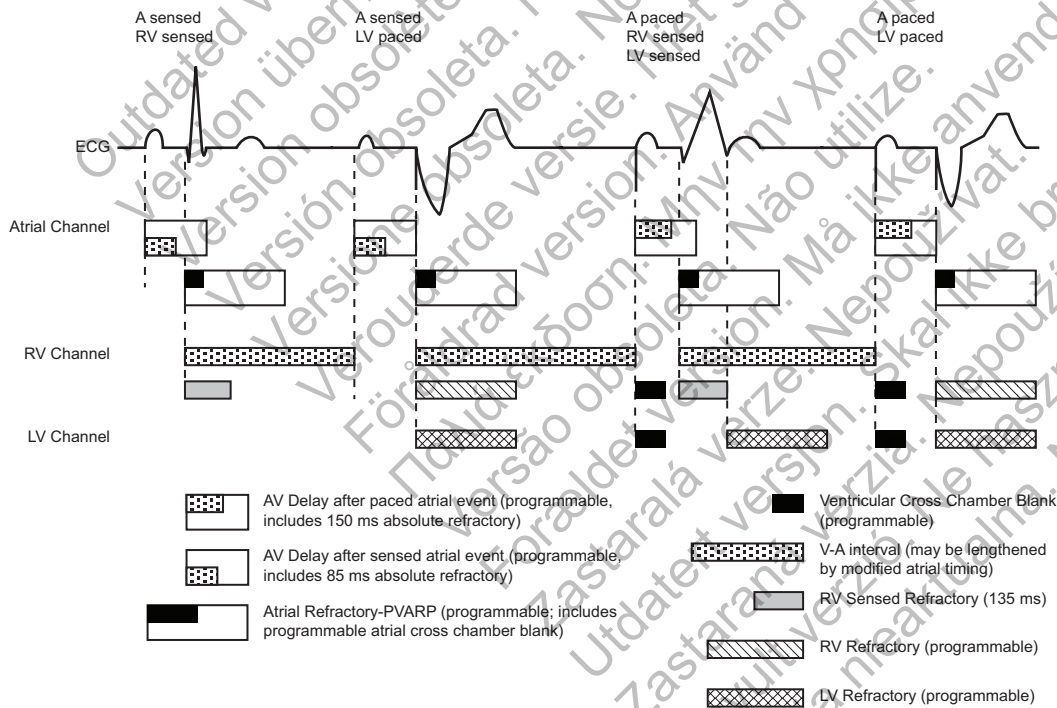
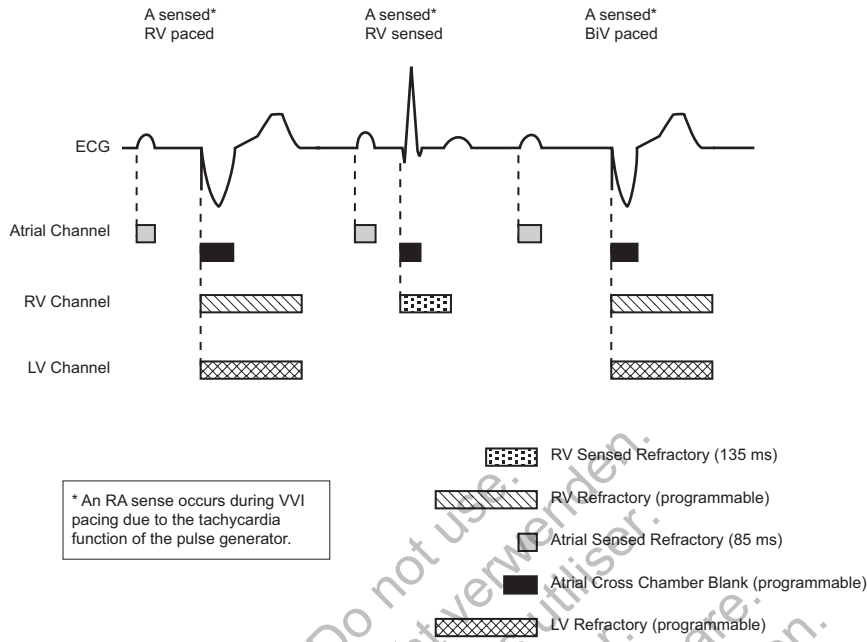
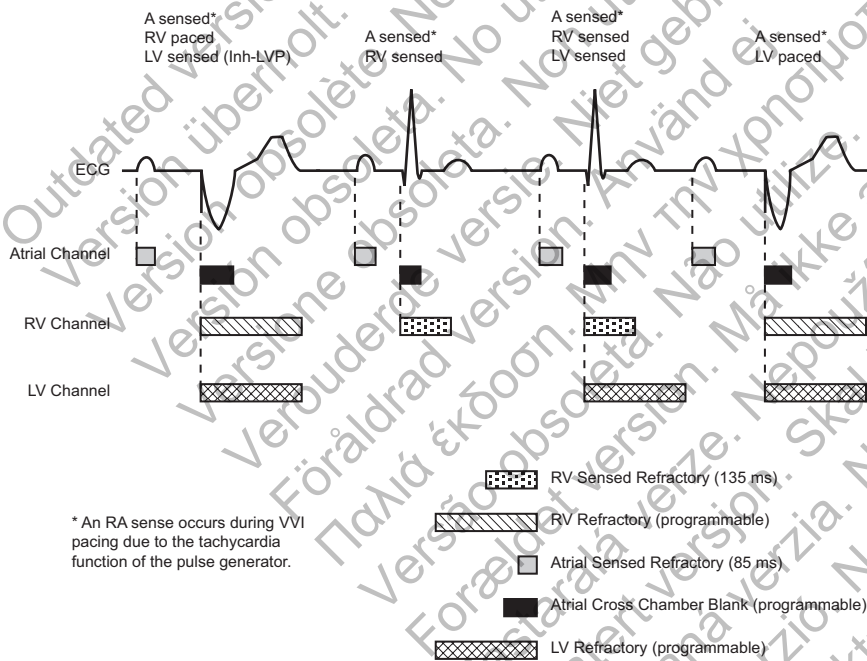


Figure 2-51. Refractory periods, dual-chamber pacing modes; LV only





**Figure 2-52. Refractory periods, VVI pacing mode; RV and BiV**



**Figure 2-53. Refractory periods, VVI pacing mode; LV only**

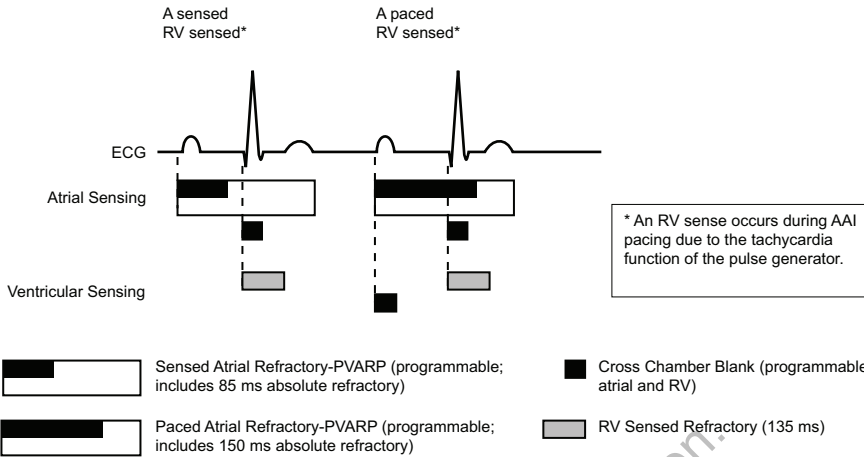


Figure 2-54. Refractory periods, AAI pacing mode; DR

## NOISE RESPONSE

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Noise windows and blanking periods are designed to prevent pacing inhibition due to cross-chamber oversensing.

Noise Response allows the clinician to choose whether to pace or inhibit pacing in the presence of noise.

A retriggerable, 40-ms noise window exists within each refractory and fixed (non-smart) cross-chamber blanking period. The window is initiated by either a sensed or paced event. Both the noise window and the refractory period must be completed for each cardiac cycle in one chamber before the next event restarts the timing in the same chamber. Recurrent noise activity may cause the noise window to restart, extending the noise window and possibly the effective refractory period or blanking period.

The Noise Response parameter can be programmed to Inhibit Pacing or an asynchronous mode. The available asynchronous mode will automatically correspond to the permanent Brady Mode (i.e., VVI permanent mode will have VOO noise response). If Noise Response is programmed to an asynchronous mode and the noise persists so that the noise window is extended longer than the programmed pacing interval, the pulse generator paces asynchronously at the programmed pacing rate until the noise ceases. If Noise Response is programmed to Inhibit Pacing and persistent noise occurs, the pulse generator will not pace in the noisy chamber until after the noise ceases. The Inhibit Pacing mode is intended for patients whose arrhythmias may be triggered by asynchronous pacing.

Refer to the following illustrations.

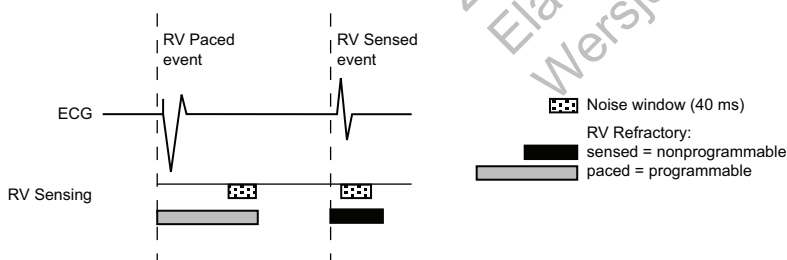


Figure 2-55. Refractory periods and noise windows, RV

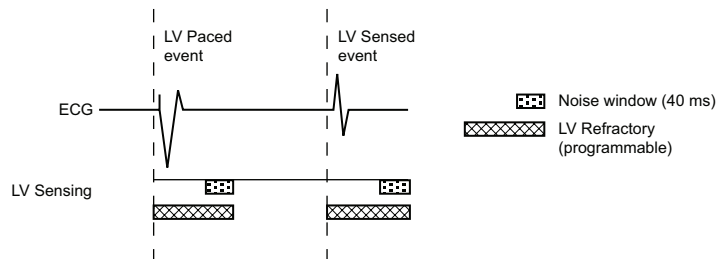


Figure 2-56. Refractory periods and noise windows, LV

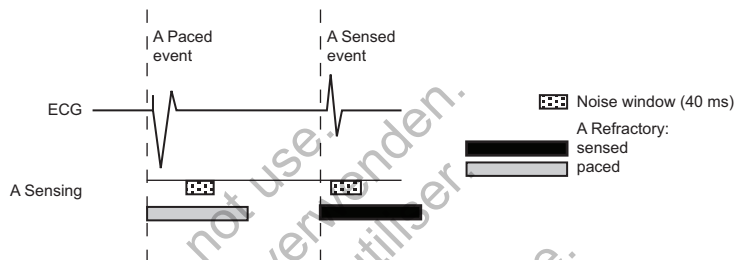


Figure 2-57. Refractory periods and noise windows, RA

In addition, a nonprogrammable Dynamic Noise Algorithm is active in rate channels where AGC Sensing is used.

The Dynamic Noise Algorithm uses a separate noise channel to continuously measure the baseline signal and adjust the sensing floor to avoid noise detection. This algorithm is intended to help prevent oversensing of myopotential signals and the problems associated with oversensing.

If event markers are being transmitted, depending on the chamber where noise is occurring, the marker [AS], [RVS], or [LVS] occurs when the noise window is initially triggered following a pace. If the noise window is retriggered for 340 ms, the markers AN, RVN, or LVN occur. With continuous retriggers, the AN, RVN, or LVN markers will occur frequently. If asynchronous pacing occurs due to continuous noise, the markers AP-Ns, RVP-Ns, or LVP-Ns will occur.

**NOTE:** In pacemaker-dependent patients, use care when considering setting Noise Response to Inhibit Pacing as pacing will not occur in the presence of noise.

**NOTE:** If noise inhibits in LV Only, the device will issue an RV pace for bradycardia support provided there is no noise in the RV channel.

#### Noise Response example

Cross-chamber sensing that occurs early in the AV Delay may be detected by the RV sense amplifiers during the fixed blanking period, but is not responded to except to extend the noise rejection interval. The 40 ms noise rejection interval continues to retrigger until the noise is no longer detected, up to the length of the AV Delay. If noise continues throughout the duration of the AV Delay, the device will deliver a pacing pulse when the AV Delay timer expires, preventing ventricular inhibition due to noise. If a ventricular pacing spike is delivered under conditions of continuous noise, a VP-Ns marker notation appears on the intracardiac electrogram (Figure 2-84 on page 2-84).

If noise ceases prior to the expiration of the AV Delay, the device can detect an intrinsic beat that occurs at any time beyond the 40 ms retriggerable noise interval and initiate a new cardiac cycle.

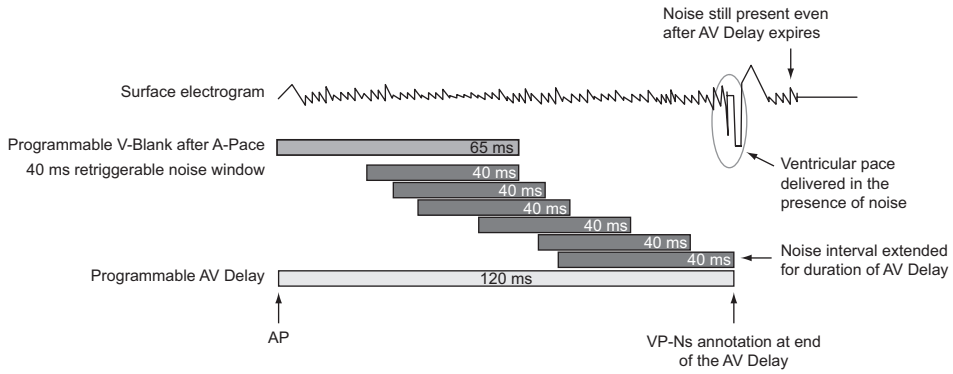


Figure 2-58. Noise Response (fixed blanking)

Outdated version. Do not use.  
 Version überholt. Nicht verwenden.  
 Version obsolète. Ne pas utiliser.  
 Versión obsoleta. No utilizar.  
 Versiões obsoletas. Não utilize.  
 Verouderde versie. Niet gebruiken.  
 Föråldrad version. Använd ej.  
 Παλιά έκδοση. Μην χρησιμοποιείτε.  
 Versão obsoleta. Não utilize.  
 Forældet version. Må ikke anvendes.  
 Zastaralá verze. Nepoužívat.  
 Utdatert versjon. Skal ikke brukes.  
 Zastaraná verzia. Nepoužívať.  
 Elavult verzió. Ne használja!  
 Wersja nieaktualna. Nie używać.

## SYSTEM DIAGNOSTICS

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### CHAPTER 3

This chapter contains the following topics:

- "Summary Dialog" on page 3-2
- "Battery Status" on page 3-2
- "Leads Status" on page 3-6
- "Post-Operative System Test (POST)" on page 3-10
- "Lead Tests" on page 3-10

Outdated version. Do not use.  
Version überholt. Nicht verwenden.  
Version obsolete. Ne pas utiliser.  
Versión obsoleta. No utilizar.  
Versione obsoleta. Non utilizzate.  
Verouderde versie. Niet gebruiken.  
Föråldrad version. Använd ej.  
Παλιά έκδοση. Μην χρησιμοποιείτε.  
Versão obsoleta. Não utilize.  
Forældet version. Må ikke anvendes.  
Zastaralá verzia. Nepoužívať.  
Utdatert versjon. Skal ikke brukes.  
Zastaraná verzia. Nepoužívať.  
Elavult verzió. Ne használja!  
Wersja nieaktualna. Nie używać.

## SUMMARY DIALOG

Upon interrogation, a Summary dialog is displayed. It includes Leads and POST information, Battery status indications, approximate time to explant, and an Events notification for any episodes since the last reset. In addition, a magnet notification will appear if the pulse generator detects the presence of a magnet.

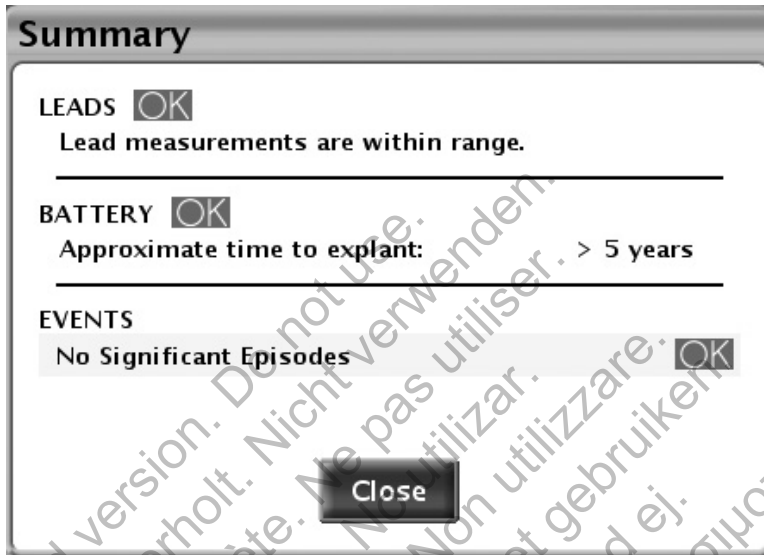


Figure 3-1. Summary dialog

Potential status symbols include OK, Attention, or Warning ("Use of Color" on page 1-7). Potential messages are described in the following sections:

- Leads—"Leads Status" on page 3-6
- Battery—"Battery Status" on page 3-2
- Events—"Therapy History" on page 4-2

Once the Close button is selected, the Warning or Attention symbols for Leads and Battery will not appear on subsequent interrogations until additional events triggering an alert condition occur. Events will continue to appear until any history counter Reset button is selected.

## BATTERY STATUS

The pulse generator automatically monitors battery capacity and performance. Battery status information is provided via several screens:

- Summary dialog—displays a basic status message about remaining battery capacity ("Summary Dialog" on page 3-2).
- Summary tab (on the Main Screen)—displays the same basic status message as the Summary dialog, along with the battery status gauge ("Main Screen" on page 1-2).
- Battery Status Summary screen (accessed from the Summary tab)—displays additional battery status information about remaining battery capacity and current Magnet Rate ("Battery Status Summary Screen" on page 3-3).

- Battery Detail screen (accessed from the Battery Status Summary screen)—provides detailed information about battery use, capacity, and performance ("Battery Detail Summary Screen" on page 3-5).

**Battery Status Summary Screen**

The Battery Status Summary screen provides the following key information about battery capacity and performance.

**Time Remaining**

This section of the screen displays the following items:

- Battery status gauge—displays a visual indication of the time remaining to explant.

**NOTE:** *Battery status can be assessed using a manually applied external magnet stronger than 70 gauss. The pacing rate activated by magnet application provides an indication of battery status on the Battery Status Summary screen. For details, refer to "Magnet Rate" below.*

- Approximate time to explant—displays the estimate of calendar time remaining until the pulse generator reaches the Explant status.

This estimate is calculated using battery capacity consumed, charge remaining, and power consumption at current programmed settings.

When insufficient usage history is available, Approximate time to explant may change between interrogation sessions. This fluctuation is normal, and occurs as the pulse generator collects new data and can calculate a more stable prediction. Approximate time to explant will be more stable after several weeks of usage. Causes of fluctuation may include the following:

- If certain brady features that affect pacing output are reprogrammed, the Approximate time to explant will be forecasted based on the expected changes in power consumption from the reprogrammed features. The next time the pulse generator is interrogated, the PRM will resume displaying Approximate time to explant based on recent usage history. As new data is collected, Approximate time to explant will likely stabilize near the initial forecast.
- For several days post-implant, the PRM will display a static Approximate time to explant based on model-dependent data. Once enough usage data has been collected, device-specific predictions will be calculated and displayed.

**Magnet Rate**

When the Magnet Response is programmed to Pace Async, magnet application converts the pulse generator Brady Mode to an asynchronous mode with a fixed pacing rate and magnet AV Delay of 100 ms.

The asynchronous pacing rate will reflect the current battery status and is displayed on the Battery Status Summary screen:

More than One Year Remaining	100 min <sup>-1</sup>
One Year or Less Remaining	90 min <sup>-1</sup>
Explant	85 min <sup>-1</sup>

Additional information about Pace Async and the Magnet Feature is available ("Magnet Feature" on page 4-20).

### Battery Detail icon

When selected, this icon displays the Battery Detail Summary screen ("Battery Detail Summary Screen" on page 3-5).

### Battery Status Indicators

The following battery status indicators appear in the battery status gauge. The indicated Approximate time to explant is calculated based on the pulse generator's current programmed parameters.

One Year Remaining—approximately one year of full pulse generator function remains (Approximate time to explant is one year).

Explant—The battery is nearing depletion, and pulse generator replacement must be scheduled. Once Explant status is reached, there is sufficient battery capacity to pace 100% under existing conditions for three months. When Explant status is reached, 1.5 hours of ZIP telemetry remain. Consider using wanded telemetry.

**NOTE:** When the 1.5 hours of telemetry are exhausted, a LATITUDE alert is generated.

Battery Capacity Depleted—pulse generator functionality is limited, and therapies can no longer be guaranteed. This status is reached three months after Explant status is reached. The patient should be scheduled for immediate device replacement. Upon interrogation, the Limited Device Functionality screen is displayed (all other screens are disabled). This screen provides battery status information and access to remaining device functionality. ZIP telemetry is no longer available.

**NOTE:** A LATITUDE alert is generated, after which LATITUDE NXT is no longer available.

When the device reaches Battery Capacity Depleted status, functionality is limited to the following:

- Brady Mode will be changed as described below:

Brady Mode prior to Battery Capacity Depleted Indicator	Brady Mode after Battery Capacity Depleted Indicator
DDD(R), DDI(R), VDD(R), VVI(R)	VVI/BIV
AAI(R)	AAI
Off	Off
DOO, VOO	VOO/BIV
AOO	AOO

- Brady Mode can be programmed to Off; no other parameters are programmable
- Wanded telemetry only (RF telemetry is disabled)
- An LRL of 50 min<sup>-1</sup>

At Battery Capacity Depleted status, the following features are disabled:

- Daily Measurement trends
- Brady enhancements (e.g., rate response, Rate Smoothing)
- PaceSafe RV Automatic Threshold (the output is fixed at the current output value)
- PaceSafe RA Automatic Threshold (the output is fixed at the current output value)



- PaceSafe LV Automatic Threshold (the output is fixed at the current output value)
- Lead Safety Switch (the lead configuration remains as it was programmed when the device reached Battery Capacity Depleted status)
- Episode storage
- Diagnostic and EP Tests
- Real-time EGMs
- MV sensor
- Accelerometer

If the device reaches a point where insufficient battery capacity is available for continued operation, the device will revert to Storage Mode. In Storage Mode, no functionality is available.

**NOTE:** *The device uses the programmed parameters and recent usage history to predict Approximate time to explant. Greater than normal battery usage may result in the subsequent day's Approximate time to explant to appear less than expected.*

### Battery Detail Summary Screen

The Battery Detail summary screen provides the following information about pulse generator battery status (Figure 3-2 on page 3-6):

- Charge Remaining (measured in ampere-hours)—the amount of charge remaining based on the pulse generator's programmed parameters until the battery is depleted.
- Power Consumption (measured in microwatts)—the average daily power being used by the pulse generator, based on currently programmed parameters. Power consumption is included in the calculations that determine Approximate time to explant and the needle position on the battery status gauge.
- Power Consumption Percentage—compares the power consumption at the pulse generator's currently programmed parameters with the power consumption of the standard parameters used to quote device longevity.

If any of the following parameters (which affect pacing output) are reprogrammed, the Power Consumption and Power Consumption Percentage values are adjusted accordingly:

- Amplitude
- Pulse Width
- Brady Mode
- LRL
- MSR
- PaceSafe

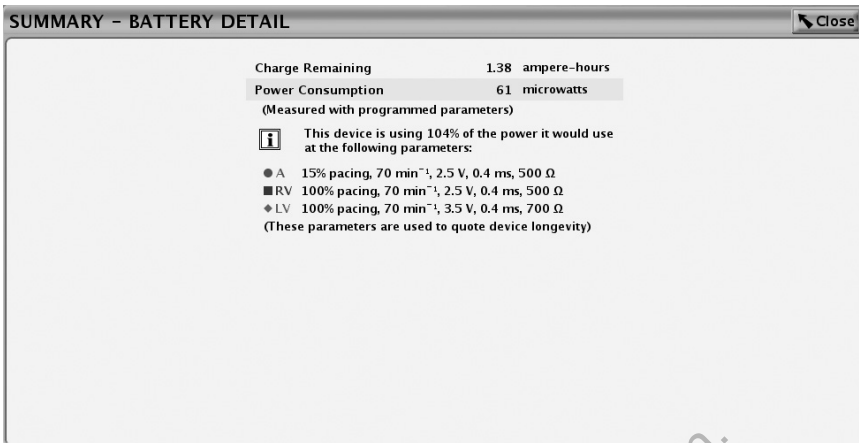


Figure 3-2. Battery Detail summary screen

## LEADS STATUS

### Daily Measurements

The device performs the following measurements every 21 hours and reports them daily:

- Daily Intrinsic Amplitude measurement: the device will automatically attempt to measure the intrinsic P- and R- wave amplitudes for each cardiac chamber in which the Daily Intrinsic Amplitude measurement is enabled regardless of the pacing mode. This measurement will not affect normal pacing. The device will monitor up to 255 cardiac cycles to find a sensed signal to obtain a successful measurement.
- Daily lead (Pace Impedance) measurement:
  - Pace lead(s)—the device will automatically attempt to measure the pace lead impedance for each chamber in which the Daily Pace Impedance test is enabled, regardless of the pacing mode. To conduct the Lead Impedance Test the device utilizes a sub-pacing threshold signal that will not interfere with normal pacing or sensing.
  - For VISIONIST and VALITUDE devices, the High Impedance Limit is nominally set to 2000  $\Omega$ , and is programmable between 2000 and 3000  $\Omega$  in 250  $\Omega$  increments. The Low Impedance Limit is nominally set to 200  $\Omega$ , and is programmable between 200 and 500  $\Omega$  in 50  $\Omega$  increments.

For INLIVEN, INTUA, and INVIVE devices, the High Impedance Limit is fixed at 2000  $\Omega$ . The Low Impedance Limit is nominally set to 200  $\Omega$ , and is programmable between 200 and 500  $\Omega$  in 50  $\Omega$  increments.

Consider the following factors when choosing a value for the impedance limits:

- For chronic leads, historical impedance measurements for the lead, as well as other electrical performance indicators such as stability over time
- For newly implanted leads, the starting measured impedance value

**NOTE:** Depending on lead maturation effects, during follow-up testing the physician may choose to reprogram the Impedance Limits.

- Pacing dependence of the patient
- Recommended impedance range for the lead(s) being used, if available

- PaceSafe daily threshold measurements—when PaceSafe is programmed to Auto or Daily Trend, the device will automatically attempt to measure the pacing threshold in the chamber for which PaceSafe is programmed. To conduct the test, the device adjusts the necessary parameters to facilitate the test.

Basic lead status information is displayed on the Summary screen. Detailed data are displayed in a graphical format on the Leads Status summary screen, which can be accessed by selecting the leads icon on the Summary screen (Figure 3-3 on page 3-8).

Possible leads status messages are as follows (Table 3-1 on page 3-7):

- Lead measurements are within range.
- Check Lead (message will specify which lead)—indicates daily lead measurement(s) are out of range. To determine which measurement is out of range, evaluate the corresponding lead’s daily measurement results.

**NOTE:** *Out-of-range lead impedance measurements may cause the lead configuration to change to Unipolar ("Lead Safety Switch" on page 2-66).*

**NOTE:** *A detailed description of PaceSafe–specific messages including notification of lead test failures and lead alerts is available ("PaceSafe" on page 2-15).*

**Table 3-1. Lead measurement reporting**

Lead Measurement	Reported Values	Out-of-Range Limits
A Pace Impedance (Ω)	200 to 3000	Low: ≤ programmed Atrial Low Impedance Limit High: ≥ 2000 (or the programmed Atrial High Impedance Limit)
RV Pace Impedance (Ω)	200 to 3000	Low: ≤ programmed Right Ventricular Low Impedance Limit High: ≥ 2000 (or the programmed Right Ventricular High Impedance Limit)
LV Pace Impedance (Ω)	200 to 3000	Low: ≤ programmed Left Ventricular Low Impedance Limit High: ≥ 2000 (or the programmed Left Ventricular High Impedance Limit)
P-Wave Amplitude (mV)	0.1 to 25.0	Low: ≤ 0.5 High: none
R-Wave (RV) Amplitude (mV)	0.1 to 25.0	Low: ≤ 3.0 High: none
R-Wave (LV) Amplitude (mV)	0.1 to 25.0	Low: ≤ 3.0 High: none

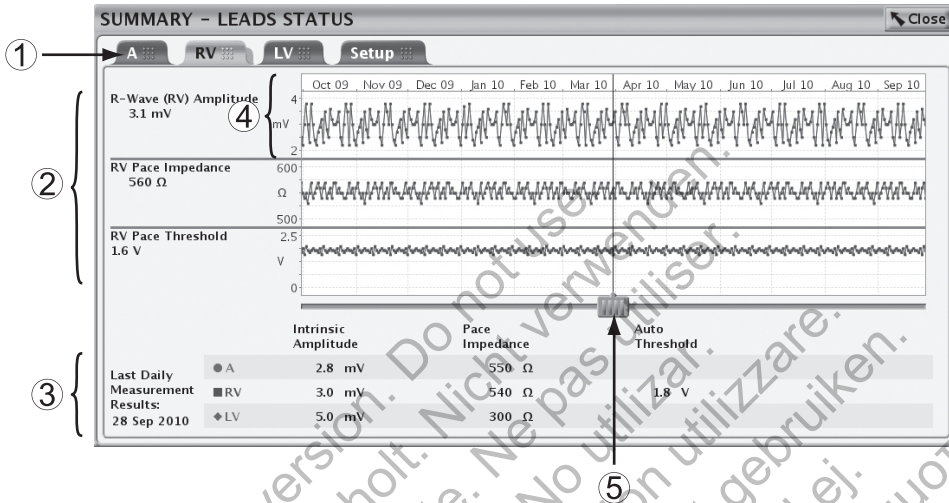
The Leads Status summary screen provides daily measurement details for applicable leads (Figure 3-3 on page 3-8):

- The graph shows daily measurements from the past 52 weeks.
- Use the tabs across the top of the screen to view data for each lead. Select the Setup tab to enable or disable specific daily lead measurements or to set the Impedance Limit values.

**NOTE:** *Disabling daily lead impedance measurements in a given chamber also disables the Lead Safety Switch feature in that chamber.*

- Each data point represents the daily measurement or POST results for a given day. To view specific results for a day, move the horizontal slider over the corresponding data point or gap.

- An out-of-range measurement will plot a point at the corresponding maximum or minimum value.
- A gap will be generated if the device is unable to obtain a valid measurement for that day.
- The most recent daily measurements or POST results are displayed at the bottom of the screen.



[1] Use tabs to select the appropriate lead [2] Results for the selected day [3] Results for most recent day [4] Y-axis adjusts based on measured results [5] Use horizontal slider to view data for a specific day

Figure 3-3. Leads Status summary screen

If the device is unable to obtain one or more daily measurements at the scheduled time, up to three re-attempts will be performed at one-hour intervals. Re-attempts do not change the timing of daily measurements. The next day's measurement will be scheduled 21 hours from the initial attempt.

If a valid measure is not recorded after the initial attempt plus three re-attempts, or is not recorded at the end of a 24-hour time block, the measurement will be reported as Invalid Data or No data collected (N/R).

When more than one measurement occurs in one day, only one will be reported. For Amplitude and Impedance, if one of the measurements is valid and one invalid, the invalid measurement will be reported. If both measurements are valid, the most recent value will be reported. For Threshold, if one measurement is valid and one invalid, the valid measurement will be reported. If both measurements are valid, the highest value will be reported.

If the Summary screen indicates that a lead should be checked and the Intrinsic Amplitude and Impedance graphs do not show any out-of-range values or gaps, the test that resulted in the out-of-range value occurred within the current 24 hours and has not yet been saved with the daily measurements.

Table 3-2. Intrinsic Amplitude: Daily Measurement Conditions, Programmer Display, and Graphical Representation

Condition	Programmer Display	Graphical Representation
In-range amplitude measurement	Measurement value	Plotted point
Electrode configuration is programmed to Off/None	No data collected	Gap
All events during the test period are paced	Paced	Gap

**Table 3-2. Intrinsic Amplitude: Daily Measurement Conditions, Programmer Display, and Graphical Representation (continued)**

Condition	Programmer Display	Graphical Representation
Noise detected during the test period	Noise	Gap
Sensed events defined as a PVC	PVC	Gap
Sensed events defined as a PAC	PAC	Gap
Out-of-range amplitude measurements (mV)	0.1, 0.2, ..., 0.5 (RA lead) with attention icon 0.1, 0.2, ..., 3.0 (ventricular lead) with attention icon	Plotted point
	< 0.1 with attention icon	Plotted point at corresponding minimum
	> 25 with attention icon	Plotted point at corresponding maximum <sup>a</sup>

a. When the value measured is > 25 mV, an attention symbol is displayed on the graph even though no alert is generated on the summary screens.

**Table 3-3. Lead Impedance: Daily Measurement Conditions, Programmer Display, and Graphical Representation**

Condition	Programmer Display	Graphical Representation
In-range amplitude measurement	Measurement value	Plotted point
Electrode Configuration is programmed Off/None	Invalid Data	Gap
Noise detected during the test period	Noise	Gap
Out-of-range impedance measurements (pace leads) ( $\Omega$ )	Measured value greater than or equal to the Pace High Impedance Limit with attention icon Measured value less than or equal to the Pace Low Impedance Limit with attention icon	Plotted point
	> Maximum Pace High Impedance Limit with attention icon < Minimum Pace Low Impedance Limit with attention icon	Plotted point at corresponding minimum or maximum <sup>a</sup>

a. Selecting these points will not display the numerical value, but will indicate that the value is above the upper range limit or below the lower range limit, as appropriate.

**Table 3-4. PaceSafe Automatic Threshold: Daily Measurement Conditions, Programmer Display, and Graphical Representation**

Condition	Programmer Display	Graphical Representation
Feature is not enabled	No data collected	Gap
Test failures or out of range measurements	Various	Gap

**NOTE:** See a detailed list of failure codes for PaceSafe Threshold tests ("PaceSafe" on page 2-15).

Under the following conditions, Intrinsic Amplitude and Lead Impedance measurements will not be attempted. The programmer display will indicate No data collected or Invalid Data, and there will be a gap in the graphical representation:

- Telemetry is active
- Device battery capacity is depleted
- LATITUDE interrogation is in progress
- Pulse generator is in Electrocautery Protection Mode
- Magnet is placed on the pulse generator (when Magnet Response set to Pace Async)

See a detailed description of conditions under which PaceSafe measurements will not be attempted ("PaceSafe" on page 2-15).

## POST-OPERATIVE SYSTEM TEST (POST)

This feature is available in VISIONIST and VALITUDE devices.

The POST feature provides an automatic device/lead check at a pre-determined time post-implant. This helps document proper system functionality without requiring manual system testing, which helps facilitate same-day discharge. The clinician can select the amount of time after lead attachment when automatic lead test results are desired. Any adjustments to the nominal test results time must be programmed prior to lead attachment.

If enabled, automatic Intrinsic Amplitude, Impedance, and Pace Threshold testing will be attempted one hour prior to the desired test results time. Upon interrogation, status of the testing (scheduled to run, in-progress, complete) will be provided on the Summary dialog and Summary screen for the first 48 hours following lead attachment. Test results can be printed on Quick Notes and Follow-Up Reports.

**NOTE:** Pacing parameters may be temporarily adjusted to help ensure a valid measurement is obtained.

If the device is unable to obtain one or more valid measurements on the initial attempt, re-attempts will be performed to help facilitate a measurement. Testing may complete up to one hour after the test results time if re-attempts are required. If a valid measurement is not obtained, and/or if automatic daily measurements occur prior to printing the report, the daily measurement result may be recorded ("Leads Status" on page 3-6).

## LEAD TESTS

The following lead tests are available (Figure 3-4 on page 3-10):

- Pace Impedance
- Intrinsic Amplitude
- Pace Threshold

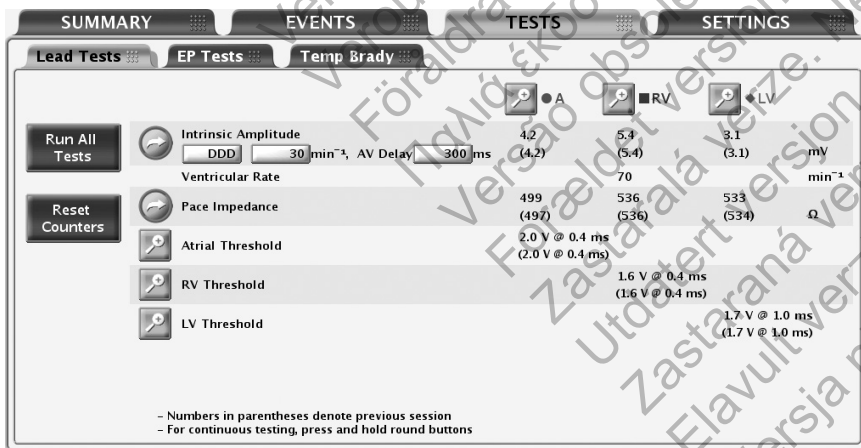


Figure 3-4. Lead Tests screen

Lead Tests can be accessed by using the following steps:

1. From the main screen, select the Tests tab.
2. From the Tests screen, select the Lead Tests tab.

All lead tests may be performed following three different processes:

- Via the Lead Tests screen—allows you to perform the same lead tests across all chambers
- By selecting the desired chamber button—allows you to perform all tests on the same lead
- By selecting the Run All Tests button—automatically performs Intrinsic Amplitude and Lead Impedance tests and allows you to perform Pace Threshold tests

## Intrinsic Amplitude Test

The Intrinsic Amplitude Test measures the intrinsic P- and R-wave amplitudes for the respective chambers.

An Intrinsic Amplitude Test can be performed from the Lead Tests screen by completing the following steps:

1. You may change the following preselected values as necessary to elicit intrinsic activity in the chamber(s) being tested:
  - Programmed Normal Brady Mode
  - LRL at 30 min<sup>-1</sup>
  - AV Delay at 300 ms
2. Select the Intrinsic Amplitude button. During the test, a window will display the test's progress. Selecting and holding the Intrinsic Amplitude Button will cause measurements to be repeated for up to 10 seconds or until the button is released. When the window closes, the same test can be performed again by selecting the Intrinsic Amplitude button. To cancel the test, select the Cancel button or press the DIVERT THERAPY key on the PRM.
3. When the test is complete, the Intrinsic Amplitude measurement will be displayed as the Current measurement (not in parentheses). If the test is repeated during the same session, the Current measurement will be updated with the new result. Note that the Previous Session measurement (displayed in parentheses) is from the most recent past session during which this test was performed.

**NOTE:** The test results from the last measurement are stored in pulse generator memory, retrieved during the initial interrogation, and displayed on the Lead Tests screen. The measurements are also provided on the Quick Notes report.

## Lead Impedance Test

A Lead Impedance Test can be performed and used as a relative measure of lead integrity over time.

If the lead integrity is in question, standard lead troubleshooting tests should be used to assess the lead system integrity.

Troubleshooting tests include, but are not limited to, the following:

- Electrogram analysis with pocket manipulation and/or isometrics
- X-ray or fluoroscopic image review
- Invasive visual inspection

A test result of NOISE is reported if a valid measurement could not be obtained (likely due to EMI).

Pace lead impedance tests can be performed from the Lead Tests screen by completing the following steps:

1. Select the desired lead impedance test button. Selecting and holding a button will cause measurements to be repeated for up to 10 seconds or until the button is released.
2. During the test, a window will display the test progress. When the window closes, the same test can be performed by once again selecting the desired lead impedance test button. To cancel the test, select the Cancel button or press the DIVERT THERAPY key on the PRM.
3. When the test is complete, the impedance measurement will be displayed as the Current measurement (not in parentheses). If the test is repeated during the same session, the Current measurement will be updated with the new result. Note that the Previous Session measurement (displayed in parentheses) is from the most recent past session during which this test was performed.
4. If the test results in NOISE, consider the following mitigation options:
  - Repeat the test
  - Switch telemetry modes
  - Remove other sources of electromagnetic interference

**NOTE:** The test results from the last measurement are stored in pulse generator memory, retrieved during the initial interrogation, and displayed on the Lead Tests screen. The measurements are also provided on the Quick Notes report.

## Pace Threshold Test

The Pace Threshold Test determines the minimum output needed for capture in a specific chamber.

The ventricular and atrial pace amplitude threshold tests can be performed manually or automatically. When PaceSafe is programmed to Auto, the results of the commanded automatic amplitude tests are used to adjust the PaceSafe output levels.

**NOTE:** For Quadripolar devices, the left ventricular pace amplitude threshold tests can only be performed manually.

Ventricular and atrial pulse width threshold tests are performed manually by selecting the Pulse Width option on the Pace Threshold details screen.

### Manual Pace Threshold Test

The minimum 2X voltage or 3X pulse width safety margin is recommended for each chamber based on the capture thresholds, which should provide an adequate safety margin and help preserve battery longevity. The test begins at a specified starting value and steps that value down (Amplitude or Pulse Width) as the test progresses. The PRM beeps with each decrement. The values used during the threshold test are programmable. The parameters are only in effect during the test.

**NOTE:** The starting values for Amplitude and Pulse Width values are automatically calculated. The device retrieves the stored results for the previous pace threshold measurement (for the parameter being tested) and sets the parameter at three steps above the previous threshold measurement. The LRL is preselected at  $90 \text{ min}^{-1}$ . For DDD mode, the LRL is further limited to  $10 \text{ min}^{-1}$  below the MTR.

**NOTE:** If DDD mode is chosen, selecting either the atrial or ventricular test will cause the pacing output to decrease only in the chamber selected.



**CAUTION:** During a manual LV Threshold test, RV Backup Pacing is unavailable.

**NOTE:** When a ventricular test is selected, only the pacing output of the selected ventricular chamber decreases; the other ventricular chamber is not paced.

Once the test is started, the device operates with the specified brady parameters. Using the programmed number of cycles per step, the device then decrements (steps down) the selected test type parameter (Amplitude or Pulse Width) until the test is complete. Real-time electrograms and annotated event markers, which include the LV pacing lead configuration (VISIONIST and VALITUDE devices) and values being tested, continue to be available during threshold testing. The display will automatically adjust to reflect the chamber being tested.

During the threshold test, the programmer displays the test parameters in a window while the test is in progress. To pause the test or perform a manual adjustment, select the Hold button on the window. Select the + or – button to manually increase or decrease the value being tested. To continue the test, select the Continue button.

The threshold test is complete and all parameters are returned to the normal programmed values when any of the following occur:

- The test is terminated via a command from the PRM (e.g., pressing the End Test button or DIVERT THERAPY key).
- The lowest available setting for Amplitude or Pulse Width is reached and the programmed number of cycles has completed.
- Telemetry communication is interrupted.

A pace threshold test can be performed from the Lead Tests screen using the following steps:

1. Select the desired chamber to be tested.
2. Select the Pace Threshold details button.
3. Select the test type.
4. Change the following parameter values as desired to elicit pacing in the chamber(s) being tested:
  - Mode
  - LRL
  - Paced AV Delay
  - Pacing Lead Configuration
  - Amplitude
  - Pulse Width
  - Cycles per Step
  - LV Protection Period (programmable only for LV Threshold test)

For DDD mode, the Normal Brady MTR is used.

**NOTE:** A long LVPP may inhibit left ventricular pacing at higher pacing rates. LVPP can be temporarily programmed (for example, to a shorter LVPP or Off) through the Pace Threshold Test screen.

5. Watch the ECG display and stop the test by selecting the End Test button or pressing the DIVERT THERAPY key when loss of capture is observed. If the test continues until the

programmed number of cycles at the lowest setting have occurred, the test is automatically terminated. The final threshold test value will be displayed (the value is one step above the value when the test was terminated). A 10 second trace (prior to loss of capture) is automatically stored and can be displayed and analyzed by selecting the Snapshot tab ("Snapshot" on page 4-8).

**NOTE:** *The threshold test result can be edited by selecting the Edit Today's Test button on the Threshold Test screen.*

6. When the test is complete, the threshold measurement will be displayed as the Current measurement (not in parentheses). If the test is repeated during the same session, the Current measurement will be updated with the new result. Note that the Previous Session measurement (displayed in parentheses) is from the most recent past session during which this test was performed.
7. To perform another test, make changes to the test parameter values if desired, then begin again. Results of the new test will be displayed.

**NOTE:** *The test results from the most recent measurement are stored in pulse generator memory, retrieved during initial interrogation, and displayed on the Lead Tests screen and on the Leads Status screen. The measurements are also provided on the Quick Notes report.*

#### **Commanded Automatic Pace Threshold Test**

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Commanded automatic threshold tests differ from the manual tests in the following ways:

- Commanded automatic threshold tests are available for Amplitude, but not Pulse Width.
- The following parameters are fixed (vs. programmable in manual tests):
  - Paced AV Delay
  - Pulse Width (RAAT and RVAT)
  - Cycles per step
  - LV Protection Period (LVAT)
  - Pacing Lead Configuration (RAAT)

**NOTE:** *Change the programmable parameters as desired to elicit pacing in the chamber being tested.*

- Additional event markers are available including loss of capture, fusion, and backup pacing (where backup pacing is available).
- Once started, a commanded automatic threshold test cannot be paused, only cancelled.
- PaceSafe automatically determines when the test is completed and automatically stops the test.
- When complete, the test automatically stops and displays the threshold, which is the last output level that demonstrated consistent capture. A 10 second trace (prior to loss of capture) is automatically stored and can be displayed and analyzed by selecting the Snapshot tab ("Snapshot" on page 4-8).
- Test results cannot be edited.

**NOTE:** No backup atrial pacing is provided during a commanded automatic right atrial threshold test.

**NOTE:** RV pacing is provided as backup during a commanded automatic left ventricular threshold test with an applied LV Offset of -80 ms.

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Version obsolète. Ne pas utiliser.  
Versión obsoleta. No utilizar.  
Versione obsoleta. Non utilizzate.  
Verouderde versie. Niet gebruiken.  
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## PATIENT DIAGNOSTICS AND FOLLOW UP

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### CHAPTER 4

This chapter contains the following topics:

- "Therapy History" on page 4-2
- "Arrhythmia Logbook" on page 4-2
- "Snapshot" on page 4-8
- "Histograms" on page 4-9
- "Counters" on page 4-9
- "Heart Rate Variability (HRV)" on page 4-10
- "Trends" on page 4-13
- "Post Implant features" on page 4-18

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## THERAPY HISTORY

The pulse generator automatically records data that can be helpful when evaluating the patient's condition and the effectiveness of pulse generator programming.

Therapy history data can be reviewed at various levels of detail using the PRM:

- Arrhythmia Logbook—provides detailed information for each detected episode ("Arrhythmia Logbook" on page 4-2)
- Histograms and Counters—displays the total number and percentage of paced and sensed events during a particular recording period ("Histograms" on page 4-9 and "Counters" on page 4-9)
- Heart Rate Variability (HRV)—measures changes in the patient's intrinsic heart rate within a 24-hour collection period ("Heart Rate Variability (HRV)" on page 4-10)
- Trends—provides a graphical view of specific patient, pulse generator, and lead data ("Trends" on page 4-13)

**NOTE:** The Summary dialog and Summary tab display a prioritized list of events that have occurred since the last reset. This list will only include VT, SVT, Nonsustained and ATR (if it lasted more than 48 hours) episodes.

## ARRHYTHMIA LOGBOOK

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Arrhythmia Logbook provides access to the following detailed information about episodes of all types (Figure 4-1 on page 4-3):

- The number, date, and time of the event
- The type of event
- A summary of event details
- Duration of the event (when applicable)
- Electrograms with annotated markers
- Intervals

**NOTE:** The data include information from all active electrodes. The device compresses the history data to store a maximum of 14 minutes of electrogram data (10 minutes with Patient Triggered Monitor enabled). However, the amount of time actually stored may vary based on the data being compressed (e.g., noise on the EGM or an episode of VT).

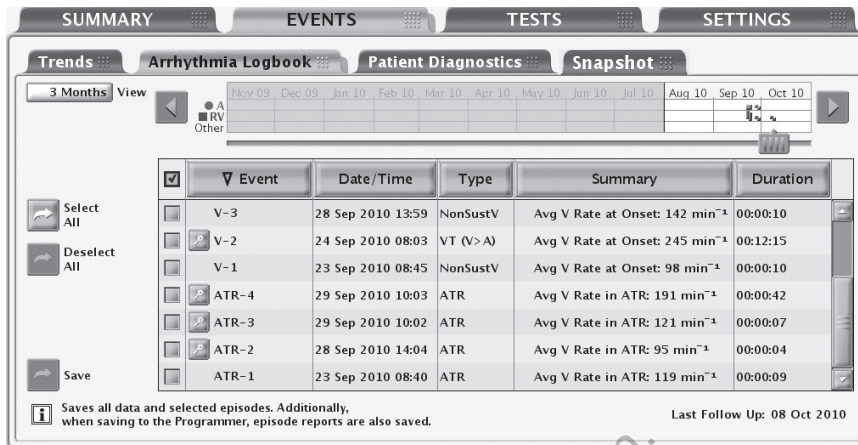


Figure 4-1. Arrhythmia Logbook screen

The priority, maximum number, and minimum number of episodes that the pulse generator stores under normal conditions varies by episode type (Table 4-1 on page 4-3). As long as device memory allocated for episode data is not full, the pulse generator stores up to the maximum number of episodes allowed for each episode type. The minimum number of episodes for each episode type ensures that all episode types are represented by protecting a few low priority episodes from being overwritten by high priority episodes when device memory is full.

Once device memory is full, the pulse generator attempts to prioritize and overwrite stored episodes according to the following rules:

1. If device memory is full, and there are episodes older than 18 months, then the oldest of the lowest priority episodes from these episode types will be deleted (regardless if the minimum number of episodes are stored) (VISIONIST and VALITUDE devices).
  2. If device memory is full, and there are episode types that have more than the minimum number of episodes stored, then the oldest of the lowest priority episodes from these episode types will be deleted. In this case, the low priority episodes are not deleted if their number of stored episodes is less than the minimum number.
  3. If device memory is full, and there are no episode types that have more than the minimum number of episodes stored, then the oldest of the lowest priority episodes of all episode types will be deleted.
  4. If the maximum number of episodes has been reached within an episode type, the oldest episode of that type will be deleted.
- An episode in progress has the highest priority until its type can be determined.

**NOTE:** Once history data is saved, it can be accessed at any time without device interrogation.

Table 4-1. Episode Priority

Episode Type	Priority	Maximum number of stored episodes	Minimum number of stored episodes with detailed reports	Maximum number of stored episodes with detailed reports
VT (V>A)	1	50	5	10
PTM (Patient Triggered Monitor)	1	5	1	1
SVT (V≤A)	2	50	3	5
NonSustV	3	10	1	2

Table 4-1. Episode Priority (continued)

Episode Type	Priority	Maximum number of stored episodes	Minimum number of stored episodes with detailed reports	Maximum number of stored episodes with detailed reports
RA Auto	3	1	1	1
RV Auto	3	1	1	1
LV Auto	4	1	1	1
ATR	4	10	1	3
PMT	4	5	1	3
SBR	4	10	1	3
APM RT <sup>a</sup>	4	1	1	1

a. Advanced Patient Management real time (APM RT) events are presenting EGMs, captured and stored on the pulse generator during LATITUDE Communicator follow-ups.

To display Arrhythmia Logbook data, use the following steps:

1. From the Events tab, select Arrhythmia Logbook. If necessary, the pulse generator will be automatically interrogated and current data will be displayed. Saved patient data also can be displayed ("Data Storage" on page 1-17).
2. While retrieving the data, the programmer will display a window indicating the progress of the interrogation. No information will be displayed if you select the Cancel button before all of the stored data are retrieved.
3. Use the slider and View button to control the range of dates for the events you want to display in the table.
4. Select the Details button of an event in the table to display the event details. Event details, available if the details button is present, are useful in evaluating each episode. The Stored Event screen will appear, and you can browse between the following tabs for more information about the event:
  - Events Summary
  - EGM
  - Intervals
5. Select a column header button to sort the events by that column. To reverse the order, select the column header again.
6. To save specific events, select the event and choose the Save button. To print specific events, select the event and choose Reports from the toolbar. Choose the Selected Episodes report and select the Print button.

**NOTE:** An "in-progress" episode will not be saved; an episode must be complete before it will be saved by the application.

To view episode details, select the Details button next to the desired episode on the Arrhythmia Logbook screen. The Stored Event screen will appear, and you can browse between the Summary, EGM, and Intervals tabs.

### Events Summary

The Events Summary screen displays additional details about the selected episode corresponding to the Arrhythmia Logbook.



The summary data may include the following:

- Episode number, date, time, type (e.g., VT, SVT, or PTM)
- Average atrial and ventricular rates
- Duration
- Average Ventricular Rate in ATR (ATR events only; may help determine if the patient's ventricular response to atrial arrhythmias is adequately controlled)
- Atrial rate at PMT start (PMT events only)

### Stored Electrograms with Annotated Markers

The pulse generator can store annotated electrograms sensed from the following channels:

- RV pace/sense lead
- LV pace/sense lead

**NOTE:** *LV electrograms are only stored for PTM episodes. LV markers are always stored when available, regardless of episode type.*

- Atrial pace/sense lead
- PaceSafe Evoked Response (ER)

The particular annotated electrograms stored depend upon the episode type. In this section, EGM refers to both electrograms and the associated annotated markers. The EGM storage capacity varies depending on EGM signal condition and heart rate. The total amount of stored EGM data associated with an episode may be limited; EGMs from the middle of the episode may be removed for episodes greater than 4 minutes in duration.

When the memory allocated to EGM storage is full, the device overwrites older EGM data segments in order to store the new EGM data. The EGM is recorded in segments consisting of episode Onset and End EGM Storage. Detailed information for the Onset segment can be viewed when the left caliper is in that section.

Episode Onset refers to the period of time (measured in seconds) of EGM prior to event declaration.

Onset includes the following information:

- Type of event
- Average RA Rate at the start of Event
- Average RV Rate at the start of Event
- Average V rate during ATR (ATR episodes only)

To view the EGM data, select the Details button of the desired episode on the Arrhythmia Logbook screen.

Use the following steps to view specific details about each episode:

1. Select the EGM tab.

- EGM strips for the appropriate sources are displayed. Each strip includes the EGMs sensed during the episode with the corresponding annotated markers. Blue vertical bars indicate the segment (Onset, End) boundaries.

**NOTE:** For marker definitions, select the Reports button on the PRM and view the Marker Legend Report.

- Use the slider under the upper display window to view different sections of the stored EGM.
- Adjust the trace Speed as needed (10, 25, 50, 100 mm/s). As the Speed is increased, the time/horizontal scale is expanded.

**NOTE:** Adjusting the trace Speed is for on-screen viewing only; the print speed of a stored EGM is set to 25 mm/s.

- Use the electronic caliper (slider bar) to measure the distance/time between signals as well as measure the amplitude of signals.
    - The distance between signals can be measured by moving each caliper to the desired points on the EGM. The time (in milliseconds or seconds) between the two calipers will be displayed.
    - The amplitude of the signal can be measured by moving the left-hand caliper over the peak of the desired signal. The value (in millivolts) of the signal will be displayed on the left side of the EGM. The signal is measured from baseline to peak, either positive or negative. Adjust the trace Speed and/or amplitude scale as needed to help facilitate an amplitude measurement.
  - Adjust the amplitude/vertical scale as needed (0.2, 0.5, 1, 2, 5 mm/mV) for each channel using the up/down arrow buttons located on the right side of the trace display. As the gain is increased, the amplitude of the signal is enlarged.
2. Select the Previous Event or Next Event button to display a different event strip.
  3. To print the entire episode report, select the Print Event button. To save the entire episode report, select the Save button.

### Intervals

The pulse generator stores event markers and associated time stamps. The PRM derives event intervals from the event markers and time stamps.

To view the episode intervals, use the following steps:

1. From the Stored Event screen, select the Intervals tab. If all of the episode data is not visible in the window, use the scroll bar to view more data.
2. Select the Previous Event or the Next Event button to display a previous or more current episode, one episode at a time.
3. Select the Print Event button to print the entire episode report.
4. Select the Save button to save the entire episode report.

### Ventricular Tachy EGM Storage

The Ventricular Tachy EGM Storage feature will detect and store an Arrhythmia Logbook episode when the patient's intrinsic ventricular rate rises above a programmable threshold. In response

to 3 consecutive fast beats, the device will begin storing an episode which will ultimately be classified as: VT ( $V > A$ ), SVT ( $V < A$ ) or a Nonsustained episode. The pulse generator will not provide any tachy therapy (e.g., shocks or ATP).

This feature is available in any Brady Mode. In a dual-chamber device programmed to AAI(R), ventricular sensing for VT detection is used in addition to atrial sensing unless the VT EGM Storage parameter is set to Off.

Tachy EGMs will be stored under the following conditions:

1. To begin storing an episode, 3 consecutive fast beats must occur above the VT Detection Rate. The episode Onset EGM segment will start 5 seconds before the third fast beat, and stop 10 seconds after the third fast beat.
2. The pulse generator then uses a sliding detection window to monitor for 8 out of 10 fast beats. The detection window is the 10 most recently detected ventricular intervals. As a new interval occurs, the window slides to encompass it and the oldest interval is eliminated.
3. Once 8 out of 10 fast beats have been detected, a V-Epsd marker is displayed and a nonprogrammable 10 second Duration begins.
4. A sustained VT episode is declared if 6 out of 10 fast beats are maintained throughout Duration. At the end of Duration, if the rate is still fast, the pulse generator applies the  $V > A$  detection enhancement to determine if the episode is VT ( $V > A$ ) or SVT ( $V \leq A$ ):

- a. At the end of Duration, the pulse generator calculates averages of the last 10 V–V intervals and the last 10 A–A intervals.

**NOTE:** *If there are fewer than 10 atrial intervals available, the available intervals will be used to determine the average atrial rate. There will always be at least 10 ventricular intervals.*

- b. These averages are compared. If the average ventricular rate is  $10 \text{ min}^{-1}$  or more faster than the average atrial rate, the episode is declared as VT. Otherwise, it is declared as SVT.

**NOTE:** *The pulse generator will respond to atrial sensing regardless of whether an atrial lead is implanted. If an atrial lead is not implanted, or is not sensing adequately, program the atrial sensing Lead Configuration to Off ("Use of Atrial Information" on page 2-62).*

5. A Nonsustained episode is declared if 8 out of 10 fast beats are not detected, or if 6 out of 10 fast beats are not maintained during Duration. The episode will be classified as NonSustV.
6. End of episode is declared under the following conditions:
  - End of Episode timer expires. Once 8 out of 10 fast beats have been detected, a nonprogrammable 10 second End of Episode timer begins whenever fewer than 6 out of 10 beats are fast. The timer is only cleared if 8 out of 10 fast beats are once again detected before the timer expires. If the timer expires, End of Episode is declared, and a V-EpsdEnd marker is displayed.
  - If 8 out of 10 fast beats have not been detected, but 10 consecutive slow beats are detected below the VT Detection Rate. No end of episode marker is provided in this scenario.
  - EP testing is initiated.
  - Ventricular Tachy EGM Storage is reprogrammed.

The episode End EGM segment will start 20 seconds before the end of the episode (may be less than 20 seconds if the Onset and End segments overlap), and stops at the end of the episode.

## SNAPSHOT

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

A 12 second trace of the ECG/EGM display can be stored at any time by pressing the Snapshot button from any screen. A trace is also automatically stored following a Pace Threshold Test. After a trace has been stored, it can be displayed and analyzed by selecting the Snapshot tab.

The traces which are currently selected on the ECG/EGM display as well as annotated markers will be captured for up to 10 seconds before and up to 2 seconds after the Snapshot button was selected. If a Snapshot was automatically stored during a Pace Threshold Test, it will be 10 seconds long, ending with the termination of the test.

**NOTE:** *The Snapshot length will be reduced if the traces on the ECG/EGM display are changed or the session started within 10 seconds of selecting the Snapshot button.*

Up to 6 time-stamped Snapshots will be stored in the PRM memory for the current session only. Once the session has been terminated by exiting the application software or by interrogating a new patient, the data will be lost. If more than 6 Snapshots are stored in one PRM session, the oldest will be overwritten.

Use the following steps to view a stored Snapshot:

1. From the Events tab, select the Snapshot tab.
2. Select the Previous Snapshot or Next Snapshot button to display a different trace.
3. Use the slider under the upper display window to view different sections of the stored Snapshot.
4. Adjust the Speed as needed (10, 25, 50, 100 mm/s). As the Speed is increased, the time/horizontal scale is expanded.

**NOTE:** *Adjusting the Speed is for on-screen viewing only; the print speed of a stored Snapshot is set to 25 mm/s.*

5. Use the electronic caliper (slider bar) to measure the distance/time between signals as well as measure the amplitude of signals.
  - The distance between signals can be measured by moving each caliper to the desired points on the Snapshot. The time (in milliseconds or seconds) between the two calipers will be displayed.
  - The amplitude of the signal can be measured by moving the left-hand caliper over the peak of the desired signal. The value (in millivolts) of the signal will be displayed on the left side of the Snapshot. The signal is measured from baseline to peak, either positive or negative. Adjust the Speed and/or amplitude scale as needed to help facilitate an amplitude measurement.
6. Adjust the amplitude/vertical scale as needed (0.2, 0.5, 1, 2, 5 mm/mV) for each channel using the up/down arrow buttons located on the right side of the trace display. As the gain is increased, the amplitude of the signal is enlarged.

- To print the Snapshot that is currently being viewed, select the Print button. To save the Snapshot that is currently being viewed, select the Save button. Select Save All Snapshots to save all stored Snapshot traces.

## HISTOGRAMS

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Histograms feature retrieves information from the pulse generator and displays the total number and percentage of paced and sensed events for the chamber.

Histograms data can provide the following clinical information:

- The distribution of the patient's heart rates
- How the ratio of paced to sensed beats varies by rate
- How the ventricle responds to paced and sensed atrial beats across rates
- The RV Rate during AT/AF events (VISIONIST and VALITUDE devices)

When combined with verified biventricular capture, Histograms can be used to determine the amount of CRT delivery. The percentage of paced and sensed ventricular events indicates the percentage of BiV pacing delivered.

Use the following steps to access the Histograms screen:

- From the Events screen, select the Patient Diagnostics tab.
- The initial display shows the paced and sensed data since the last time the counters were reset.
- Select the Details button to display the data type and time period.
- Select the Rate Counts button on the Details screen to view rate counts by chamber as well as RV rate counts during AT/AF events (VISIONIST and VALITUDE devices).

All Histograms can be reset by selecting the Reset button from any Patient Diagnostics Details screen. Histogram data can be saved to the PRM and printed via the Reports tab.

## COUNTERS

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The following counters are recorded by the pulse generator and displayed on the Patient Diagnostics screen:

- Tachy
- Brady/CRT

### Ventricular Tachy Counters

Information about Ventricular Episode Counters is available by selecting the Tachy Counters Details button. For each counter, the number of events since last reset and device totals are displayed. Ventricular Episode Counters contains the following data:

- Total Episodes

- VT Episodes ( $V > A$ )
- SVT Episodes ( $V \leq A$ )
- Nonsustained Episodes

## Brady/CRT Counters

Information about Brady/CRT Counters are displayed by selecting the Brady/CRT Counters Details button. This screen displays the Brady/CRT episode counters. For each counter, the number of events since last reset and reset before last are displayed. Brady/CRT Counters contains the following details:

- Percent of atrial paced
- Percent of RV paced

**NOTE:** The RV pace event for a BiVentricular Trigger pace will be counted as an RV sense.

- Percent of LV paced
- Intrinsic Promotion—includes Rate Hysteresis % Successful
- Atrial Arrhythmia—includes percentage of time in AT/AF, Total Time in AT/AF (min, hr, or days), Episodes by Duration and Total PACs. When at least one ATR event has been stored since the last reset, data for the Longest AT/AF and Fastest RVS Rate in AT/AF is presented on the Summary screen and on printed reports (VISIONIST and VALITUDE devices).

**NOTE:** AT/AF % and Total Time in AT/AF records and displays data for a maximum of one year.

- Ventricular Counters—includes Total PVCs and Three or More PVCs

All Counters can be reset by selecting the Reset button from any Patient Diagnostics Details screen. Counter data can be saved to the PRM and printed via the Reports tab.

## HEART RATE VARIABILITY (HRV)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Heart Rate Variability (HRV) is a measure of the changes in a patient's intrinsic heart rate within a 24-hour collection period.

This feature can assist in evaluating the clinical status of heart failure patients.

HRV, as measured by SDANN and HRV Footprint, is an objective, physiological measure that can identify heart failure patients at higher risk of mortality. Specifically, depressed HRV can be used as a predictor of risk of mortality after an acute myocardial infarction.<sup>1</sup> A normal SDANN value is 127 plus or minus 35 ms.<sup>1</sup> Higher SDANN values (indicating greater variability of heart rate) have been associated with lower risk of mortality.<sup>2 3 4</sup> Similarly, a larger HRV Footprint also indicates greater heart rate variability and has been associated with lower mortality risk.<sup>2 3 4</sup>

1. Electrophysiology Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation*, 93:1043-1065, 1996.
2. F.R. Gilliam et al., *Journal of Electrocardiology*, 40:336-342, 2007.
3. F.R. Gilliam et al., *PACE*, 30:56-64, 2007.
4. J.P. Singh et al., *Europace*, 12:7-8, 2010.

The HRV monitor feature provides the following information using the intrinsic interval data from the 24-hour collection period that meets the HRV collection criteria (Figure 4-2 on page 4-11):

- Date and time the 24-hour collection period was completed.
- % of Time Used—displays the percentage of time during the 24-hour collection period in which there are valid intrinsic beats. If the % of Time Used falls below 67%, data will not be displayed for that collection period.
- HRV Footprint plot—shows the percentage of the graph area used by the HRV plot. The graph area portrays an “at-a-glance snapshot” of the distribution of variability versus heart rate over a 24-hour period. The trended percentage is a normalized score based on the footprint in the graph.
- Standard Deviation of Averaged Normal R to R intervals (SDANN)—the HRV collection period comprises 288 5-minute segments (24-hours) of intrinsic intervals. The SDANN is the standard deviation of the averages of intrinsic intervals in the 288 5-minute segments. This measurement is also available in the Trends.
- Current Normal Brady/CRT parameters—Mode, LRL, MTR, Sensed AV Delay, and Pacing Chamber with LV Offset.
- An HRV plot for current and previous collection periods including a line that shows the mean heart rate. The HRV plot summarizes the cardiac variation on a cycle-to-cycle basis. The x-axis shows the heart rate range; the y-axis shows the beat-to-beat variability displayed in milliseconds. The color indicates the frequency of beats at any particular heart rate and heart rate variability combination.

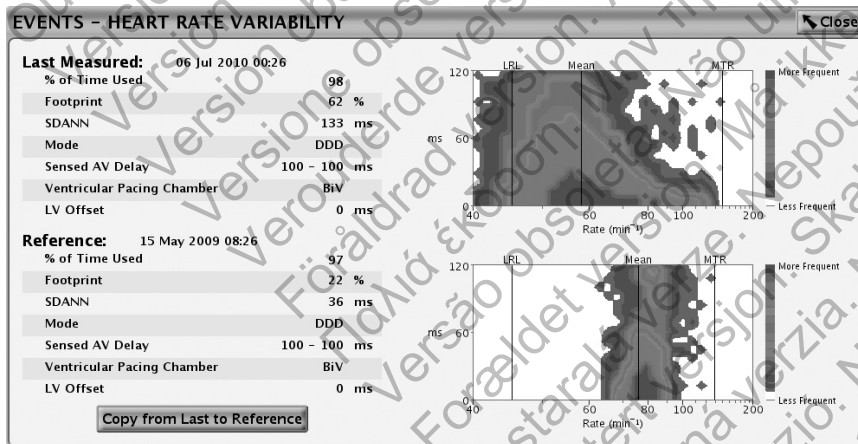


Figure 4-2. Heart Rate Variability display

Consider the following information when using HRV:

- The cardiac cycle (R–R interval) in HRV is determined by RV sensed and paced events (LV paced events when the Pacing Chamber is programmed to LV Only).
- Programming the pacing parameters causes the data acquired for the current 24-hour collection period to be invalid.
- The device saves only one set of values and corresponding HRV plot for the Reference portion of the screen. Once the values are copied from Last Measured to Reference, older data cannot be retrieved.

- The first time the HRV feature is used, the Reference screen will show the data from the first valid 24-hour collection period.

Follow the steps below to view HRV:

1. To access the HRV monitor screen, select the Events tab.
2. From the Events screen, select the Patient Diagnostics tab.
3. Select the Heart Rate Variability Details button to view the Last Measured and Reference data.
4. To copy the Last Measured HRV measurements into the Reference section, select the Copy From Last to Reference button.

The HRV monitor screen displays a set of measurements and a HRV plot based on the most recent 24-hour collection period in the Last Measured portion of the screen; measurements from a previously saved collection period are displayed in the Reference portion of the screen. Both collection periods can be viewed simultaneously to compare data that could show trends in the patient's HRV changes over a period of time. By saving the Last Measured values to the Reference portion of the screen, you can view the last measured data during a later session.

#### HRV Collection Criteria

Only valid sinus rhythm intervals are used in the HRV data calculations. For HRV, valid intervals are those which include only valid HRV events.

Valid HRV events are listed below:

- AS with an interval not faster than MTR, followed by a VS
- AS followed by VP at the programmed AV Delay

Invalid HRV events are as follows:

- AP/VS or AP/VP
- AS with an interval faster than MTR
- Non-tracked VP events
- Consecutive AS events (no intervening V event)
- VP-Ns
- Rate Smoothing events (e.g., RVP↑)
- PVC

HRV data may not be reported for a variety of reasons; the most common are as follows:

- Less than 67% of the 24-hour collection period (approximately 16 hours) contains valid HRV events
- Brady Parameters were programmed within the last 24 hours

An example of how HRV data is recorded is shown (Figure 4-3 on page 4-13). In this example, the HRV data in the first collection period is invalid because the Brady Parameters were programmed after the device was taken out of Storage. HRV data is successfully calculated



and reported at the end of the second 24-hour collection period. Subsequent HRV data is not reported until the end of Collection Period 5.

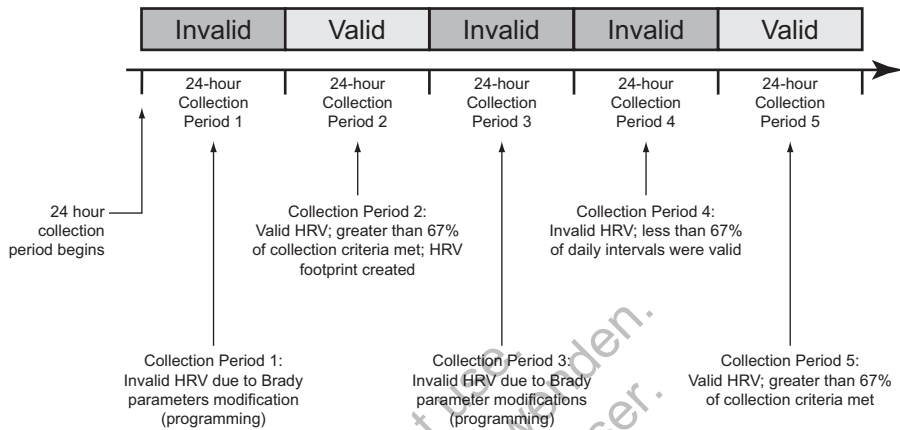


Figure 4-3. Example of HRV data collection

## TRENDS

Trends provide a graphical view of specific patient, device, and lead data. This data can be useful when evaluating your patient's condition and the effectiveness of programmed parameters. Unless otherwise noted below, data for all trends is reported every 24 hours and is available for up to 1 year. For many trends, a value of "N/R" is reported if there is insufficient or invalid data for the collection period.

The following trends are available:

- **Events**—displays both atrial and ventricular events stored in the Arrhythmia Logbook, organized by date and type ("Arrhythmia Logbook" on page 4-2). This trend is updated whenever an episode is completed, and may contain data that is older than 1 year.
- **Activity Level**—displays a measure of the patient's daily activity represented by the "Percent of Day Active".
- **AT/AF Burden**—displays a trend of the total number of ATR Mode Switch events and the total amount of time spent in an ATR Mode Switch per day.
- **RV Rate during AT/AF (VISIONIST and VALITUDE devices)**—displays a trend of the patient's Mean and Maximum RV rate during ATR events. The Mean rate is calculated using both paced and sensed beats while the Maximum rate is a rolling average of sensed beats. In some cases, the Mean rate may be higher than the Maximum rate.
- **Pacing Percent (VISIONIST and VALITUDE devices)**—displays the percentage of paced events for each chamber.
- **Respiratory Rate**—displays a trend of the patient's daily minimum, maximum, and median respiratory rate values ("Respiratory Rate Trend" on page 4-15).
- **AP Scan**—displays a trend of the average number of respiratory disturbance events as measured by the pulse generator that the patient experiences per hour during the programmed sleep period ("AP Scan" on page 4-15).

- Heart Rate—displays a trend of the patient's daily maximum, mean, and minimum heart rate. Intervals used in this calculation must be valid sinus rhythm intervals.

The validity of an interval and the Heart Rate Trend data for the 24-hour collection period is determined by the HRV collection criteria ("Heart Rate Variability (HRV)" on page 4-10).

- SDANN (Standard Deviation of Averaged Normal-to-Normal R-R intervals)—displays a trend of the standard deviation of the averages of intrinsic intervals over the 24-hour collection period (which is comprised of 288 5-minute segments). Only intervals that meet the HRV collection criteria are considered valid.

A normal SDANN value is 127 plus or minus 35 ms.<sup>5</sup>

- HRV Footprint—displays the percentage of the graph area used by the HRV Footprint plot, illustrating the distribution of variability versus heart rate over a 24-hour period. The trended percentage is a normalized score based on the footprint in the graph. Refer to additional information about HRV ("Heart Rate Variability (HRV)" on page 4-10).
- ABM (Autonomic Balance Monitor)—displays a trend of the LF/HF ratio.<sup>6</sup> Normal range for the LF/HF ratio is 1.5 - 2.0.<sup>5</sup> ABM is a device calculation based on R-R interval measurements, which mathematically functions as a surrogate measurement for LF/HF ratio. Intervals used in the calculation must be valid sinus rhythm intervals as determined by the HRV collection criteria. If the HRV data is invalid for the 24-hour collection period, then the ABM is not calculated and a value of "N/R" is displayed.
- Lead impedance and amplitude—displays trends of the daily intrinsic amplitude and lead impedance measurements ("Leads Status" on page 3-6).
- A Pace Threshold—displays a trend of the daily right atrial pacing thresholds.
- RV Pace Threshold—displays a trend of the daily right ventricular pacing thresholds.
- LV Pace Threshold—displays a trend of the daily left ventricular pacing thresholds.

Follow the steps below to access Trends:

1. From the Events screen, select the Trends Tab.
2. Choose the Select Trends button to specify the trends you want to view. You can choose from the following categories:
  - Heart Failure—includes Heart Rate, SDANN, and HRV Footprint trends.
  - Atrial Arrhythmia—includes AT/AF Burden, RV Rate during AT/AF, and Respiratory Rate (VISIONIST and VALITUDE devices). For other models, the Atrial Arrhythmia category includes Events, Heart Rate, and AT/AF Burden trends.
  - Activity—includes Heart Rate, Activity Level, and Respiratory Rate trends.
  - Custom—allows you to select various trends to customize the information displayed on the Trends screen.

5. Electrophysiology Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation*, 93:1043-1065, 1996.
6. Parasympathetic tone is primarily reflected in the high-frequency (HF) component of spectral analysis. The low-frequency (LF) component is influenced by both the sympathetic and parasympathetic nervous systems. The LF/HF ratio is considered a measure of sympathovagal balance and reflects sympathetic modulations. (Source: ACC/AHA Guidelines for Ambulatory Electrocardiography—Part III, *JACC VOL. 34, No. 3, September 1999:912-48*).

The display on the screen can be viewed in the following manner:

- Select the desired time on the View button to choose the length of visible trend data.
- Adjust the start and end dates by moving the horizontal slider at the top of the window. You can also adjust these dates using the scroll left and scroll right icons.
- Move the vertical axis across the graph by moving the horizontal slider at the bottom of the display window.

Trends data can be saved to the PRM and printed via the Reports tab. Printed Trends display a timeline which shows PRM and device interactions including programming, office interrogations, and counter resets (VISIONIST, VALITUDE).

### Respiratory Rate Trend

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The Respiratory Rate trend displays a graph of the patient's daily minimum, maximum, and median respiratory rate values. These daily values are stored for up to one year to create a longitudinal display of physiological data.

**NOTE:** *The American College of Cardiology (ACC)/American Heart Association (AHA) guidelines recommend the measurement and documentation of physiological vital signs including respiratory rate for cardiac patients.<sup>7</sup>*

Ensure the MV/Respiratory Sensor is programmed to On (or Passive for the MV Sensor) for Respiratory Rate trend data to be collected and displayed ("Minute Ventilation (MV)/Respiratory Sensor" on page 4-16).

Move the horizontal slider over a data point to view the values for a given date. At least 16 hours of data must be collected for values to be calculated and plotted to the Respiratory Rate trend. If insufficient data was collected, no data point will be plotted and there will be a gap in the trend line. This gap will be labeled as N/R to indicate that insufficient or no data was collected.

### AP Scan

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

AP Scan is a trend of the average number of respiratory disturbance events as measured by the pulse generator that the patient experiences per hour during the programmed sleep period. This trend is not intended to diagnose patients with sleep apnea. Standard clinic methods such as polysomnogram should be used for actual diagnosis. Data provided by this trend can be used along with other clinical information to follow changes in patients who may be at high risk for sleep-disordered breathing.

AP Scan is modeled after accepted sleep clinic scoring methodologies for detection of apnea and hypopnea.<sup>8</sup> The pulse generator considers a respiratory disturbance event to be a 26% or greater reduction in respiratory signal amplitude, lasting at least 10 seconds. The average is calculated by dividing the total number of respiratory disturbance events observed during the programmed sleep period by the number of hours in the sleep period. These averages are plotted once a day to the AP Scan trend.

7. ACC/AHA Heart Failure Clinical Data Standards. *Circulation*, Vol. 112 (12), September 20, 2005.

8. Meoli et al., *Sleep*, Vol. 24 (4), 469–470, 2001.

Consider the following when using AP Scan:

- To aid in interpreting the trend, a threshold is displayed on the graph at 32 average events per hour. This threshold is intended to approximately correlate to a clinical threshold for severe apnea. Data points above this threshold may indicate the need to further investigate the presence of severe sleep-disordered breathing.
- Respiratory signal amplitude can be affected by factors such as patient posture or movement.
- The accuracy of the AP Scan trend can be diminished under any of the following conditions:
  - The patient is not asleep during part or all of the defined sleep period
  - The patient experiences milder sleep-disordered breathing that the pulse generator cannot accurately detect
  - The patient has low respiratory signal amplitudes, making it difficult for the pulse generator to detect respiratory disturbance events
  - The patient is receiving treatment for sleep apnea (e.g., continuous positive airway pressure therapy)

To activate AP Scan, perform the following steps:

1. Ensure the MV/Respiratory Sensor is programmed to On (or Passive for the MV Sensor) ("Minute Ventilation (MV)/Respiratory Sensor" on page 4-16).
2. Program the following Sleep Schedule parameters (available on the General tab of the Patient Information screen):
  - Sleep Start Time—time when you expect the patient to typically fall asleep each night
  - Sleep Duration—amount of time you expect the patient to typically sleep each night

**NOTE:** Ensure the MV/Respiratory Sensor is programmed to On (or Passive for the MV Sensor) to activate AP Scan. Programming the Sleep Schedule parameters will have no effect if the MV/Respiratory Sensor is Off.

To increase the likelihood that the patient is sleeping during data collection, the pulse generator does not begin collecting data until 1 hour after the Sleep Start Time, and stops collecting data 1 hour before the Sleep Duration period would otherwise have expired.

*Example:* If you select a Sleep Start Time of 22:00 and a Sleep Duration of 8 hours, the pulse generator will monitor for respiratory disturbance events starting at 23:00 and stopping at 05:00.

Move the horizontal slider over a data point to view the average for a given date. At least 2 hours of data must be collected for an average to be calculated and plotted to the AP Scan trend. If insufficient data was collected, no data point will be plotted and there will be a gap in the trend line. This gap will be labeled as N/R to indicate that insufficient or no data was collected.

### Minute Ventilation (MV)/Respiratory Sensor

The Minute Ventilation (MV) feature is available in VISIONIST and INLIVEN devices. The Respiratory Sensor is available in VALITUDE, INTUA, and INVIVE devices.

The MV/Respiratory Sensor uses transthoracic impedance measurements to collect respiration-related data for use in generating the Respiratory Rate and AP Scan trends.

**CAUTION:** Program the MV/Respiratory Sensor to Off during mechanical ventilation. Otherwise, the following may occur:

- Inappropriate MV sensor-driven rate
- Misleading respiration-based trending

Approximately every 50 ms (20 Hz), the pulse generator drives a current excitation waveform between the RA Ring electrode and Can (primary vector). The application of the current between these electrodes creates an electrical field (modulated by respiration) across the thorax. During inspiration, the transthoracic impedance is high, and during expiration it is low. The pulse generator will detect the resulting voltage modulations between the RA Tip electrode and Can. Due to advanced filtering, breathing rates up to 72 (MV Sensor) or 65 (Respiratory Sensor) breaths per minute are supported.

**CAUTION:** Any medical equipment, treatment, therapy, or diagnostic test that introduces electrical current into the patient has the potential to interfere with pulse generator function.

- External patient monitors (e.g., respiratory monitors, surface ECG monitors, hemodynamic monitors) may interfere with the pulse generator's impedance-based diagnostics (e.g., Respiratory Rate trend). This interference may also result in accelerated pacing, possibly up to the maximum sensor-driven rate, when MV is programmed to On. To resolve suspected interactions with the MV sensor, deactivate the sensor either by programming it to Off (no MV rate driving or MV sensor-based trending will occur), or Passive (no MV rate driving will occur). Alternatively, program the Brady Mode to a non-rate responsive mode (no MV rate driving will occur). If a PRM is not available and the pulse generator is pacing at the sensor-driven rate, apply a magnet to the pulse generator to initiate temporary asynchronous, non-rate responsive pacing.

To resolve suspected interactions with Respiratory Sensor-based diagnostics, deactivate the pulse generator's Respiratory Sensor by programming it to Off.

**NOTE:** *The MV Sensor signal does not cause an increase in heart rate if it is programmed to Passive. The Respiratory Sensor signal does not cause an increase in heart rate.*

Consider the following when programming the sensor:

- Examine real-time EGMs before and after activating the sensor. The sensor signal can sometimes be observed on EGMs.

**CAUTION:** If MV/Respiratory Sensor signal artifacts are observed on EGMs, and the leads are otherwise shown to be performing appropriately, consider programming the sensor to Off to prevent oversensing.

- Program the sensor to Off if you detect or suspect any loss of lead integrity.

**CAUTION:** Do not program the MV sensor to On until after the pulse generator has been implanted and system integrity has been tested and verified.

The pulse generator may temporarily suspend the sensor in the following circumstances:

- Excessive electrical noise levels—The pulse generator continuously monitors electrical noise levels. The sensor is temporarily suspended if noise is excessive (the MV Sensor Status will indicate Suspended: Noise Detected), and is turned on again when noise decreases to an acceptable level.

- Loss of lead integrity—Lead impedances for the sensor are evaluated hourly (separate from daily lead measurements). If either impedance measurement is out of range, the following occurs:
  - The pulse generator evaluates the lead impedances for a secondary vector driven from the RV Ring electrode to the Can, and measured from the RV Tip electrode to the Can. If these impedance measurement are in range, the sensor reverts to this secondary vector. If either lead impedance is also out of range with the secondary vector, the sensor is suspended for the next hour.
 

**NOTE:** *If an RA lead is not used, only the secondary vector is available.*
  - The pulse generator will continue to monitor lead impedance every hour to determine if the sensor should be returned to the primary or secondary vector, or remain suspended. Acceptable lead impedance values are 200–2000  $\Omega$  for the tip to can vectors and 100–1500  $\Omega$  for the ring to can vectors.

To program the MV Sensor, use the following steps:

1. From the Settings tab on the main screen, select Settings Summary.
2. Select the Brady Settings button.
3. Select the desired option for MV Sensor.

To program the Respiratory Sensor, use the following steps:

1. From the Summary tab, select Leads.
2. Select the Setup button.
3. Select the desired option for Respiration-related Trends.

**CAUTION:** To obtain an accurate MV baseline, the MV sensor will be calibrated automatically or can be calibrated manually. A new, manual calibration should be performed if the pulse generator is removed from the pocket following implant, such as during a lead repositioning procedure, or in cases where the MV baseline may have been affected by factors such as lead maturation, air entrapment in the pocket, pulse generator motion due to inadequate suturing, external defibrillation or cardioversion, or other patient complications (e.g., pneumothorax).

## POST IMPLANT FEATURES

### Patient Triggered Monitor (PTM)

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

Patient Triggered Monitor allows the patient to trigger the storage of EGMs, intervals, and annotated marker data during a symptomatic episode by placing a magnet over the device. Instruct the patient to place the magnet on the device briefly and one time only.

Patient Triggered Monitor is enabled by selecting Store EGM as the desired Magnet Response. This can be found in the Timing, Rate Enhancements, Magnet, Noise section on the Brady/CRT Settings screen.

When PTM is enabled, the patient can trigger data storage by holding a magnet over the device for at least 2 seconds. The device will store data for up to 2 minutes prior to and up to 1 minute after magnet application. The stored data include the episode number, rates at magnet application, and start time and date of magnet application. After one EGM is generated and

stored, PTM is disabled. To store another EGM, the PTM feature must be re-enabled using the programmer. If 60 days elapse and the patient did not trigger data storage, PTM is automatically disabled.

When data are stored, the corresponding episode type is recorded as PTM in the Arrhythmia Logbook.

**CAUTION:** Use care when using Patient Triggered Monitor, because the following conditions will exist while it is enabled:

- All other magnet features, including asynchronous pacing, are disabled. The Magnet feature will not indicate magnet position.
- Device longevity is impacted. To help reduce the longevity impact, PTM only allows storage of one episode, and PTM is automatically disabled after 60 days if data storage was never triggered.
- Once the EGM is stored (or 60 days elapses), PTM is disabled and the device Magnet Response automatically will be set to Pace Async. However, if a magnet is used, the pulse generator will not revert to asynchronous operation until the magnet is removed for 3 seconds and placed on the device again.

To program the Patient Triggered Monitor feature, follow these steps:

1. From the Settings tab on the main screen, select Settings Summary.
2. From the Settings Summary tab, select Brady Settings.
3. From Brady Settings, select Timing, Rate Enhancements, Magnet, Noise.
4. Program the Magnet Response to Store EGM.
5. Determine if the patient is capable of activating this feature prior to being given the magnet and prior to enabling Patient Triggered Monitor. Remind the patient to avoid strong magnetic fields so the feature is not inadvertently triggered.
6. Consider having the patient initiate a stored EGM at the time Patient Triggered Monitor is enabled to assist with patient education and feature validation. Verify the activation of the feature on the Arrhythmia Logbook screen.

**NOTE:** *Ensure that Patient Triggered Monitor is enabled prior to sending the patient home by confirming the Magnet Response is programmed to Store EGM. If the feature is inadvertently left in the Pace Async setting, the patient could potentially cause the device to pace asynchronously by applying the magnet.*

**NOTE:** *Once the Patient Triggered Monitor feature has been triggered by the magnet and an EGM has been stored, or after 60 days have elapsed from the day that Store EGM was enabled, the Magnet Response programming automatically will be set to Pace Async.*

7. Patient Triggered Monitor can only be enabled for a 60-day period of time. To disable the feature within the 60-day time period, reprogram the Magnet Response to a setting other than Store EGM. When 60 days have passed since enabling Patient Triggered Monitor, the feature will automatically disable itself and the Magnet Response will revert to Pace Async. To re-enable the feature, repeat these steps.

For additional information, contact Boston Scientific using the information on the back cover.

## Magnet Feature

This feature is available in VISIONIST, VALITUDE, INLIVEN, INTUA, and INVIVE devices.

The magnet feature allows certain device functions to be triggered when a magnet is placed in close proximity to the pulse generator (Figure 4-4 on page 4-20).

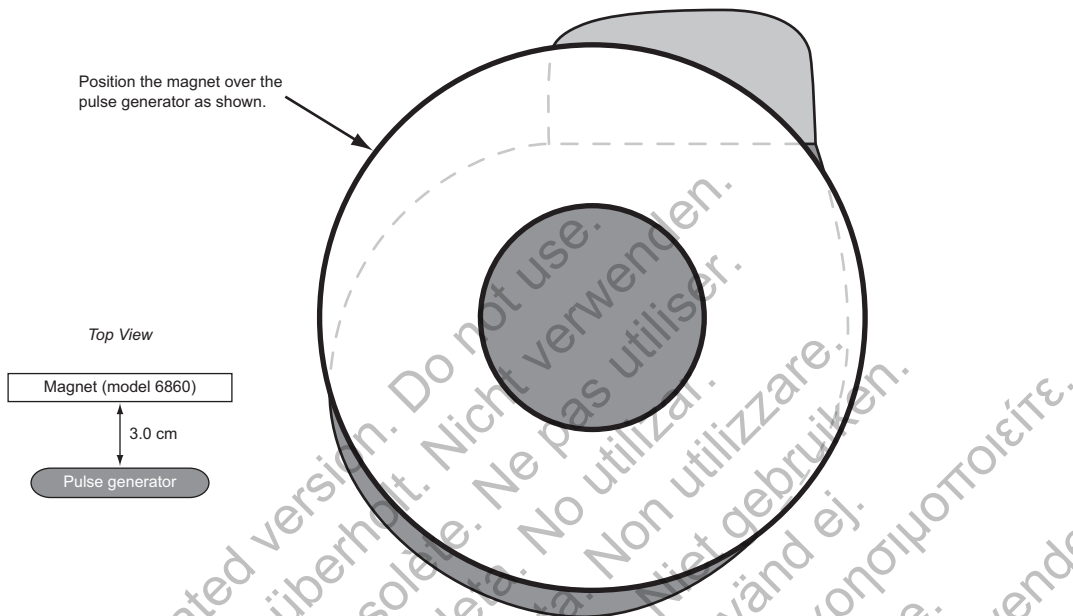


Figure 4-4. Proper position of magnet Model 6860 to activate the pulse generator magnet feature

The pulse generator Magnet Response settings can be programmed to control the behavior of the pulse generator when a magnet is detected. The Magnet Response settings are located in the Timing, Rate Enhancements, Magnet, Noise section of the Brady Settings screen.

The following Magnet Response settings are available:

- Off—no response
- Store EGM—patient monitoring data will be stored
- Pace Async—pacing will occur asynchronously at a rate reflective of the current battery status ("Battery Status Summary Screen" on page 3-3)

### Off

When the Magnet Response is programmed to Off, application of the magnet will have no effect on the pulse generator.

### Store EGM

When the Magnet Response is programmed to Store EGM, application of the magnet will activate the Patient Triggered Monitor functionality ("Patient Triggered Monitor (PTM)" on page 4-18).

### Pace Async

When the Magnet Response is programmed to Pace Async, magnet application converts the pulse generator Brady Mode to an asynchronous mode, with a fixed pacing rate that reflects battery status ("Battery Status Summary Screen" on page 3-3) and magnet AV Delay of 100 ms.



If Magnet Response is programmed to Off, the pulse generator will not revert to asynchronous operation in the presence of magnet. If Magnet Response is programmed to Store EGM, the pulse generator will not revert to asynchronous operation until the magnet is removed for 3 seconds and placed on the device again.

Initial Brady Modes and their corresponding magnet Modes are listed below:

- Brady Modes DDD, DDDR, DDI, and DDIR convert to Magnet Mode DOO
- Brady Modes VDD, VDDR, VVI, and VVIR convert to Magnet Mode VOO
- Brady Modes AAI and AAIR convert to Magnet Mode AOO

The third pulse during the Pace Async Magnet Response will be issued at 50% of the programmed Pulse Width. If loss of capture is observed at the third beat after magnet application, consider re-assessing the safety margin.

The Pacing Chamber is set to BiV, and LV Offset is set to 0 ms.

The pulse generator remains in Magnet Response as long as the magnet is positioned over the middle of the pulse generator, parallel to the device header. When the magnet is removed, the pulse generator automatically resumes operating according to previously programmed parameters.

**NOTE:** *If rate adaptive pacing has been programmed, it is suspended for the duration of magnet application. If PaceSafe Right Ventricular Automatic Threshold has been programmed, the pre-magnet output level is maintained during the duration of magnet application.*

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# ELECTROPHYSIOLOGIC TESTING

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## CHAPTER 5

This chapter contains the following topics:

- "EP Test Features" on page 5-2
- "Induction Methods" on page 5-3

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## EP TEST FEATURES

Electrophysiologic (EP) Testing features enable you to induce and terminate arrhythmias noninvasively.

**WARNING:** Always have external defibrillation equipment available during implant and electrophysiologic testing. If not terminated in a timely fashion, an induced ventricular tachyarrhythmia can result in the patient's death.

The features allowing noninvasive EP testing of arrhythmias include the following:

- Programmed electrical stimulation (PES) induction/termination
- Manual Burst pacing induction/termination

### EP Test Screen

The EP Test screen displays the real-time status of the episode detection and brady pacing therapy of the pulse generator when telemetry communication is occurring.

Refer to the EP Test screen (Figure 5-1 on page 5-2):

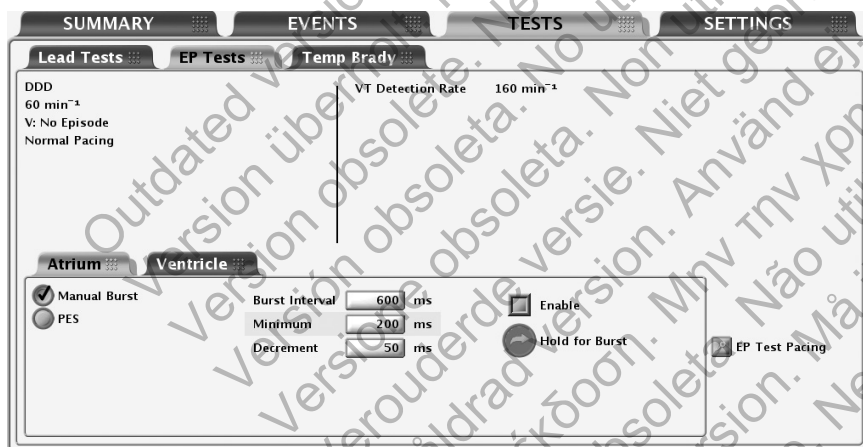


Figure 5-1. EP Test Screen

The screen provides the following information:

- Ventricular episode status—if an episode is occurring, the duration of the episode is displayed (if it is greater than 10 minutes, then it is displayed as > 10:00 m:s)
- Atrial episode status—if an episode is occurring, the duration of the episode is displayed (if it is greater than 100 minutes, then it is displayed as > 99:59 m:s)
- Brady pacing status

Follow the steps below to perform EP Test functions:

1. Select the Tests tab, then select the EP Tests tab.
2. Establish telemetry communication. Telemetry communication between the programmer and the pulse generator should be maintained throughout all EP test procedures.
3. Set Backup Pacing and EP Test Pacing Outputs as desired.

## INDUCTION METHODS

Each EP Test method available from the EP Test screen is described below with instructions. During any type of induction/termination, the pulse generator performs no other activity until the test has ceased, at which time the programmed mode will take effect and the pulse generator will respond accordingly.

Consider the following information when using these methods:

- Ventricular PES is BiV
- Ventricular Manual Burst is RV Only
- Pacing pulses during induction are delivered at the programmed EP Test pacing parameters

### Backup Ventricular Pacing During Atrial EP Testing

Backup biventricular pacing is available during atrial EP testing (PES, Manual Burst) regardless of the programmed Normal Brady Mode.

**NOTE:** Backup Pacing is performed in VOO mode.

Program the backup pacing parameters by selecting the EP Test Pacing button. Backup Pacing parameters are independently programmable from the permanent pacing parameters. Backup Pacing can also be disabled by programming the Backup Pacing Mode to Off.

### Programmed Electrical Stimulation (PES)

PES induction allows the pulse generator to deliver up to 30 equally timed pacing pulses (S1) followed by up to 4 premature stimuli (S2–S5) to induce or terminate arrhythmias. Drive pulses, or S1 pulses, are intended to capture and drive the heart at a rate slightly faster than the intrinsic rate. This ensures that the timing of the premature extra stimuli will be accurately coupled with the cardiac cycle (Figure 5-2 on page 5-3).

The initial S1 pulse is coupled to the last sensed or paced beat at the S1 interval. All pulses are delivered in XOO modes (where X is the chamber) at the programmed EP Test pacing parameters.

For Atrial PES, backup pacing parameters are provided.

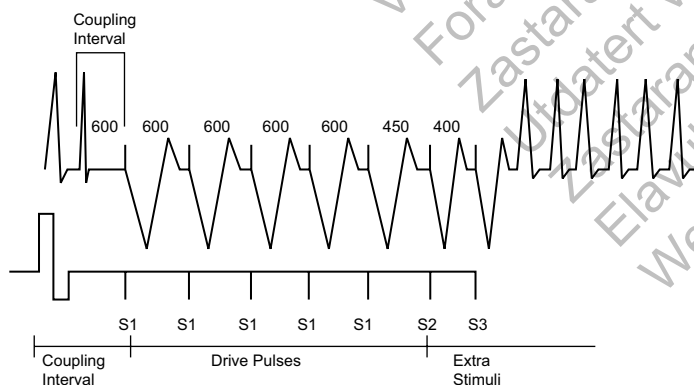


Figure 5-2. PES induction drive train

### Performing PES Induction

1. Choose the Atrium or Ventricle tab, depending on which chamber you want to pace
2. Select the PES option. Buttons for the S1–S5 pulses and the corresponding burst cycle lengths are displayed.
3. Select the desired value for the S1–S5 intervals (Figure 5-3 on page 5-4). You can either select a value box for the desired S interval and choose a value from the box or use the plus or minus symbols to change the value visible in the value box.

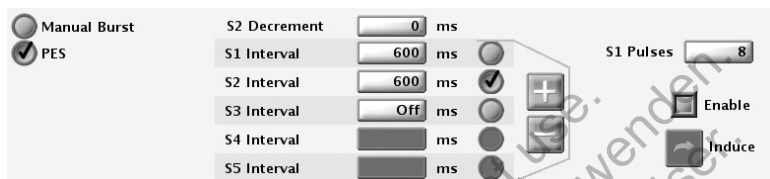


Figure 5-3. PES induction options

4. Select the Enable checkbox.
5. Select (do not hold) the Induce button to begin delivery of the drive train. When the programmed number of S1 pulses is delivered, the pulse generator will then deliver the programmed S2–S5 pulses. The pulses are delivered in sequence until a pulse is encountered that is set to Off (e.g., if S1 and S2 are set to 600 ms, and S3 is Off, then S3, S4, and S5 will not be delivered). Once induction is initiated, the PES delivery will not stop if you interrupt telemetry communication. (While telemetry is active, pressing the DIVERT THERAPY key will stop induction delivery.)
6. PES induction is complete when the drive train and extra stimuli are delivered, at which time the pulse generator automatically restarts detection.

**NOTE:** Ensure the PES induction is complete before beginning another induction.

**NOTE:** When PES is used to terminate an arrhythmia that has been detected (and an episode declared), the episode is terminated when the PES is commanded regardless of whether it is successful or not. A new episode can be declared after the PES induction is completed. The PES itself is not recorded in therapy history; this may result in several episodes being counted in therapy history.

**NOTE:** Real-time EGMs and annotated event markers will continue to be displayed during the entire test sequence.

### Manual Burst Pacing

Manual Burst pacing is used to induce or terminate arrhythmias when delivered to the desired chamber. Pacing parameters are programmable for Manual Burst.

Manual Burst pacing pulses are delivered in XOO mode (where X is the chamber) at the programmed EP Test pacing parameters. For Atrial Manual Burst, backup pacing parameters are provided.

#### Performing Manual Burst Pacing

1. Choose the Atrium or Ventricle tab, depending on which chamber you want to pace.
2. Select the Manual Burst option.

3. Select the desired value for the Burst Interval, Minimum, and Decrement. This indicates the cycle length of the intervals in the drive train.
4. Select the Enable checkbox.
5. To deliver the burst, select and hold the Hold for Burst button.

The ventricular Manual Burst will be delivered up to 30 seconds as long as the Hold for Burst button is held and the telemetry link is maintained.

The atrial Manual Burst will be delivered up to 45 seconds as long as the Hold for Burst button is held and the telemetry link is maintained.

The intervals will continue to be decremented until the Minimum interval is reached, then all further pulses will be at the Minimum interval.

6. To stop the burst delivery, release the Hold for Burst button. The Hold for Burst button will become dimmed again.
7. To deliver additional Manual Burst pacing, repeat these steps.

**NOTE:** *Real-time EGMs and annotated event markers will continue to be displayed during the entire test sequence.*

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# PROGRAMMABLE OPTIONS

## APPENDIX A

**Table A-1. ZIP Telemetry settings**

Parameter	Programmable Values	Nominal <sup>a</sup>
Communication Mode	Enable use of ZIP telemetry (May require limited use of wand); Use wand for all telemetry	Enable use of ZIP telemetry (May require limited use of wand)

a. If the Communication Mode is selected via the Utilities button on the PRM Startup screen, the Nominal setting within the ZOOMVIEW Programmer software application will correspond to the value chosen on the Startup screen.

**Table A-2. Device Mode**

Parameter	Programmable Values	Nominal
Device Mode	Exit Storage; Enable Electrocautery Protection	Storage

**Table A-3. Pacing therapy parameters (specified into a 750  $\Omega$  load)**

Parameter	Programmable Values	Nominal
Mode <sup>a b d</sup>	DDD(R); DDI(R); DOO; VDD(R); VVI(R); VOO; AAI(R); AOO; Off; Temporary: DDD; DDI; DOO; VDD; VVI; VOO; AAI; AOO; Off	DDD
Ventricular Pacing Chamber <sup>a d</sup>	RV Only; LV Only; BiV	BiV
LV Offset <sup>a d</sup> (ms)	-100; -90; ...; 100	0 (Tolerance $\pm$ 5 ms)
BiV Trigger <sup>f</sup>	Off; On	Off
BiV Trigger/VRR Maximum Pacing Rate <sup>i</sup> (min <sup>-1</sup> )	50; 55; ...; 185	130 (Tolerance $\pm$ 5 ms)
Lower Rate Limit (LRL) <sup>a c d</sup> (min <sup>-1</sup> )	30; 35; ...; 185	45 (Tolerance $\pm$ 5 ms)
Maximum Tracking Rate (MTR) <sup>a d</sup> (min <sup>-1</sup> )	50; 55; ...; 185	130 (Tolerance $\pm$ 5 ms)
Maximum Sensor Rate (MSR) <sup>f</sup> (min <sup>-1</sup> )	50; 55; ...; 185	130 (Tolerance $\pm$ 5 ms)
Pulse Amplitude <sup>a d e k</sup> (atrium) (V)	Auto; 0.1; 0.2; ...; 3.5; 4.0; ...; 5.0; Temporary: 0.1; 0.2; ...; 3.5; 4.0; ...; 5.0	3.5 (Tolerance $\pm$ 15% or 100 mV, whichever is greater)
Pulse Amplitude <sup>a d e</sup> (right ventricle) (V)	Auto; 0.1; 0.2; ...; 3.5; 4.0; ...; 7.5; Temporary: 0.1; 0.2; ...; 3.5; 4.0; ...; 7.5	3.5 (Tolerance $\pm$ 15% or 100 mV, whichever is greater)
Pulse Amplitude <sup>a d e k</sup> (left ventricle) (V)	Auto; 0.1; 0.2; ...; 3.5; 4.0; ...; 7.5; Temporary: 0.1; 0.2; ...; 3.5; 4.0; ...; 7.5	3.5 (Tolerance $\pm$ 15% or 100 mV, whichever is greater)
PaceSafe LV Automatic Threshold Maximum Amplitude (V)	2.5; 3.0; ...; 7.5	5.0
PaceSafe LV Automatic Threshold Safety Margin (V)	0.5; 1.0; ...; 2.5	1.0
Pulse Amplitude Daily Trend <sup>g</sup> (independently programmable in each chamber that has the Pacesafe feature)	Disabled; Enabled	Enabled (VISIONIST and VALITUDE devices)  Disabled (INLIVEN, INTUA and INVIVE devices)
Pulse Width <sup>a d e h</sup> (atrium, right ventricle, left ventricle) (ms)	0.1; 0.2; ...; 2.0	0.4 (Tolerance $\pm$ 0.03 ms at < 1.8 ms; $\pm$ 0.08 ms at $\geq$ 1.8 ms)
Accelerometer <sup>f</sup>	On; Passive	Passive
Accelerometer Activity Threshold	Very Low; Low; Medium Low; Medium; Medium High; High; Very High	Medium
Accelerometer Reaction Time (sec)	10; 20; ...; 50	30
Accelerometer Response Factor	1; 2; ...; 16	8

Table A-3. Pacing therapy parameters (specified into a 750 Ω load) (continued)

Parameter	Programmable Values	Nominal
Accelerometer Recovery Time (min)	2; 3; ...; 16	2
Minute Ventilation <sup>f</sup>	On; Passive; Off	Passive
Minute Ventilation Response Factor	1; 2; ...; 16	8
Minute Ventilation Fitness Level	Sedentary; Active; Athletic; Endurance Sports	Active
Patient's Age <sup>l</sup>	≤ 5; 6–10; 11–15; ...; 91–95; ≥ 96	56–60
Patient's Gender <sup>l</sup>	Male; Female	Male
Ventilatory Threshold ( min <sup>-1</sup> )	30; 35; ...; 185	115 (Tolerance ± 5 ms)
Ventilatory Threshold Response (%)	Off; 85; 70; 55	70
Respiration-related Trends <sup>i</sup>	Off; On	On
Tracking Preference <sup>f</sup>	Off; On	On
Rate Hysteresis Hysteresis Offset <sup>f</sup> ( min <sup>-1</sup> )	-80; -75; ...; -5; Off	Off (Tolerance ± 5 ms)
Rate Hysteresis Search Hysteresis <sup>f</sup> (cycles)	Off; 256; 512; 1024; 2048; 4096	Off (Tolerance ± 1 cycle)
Rate Smoothing (Up, Down) <sup>f</sup> (%)	Off; 3; 6; 9; 12; 15; 18; 21; 25	Off (Tolerance ± 1%)
Rate Smoothing Maximum Pacing Rate ( min <sup>-1</sup> )	50; 55; ...; 185	130 (Tolerance ± 5 ms)
Sudden Brady Response (SBR) <sup>f</sup>	Off; On	Off
SBR Atrial Paces Before Therapy	1; 2; ...; 8	3
SBR Atrial Pacing Rate Increase ( min <sup>-1</sup> )	5; 10; ...; 40	20
SBR Therapy Duration (min)	1; 2; ...; 15	2
SBR Inhibit During Rest	Off; On	On
Atrial Pace/Sense Configuration <sup>a d</sup>	Unipolar; Bipolar; Bipolar/Unipolar; Unipolar/Bipolar; Unipolar/Off; Bipolar/Off	Bipolar
Right Ventricle Pace/Sense Configuration <sup>a d</sup>	Unipolar; Bipolar; Bipolar/Unipolar; Unipolar/Bipolar	Bipolar
Left Ventricular Electrode Configuration <sup>a</sup>	Dual; Single; None	None
Left Ventricular Electrode Configuration <sup>a</sup>	Quadripolar (Non-programmable)	Quadripolar
Left Ventricular Pace Configuration <sup>a d</sup>	Single or Dual: LVtip>>Can LVtip>>RV Dual Only: LVring>>Can LVring>>RV LVtip>>LVring LVring>>LVtip	Single: LVtip>>RV Dual: LVtip>>LVring
Left Ventricular Pace Configuration <sup>a d</sup>	Quadripolar: LVTip1>>LVRing2 LVTip1>>LVRing3 LVTip1>>LVRing4 LVTip1>>RV LVTip1>>Can LVRing2>>LVRing3 LVRing2>>LVRing4 LVRing2>>RV LVRing2>>Can LVRing3>>LVRing2 LVRing3>>LVRing4 LVRing3>>RV LVRing3>>Can LVRing4>>LVRing2 LVRing4>>LVRing3 LVRing4>>RV LVRing4>>Can	LVTip1>>LVRing2

**Table A-3. Pacing therapy parameters (specified into a 750 Ω load) (continued)**

Parameter	Programmable Values	Nominal
Left Ventricular Sense Configuration <sup>a d</sup>	Single or Dual: LVtip>>Can LVtip>>RV Off Dual Only: LVring>>Can LVring>>RV LVtip>>LVring	Single: LVtip>>RV Dual: LVtip>>LVring
Left Ventricular Sense Configuration <sup>a d</sup>	Quadripolar: LVTip1>>LVRing2 LVTip1>>LVRing3 LVTip1>>LVRing4 LVTip1>>RV LVTip1>>Can LVRing2>>LVRing3 LVRing2>>RV LVRing2>>Can Off (Disable Sensing)	LVTip1>>LVRing2
Safety Switch (independently programmable in each chamber)	Off; On	On
Maximum Paced AV Delay <sup>a d</sup> (ms)	30; 40; ...; 300	180 (Tolerance ± 5 ms)
Minimum Paced AV Delay <sup>a d</sup> (ms)	30; 40; ...; 300	180 (Tolerance ± 5 ms)
Maximum Sensed AV Delay <sup>a d</sup> (ms)	30; 40; ...; 300	120 (Tolerance ± 5 ms)
Minimum Sensed AV Delay <sup>a d</sup> (ms)	30; 40; ...; 300	120 (Tolerance ± 5 ms)
Maximum A-Refractory (PVARP) <sup>a d</sup> (ms)	150; 160; ...; 500	280 (Tolerance ± 5 ms)
Minimum A-Refractory (PVARP) <sup>a d</sup> (ms)	150; 160; ...; 500	240 (Tolerance ± 5 ms)
Maximum RV-Refractory (RVRP) <sup>a d</sup> (ms)	150; 160; ...; 500	250 (Tolerance ± 5 ms)
Minimum RV-Refractory (RVRP) <sup>a d</sup> (ms)	150; 160; ...; 500	230 (Tolerance ± 5 ms)
LV-Refractory (LVRP) <sup>a d</sup> (ms)	250; 260; ...; 500	250 (Tolerance ± 5 ms)
LV Protection Period (LVPP) <sup>a</sup> (ms)	300; 350; ...; 500	400 (Tolerance ± 5 ms)
PVARP after PVC <sup>a</sup> (ms)	Off; 150; 200; ...; 500	400 (Tolerance ± 5 ms)
A-Blank after V-Pace <sup>a d m</sup> (ms)	Smart; 85; 105; 125; 150; 175; 200	125 (Tolerance ± 5 ms)
A-Blank after RV-Sense <sup>a d m</sup> (ms)	Smart; 45; 65; 85	45 (Tolerance ± 5 ms)
RV-Blank after A-Pace <sup>a d</sup> (ms)	45; 65; 85	65 (Tolerance ± 5 ms)
LV-Blank after A-Pace <sup>a d m</sup> (ms)	Smart; 45; 65; 85	65 (Tolerance ± 5 ms)
Noise Response <sup>a</sup>	AOO; VOO; DOO; Inhibit Pacing	DOO for DDD(R) and DDI(R) modes; VOO for VDD(R) and VVI (R) modes; AOO for AAI(R) mode
Magnet Response	Off; Store EGM; Pace Async	Pace Async

- a. The programmed Normal Brady values will be used as the nominal values for Temporary Brady pacing.
- b. Refer to the NASPE/BPEG codes below for an explanation of the programmable values. The identification code of the North American Society of Pacing and Electrophysiology (NASPE) and the British Pacing and Electrophysiology Group (BPEG) is based on the categories listed in the table.
- c. The basic pulse period is equal to the pacing rate and the pulse interval (no hysteresis). Runaway protection circuitry inhibits bradycardia pacing above 205 min<sup>-1</sup>. Magnet application may affect pacing rate (test pulse interval).
- d. Separately programmable for Temporary Brady.
- e. For INLIVEN, INTUA and INVIVE devices, values are not affected by temperature variation within the range 20°C – 43°C. For VISIONIST and VALITUDE devices, values are not affected by temperature variation within the range 20°C – 45°C.
- f. This parameter is disabled during Temporary Brady.
- g. This parameter is automatically enabled if Auto is selected for the Pulse Amplitude.
- h. When the Pulse Amplitude is set to Auto or Pulse Amplitude Daily Trend is enabled the Pulse Width is fixed at 0.4 ms.
- i. This value is located on the Lead Setup screen.
- j. The BiV/VRR Maximum Pacing Rate is shared by BiV Trigger and VRR, changing the value for BiV MPR will also change the value for VRR MPR.
- k. Auto is available in models which contain the Pacesafe feature.
- l. This parameter is used for calculating Ventilatory Threshold Response.
- m. Smart is available when AGC is selected as the Sensing Method.

Table A-4. Brady Mode values based on NASPE/BPEG codes

Position	I	II	III	IV	V
Category	Chambers Paced	Chambers Sensed	Response to Sensing	Programmability, rate modulation	Antitachyarrhythmia Functions
Letters	0–None	0–None	0–None	0–None	0–None
	A–Atrium	A–Atrium	T–Triggered	P–Simple Programmable	P–Pacing (Antitachyarrhythmia)
	V–Ventricle	V–Ventricle	I–Inhibited	M–Multiprogrammable	S–Shock
	D–Dual (A&V)	D–Dual (A&V)	D–Dual (T&I)	C–Communicating	D–Dual (P&S)
				R–Rate Modulation	
Mfrs. Designation Only	S–Single (A or V)	S–Single (A or V)			

Table A-5. Sensor Trending

Parameter	Programmable Values	Nominal
Recording Method	Beat To Beat; Off; 30 Second Average	30 Second Average
Data Storage	Continuous; Fixed	Continuous

Table A-6. Ventricular Tachy EGM Storage

Parameter	Programmable Values	Nominal
Ventricular Tachy EGM Storage	Off; On	On
VT Detection Rate <sup>a</sup> ( min <sup>-1</sup> )	90; 95; ...; 210; 220	160 (Tolerance ± 5 ms)

a. The VT Detection Rate must be ≥ 5 min<sup>-1</sup> higher than the Maximum Tracking Rate, Maximum Sensor Rate, and the Maximum Pacing Rate, and must be ≥ 15 min<sup>-1</sup> higher than the Lower Rate Limit.

Table A-7. Atrial Tachy Parameters

Parameter	Programmable Values	Nominal
ATR Mode Switch <sup>a</sup>	Off; On	On
ATR Trigger Rate <sup>a e</sup> ( min <sup>-1</sup> )	100; 110; ...; 300	170 (Tolerance ± 5 ms)
ATR Duration <sup>a</sup> (cycles)	0; 8; 16; 32; 64; 128; 256; 512; 1024; 2048	8 (Tolerance ± 1 cardiac cycle)
ATR Entry Count <sup>a</sup> (cycles)	1; 2; ...; 8	8
ATR Exit Count <sup>a</sup> (cycles)	1; 2; ...; 8	8
ATR Fallback Mode <sup>f</sup>	VDI; DDI; VDIR; DDIR	DDI
ATR Fallback Time <sup>a</sup> (min:sec)	00:00; 00:15; 00:30; 00:45; 01:00; 01:15; 01:30; 01:45; 02:00	00:30
ATR Fallback LRL <sup>a</sup> ( min <sup>-1</sup> )	30; 35; ...; 185	70 (Tolerance ± 5 ms)
ATR Ventricular Rate Regulation (VRR) <sup>a</sup>	Off; Min; Med; Max	Min
ATR BiV Trigger <sup>a</sup>	Off; On	On
ATR Maximum Pacing Rate (MPR) <sup>a d</sup> ( min <sup>-1</sup> )	50; 55; ...; 185	130 (Tolerance ± 5 ms)
Atrial Flutter Response <sup>b</sup>	Off; On	On
Atrial Flutter Response Trigger Rate <sup>e</sup> ( min <sup>-1</sup> )	100; 110; ...; 300	170 (Tolerance ± 5 ms)
PMT Termination <sup>b</sup>	Off; On	On
Ventricular Rate Regulation (VRR) <sup>b</sup>	Off; Min; Med; Max	Off
BiV/VRR Maximum Pacing Rate (MPR) <sup>b c</sup> ( min <sup>-1</sup> )	50; 55; ...; 185	130 (Tolerance ± 5 ms)

**Table A-7. Atrial Tachy Parameters** (continued)

Parameter	Programmable Values	Nominal
APP/ProACT <sup>b</sup>	Off; On	Off
APP/ProACT Max Pacing Rate ( min <sup>-1</sup> )	50; 55; ...; 185	80 (Tolerance ± 5 ms)

- a. The programmed Normal Brady values will be used as the nominal values for Temporary Brady pacing.
- b. This parameter gets disabled during Temporary Brady.
- c. The BiV/VRR MPR is shared by VRR and BiV Trigger. Changing this parameter for VRR will also change the MPR value for BiV Trigger.
- d. The ATR MPR is shared by ATR VRR and ATR BiV Trigger. Changing this parameter for ATR VRR will also change the MPR value for ATR BiV Trigger.
- e. ATR Trigger Rate and Atrial Flutter Response Trigger Rate are linked. If either of these rates is reprogrammed, the other will automatically change to the same value.
- f. If Normal Brady ATR Fallback Mode is DDIR or DDI, then Temporary Brady ATR Fallback Mode is DDI. If Normal Brady ATR Fallback Mode is VDIR or VDI, then Temporary Brady ATR Fallback Mode is VDI.

**Table A-8. Sensitivity**

Parameter <sup>a b</sup>	Programmable Values	Nominal
Sensing Method <sup>c</sup>	AGC; Fixed	Fixed
Atrial Sensitivity (AGC) (mV)	AGC 0.15; AGC 0.2; AGC 0.25; AGC 0.3; AGC 0.4; ...; AGC 1.0; AGC 1.5	AGC 0.25
Right Ventricular Sensitivity (AGC) (mV)	AGC 0.15; AGC 0.2; AGC 0.25; AGC 0.3; AGC 0.4; ...; AGC 1.0; AGC 1.5	AGC 0.6
Left Ventricular Sensitivity (AGC) (mV)	AGC 0.15; AGC 0.2; AGC 0.25; AGC 0.3; AGC 0.4; ...; AGC 1.0; AGC 1.5	AGC 1.0
Atrial Sensitivity (Fixed) (mV)	Fixed 0.15; Fixed 0.25; Fixed 0.5; Fixed 0.75; Fixed 1.0; Fixed 1.5; ...; Fixed 8.0; Fixed 9.0; Fixed 10.0	Fixed 0.75
Right Ventricular Sensitivity (Fixed) (mV)	Fixed 0.25; Fixed 0.5; Fixed 0.75; Fixed 1.0; Fixed 1.5; ...; Fixed 8.0; Fixed 9.0; Fixed 10.0	Fixed 2.5
Left Ventricular Sensitivity (Fixed) (mV)	Fixed 0.25; Fixed 0.5; Fixed 0.75; Fixed 1.0; Fixed 1.5; ...; Fixed 8.0; Fixed 9.0; Fixed 10.0	Fixed 2.5

- a. Separately programmable for Temporary Brady.
- b. The programmed Normal Brady values will be used as the nominal values for Temporary Brady pacing.
- c. The programmed value for Sensing Method determines the applicable values (AGC or Fixed) in each chamber.

**Table A-9. Daily Lead Measurements**

Parameter	Programmable Values	Nominal
Atrial Intrinsic Amplitude	On; Off	On
Right Ventricular Intrinsic Amplitude	On; Off	On
Left Ventricular Intrinsic Amplitude	On; Off	On
Atrial Pace Impedance	On; Off	On
Right Ventricular Pace Impedance	On; Off	On
Left Ventricular Pace Impedance	On; Off	On
Atrial Low Impedance Limit (Ω)	200; 250; ...; 500	200
Atrial High Impedance Limit (Ω)	2000; 2250; ...; 3000	2000
Right Ventricular Low Impedance Limit (Ω)	200; 250; ...; 500	200
Right Ventricular High Impedance Limit (Ω)	2000; 2250; ...; 3000	2000
Left Ventricular Low Impedance Limit (Ω)	200; 250; ...; 500	200
Left Ventricular High Impedance Limit (Ω)	2000; 2250; ...; 3000	2000
Post-Operative System Test (POST) (hours)	Off; 2; 3; ...; 24	4

**Table A-10. Backup EP Test**

Parameter	Programmable Values	Nominal
Backup Pacing Mode <sup>a</sup>	Off; On	On

**Table A-10. Backup EP Test (continued)**

Parameter	Programmable Values	Nominal
Backup Pacing Lower Rate Limit <sup>a b</sup> (min <sup>-1</sup> )	30; 35; ...; 185	45 (Tolerance ± 5 ms)
Backup Pacing RV Refractory <sup>a b</sup> (ms)	150; 160; ...; 500	250 (Tolerance ± 5 ms)
Backup Pacing Ventricular Pacing Chamber <sup>a</sup>	BiV (nonprogrammable)	BiV
EP Test Pacing Outputs Atrial Amplitude (when test is in the atrium) (V)	Off; 0.1; 0.2; ...; 3.5; 4.0; ...; 5.0	5.0 (Tolerance ± 15% or 100 mV, whichever is greater)
EP Test Pacing Outputs RV Amplitude (V)	Off; 0.1; 0.2; ...; 3.5; 4.0; ...; 7.5	7.5 (Tolerance ± 15% or 100 mV, whichever is greater)
EP Test Pacing Outputs LV Amplitude (V)	Off; 0.1; 0.2; ...; 3.5; 4.0; ...; 7.5	7.5 (Tolerance ± 15% or 100 mV, whichever is greater)
EP Test Pacing Outputs Atrial Pulse Width (when test is in the atrium) (ms)	0.1; 0.2; ...; 2.0	1.0 (Tolerance ± 0.03 ms at < 1.8 ms; ± 0.08 ms at ≥ 1.8 ms)
EP Test Pacing Outputs RV Pulse Width (ms)	0.1; 0.2; ...; 2.0	1.0 (Tolerance ± 0.03 ms at < 1.8 ms; ± 0.08 ms at ≥ 1.8 ms)
EP Test Pacing Outputs LV Pulse Width (ms)	0.1; 0.2; ...; 2.0	1.0 (Tolerance ± 0.03 ms at < 1.8 ms; ± 0.08 ms at ≥ 1.8 ms)

a. This parameter only applies when the test is in the atrium.

b. The programmed Normal Brady value will be used as the nominal value.

**Table A-11. PES (Programmed Electrical Stimulation)**

Parameter <sup>a</sup>	Programmable Values	Nominal
Number of S1 Intervals (pulses)	1; 2; ...; 30	8
S2 Decrement (ms)	0; 10; ...; 50	0
S1 Interval (ms)	120; 130; ...; 750	600 (Tolerance ± 5 ms)
S2 Interval (ms)	Off; 120; 130; ...; 750	600 (Tolerance ± 5 ms)
S3 Interval (ms)	Off; 120; 130; ...; 750	Off (Tolerance ± 5 ms)
S4 Interval (ms)	Off; 120; 130; ...; 750	Off (Tolerance ± 5 ms)
S5 Interval (ms)	Off; 120; 130; ...; 750	Off (Tolerance ± 5 ms)

a. Applied to the atrium or ventricle as commanded by the programmer.

**Table A-12. Manual Burst Pacing**

Parameter <sup>a</sup>	Programmable Values	Nominal
Burst Interval (ms)	100; 110; ...; 750	600 (Tolerance ± 5 ms)
Minimum Interval (ms)	100; 110; ...; 750	200 (Tolerance ± 5 ms)
Decrement (ms)	0; 10; ...; 50	50 (Tolerance ± 5 ms)

a. Applied to the atrium or ventricle depending on the chamber selected.

## SYMBOLS ON PACKAGING

### APPENDIX B

### SYMBOLS ON PACKAGING

The following symbols may be used on packaging and labeling (Table B-1 on page B-1):

Table B-1. Symbols on packaging




























Symbol	Description
	Reference number
	Package contents
	Pulse generator
	Torque wrench
	Literature enclosed
	Serial number
	Use by
	Lot number
	Date of manufacture
	Sterilized using ethylene oxide
	Do not resterilize
	Do not reuse
	Do not use if package is damaged
	Consult instructions for use on this website: <a href="http://www.bostonscientific-international.com/manuals">www.bostonscientific-international.com/manuals</a>
	Temperature limitation
	CE mark of conformity with the identification of the notified body authorizing use of the mark
	Place telemetry wand here
	Open here

Table B-1. Symbols on packaging (continued)

Symbol	Description
	Authorized Representative in the European Community
	Manufacturer
	C-Tick with supplier codes
	Australian Sponsor Address
	Pacemaker RV
	Pacemaker RA, RV
	CRT-P RA, RV, LV
	Uncoated device
	RF Telemetry

Outdated version. Do not use.  
 Version überholt. Nicht verwenden.  
 Version obsolete. Ne pas utiliser.  
 Versión obsoleta. No utilizar.  
 Versione obsolete. Non utilizzare.  
 Verouderde versie. Niet gebruiken.  
 Föråldrad version. Använd ej.  
 Παλιά έκδοση. Μην την χρησιμοποιείτε.  
 Versão obsoleta. Não utilize.  
 Forældet version. Må ikke anvendes.  
 Zastaralá verze. Nepoužívat.  
 Utdatert versjon. Skal ikke brukes.  
 Zastaraná verzia. Nepoužívať.  
 Elavult verzió. Ne használja!  
 Wersja nieaktualna. Nie używać.



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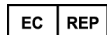
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