Medtronic

ADAPTA®/VERSA®/SENSIA®/ RELIA™

Adapta ADDR01/03/06
Adapta S ADDRS1
Adapta L ADDRL1
Adapta ADD01
Adapta ADVDD01
Adapta ADSR01/03/06
Versa VEDR01
Sensia SEDR01
Sensia L SEDRL1
Sensia SED01
Sensia SESR01
Sensia SES01
Relia REDR01
Relia RED01
Relia RESR01
Relia RES01
Relia REVDD01

Pacemaker Reference Guide

Contents

Adapta/Versa/Sensia/Relia

Pacemaker Reference Guide

A guide to the Adapta/Versa/Sensia/Relia pacemakers

Refer to the Adapta/Versa/Sensia/Relia Pacemaker Programming Guide for information on software and programming.

How to use this guide

Information is contained in two guides

Product information about Adapta/Versa/Sensia/Relia pacemakers and the associated software for the 9790/C series programmer and the 2090 programmer is presented in two separate guides.

The Pacemaker Reference Guide (PRG) provides detailed information on the pacemakers.

The Pacemaker Programming Guide (PPG) contains instructions on how to use the programmer and the programming software.

About the Pacemaker Reference Guide

The Pacemaker Reference Guide describes in detail how the pacemakers operate and specifies the capabilities of the pacemakers. The PRG includes the following information:

- Describes the pacing modes, rate response options, special therapy features, telemetry types, and data collection options. In some cases, guidelines are given on how to configure the pacemaker operation.
- Contains troubleshooting information for electrical and hemodynamic problems.
- Specifies parameter and data collection capabilities, longevity projections, and mechanical and electrical specifications.
- Provides general warnings and cautions, potential interference sources, and general indications for pacing.
- Contains a glossary of terms.

About the Pacemaker Programming Guide

The Pacemaker Programming Guide describes how to program Adapta, Versa, Sensia, and Relia pacemakers using a programmer. The PPG presents the following information:

- How to set up and configure the programmer and access online help.
- How to start a patient session, use the various follow-up features during the session, and properly end the session.
- How to use Checklist to streamline a follow-up session.
- How to view and print the patient's ECG and EGM waveform traces.
- How to configure the pacemaker to collect diagnostic data and how to retrieve and view this information.
- How to measure stimulation thresholds and sensing levels.
- How to use TherapyGuide to obtain suggested parameter values.
- How to program parameter values and verify rate response parameters settings.
- How to run EP Studies.

The Implant Manuals supplement these guides

For each pacemaker model in the Adapta/Versa/Sensia/Relia family, there is an Implant Manual. The Pacemaker Programming Guide and the Pacemaker Reference Guide do not specify which features apply to each individual pacemaker model. Refer to the applicable implant manual for specific capabilities of individual models.

Also, in various places throughout this manual, for example "Programmable modes and parameters" on page 300, you are asked to refer to the applicable implant manual for specific capabilities of individual models

New nomenclature for product battery life terms

This manual uses a new nomenclature for certain terms related to product battery life. This new nomenclature is defined in CENELEC pacemaker standard EN 45502-2-1:2003, which applies to Active Implantable Medical Devices (AIMD) intended to treat bradyarrhythmias. This standard was approved and published in December 2003.

Medtronic has adopted the new nomenclature to comply with the CENELEC standard and in anticipation of the nomenclature becoming an international standard.

The new nomenclature, and the terms replaced by the new nomenclature, are presented in the following table:

New nomenclature		**Old nomenclature**	
BOS	Beginning of Service	BOL	Beginning of Life
EOS	End of Service	EOL	End of Life
RRT/ERI	Recommended Replacement Time (RRT/ERI)	ERI	Elective Replacement Indicator
Prolonged service period		Post-ERI conditions	
Projected service life		Longevity	

Pacing modes 1

Introduction

Pacing mode selection

This chapter provides an introduction to pacemaker modes as an aid to pacing mode selection. The chapter is organized as follows:

Definition of basic pacing modes – The names for most of the pacing modes are defined on the 1991 ACC/AHA guidelines for pacemaker implantation.[1]

Rationale for mode selection – In order to get pacing mode suggestions, the use of TherapyGuide is recommended. TherapyGuide is a programmer feature that suggests parameter settings based on a patient's clinical conditions. For models which do not contain TherapyGuide, refer to the device implant manual for guidance in mode selection.

Mode descriptions – These descriptions provide indications and contraindications for modes available with the pacemaker and brief descriptions of how these modes operate.

NBG pacing codes

The pacemaker modes are defined in NBG Code.[2] Each five-letter NBG code describes a specific type of operation for implantable pacemakers. For simplicity, this manual uses only the first three or four letters, such as DDD, DDIR, DVIR, and so forth. Figure 1-1 describes the first four letters of the NBG code.

[1] Dreifus LS, Fisch C, Griffin JC, et al. Guidelines for implantation of cardiac pacemakers and antiarrhythmia devices. A report of the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Committee on Pacemaker Implantation). *Journal of the American College of Cardiology.* 1991; 18: 1-13.

[2] Bernstein A., et al., "The NASPE/BPEG Pacemaker Code," PACE, 10(4), Jul-Aug 1987. ("NBG" stands for The North American Society of Pacing and Electrophysiology [NASPE] and the British Pacing and Electrophysiology Group [BPEG] Generic. NBG's five-letter code supersedes the ICHD Code.

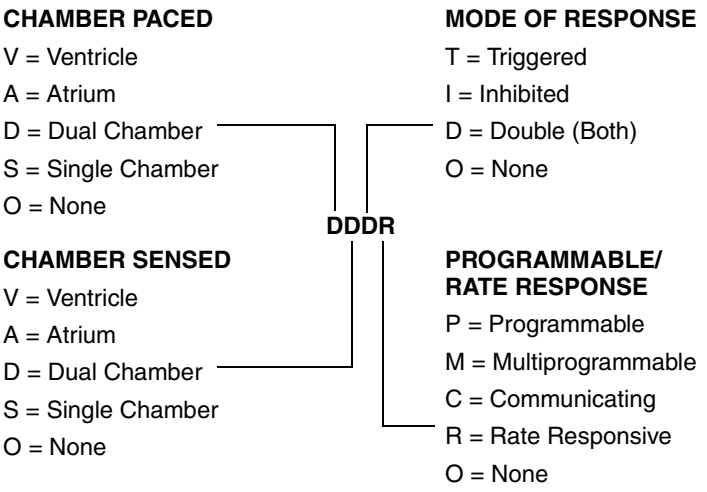


Figure 1-1. NBG pacing codes

Further information

The mode descriptions in this chapter provide only a basic overview of each mode. For further details on the rate response, timing, and therapy capabilities, refer to “Rate response” on page 36, “Pacemaker timing” on page 55, and “Special therapy options” on page 133.

Rationale for mode selection

TherapyGuide offers a simple clinically-focused method for a clinician to obtain suggested parameter values. At implant or an early follow-up appointment, the clinician enters information about the patient's clinical conditions. Based on those inputs the programmer suggests parameter settings. The suggestions are based on clinical studies, literature, current practice, and the consensus of physicians.

For more information about TherapyGuide, refer to page 179.

For each pacemaker model, TherapyGuide suggests a programmable mode. It bases the suggestion on clinical conditions such as the condition of the sinus node and the quality of AV conduction.

TherapyGuide offers a Rationale screen that shows the basis for each setting of pacing modes and of other parameters. Figure 1-2 shows a typical Rationale screen. To access the screen, perform the following steps:

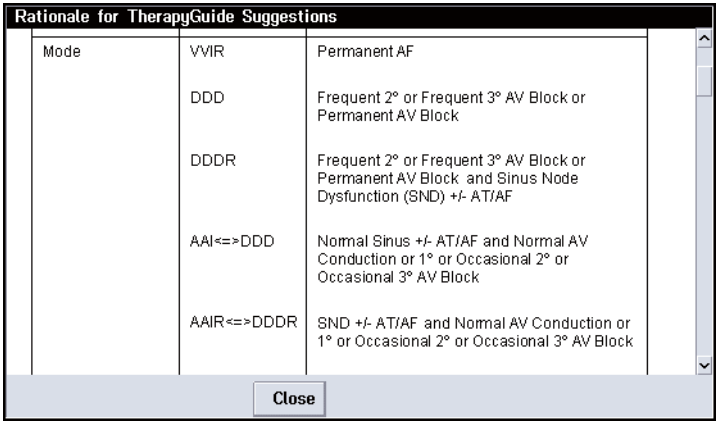


Figure 1-2. Mode selection rationale used by TherapyGuide

1. Interrogate the pacemaker (before or after implant).
2. Select the Params icon. On the Therapy Parameters screen, select the **[TherapyGuide]** button to open the TherapyGuide window.
3. Select the **[Rationale…]** button to open the Rationale window.
4. Select **[Close]** twice to return to the Therapy Parameters screen.

Note: It is not necessary to do any parameter programming at this time. Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for instructions on programming parameters using TherapyGuide.

Indications

Note: This section contains information for all models of the Medtronic Adapta/Versa/Sensia/Relia implantable pulse generators. For information about a specific model or series, refer to the implant manual for that device.

These Medtronic Adapta/Versa/Sensia/Relia implantable pulse generators (IPGs) are indicated for use to improve cardiac output, prevent symptoms, or protect against arrhythmias related to cardiac impulse formation or conduction disorders.

These devices are indicated for use in patients who are experiencing exercise intolerance or exercise restrictions related to an arrhythmia. Using rate response modes may restore heart rate variability and improve cardiac output.

Adapta/Versa/Sensia/Relia implantable pulse generators are indicated for single use only.

This device is also indicated for VDD pacing in patients who have adequate rates and one or both of the following conditions.

- A requirement for ventricular pacing when adequate atrial rates and adequate intracavitary atrial complexes are present. This includes the presence of complete AV block when atrial contribution is needed for hemodynamic benefit or when pacemaker syndrome had existed or is anticipated.
- A requirement for intermittent ventricular pacing despite a normal sinus rhythm and normal AV conduction.

Contraindications

Note: This section contains information for all models of the Medtronic Adapta/Versa/Sensia/Relia implantable pulse generators. For information about a specific model or series, refer to the implant manual for that device.

There are no known contraindications for the use of pacing as a therapy to control heart rate. The patient's age and medical condition may influence the selection of the pacing system, the mode of operation, and the implant technique used by the physician.

Rate responsive modes may be contraindicated for patients who cannot tolerate pacing rates above the programmed Lower Rate.

Medtronic Adapta/Versa/Sensia/Relia implantable pulse generators (IPGs) are contraindicated for the following applications:

- Use of an implantable cardioverter defibrillator (ICD) with a unipolar-only IPG or in those cases in which unipolar leads are implanted for the other models described. Pacing in the unipolar configuration may cause the ICD to deliver inappropriate therapy or to withhold appropriate therapy.
- Dual chamber pacing in patients with chronic or persistent supraventricular tachycardias, including atrial fibrillation or flutter.
- VDD mode operation in patients with sinus disorders.
- Single chamber atrial pacing in patients with AV conduction disturbance.

MVP modes

Two MVP modes are available: AAIR<=>DDDR and AAI<=>DDD.

Note: For information about AAIR<=>DDDR and AAI<=>DDD modes, refer to “Managed Ventricular Pacing (MVP)” on page 142.

DDDR mode

Note: For information about the AAIR<=>DDDR mode, refer to “Managed Ventricular Pacing (MVP)” on page 142.

In the DDDR mode, the pacemaker tracks the faster of the intrinsic atrial rate or the sensor-indicated rate. If the intrinsic rate is faster, the DDDR mode provides atrial synchronous pacing; otherwise, AV sequential pacing occurs at the sensor-indicated rate.

- Rate limits for atrial tracking (Upper Tracking Rate)[1] and sensor tracking (Upper Sensor Rate) are separately programmable.

[1] The Total Atrial Refractory Period (TARP) may limit the tracking rate to a lesser value. Refer to Chapter 3 for more information on TARP.

- The AV intervals that follow sensed atrial events (SAV) and paced atrial events (PAV) are separately programmable, and they can be programmed to shorten with increasing rates (Rate Adaptive AV) or to change with intrinsic conduction times (Search AV+).
- A nonrefractory sensed event in either chamber inhibits pacing in that chamber. A ventricular nonrefractory sensed event in the VA interval that is not preceded by an atrial sense (AS or AR) is a pacemaker-defined PVC and starts a new VA interval.

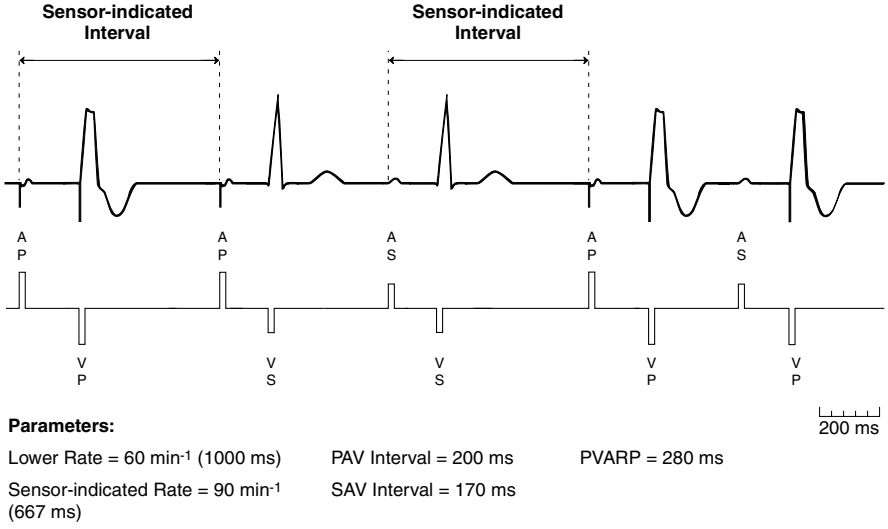


Figure 1-3. Example of DDDR mode operation

DDD mode

Note: For information about the AAI<=>DDD mode, refer to “Managed Ventricular Pacing (MVP)” on page 142.

The DDD mode provides atrial synchronous pacing in the presence of intrinsic atrial activity; otherwise, AV sequential pacing occurs at the Lower Rate.

- Each atrial paced or nonrefractory atrial sensed event starts an AV interval and a lower rate interval. The AV intervals that follow sensed atrial events (SAV) and paced atrial events (PAV) are separately programmable, and the SAV may be optionally programmed to shorten with increasing rate (Rate Adaptive AV) or to change with intrinsic conduction times (Search AV+).
- A ventricular paced event may track an atrial sensed event up to the programmed Upper Tracking Rate.[1]
- A ventricular nonrefractory sensed event in the VA interval that is not preceded by an atrial sense (AS or AR) is a pacemaker-defined PVC and starts a new VA interval.

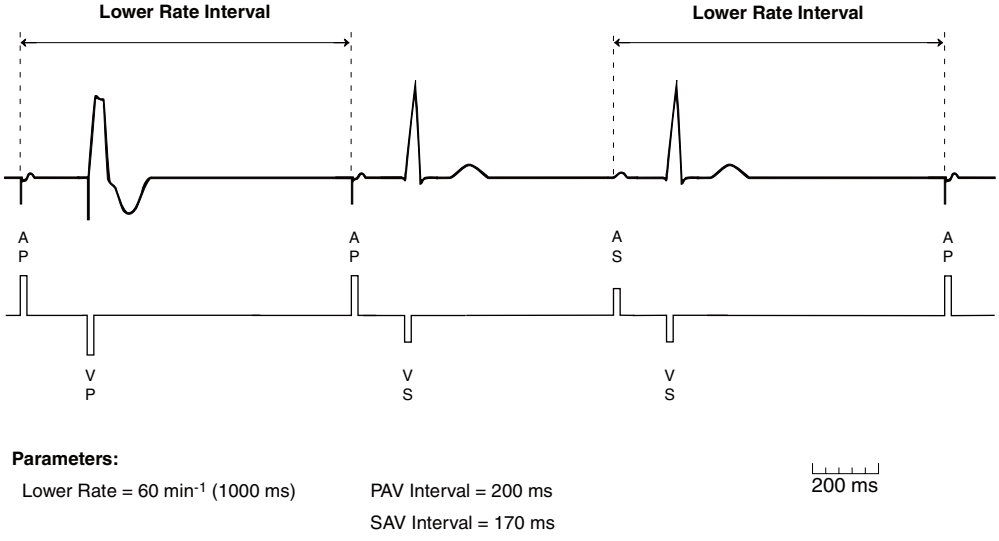


Figure 1-4. Example of DDD mode operation

[1] The Total Atrial Refractory Period (TARP) may limit the tracking rate to a lesser value.

DDIR mode

The DDIR mode provides dual chamber, sensor-driven, atrioventricular (AV) sequential pacing for heart rate variation without atrial tracking.

- Atrial pacing occurs at the sensor-indicated rate. If it is not inhibited, ventricular pacing occurs at the end of the PAV interval.
- The AV intervals that follow paced atrial events (PAV) are separately programmable, and they can be programmed to shorten with increasing rates (Rate Adaptive AV) or to change with intrinsic conduction times (Search AV+).
- An atrial event sensed outside the PVARP will inhibit a scheduled atrial stimulus but will not start an AV interval. That is, ventricular paced events after such sensed atrial events occur at the sensor-indicated rate. The following ventriculoatrial (VA) interval may be extended slightly to avoid an increasing atrial paced rate.
- A ventricular nonrefractory sensed event in the VA interval starts a new VA interval.

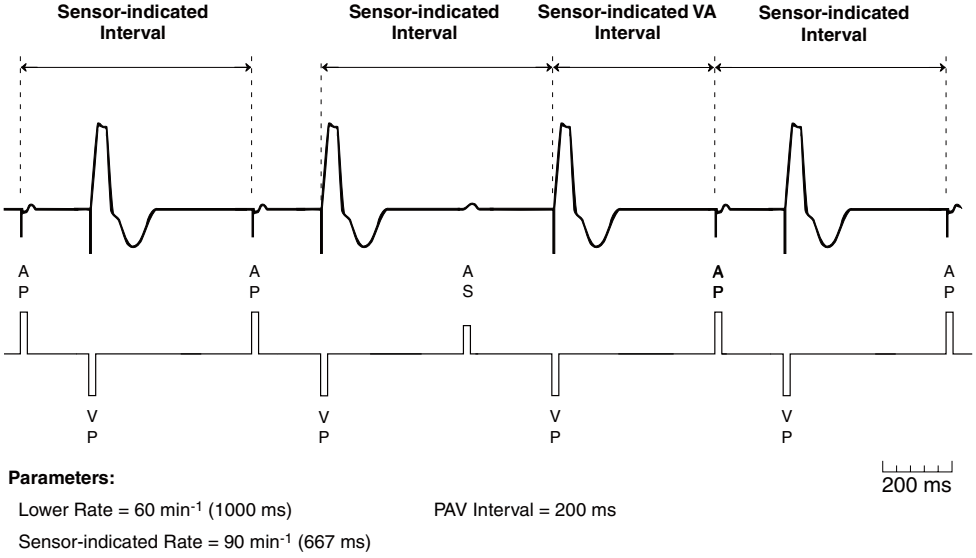


Figure 1-5. Example of DDIR mode operation

DDI mode

The DDI mode provides dual chamber atrioventricular (AV) sequential pacing with atrial sensing but without atrial tracking.

- Atrial pacing occurs at the Lower Rate. If it is not inhibited, ventricular pacing occurs at the end of the PAV interval.
- The AV intervals that follow paced atrial events (PAV) are separately programmable, and they can be programmed to change with intrinsic conduction times (Search AV+).
- An atrial event sensed outside the PVARP will inhibit a scheduled atrial stimulus but will not start an AV interval. Ventricular paced events after such sensed atrial events occur at the Lower Rate.
- A ventricular nonrefractory sensed event in the ventriculoatrial (VA) interval starts a new VA interval.

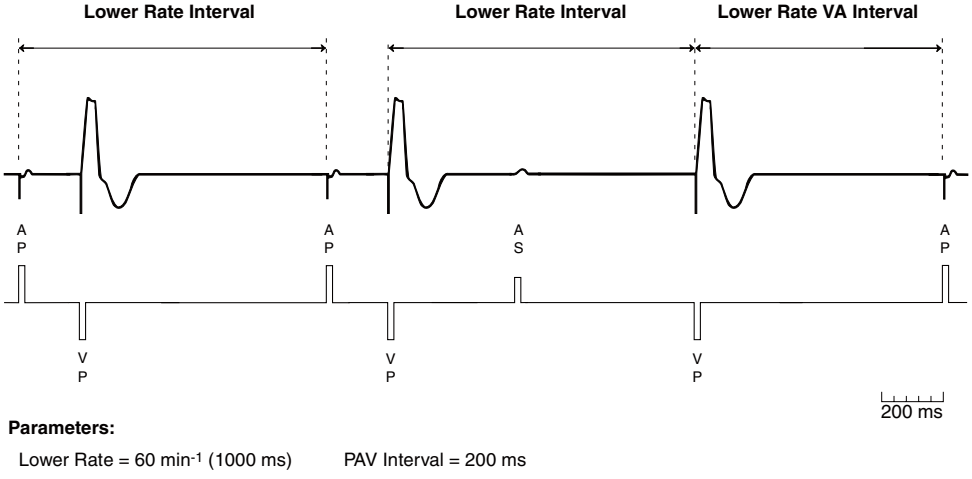


Figure 1-6. Example of DDI mode operation

DVIR mode

The DVIR mode provides AV sequential pacing at the sensor-indicated rate unless inhibited by ventricular sensed events.

- Atrial pacing occurs at the sensor-indicated rate. If it is not inhibited, ventricular pacing occurs at the end of the PAV interval.
- The AV intervals that follow paced atrial events (PAV) are separately programmable, and they can be programmed to shorten with increasing rates (Rate Adaptive AV) or to change with intrinsic conduction times (Search AV+).
- The DVIR mode ignores intrinsic atrial events. Sensing occurs only in the ventricle. A ventricular nonrefractory sensed event during the ventriculoatrial (VA) interval starts a new VA interval.

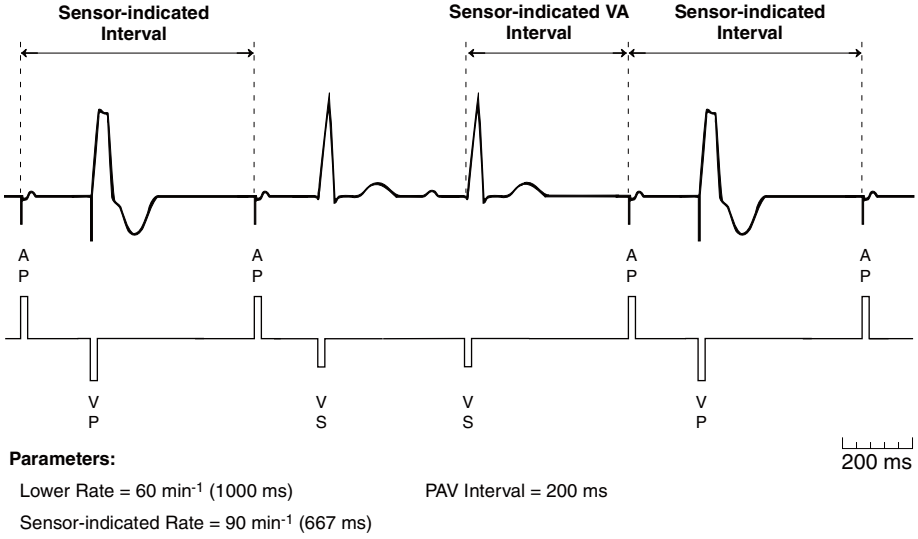


Figure 1-7. Example of DVIR mode operation

DVI mode

The DVI mode provides dual chamber AV sequential pacing without atrial sensing/tracking.

- Atrial pacing occurs at the Lower Rate. If it is not inhibited, ventricular pacing occurs at the end of the PAV interval.
- The AV intervals that follow paced atrial events (PAV) are separately programmable, and they can be programmed to change with intrinsic conduction times (Search AV+).
- Sensing occurs only in the ventricle, and intrinsic atrial events are ignored. A ventricular nonrefractory sensed event during the VA interval starts a new ventriculoatrial (VA) interval.

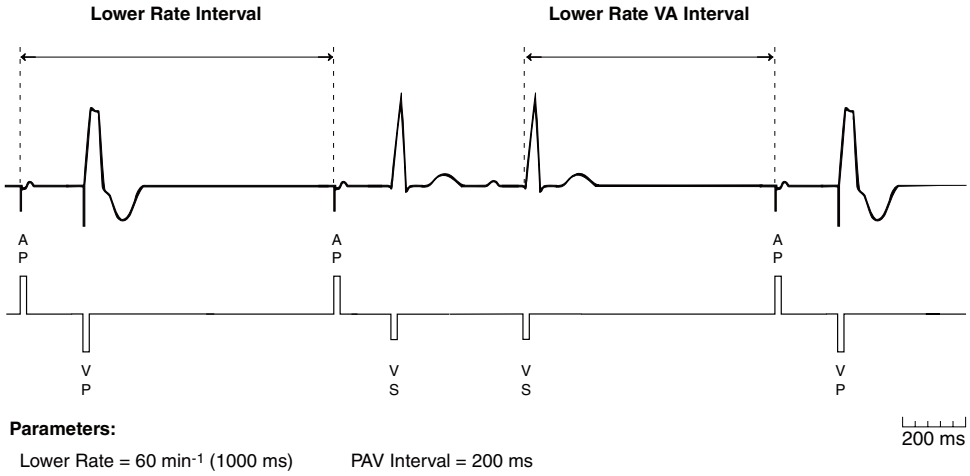


Figure 1-8. Example of DVI mode operation

VDD mode

The VDD mode provides atrial synchronous pacing (or VVI pacing at the Lower Rate). The ventricle is paced synchronously up to the programmed Upper Tracking Rate.[1] Sensing occurs in both the atrium and ventricle, but pacing occurs only in the ventricle.

- To promote atrial synchronous pacing at slow rates, a sensed atrial event occurring near the end of the Lower Rate interval will be followed by the programmed SAV interval. The result is an extension of the ventricular lower rate.
- The AV intervals that follow sensed atrial events (SAV) are separately programmable, and they can be programmed to shorten with increasing rates (Rate Adaptive AV) or to change with intrinsic conduction times (Search AV+).
- A ventricular nonrefractory sensed event in the V-V interval that is not preceded by an atrial sense (AS or AR) is a pacemaker-defined PVC, and it starts a new V-V interval.

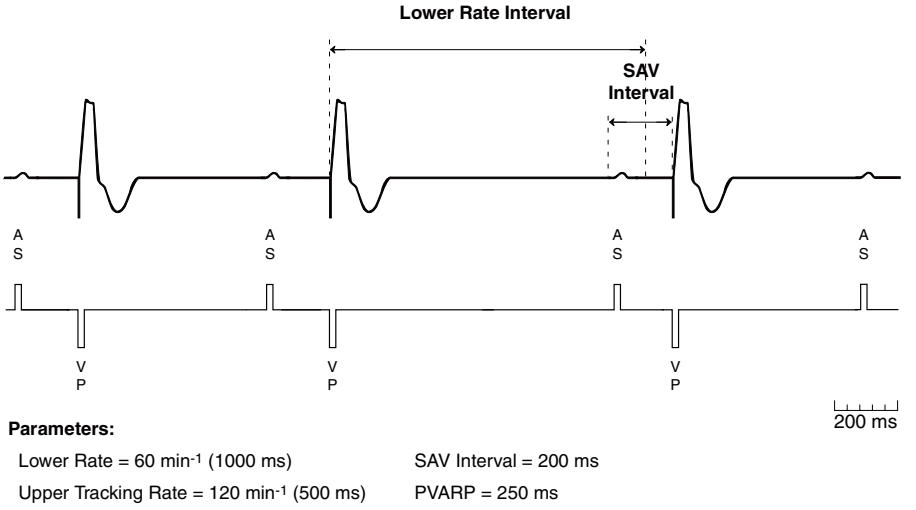


Figure 1-9. Example of VDD mode operation

[1] The Total Atrial Refractory Period (TARP) may limit the tracking rate to a lesser value.

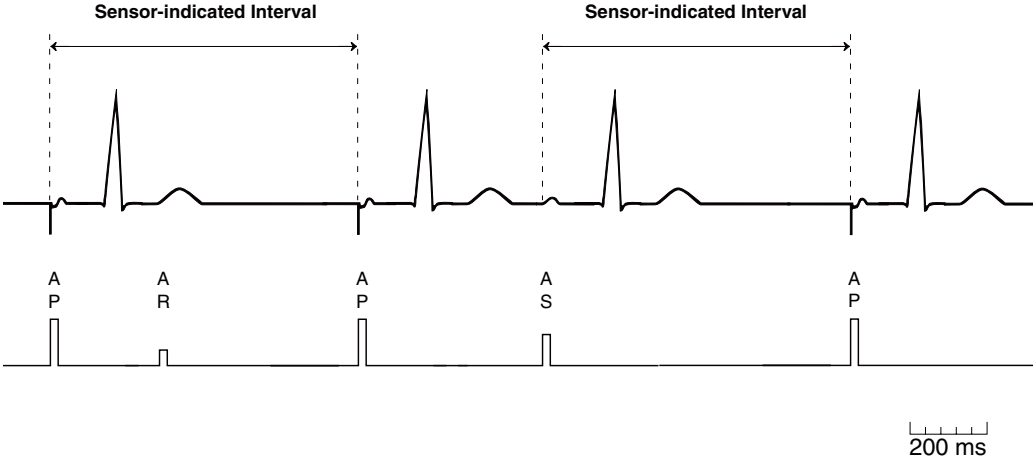
AAIR / ADIR modes

Note: For information about the AAIR<=>DDDR mode, refer to “Managed Ventricular Pacing (MVP)” on page 142.

The AAIR mode provides atrial-based rate responsive pacing in patients with intact AV conduction. Sensing and pacing occur only in the atrium. In the absence of sensed events, the chamber is paced at the sensor-indicated rate.

The ADIR mode operates the same as the AAIR mode except that events sensed in the ventricle are recorded by the diagnostics. When used in conjunction with Marker Channel recordings and concurrent ECG, this mode may be used to observe the conducted ventricular rhythm without affecting atrial pacing.

Note: In the AAIR and ADIR modes, atrial refractory sensed events do not restart the Upper Sensor Rate interval.



Parameters:

Sensor-indicated Rate = 75 min^{-1} (800 ms) Atrial Refractory Period = 250 ms

Upper Sensor Rate = 100 min^{-1} (600 ms)

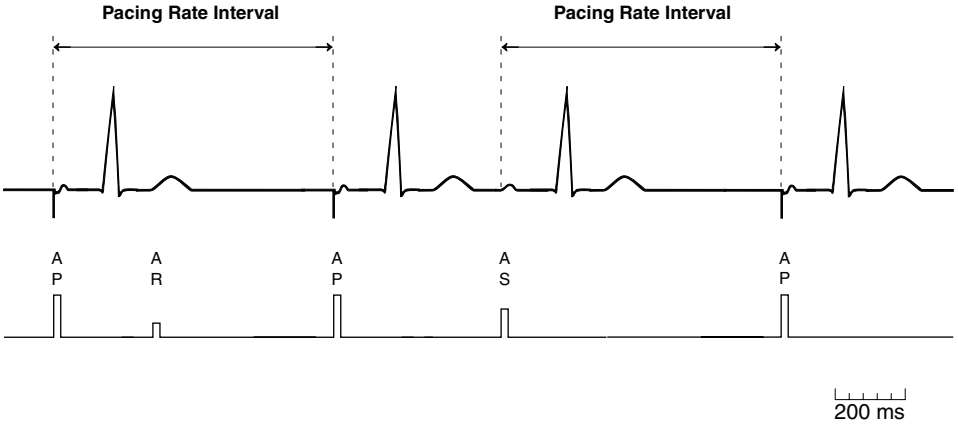
Figure 1-10. Example of AAIR mode operation

AAI / ADI modes

Note: For information about the AAI<=>DDD mode, refer to “Managed Ventricular Pacing (MVP)” on page 142.

The AAI mode provides single chamber inhibited atrial pacing. Sensing and pacing occur only in the atrium. Pacing occurs at the programmed Pacing Rate unless inhibited by sensed events.

The ADI mode operates the same as the AAI mode except that events sensed in the ventricle are recorded by the diagnostics. When used in conjunction with Marker Channel recordings and concurrent ECG, this mode may be used to observe the conducted ventricular rhythm without affecting atrial pacing.



Parameters:

Pacing Rate = 75 min^{-1} (800 ms) Atrial Refractory Period = 250 ms

Figure 1-11. Example of AAI mode operation

VVIR / VDIR modes

The VVIR mode provides ventricular rate responsive pacing in patients for whom atrial-based pacing is deemed unnecessary or inappropriate. In the absence of sensed events, the ventricle is paced at the sensor-indicated rate.

The VDIR mode operates the same as the VVIR mode except that events sensed in the atrium are recorded by the diagnostics. When used in conjunction with Marker Channel recordings and concurrent ECG, this mode may be used to observe the underlying atrial rhythm without affecting ventricular pacing.

Note: In the VVIR and VDIR modes, ventricular refractory sensed events restart the Upper Sensor Rate interval.

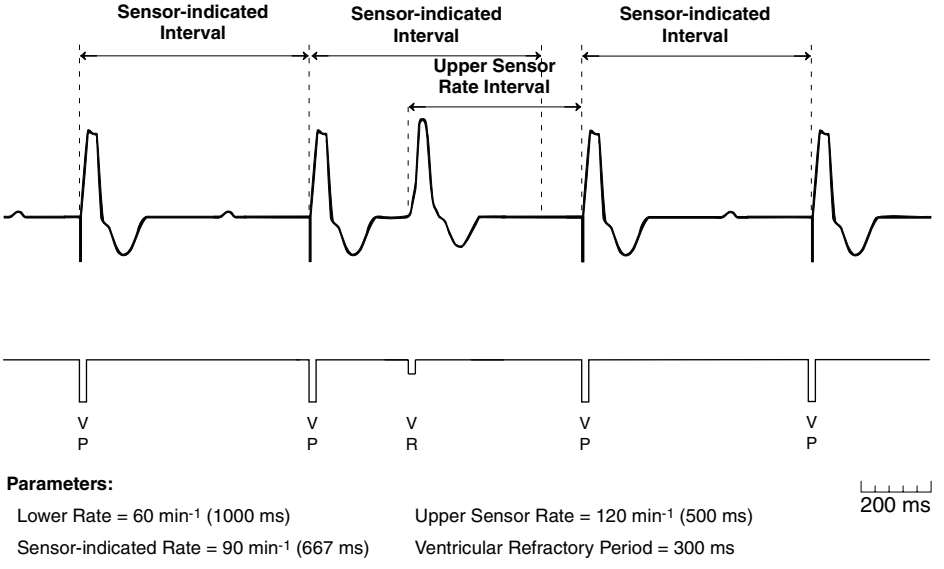
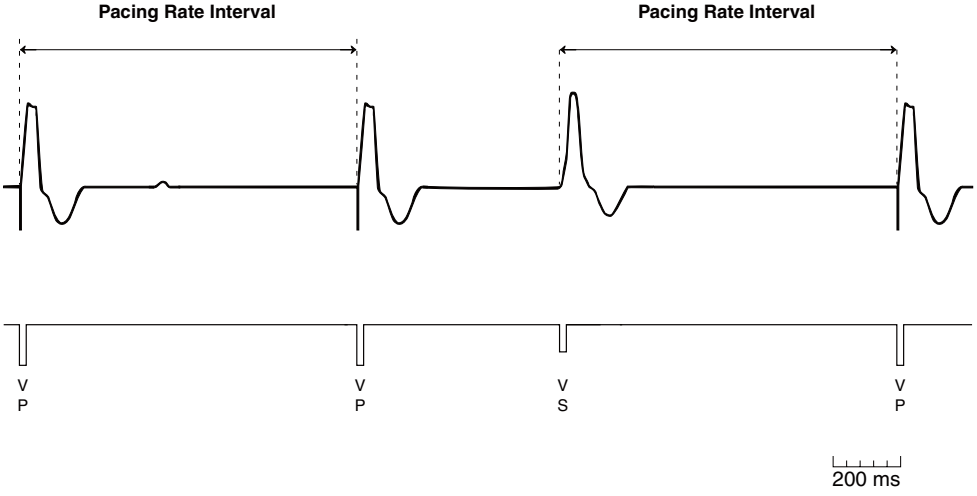


Figure 1-12. Example of VVIR mode operation

VVI / VDI modes

The VVI mode provides single chamber inhibited pacing at the programmed Pacing Rate unless inhibited by sensed events. Sensing occurs only in the ventricle.

The VDI mode operates the same as the VVI mode except that events sensed in the atrium are recorded by the diagnostics. When used in conjunction with Marker Channel recordings and concurrent ECG, this mode may be used to observe the underlying atrial rhythm without affecting ventricular pacing.



Parameters:

Pacing Rate = 60 min^{-1} (1000 ms)

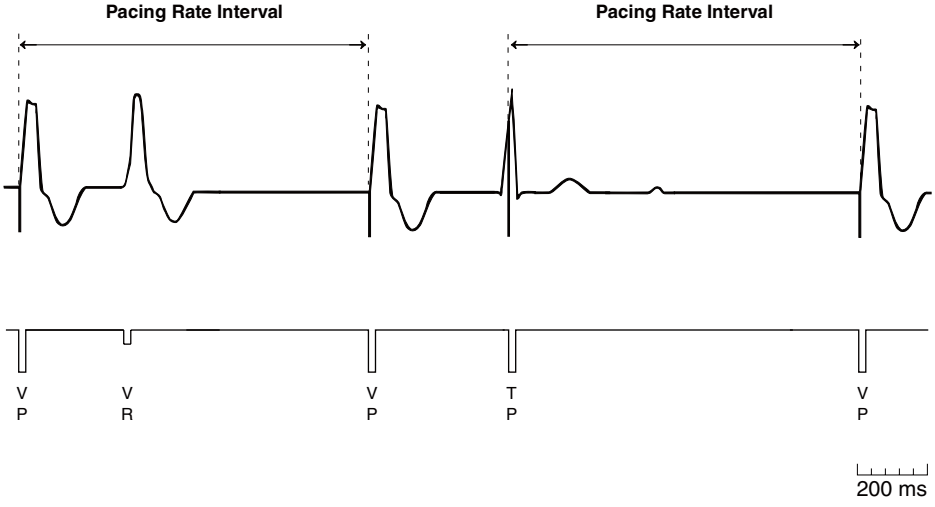
Ventricular Refractory Period = 300 ms

Figure 1-13. Example of VVI mode operation

AAT / VVT modes

In the AAT and VVT modes, pacing occurs at the programmed Lower Rate, but a nonrefractory sensed event triggers an immediate pacing output (rather than inhibiting such output). With the exception that pacing outputs occur when events are sensed, the triggered modes operate identically to the corresponding inhibited modes.

Note: Programmed triggered pacing will not occur faster than 300 ms (200 min^{-1}) from the previous paced event. Temporary programmed triggered pacing is not limited to 300 ms (200 min^{-1}).



Parameters:

Pacing Rate = 60 min^{-1} (1000 ms)

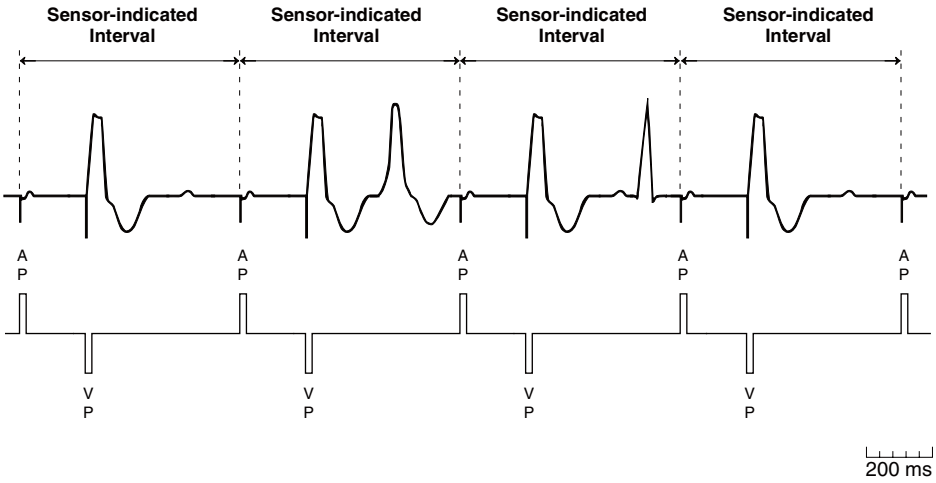
Ventricular Refractory Period = 300 ms

Figure 1-14. Example of VVT mode operation

DOOR / AOOR / VOOR modes

The DOOR, AOOR, and VOOR modes operate as follows:

- The DOOR mode provides asynchronous AV sequential pacing at the sensor-indicated rate. Intrinsic events are ignored.
- The AOOR and VOOR modes provide single chamber pacing at the sensor-indicated rate. Intrinsic events are ignored.



Parameters:

Lower Rate = 60 min^{-1} (1000 ms)
PAV Interval = 200 ms
Sensor-indicated Rate = 90 min^{-1} (667 ms)

Figure 1-15. Example of DOOR mode operation

DOO / AOO / VOO modes

The DOO, AOO, and VOO modes operate as follows:

- The DOO mode provides AV sequential pacing at the programmed Lower Rate with no inhibition by intrinsic events.
- The AOO and VOO modes provide pacing at the programmed Lower Rate with no inhibition by intrinsic events in the applicable chamber.

In addition to being directly programmable, the DOO mode is the Magnet mode of the corresponding dual chamber modes, except for the VDD mode, which is the VOO mode. AOO and VOO modes are the Magnet modes of the corresponding atrial and ventricular single chamber modes, respectively.

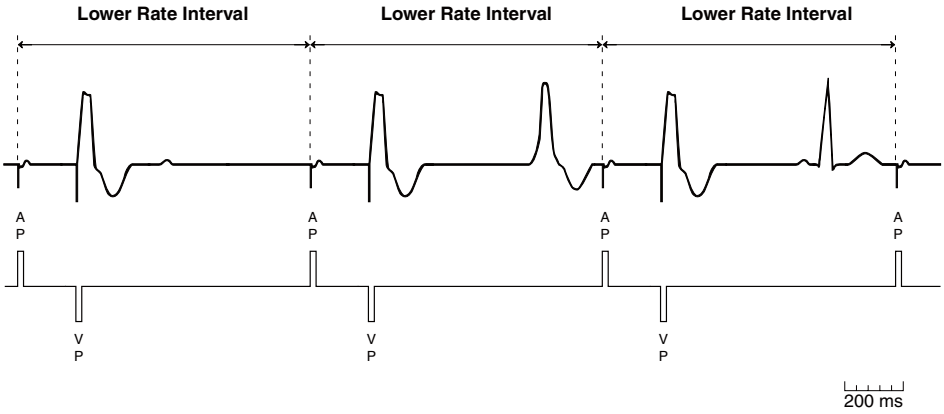


Figure 1-16. Example of DOO mode operation

ODO / OAO / OVO modes

Warning: Never program these modes for pacemaker-dependent patients. For such patients, use the programmer's inhibit function for brief interruption of outputs.

In the ODO, OAO, and OVO modes, sensing occurs in the designated chamber or chambers. When used in conjunction with Marker Channel telemetry and concurrent ECG, these modes may be used to observe underlying rhythms.

- Blanking periods in these modes are automatically minimized to maximize the sensing window or windows. Thus, Marker Channel telemetry may display sense markers for cardiac events (for example, far-field R waves) that otherwise would not appear due to longer blanking.
- No timing intervals or refractory periods are used.

Rate response 2

Introduction to rate responsive pacing

Rate response

The pacemaker may provide appropriate rate response for patients who require cardiac pacing support at both submaximal and maximal rates. Submaximal rates are moderate pacing rates near the Activities of Daily Living Rate (ADL Rate) obtained during typical daily activities, such as walking or daily chores. Maximal rates are rates (at or near the Upper Sensor Rate) obtained during vigorous activities. To achieve appropriate rate response, the pacemaker provides activity sensor-driven pacing with rate response control in both the ADL rate range and the exertion rate range.

The pacemaker provides appropriate rate response by employing the following operations:

- Three programmable rates control the submaximal and maximal rate ranges: Lower Rate, ADL Rate (Activities of Daily Living Rate), and Upper Sensor Rate. The ADL Rate is equivalent to the average target rate that the patient achieves for moderate activities.
- Independent control of rate response is provided in both the ADL and exertion rate ranges.

Automatic features

For models in a rate responsive mode, the pacemaker automatically enables rate response after implant and automatically adjusts rate response, if necessary, once each day.

- During the first 30 minutes after implant, pacing occurs at the implanted mode but without rate response. 30 minutes after implant, rate response operation is enabled.
- Once each day, rate response is assessed and adjusted, if necessary, in the ADL and exertion rate ranges. The assessment is based on comparing the pacemaker's historical sensor-indicated rate profiles against a clinician prescribed target rate profile of the patient. If the rate profiles differ, rate response is adjusted slightly in the appropriate rate range, and the assessment is repeated again the next day.

For further information

Refer to “Rate Profile Optimization operation” on page 39 for information on how the pacemaker optimizes rate response.

Preset rate response at implant

Overview

Pacemakers shipped in rate responsive modes operate in a non rate responsive mode until implant detection is completed, which is typically 30 minutes after implant. Thereafter, the pacemakers automatically enable rate responsive pacing. Consequently, no programming is required for rate response operation.

Three pacing rate controls

If customization of rate response is desired, three pacing rates are provided to control the ADL and exertion rate ranges:

- Lower Rate defines the slowest rate at which pacing occurs in the absence of a sinus rate or physical activity.
- ADL Rate (Activities of Daily Living Rate) is the approximate rate that the patient’s heart is expected to reach during moderate exercise.
- Upper Sensor Rate provides the upper limit for the sensor-driven rate during vigorous exercise.

Refer to “Rates” on page 56 for additional considerations when selecting pacemaker rates.

Starting rate response immediately

In situations where the clinician wishes to start rate responsive pacing before the 30-minute implant detection period is completed, perform the following steps:

1. After the device is implanted, program Implant Detection to “Off/Complete.”
2. Configure pace and sense lead polarities and Lead Monitor.
3. Verify that Rate Profile Optimization is On.
4. Verify that the parameter values for Lower Rate, ADL Rate, and Upper Sensor Rate are appropriate.
5. Verify that the parameter values for ADL Response, Exertion Response, Activity Threshold, Activity Acceleration, and Activity Deceleration are appropriate.

For further information

Refer to “Rate Profile Optimization operation” on page 39 and “Individualizing Rate Profile Optimization” on page 46.

Rate Profile Optimization operation

Overview

When Rate Profile Optimization is programmed On, the pacemaker can adapt ADL and exertion rate response levels once each day by comparing the patient's current sensor rate profiles against a target rate profile. This feature is intended to provide automatic and independent monitoring of rate response at both moderate rates for daily patient activities, such as walking and daily chores, and at exertion rates for vigorous patient activities.

Optimization can be individualized to the patient's activity levels. Refer to "Individualizing Rate Profile Optimization" on page 46.

Optimization can also operate in the background when a non rate responsive mode is programmed. This can provide appropriate rate response to patient activity if rate response is needed later or for certain therapy features, such as mode switching to a non-atrial tracking rate responsive mode.

Rate control in the ADL and exertion rate ranges

The pacemaker maintains linear rate control between the activity sensor signal and the sensor-indicated rate from the Lower Rate to the ADL Rate. Refer to "How Activity Threshold influences rate" on page 48. It maintains independent linear rate control in the exertion rate range. Optimization controls how rapidly and to what level the sensor-indicated rate increases and decreases in these two rate ranges. The three programmable rate controls [Lower Rate, ADL Rate (Activities of Daily Living Rate), and Upper Sensor Rate] define the rate ranges (see Figure 2-1).

- Moderate pacing rates are achieved during typical daily patient activities. These rates (in the ADL rate range) are at or near the ADL Rate.
- Exertion pacing rates are achieved during vigorous activities. These rates (in the exertion rate range) are at or near the Upper Sensor Rate

Figure 2-1 shows a graph of sensor-indicated rate as a function of increasing activity. The sensor-indicated rate curve has two slopes. The first slope, which controls how aggressively the pacing rate increases from the Lower Rate to the ADL Rate, is determined by the programmed ADL Response parameter. The second slope, which controls how aggressively the pacing rate approaches the Upper Sensor Rate, is determined by the programmed Exertion Response parameter.

When you program new values for rates or Rate Profile Optimization, immediate changes occur. The new values are predictions based on automatic diagnostic data and the selected Rate Profile Optimization settings. The pacemaker continues to adjust Rate Response over time.

Note: If the patient does not have any data in the Sensor Indicated Rate Profile diagnostic, optimization does not adjust immediately when these parameters are programmed. 24 hours of diagnostic data are required.

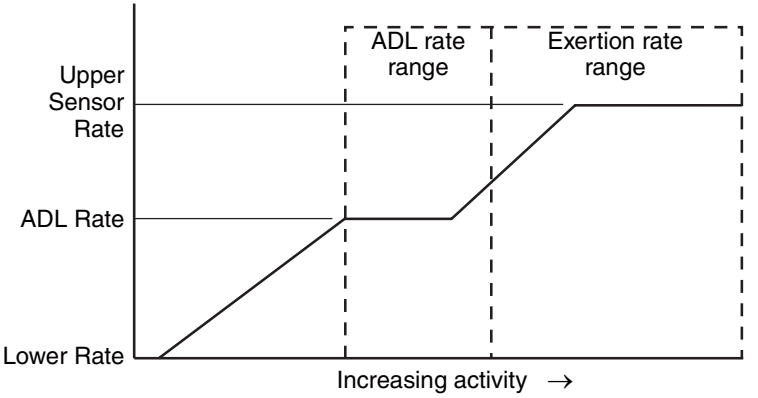


Figure 2-1. A sensor-indicated rate curve

Optimization using rate profiles

Optimization of rate response occurs independently in both the ADL rate range and the exertion rate range. The sensor-indicated rate curve is assessed daily based on the following rate profile data:

Sensor rate profile – An actual rate versus time distribution of the patient's averaged sensor-indicated rates. Once each day, the pacemaker collects a daily sensor rate profile and cumulates the data into a long-term average. Both the daily and long-term rate profiles are assessed each day to determine if adjustments to rate response are required. The long-term sensor rate profile is automatically stored in the Sensor Indicated Rate Profile diagnostic.

Target rate profile – A programmable rate versus time distribution of the patient's desired rates. The ADL Response and Exertion Response parameters define the percentage of time that the sensor-indicated rate stays in the ADL rate range and in the exertion rate range, respectively.

Figure 2-2 shows a typical rate profile (either a sensor rate profile or a target rate profile).

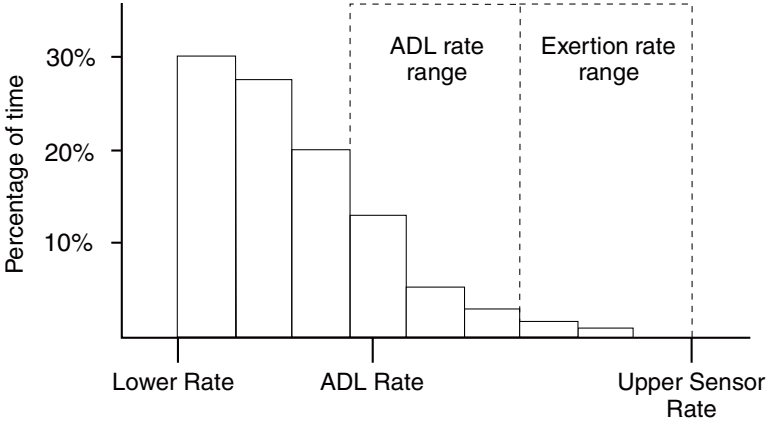


Figure 2-2. Example of a rate profile

Daily optimization of rate response

Once each day, the pacemaker evaluates the percentage of time the sensor rate is in the ADL and exertion rate ranges by comparing the daily and long-term sensor rate profiles against the target rate profile. This operation follows the sequence shown in Figure 2-3.

- The pacemaker calculates the sensor indicated rate based on the activity sensor signal.
- From the actual sensor indicated rate values, it generates a daily sensor rate profile. It also merges that data into a long-term sensor rate profile.
- It compares the target rate profile to the daily and long-term sensor rate profiles. Refer to Figure 2-4 and Figure 2-5 for details.
- If the sensor rate profiles match the target rate profile or if the daily and long-term sensor rate profiles contradict each other, no rate response adjustments occur.
- Otherwise it makes an automatic adjustment to rate response, which affects the calculation of the sensor-indicated rate in either or both of the rate ranges.
- This sequence repeats each day.

As a result of this operation, the pacemaker automatically adjusts rate response in the ADL and exertion ranges, if necessary, based on the following criteria:

- If the sensor rate profiles show a higher percentage of time spent pacing than the target rate profile, rate response for the pertinent rate range is set to be less responsive. Conversely, if a lower percentage of time spent pacing is profiled than targeted for, rate response is set to be more responsive.
- If the sensor rate profiles match the target rate profile or the daily and long-term sensor rate profiles contradict each other, no rate response adjustments occur.

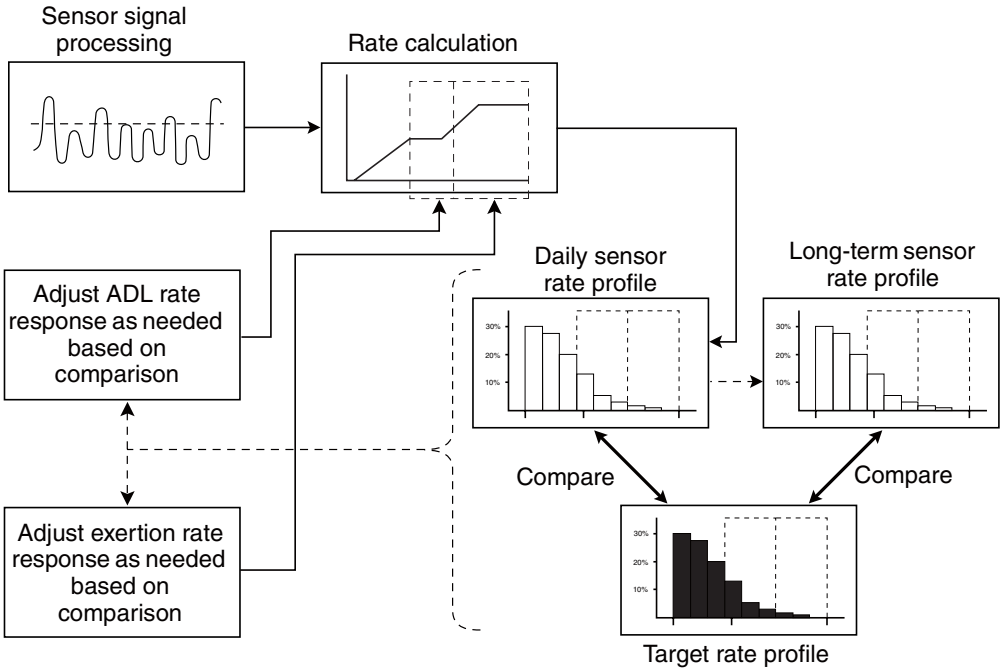


Figure 2-3. Daily operation of Rate Profile Optimization

The goal of this operation is to keep the patient's sensor rate profiles equivalent to the target rate profile. This is shown in two examples.

In Figure 2-4, a comparison of the sensor rate profile and target rate profile shows that pacing in the ADL rate range occurs for a larger percentage of time than was targeted. In the sensor rate curve, rate response is adjusted to be less aggressive in this range.

The same comparison shows that pacing in the exertion rate range occurs for a smaller percentage of time than was targeted. In the sensor rate curve, rate response is adjusted to be more aggressive in this range.

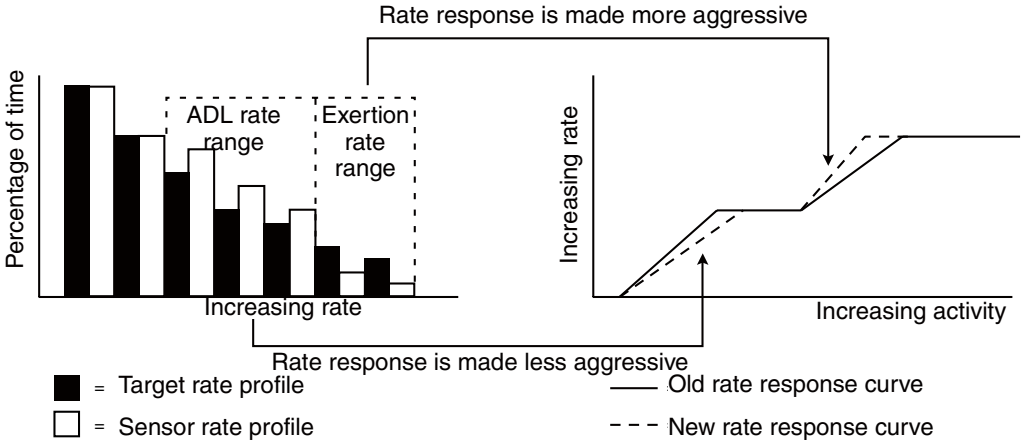


Figure 2-4. Result of comparing rate profiles: first example

The example in Figure 2-5 is the opposite of the one in Figure 2-4. Lower than targeted pacing in the ADL rate range results in a rate response adjustment to make rate response more aggressive in this range. Higher than targeted pacing in the exertion rate range results in rate response that is less aggressive in this range.

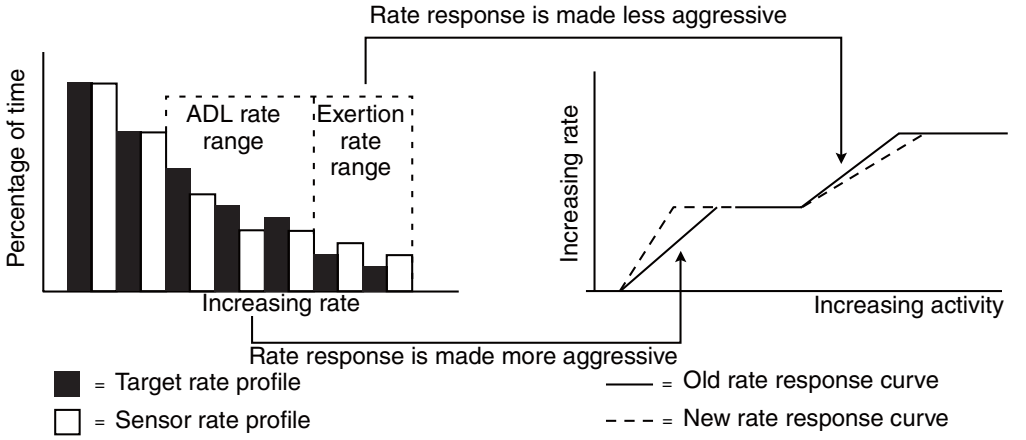


Figure 2-5. Result of comparing rate profiles: second example

Note: Two additional cases are possible:

- Lower than targeted pacing in both the ADL and exertion rate range. Rate response is adjusted to be more aggressive in both ranges.
- Higher than targeted pacing in both the ADL and exertion rate range. Rate response is adjusted to be less aggressive in both ranges.

Adaptations in Optimization operation

The pacemaker adapts rate response more rapidly for the first ten days after Optimization is first activated post-implant or after certain rate response parameters are manually reprogrammed (e.g., Lower Rate, ADL Rate, Upper Sensor Rate, ADL Response, or Exertion Response). The intent is to quickly match rate response to the target rate profile prescribed by the parameter changes.

When you program new values for rates or Rate Profile Optimization, immediate changes occur. The new values are predictions based on automatic diagnostic data and the selected Rate Profile Optimization settings. The pacemaker continues to adjust Rate Response over time.

Note: If the patient does not have any data in the Sensor Indicated Rate Profile diagnostic, optimization does not adjust immediately when these parameters are programmed.

Optimization is skipped on any day that a device interrogation or parameter programming occurs.

Individualizing Rate Profile Optimization

Overview

The clinician can prescribe a target rate profile using the ADL Response and Exertion Response parameters to match the patient's life-style or activity levels. The programmable ADL Response parameter alters the targeted rate distribution in the ADL rate range, while the Exertion Response parameter alters the rate distribution in the exertion rate range.

ADL rate profiles

The nominal setting for the ADL Response parameter is "3." Programming a higher number redefines the target rate profile to spend more time pacing at or above the ADL Rate, thereby increasing rate responsiveness in the ADL rate range. Programming a lower number redefines the rate profile to spend less time pacing at or above the ADL Rate, thereby decreasing rate responsiveness.

Exertion rate profiles

The nominal setting for the Exertion Response parameter is “3.” Programming a higher number redefines the target rate profile to spend more time pacing near the Upper Sensor Rate, thereby increasing rate responsiveness in the exertion rate range. Programming a lower number redefines the rate profile to spend less time pacing near the Upper Sensor Rate, thereby decreasing rate responsiveness.

Programming guidelines

If it is necessary to adjust rate response from the nominal setting, first verify that the three rate controls are appropriate for the patient. Refer to “Three pacing rate controls” on page 37.

If these rate control settings are appropriate, the ADL Response and/or Exertion Response settings can then be adjusted based on the guidelines in Table 2-1.

Table 2-1. ADL Response and Exertion Response guidelines

Rate region	Patient	Select these settings
		ADL Response
Lower Rate to ADL Rate	Reached ADL Rate too quickly	Lower number (less rate response)
	Reached ADL Rate too slowly	Higher number (more rate response)
		Exertion Response
ADL Rate to Upper Sensor Rate	Reached Upper Sensor Rate too quickly	Lower number (less rate response)
	Reached Upper Sensor Rate too slowly	Higher number (more rate response)[a]

[a] If a higher Exertion Response setting has not produced the desired rate response, increase the ADL Response setting.

For more detailed programming guidelines, refer to Table E-14 and Table E-15, which list the targeted time spent pacing for the five ADL Response and Exertion Response settings.

Activity sensor operation

Overview

Activity sensor based pacing is controlled by the following programmable parameters:

- Activity Threshold determines the minimum intensity of detected physical activity to which the pacemaker responds.
- Activity Acceleration and Activity Deceleration times control how rapidly the pacing rate changes in response to increased or decreased activity. One programmable Activity Deceleration setting, “Exercise,” provides an extended deceleration period following prolonged exercise.

Note that Activity Threshold, Activity Acceleration, and Activity Deceleration are automatically set to shipping settings 30 minutes after implant or can be manually programmed.

How Activity Threshold influences rate

A transducer, bonded to the pacemaker circuitry, is deflected by physical motion. The activity sensor converts detected motion into electrical signals. The programmed Activity Threshold screens out activity signals below the selected setting. Detected sensor signals vary from patient to patient. Only sensor signals whose amplitude exceeds the programmed Activity Threshold (as shown in Figure 2-6) are used in computing the sensor-indicated rate. The lower the Activity Threshold, the smaller the signal required to influence the sensor-indicated rate.

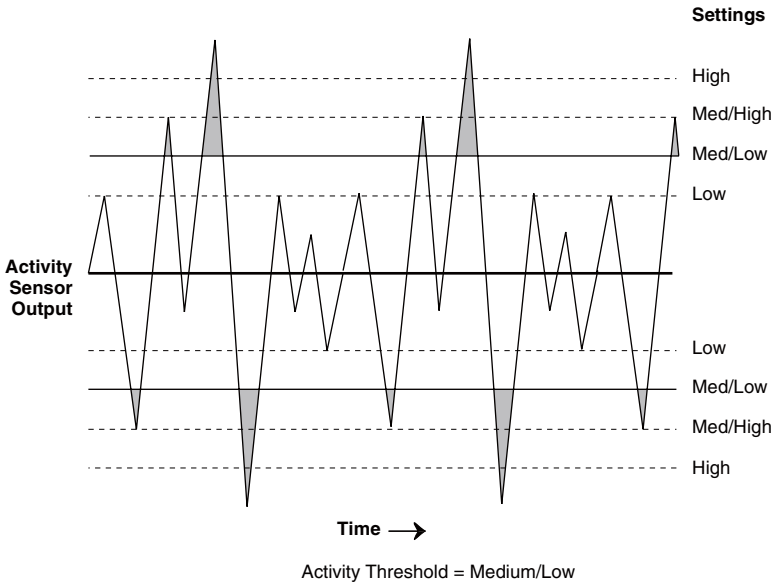


Figure 2-6. Activity sensor signal (threshold set to medium/low)

Evaluating the Activity Threshold setting

Activities such as walking increase the pacing rate; sitting results in pacing at or near the programmed Lower Rate. Use Table 2-2 as a guide for selecting an appropriate setting.

Table 2-2. Activity Threshold guidelines

Programmable settings	Typical rate performance
Low	Responds to most body activity, including minimal exertion.
Medium/Low	Limited response to minimal exertion; responds to moderate or greater exertion.
Medium/High	Limited response to moderate body movements and exertion.
High	Responds to only vigorous body movements and exertion.

How Activity Acceleration and Deceleration influence rate

Activity Acceleration and Activity Deceleration times control how rapidly the pacing rate changes in response to increased or decreased physical activity. One programmable Activity Deceleration setting, “Exercise,” provides an extended deceleration period following prolonged exercise.

- Activity Acceleration time is the time required to achieve approximately 90% of the difference between the current rate and a higher steady-state rate consistent with the current level of activity. Figure 2-7 shows a graphic representation of the acceleration curves at the onset of strenuous exercise.
- Activity Deceleration time is the time required to achieve approximately 90% of the difference between the current rate and a lower steady-state rate consistent with the current level of activity. Figure 2-8 shows a graphic representation of the deceleration curves at an abrupt cessation of strenuous exercise.

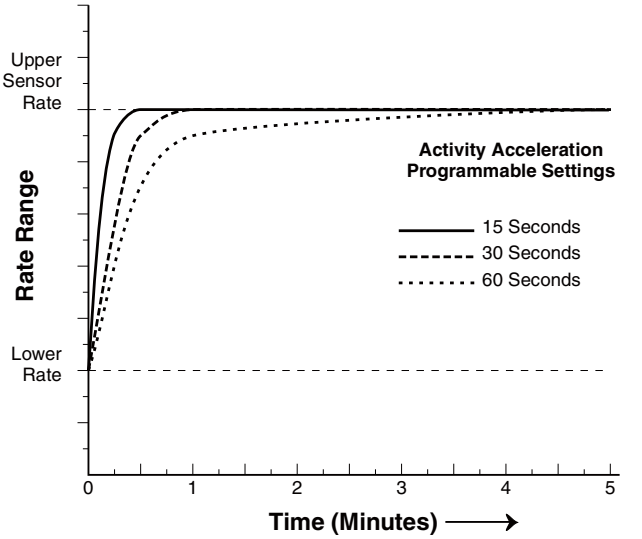


Figure 2-7. Activity Acceleration curves

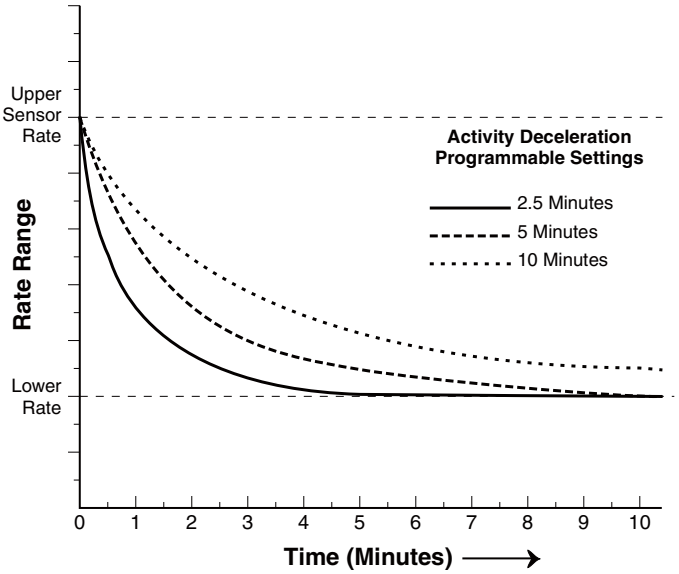


Figure 2-8. Activity Deceleration curves

Exercise Deceleration operation

Activity Deceleration programmed to “Exercise” extends the rate slowing period following an exercise episode, providing up to 20 minutes of rate deceleration. When it is programmed on, the pacemaker uses activity sensor data to detect periods of vigorous, prolonged exercise. At the end of such an exercise period, the pacemaker uses a longer deceleration curve for the central portion of the programmed rate range. The actual deceleration rate is determined dynamically based on the intensity and duration of exercise and the new level of activity. Figure 2-9 shows the composite deceleration curve that applies after the abrupt cessation of sustained exercise.

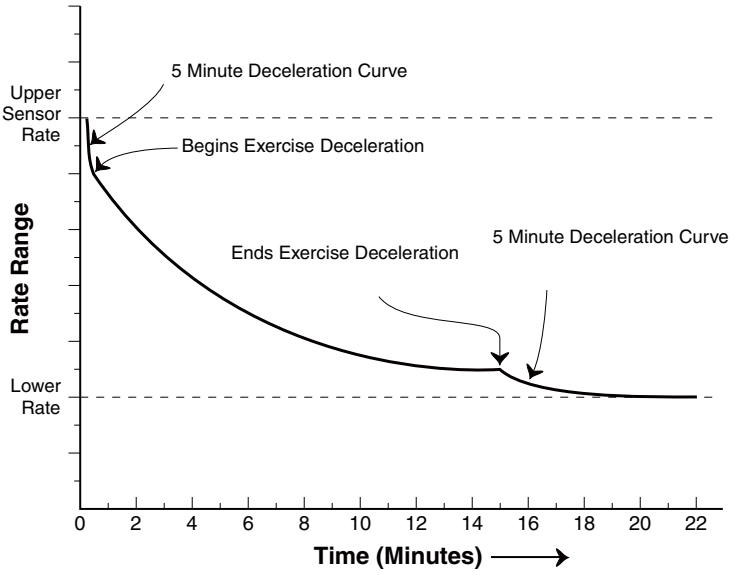


Figure 2-9. Exercise Deceleration

Manual control of Rate Profile Optimization

Overview

As an alternative to automatic Rate Profile Optimization, a programmer assisted Exercise test can be used to manually set rate response for the ADL and exertion rate ranges. The Exercise test is used to immediately set rate response to certain levels. Rate response parameters remain set to their programmed values if Optimization is Off. When Optimization is On, it can adjust these parameters once each day.

Evaluate and program rate response

The Exercise test is used to evaluate the patient's rate response and allow the programmer to customize two rate response control parameters:

- ADL Setpoint (Activities of Daily Living Setpoint) determines the minimum sensor response to pace at the ADL Rate, which falls within the ADL rate range.
- UR Setpoint (Upper Rate Setpoint) determines the minimum sensor response to pace at the Upper Sensor Rate, which is at the upper limit of the exertion rate range.

Note: The programmed ADL Setpoint setting must be less than the UR Setpoint setting.

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for programming instructions.

Pacemaker timing 3

Rates

Overview

The following programmable rates control timing in the pacemaker:

- Normal operating rates:
  - Lower Rate
  - ADL Rate
  - Upper Tracking Rate
  - Upper Sensor Rate
- Other operating rates:
  - Sleep Rate (for Sleep function)
  - Hysteresis Rate (for single chamber demand and triggered modes)
  - Sinus Preference Zone (for Sinus Preference)
  - Intervention Rate (for Rate Drop Response)
  - Overdrive Rate (for Post Mode Switch Overdrive Pacing)
  - Maximum Rate (for Conducted AF Response)
  - Maximum Rate (for Atrial Preference Pacing)

Additionally, rates calculated by the pacemaker are used for some operations. These are:

- Sensor-indicated rate
- Mean atrial rate

The other operating rates are described in “Special therapy options” on page 133 along with the functions that use them. The normal rates are described in this chapter.

A-A and V-V timing

A-A timing – In all modes that pace the atrium, the pacemaker times from atrial event to atrial event (A-A timing). This timing method mimics a natural sinus rhythm, producing A-A intervals that are nearly equal, except when timing is interrupted by one of the following:

- PACs in DDIR and DDI modes
- PVCs in DDDR, DDD, DDIR, DDI modes (PVC Response operation)
- A ventricular sensed event during the VA interval in the DVIR and DVI modes
- An atrial refractory sensed event that triggers an NCAP extension

VA intervals vary due to adjustments by A-A timing operations in order to achieve sensor-indicated or lower rate operation in the presence of varying AV conduction.

V-V timing – In modes that do not pace the atrium (e.g., VDD or VDIR) or single chamber ventricular modes, the pacemaker times from ventricular event to ventricular event (V-V timing).

Lower Rate

The programmed Lower Rate defines the slowest rate at which pacing occurs during a mode's basic operation. In rate responsive modes, in the absence of sensor-detected activity, the sensor-indicated rate is equal to the programmed Lower Rate.

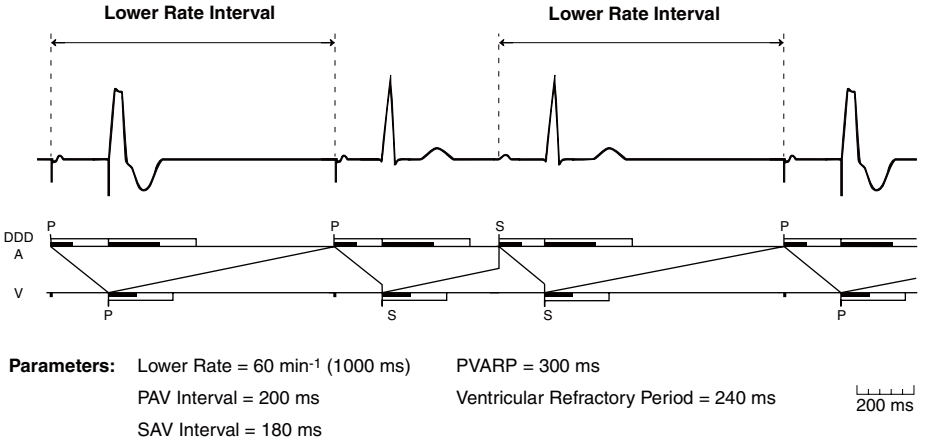


Figure 3-1. Example of Lower Rate operation

Operating lower rate

Under certain circumstances, the programmed Lower Rate may be overridden by an operating lower rate that is higher or lower than the programmed value. The following rates may become the operating lower rate:

- Switching from and back to atrial tracking mode (for Mode Switch)
- Conducted AF Response determined rate
- Sinus Preference Zone (for Sinus Preference)
- Sleep Rate (for Sleep function)
- Intervention Rate (for Rate Drop Response)
- Hysteresis Rate (for single chamber modes)
- Threshold Margin Test rate of 100 min^{-1}
- Magnet Mode rate of 85 min^{-1}
- Recommended Replacement Time (RRT/ERI) rate of 65 min^{-1}
- Overdrive Rate (for Post Mode Switch Overdrive Pacing function)
- Rate determined by Atrial Preference Pacing
- Rate determined by Capture Management (ACM and VCM)
- Sensor indicated rate

Selecting a Lower Rate

Program the Lower Rate to maintain adequate heart rates during periods of inactivity or during pauses in atrial rhythms when the pacemaker is operating in the DDDR, DDD, VDD, AAIR, ADIR, AAI, and ADI modes.

Note: In the VDD mode, atrial tracking near the Lower Rate may result in V-V intervals that exceed the Lower Rate interval. This is normal operation.

Lower Rates from 120 to 130 min^{-1} are intended for pediatric patients. Lower Rates below 50 min^{-1} and above 100 min^{-1} are primarily intended for diagnostic purposes.

Sensor-indicated rate

The sensor-indicated rate is the basic pacing rate when the pacemaker is operating in a rate responsive mode (DDDR, DDIR, DVIR, DOOR, VVIR, VDIR, VOOR, AAIR, ADIR, or AOOR). It is determined by the pacemaker based on the sensor-detected level of patient activity and the programmed rate response parameters. The sensor-indicated rate will never be greater than the Upper Sensor Rate or less than the Lower Rate.

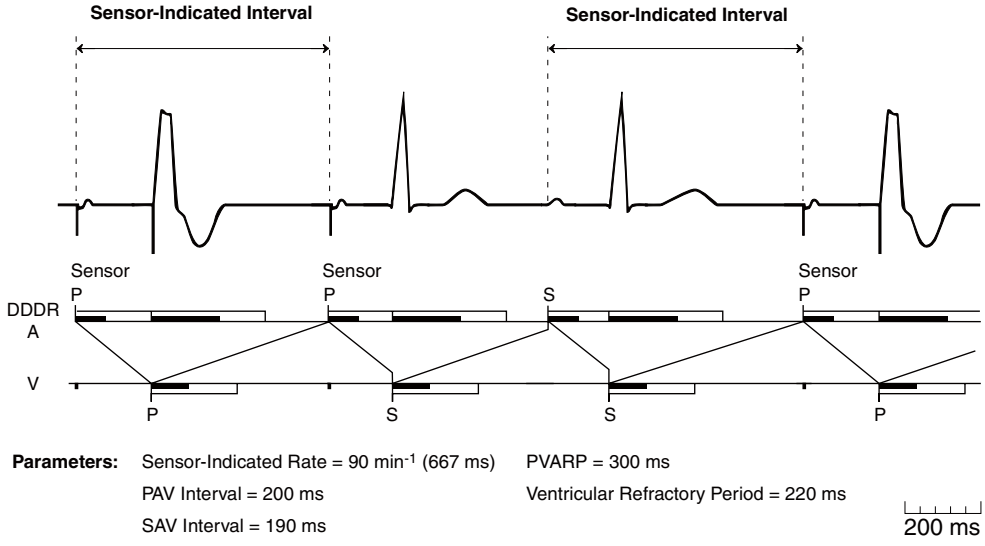


Figure 3-2. Example of sensor-indicated rate operation

In rate responsive modes, the sensor-indicated rate tracks the activity sensor, which is detected by the transducer sensor's frequency and amplitude.

- In dual chamber rate responsive modes, the sensor-indicated interval is the AS-AP or AP-AP interval.
- In single chamber rate responsive modes, the sensor-indicated interval is the A-A or V-V interval. In these modes, sensor-indicated rate intervals start with a sensed or paced event in the chamber being paced.

Sensor indicated rate effect on other intervals

The sensor-indicated rate is used to determine the values of certain other timing intervals. These intervals are:

- Rate adaptive paced AV (PAV) interval
- Sensor-varied PVARP (even in non-rate responsive DDD and VDD modes)
- PVARP extension (sensor-corroboration before PMT intervention)

ADL Rate

The ADL Rate (Activities of Daily Living Rate) is the target rate which the patient's heart rate is expected to reach during moderate exercise.

Upper Tracking Rate

The programmable Upper Tracking Rate is the maximum rate at which the ventricle may be paced in response to sensed atrial events when the pacemaker is operating in the DDDR, DDD, and VDD modes. Sensed atrial events below the Upper Tracking Rate will be tracked at a 1:1 ratio, but sensed events above the Upper Tracking Rate will result in pacemaker Wenckebach (for example, 6:5, 4:3, 3:2, or 2:1 block). The Upper Tracking Rate usually should be programmed to a value less than the 2:1 block rate. Refer to "High rate atrial tracking" on page 84 for details.

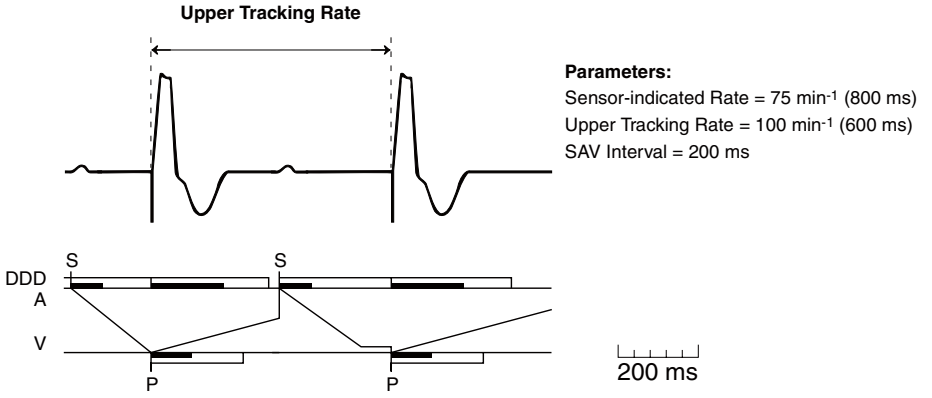


Figure 3-3. Example of Upper Tracking Rate (Wenckebach) operation

Upper Sensor Rate

In rate responsive modes, the programmable Upper Sensor Rate provides the upper limit for the sensor-indicated rate during physical activity, particularly during vigorous exercise. In the DDDR mode, the Upper Sensor Rate may be higher than, lower than, or the same as the Upper Tracking Rate.

Programming considerations and restrictions

ADL Rate – It is recommended that the ADL Rate be at least 10 min^{-1} less than the Upper Sensor Rate or 20 min^{-1} greater than the Lower Rate. However, programming the ADL Rate above or below these limits is permitted.

Upper rates – Programming a combination of high Upper Sensor Rate and Upper Tracking Rate and a long refractory period may result in a shorter “sensing window.” Loss of sensing in such cases could result in competitive pacing (unless Non-Competitive Atrial Pacing is programmed On). See “Non-competitive atrial pacing” on page 148 for more information.

- Programming the Upper Tracking Rate to a value greater than the Upper Sensor Rate permits the atrial rhythm to be tracked to a rate higher than the sensor-driven rate.
- The Upper Sensor Rate and/or Upper Tracking Rate must be greater than the Lower Rate. The Upper Sensor Rate must be greater than the ADL Rate.

Rate limit

An internal circuit, independent of the pacing timers, limits single chamber atrial or ventricular pacing rates to 200 min^{-1} ($\pm$ 20 min^{-1}) for most single component failures. For dual chamber modes, atrial and ventricular rates are limited independently to 200 min^{-1} ($\pm$ 20 min^{-1}). The rate limit is automatically disabled during temporary pacing in the AAI, ADI, AAT, AOO, VVI, VDI, VVT, and VOO modes to allow high rate pacing for diagnostic or therapeutic purposes.

Note: When the Upper Tracking Rate is programmed to 190, 200, or 210, the circuit limit is 227 min^{-1} ($\pm$ 17 min^{-1}).

Possible atrial competition at high rates

At high sensor-driven rates when the pacemaker is operating in the DDDR and DDIR modes, sensor-driven pacing may approximate the intrinsic atrial rate, with some intrinsic atrial events falling into the PVARP. This could result in asynchronous pacing with the potential for competitive atrial pacing. Consider the potential for asynchronous pacing at high rates before selecting an Upper Sensor Rate, especially for patients known to be susceptible to induction of atrial tachyarrhythmias. Weigh the benefits of high rate sensor-driven pacing against the potential for competitive pacing.

Note: Use of the Rate Adaptive AV feature and sensor-varied or automatic PVARP can reduce the likelihood of the type of asynchronous pacing described above. When the pacemaker is operating in the DDDR mode, Sinus Preference and NCAP can also be considered.

Mean atrial rate

The mean atrial rate (MAR) is a running average of the atrial rate for use by the Rate Adaptive AV and automatic PVARP features. The average uses all A-A intervals (except AS-AP or AR-AP intervals). In order to respond quickly to rapidly increasing atrial rates, the average gives preference to shorter A-A intervals over longer intervals when calculating the MAR. Figure 3-4 shows how the MAR tracks an increasing intrinsic atrial rate.

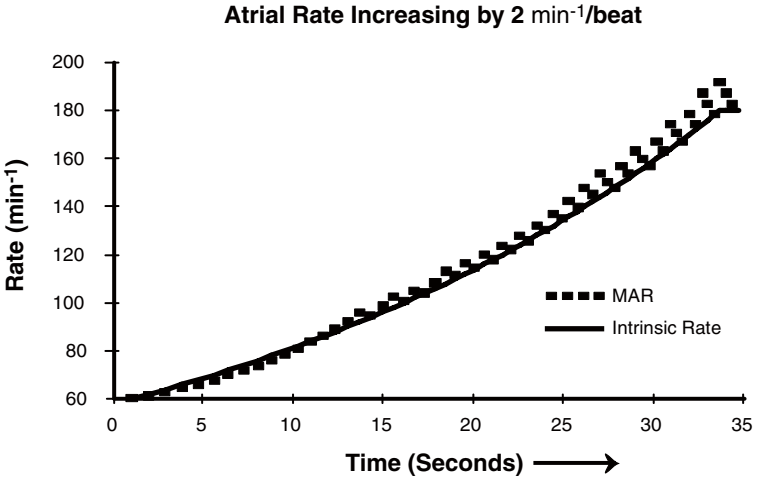


Figure 3-4. Increasing mean atrial rate

AV intervals

Overview

In dual chamber modes, the AV intervals determine the time between the occurrence of an atrial event and the scheduled delivery of a ventricular stimulus. Separate AV intervals for paced and sensed atrial events are available. The lengths of these intervals may be programmed to fixed values or (optionally) rate adaptive or therapeutically determined.

Paced AV Interval (PAV) – PAV follows an atrial pace when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, DVIR, DVI, DOOR, and DOO modes. The PAV interval duration may differ from the programmed value due to one of the following operations:

- Rate Adaptive AV
- Search AV+
- Ventricular Safety Pacing
- Non-Competitive Atrial Pacing

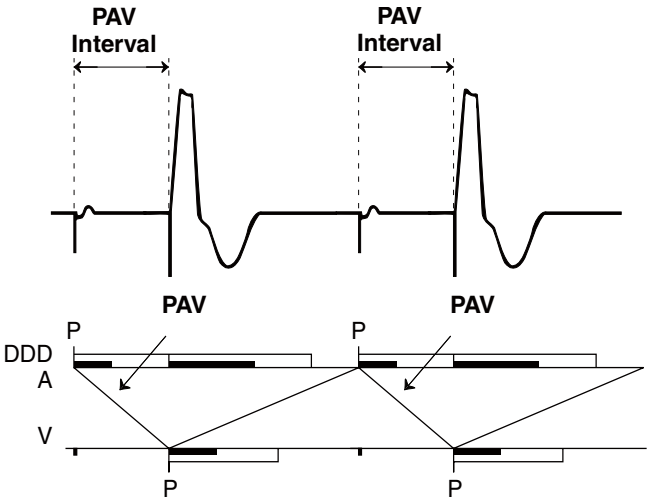


Figure 3-5. Example of PAV interval operation

Sensed AV Interval (SAV) – SAV follows an atrial sensed event when the pacemaker is operating in an atrial synchronous pacing mode (DDDR, DDD, and VDD). The SAV interval duration may differ from the programmed value due to one of the following operations:

- Rate Adaptive AV
- Automatic PVARP
- Search AV+
- Wenckebach

For Wenckebach operation, the SAV is extended to avoid violation of the Upper Tracking Rate or the total atrial refractory period while tracking a fast intrinsic atrial rate.

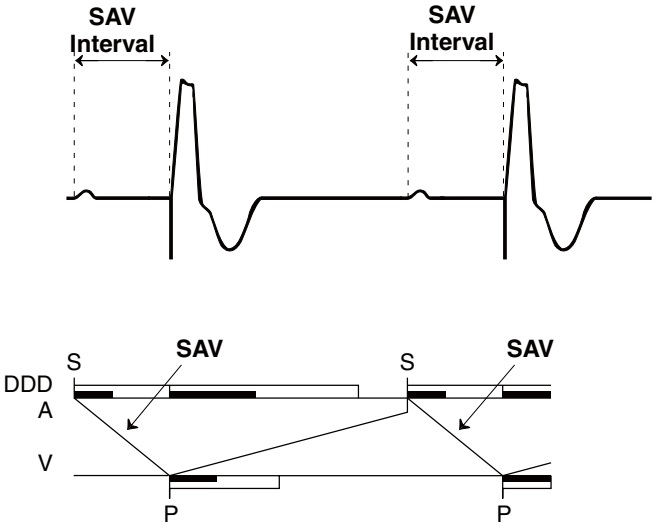


Figure 3-6. Example of SAV Interval operation

Selecting PAV and SAV

Using MVP or Search AV+ should eliminate the need to manually adjust the AV intervals for most patients. It is recommended that MVP or Search AV+ be used to reduce pacing in the right ventricle.

However, when programming AV intervals in patients with third degree block, the general hemodynamic goal is to assure that, to the extent possible, left-atrial systole is completed before left-ventricular systole begins. To achieve this, the AV interval durations may be adjusted independently of each other.

- To accommodate the difference in interatrial conduction times, the SAV usually should be programmed to a shorter duration than the PAV, typically 30 to 50 ms shorter. If an SAV greater than the PAV is selected, the programmer notes that this is not usual, but the selected values may be programmed if clinically warranted.
- When the SAV is longer than the PAV, a V pace following an atrial sense will always occur after the full SAV, even when the sensor-indicated rate or Lower Rate interval expires first.
- In certain patients, short AV intervals may be used as a prophylaxis for AV nodal or accessory pathway reentrant tachycardias in dual chamber modes.

- Long PAV intervals (greater than or equal to 250 ms) should be used with caution. If intrinsic ventricular events occur and are not sensed, a long PAV may result in pacing into the ventricle's relative refractory period, including the T wave, or loss of AV synchrony, which may precipitate retrograde activation of the atria with corresponding hemodynamic consequences and symptoms. Long PAV intervals may also result from some Search AV+ settings (see "Search AV+ and diagnostic" on page 69 and "Ventricular blanking" on page 74.

Rate Adaptive AV

Overview

In the normal heart, AV conduction times tend to shorten as the heart rate increases and to lengthen as the heart rate decreases. The Rate Adaptive AV (RAAV) feature, available when the pacemaker is operating in the DDDR, DDD, DDIR, DVIR, DOOR, and VDD modes, mimics this physiologic response. When RAAV is programmed On, the pacemaker shortens AV intervals for atrial rates within a programmed rate range. This feature provides increased opportunity for atrial sensing, as follows:

- Shortened SAV intervals increase the tracking range at fast atrial rates by shortening the total atrial refractory period (TARP) and increasing the 2:1 block rate. Refer to "Total Atrial Refractory Period (TARP)" on page 79 and "High rate atrial tracking" on page 84 for more information.
- Shortened PAV intervals lengthen the atrial sensing window of the VA interval at higher sensor-driven rates.

Note: RAAV will not shorten PAV intervals to less than 30 ms or shorten SAV intervals to less than 10 ms.

Programming for Rate Adaptive AV

For RAAV operation, the SAV and PAV are programmed (as applicable) to the values desired for low rates. Three additional programmable parameters control how AV intervals are adjusted at higher rates:

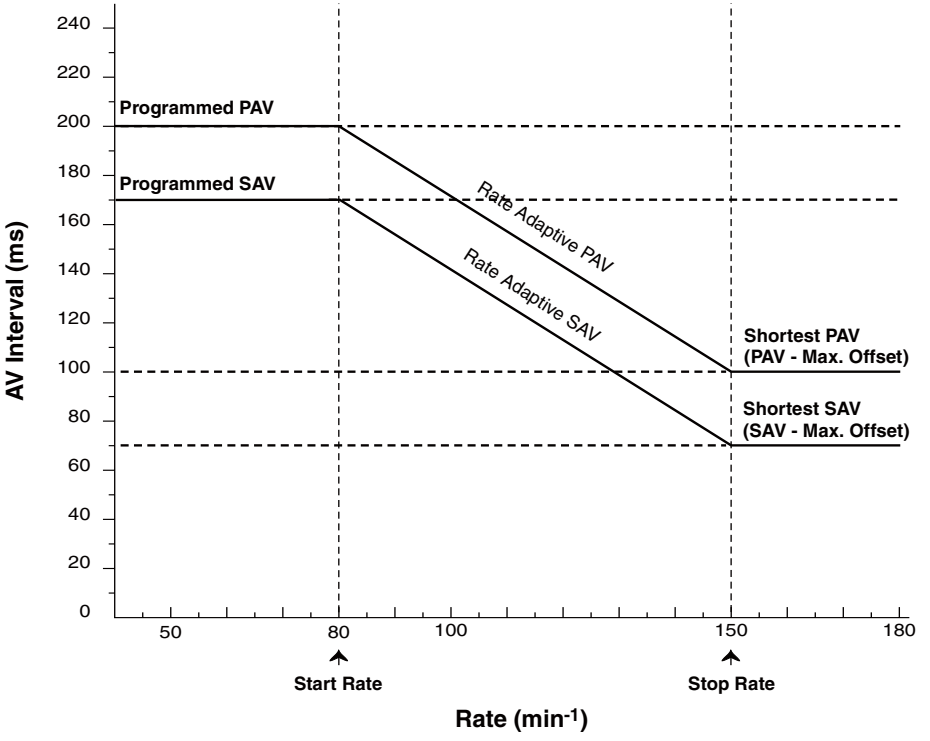
Start Rate – RAAV operation of shortening SAV and PAV intervals begins at this rate.

Stop Rate – The shortest SAV and PAV occur at this rate and at all higher rates, up to the upper rate limits.

Maximum Offset – The maximum amount of time (in ms) by which the SAV and PAV intervals can be shortened.

The PAV minus the Maximum Offset gives the shortest PAV interval at the Stop Rate (e.g., 200 ms - 100 ms = 100 ms). Subtracting the Maximum Offset from the SAV gives the shortest SAV interval (e.g., 170 ms - 100 ms = 70 ms).

Figure 3-7 shows how the SAV and PAV intervals are linearly shortened as the rate increases from below the Start Rate to above the Stop Rate.



Parameters: Programmed SAV = 170 ms Start Rate = 80 min^{-1} Maximum Offset = –30 ms
Programmed PAV = 200 ms Stop Rate = 150 min^{-1}

Figure 3-7. Rate Adaptive AV operation (DDDR Mode)

RAAV operations

Shortening of the AV interval(s) occurs when the appropriate rate exceeds the programmed Start Rate, as follows:

SAV – The mean atrial rate determines SAV adjustments. Because of how the mean atrial rate is calculated:

- SAV adjustments will lag during rapid increases or decreases in intrinsic atrial rates.
- The SAV is not adjusted for isolated events (PACs).
- AS-AP or AR-AP intervals may affect the SAV value since these intervals are not used in the mean atrial rate calculation.

PAV – The sensor-indicated rate determines PAV adjustments.

The approximate difference between programmed SAV and PAV is maintained as the SAV and PAV intervals are adjusted.

Programming considerations and restrictions

Search AV+ – RAAV can be enabled while Search AV+ is enabled. Search AV+ will operate using the AV intervals determined by the RAAV rather than the programmed AV intervals.

RAAV and sick sinus syndrome

If RAAV is activated for a sick sinus syndrome patient who has AV conduction, consider the following:

- The rate at which AV conduction is lost should not be too low (i.e., below 90 min^{-1}).
- Review of the AV Conduction Histogram diagnostic data may aid in appropriate programming of Start Rate and Stop Rate to maintain AV conduction as long as possible.

Search AV+ and diagnostic

Overview

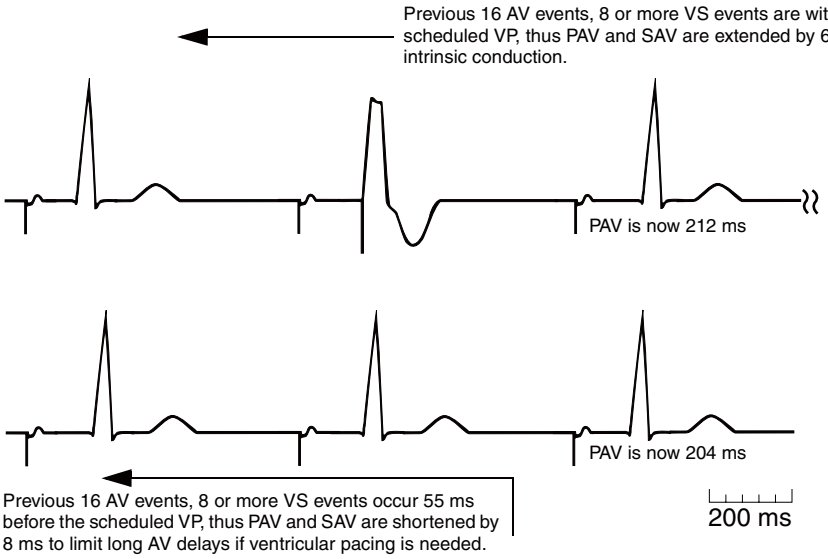
The Search AV+ feature is intended to promote intrinsic ventricular activation in patients with intact or intermittent AV conduction and prevent inappropriate therapy in patients without conduction. Search AV+ is available when the pacemaker is programmed to the DDDR, DDD, DDIR, DDI, DVIR, DVI, or VDD mode. The pacemaker searches for the patient's intrinsic AV conduction time and adjusts the SAV and PAV intervals either longer or shorter to promote intrinsic activation of the ventricles. When Rate Adaptive AV is active, the pacemaker also adjusts the SAV and PAV intervals relative to the rate adaptive values. If the pacemaker does not observe intrinsic ventricular activation during its periodic searches over the course of a week, it turns off the Search AV+ feature.

Programming to Search AV+

Programming Search AV+ to "On" requires setting the Max Increase to AV parameter. This parameter defines the maximum amount of time (in ms) by which the operating SAV and PAV intervals can be lengthened to allow ventricular sensing to occur. The operating SAV and PAV intervals will adapt to the observed conduction time, but will not exceed the Max Increase to AV parameter.

Search AV+ operation

The pacemaker attempts to keep intrinsic conducted events in an "AV delay window" that precedes scheduled paced events. The AV delay window is set to promote intrinsic conduction to the ventricles, but end early enough to avoid fusion or pseudo-fusion beats if pacing is necessary (see Figure 3-8).



Parameters:	DDDR	SAV = 120 ms
	Lower Rate = 60 min^{-1}	PAV = 150 ms
	Sensor-Indicated Rate = 90 min^{-1}	Max. Increase to AV= 170 ms

Figure 3-8. Search AV+ operation

To determine when intrinsic conducted events occur, the pacemaker assesses the 16 most recent AV conduction sequences that start with a nonrefractory atrial sense (when the pacemaker is operating in the DDDR, DDD, and VDD modes) or an atrial pace (when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, DVIR, and DVI modes) and end with a ventricular pace or a nonrefractory ventricular sense.

Search criteria of AV conduction times – The measured AV conduction times are classified as on time, too short or too long.

- Too long means 8 or more of the last 16 ventricular sensed events occurred within 15 ms of the scheduled ventricular pace, or 8 or more of the last 16 ventricular events were paced events.
- Too short means 8 or more of the last 16 ventricular sensed events occurred more than 55 ms before the scheduled ventricular pace.

Adjustment of SAV and PAV intervals – If AV conduction times are classified as too long, the pacemaker lengthens the operating SAV and PAV intervals by 62 ms for the next 16 pacing cycles to promote intrinsic conduction. The maximum that the SAV and PAV can be lengthened is limited by the Search AV+ Maximum Increase to AV parameter.

If the previous 16 AV intervals are classified as too short, the pacemaker shortens the operating SAV and PAV intervals by 8 ms for the next 16 pacing cycles. The maximum that SAV and PAV can be shortened is limited by the programmed SAV and PAV values or the RAAV Maximum Offset parameter, if RAAV is On.

Suspension of Search AV+ operation

Search AV+ promotes conduction in patients with intrinsic conduction and prevents inappropriate therapy for patients without intrinsic conduction. If AV conduction is not found, Search AV+ suspends operation for progressively longer periods: 15 minutes, 30 minutes, 1, 2, 4, 8, and 16 hours. If AV conduction is not found following 10 consecutive 16-hour suspensions (approximate duration, 1 week), the device automatically turns Search AV+ to Off.

Programming considerations and restrictions

Both Automatic PVARP and Rate Adaptive AV can shorten the AV intervals at higher rates and potentially lead to ventricular pacing.

Automatic PVARP – When automatic PVARP is active and Search AV+ is set to On, the pacemaker will ignore conduction times that are the result of automatic PVARP shortening of the SAV interval.

Rate Adaptive AV – RAAV can be enabled while Search AV+ is enabled. Search AV+ will operate using the RAAV-determined AV intervals rather than the programmed AV intervals.

MVP modes – Search AV+ is not pertinent and cannot be enabled if the pacemaker is programmed to an MVP mode (AAIR<=>DDDR or AAI<=>DDD).

Recording AV interval adaptations

AV interval diagnostics record data about AV operations for the Search AV+ feature.

Automatic Search AV+ Histogram

Programming Search AV+ parameters automatically initiates recording of data by the Search AV+ Histogram diagnostic. This histogram shows the percentage of A-VS, VS from Search, and A-VP intervals versus rate. A histogram can be displayed or printed from the Data icon.

Clearing AV interval data

AV interval data is normally cleared by the pacemaker one hour after a programming session.

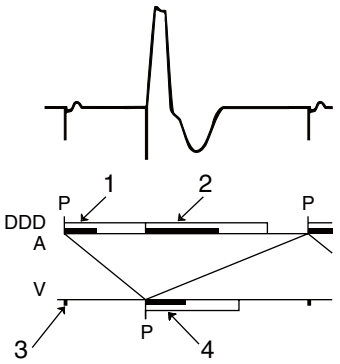
However, you can select the option to clear data immediately. Be sure to save the session data or print the episode report before ending the patient session.

Search AV+ and compromised ventricular function

Consider turning Search AV+ off if intrinsic ventricular activation is not desired.

Blanking periods

Blanking periods disable sensing for a programmable or nonprogrammable interval. Signals that are blanked may originate in either chamber or from outside sources such as noise from muscle movement.



Note: Black bars indicate blanking periods.

1 Nonprogrammable Atrial Blanking
2 Programmable Post-Ventricular Atrial Blanking
3 Programmable Ventricular Blanking
4 Nonprogrammable Ventricular Blanking

Figure 3-9. Example of dual chamber blanking operation

Nonprogrammable blanking periods

Immediately following a sensed or paced event in either chamber, sensing for that chamber is blanked for a nonprogrammable period that may typically vary from 50 to 100 ms. The actual duration of the blanking period is determined dynamically by the pacemaker, based on the strength and duration of the signal. Dynamic blanking prevents sensing the same signal twice, while minimizing total blanking time.

Post-Ventricular Atrial Blanking

The programmable Post-Ventricular Atrial Blanking (PVAB) period, used when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, VDD, VDIR, and VDI modes, prevents sensing of ventricular paced events or far-field R waves on the atrial lead. Any ventricular event (paced or sensed) starts the PVAB, which is also the first portion of the Post-Ventricular Atrial Refractory period (PVARP). The PVAB is limited to values equal to or less than the programmed PVARP, except in VDIR and VDI modes where PVARP does not apply.

Note: PVAB is programmed to a value less than or equal to PVARP.

Ventricular blanking

The programmable Ventricular Blanking period, which follows an atrial pacing stimulus when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, DVIR, and DVI modes, prevents ventricular inhibition or ventricular safety pacing due to sensing of the atrial stimulus on the ventricular lead (crosstalk). The Ventricular Blanking period also applies to the ADIR and ADI modes to prevent sensing of the atrial stimulation.

- Long blanking periods (36 ms or greater) increase the possibility of unsensed ventricular events.
- Long blanking periods used in conjunction with long PAV intervals (250 ms or greater) may result in pacing into the T wave when intrinsic ventricular events are blanked and not sensed. PAV values (200 ms or less) should reduce the possibility of T wave pacing.
- Long PAV intervals may also result from some Search AV+ operation (See “Search AV+ and diagnostic” on page 69). To minimize the possibility of undersensing intrinsic events, Search AV+ reduces ventricular blanking to 20 ms unless Ventricular Safety Pacing is observed.

Single chamber atrial blanking

The programmable single chamber atrial blanking period, used when the pacemaker is operating in the AAIR, ADIR, AAI, ADI, and AAT mode, prevents sensing of far-field R waves. It is started by a paced, sensed, or refractory sensed atrial event.

Note: Atrial Blanking must be programmed at least 50 ms less than the Atrial Refractory Period.

Refractory periods

Overview

A refractory period is an interval during which an intrinsic event sensed on a particular lead channel cannot start certain timing intervals. Each refractory period begins with a blanking period, during which no sensing occurs. During the unblanked portion of a refractory period, sensing occurs, but sensed events may not directly affect timing operations. Refractory periods are intended to prevent certain timing intervals from being started by inappropriate signals such as retrograde P waves, far-field R waves, or electrical noise.

Though they may not start timing intervals, refractory sensed events are monitored by the pacemaker, and they affect the operation of PVC Response, Mode Switch, Rate Adaptive AV operation, automatic PVARP, Non-Competitive Atrial Pacing, and other features for which the periodicity or number of sensed events are pertinent. Refractory sensed events are included on Marker Channel recordings.

Post-Ventricular Atrial Refractory Period

The Post-Ventricular Atrial Refractory Period (PVARP) follows a paced, sensed, or refractory sensed ventricular event when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, and VDD modes. It is intended primarily to prevent the sensing of retrograde P waves that might promote Pacemaker-Mediated Tachycardias (PMTs) in atrial tracking modes. When the pacemaker is operating in the DDIR and DDI modes, PVARP prevents atrial inhibition from retrograde P waves.

The first portion of the PVARP is the programmable Post-Ventricular Atrial Blanking period (PVAB). During the remainder of the PVARP, intrinsic atrial events may be sensed as refractory sensed events (AR) and identified on Marker Channel recordings, but they do not affect stimulus timing.

- When the pacemaker is operating in the DDDR, DDD, and VDD modes, an SAV is not started.
- When the pacemaker is operating in the DDDR, DDD, DDIR, and DDI modes, the scheduled atrial pace is not inhibited.

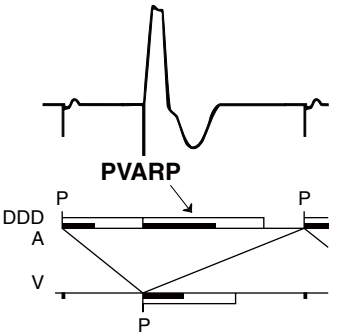


Figure 3-10. Example of PVARP operation

The duration of the PVARP may be selected as follows:

- The PVARP should be programmed to a value greater than the patient's ventriculoatrial (VA) retrograde time when retrograde conduction is present.
- Excessively long PVARPs may induce 2:1 block at high intrinsic rates when the pacemaker is operating in an atrial tracking mode (DDDR, DDD, or VDD).
- To reduce the 2:1 block point, PVARP can be set to vary based on the sensor-indicated rate (sensor-varied PVARP) or the mean atrial rate (automatic PVARP).

Sensor-varied PVARP

When sensor-varied PVARP is programmed, the pacemaker determines a value for the PVARP based on the sensor-indicated rate. The intended purpose of the sensor-varied PVARP depends upon the mode:

- When the pacemaker is operating in the DDDR, DDD, and VDD modes, sensor-varied PVARP is intended to do the following:
  - Enhance protection against PMT at lower rates by providing longer PVARPs at low sensor-indicated rates.
  - Allow tracking of higher atrial rates (that is, provide a higher 2:1 block rate) by shortening the PVARP at high sensor-indicated rates.

- When the pacemaker is operating in the DDIR mode, the sensor-varied PVARP is intended to promote AV synchrony by preventing inhibition of atrial pacing by an atrial sense early in the VA interval. It also reduces the likelihood of competitive atrial pacing at high sensor-indicated rates.

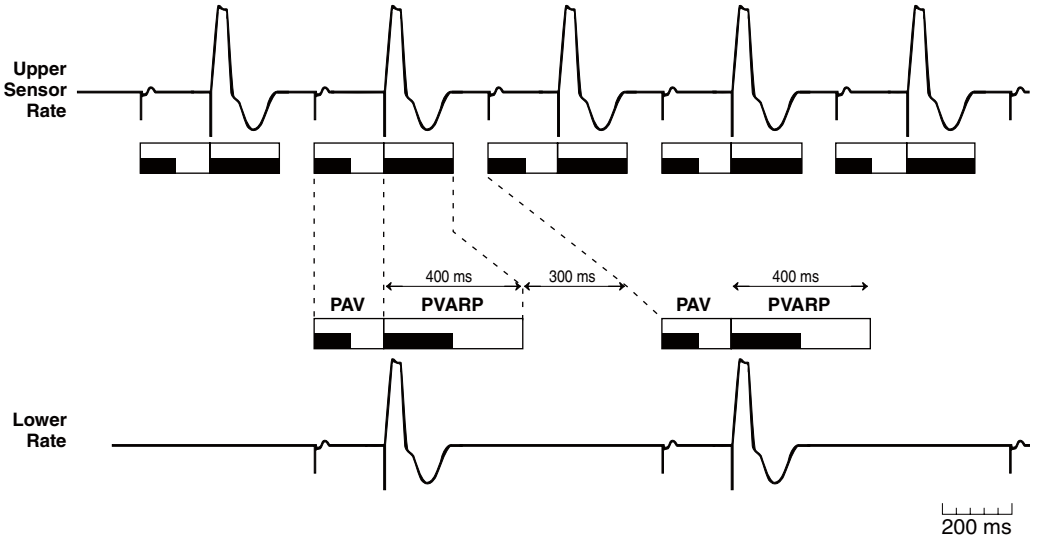


Figure 3-11. Sensor-varied PVARP operation (DDDR Mode)

Determining sensor-varied PVARP

The pacemaker determines the duration of the sensor-varied PVARP as follows:

- When the pacemaker is operating in the DDDR, DDD, and VDD modes, the sensor-varied PVARP is limited to 400 ms at low rates and the programmed PVAB at high rates (as shown in Figure 3-11).
- When the pacemaker is operating in the DDIR mode, the sensor-varied PVARP is approximately 400 ms at low rates and the programmed PVAB at high rates.
- When the pacemaker is operating in the DDDR, DDD, DDIR, and VDD modes, the sensor-varied PVARP is automatically adjusted to maintain a 300 ms sensing window (as shown in Figure 3-11).

Automatic PVARP

When automatic PVARP is programmed, the pacemaker determines a value for the PVARP based on the mean atrial rate (which is an average of all A-A intervals except those starting with an atrial sense or atrial refractory sense and ending with an atrial pace). When the pacemaker is operating in the DDDR, DDD, and VDD modes, automatic PVARP is intended to provide a higher 2:1 block rate by shortening the PVARP and SAV (if necessary) at higher tracking rates and protect against PMTs at lower rates by providing a longer PVARP.

Determining automatic PVARP

The pacemaker determines the duration of the automatic PVARP as follows:

- After every four pacing cycles, a 2:1 block rate is calculated that is 30 min^{-1} above the current mean atrial rate.
- PVARP is then adjusted so the total atrial refractory period equals the calculated 2:1 block rate. The programmable Minimum PVARP parameter controls the minimum value that PVARP can be shortened to.
- If the minimum PVARP value is reached and the 2:1 block rate is still too low, the SAV interval can be shortened to increase the 2:1 block rate. The minimum SAV that can be set is the rate adaptive SAV value (i.e., the programmed SAV value minus the RAAV Maximum Offset value).

The minimum adjustable 2:1 block rate is 100 min^{-1}. The maximum adjustable 2:1 block rate is the Upper Tracking Rate plus 35 min^{-1}. If Mode Switch is On, the maximum 2:1 block rate can be the Detect Rate if this rate is less than the Upper Tracking Rate calculation.

Programming restrictions for automatic PVARP

Rate Drop Response – Automatic PVARP is not available when Rate Drop Response is programmed On.

Spontaneous PVARP extension

The programmed PVARP duration, the sensor-varied PVARP, and the automatic PVARP may be overridden by the PVC Response and PMT Intervention features, as follows:

- When the PVC Response feature is programmed On and a pacemaker-defined PVC occurs, the PVARP is forced to 400 ms for one cycle if a lesser value is in effect.
- When PMT Intervention is programmed On and a pacemaker-defined PMT is detected, the PVARP is forced to 400 ms for one cycle after the ninth paced ventricular event of the PMT.

Refer to “PMT intervention” on page 150 and “PVC Response” on page 153 for further details on the PMT Intervention and PVC Response features and their interactions with PVARP.

Total Atrial Refractory Period (TARP)

In dual chamber modes that sense in the atrium, the Total Atrial Refractory Period (TARP) is the sum of two intervals, as follows:

AV Interval – The AV interval begins with an atrial event and ends with a ventricular event. The first portion is a nonprogrammable blanking period. Its complete duration is determined as follows:

- When the pacemaker is operating in the DDDR, DDD, and VDD modes, the PAV or SAV interval is the AV interval.
- When the pacemaker is operating in the DDIR and DDI modes, the AV interval starts with the first atrial sensed event in the VA interval or with an atrial pacing stimulus; it ends when the PAV expires, even when ventricular pacing is inhibited.

Post-Ventricular Atrial Refractory Period (PVARP) – The PVARP is described on page 75.

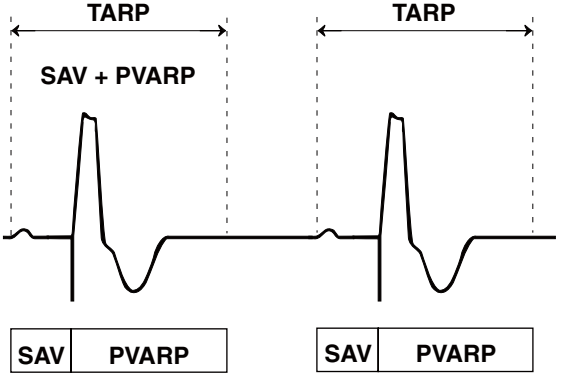


Figure 3-12. Total Atrial Refractory Period

During atrial tracking, TARP = SAV + PVARP, and its duration determines the rate at which 2:1 block occurs. Refer to “High rate atrial tracking” on page 84 for more information.

Ventricular Refractory Period

The programmable Ventricular Refractory Period (VRP) follows paced, sensed, and refractory sensed ventricular events (including PVCs) in all dual chamber and ventricular modes that sense in the ventricle. The VRP is intended to prevent sensing of the T wave or a PVC. The first portion of the VRP is a nonprogrammable blanking period. A ventricular refractory sensed event affects pacemaker timing as follows:

- Ventricular blanking and refractory periods restart in all modes.
- When the pacemaker is operating in the DDDR, DDD, and VDD modes, the upper tracking rate interval, PVARP, and PVAB also restart.
- When the pacemaker is operating in the VVIR and VDIR modes, the upper sensor rate interval restarts.

Note: In dual chamber modes, the VRP should be programmed shorter than the PVARP.

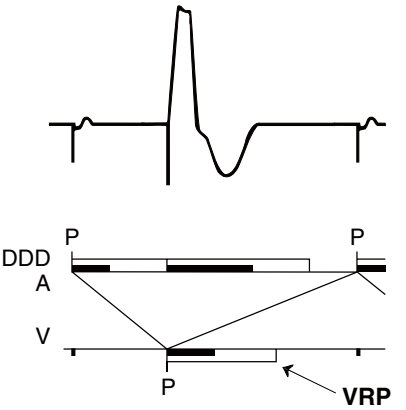


Figure 3-13. Example of Ventricular Refractory Period operation

In dual chamber modes, a ventricular refractory sensed event does not affect a scheduled sensor-driven or lower rate atrial output. Thus, a sensor-driven atrial output pulse will initiate a PAV with a ventricular output pulse following, unless inhibited.

Atrial Refractory Period (single chamber)

The programmable Atrial Refractory Period (ARP) follows paced, sensed, and refractory sensed atrial events. The ARP is used in the AAIR, ADIR, AAI, ADI, and AAT modes. It is intended to prevent inhibition due to far-field R wave sensing. The first portion of the ARP is a programmable blanking period. The ARP should be programmed to a value long enough (180 ms or greater) to prevent far-field R wave sensing but short enough to ensure atrial sensing up to the programmed Upper Sensor Rate.

If the pacemaker is programmed to an MVP mode (AAIR<=>DDDR or AAI<=>DDD) and is operating in AAIR or AAI mode, the ARP is automatically adjusted to 75% of the cardiac cycle length, up to a maximum of 600 ms.

Noise reversion

When sensing occurs during the Atrial Refractory Period (ARP) or Ventricular Refractory Period (VRP), the refractory period (and its blanking period) are restarted. The operation associated with continuous refractory sensing in the ARP or VRP is called noise reversion. Multiple restarts of the ARP or VRP (continuous noise reversion) do not inhibit scheduled pacing. Pacemaker behavior during continuous noise reversion is as follows:

- Pacing occurs at the sensor-indicated rate for all rate responsive modes (except VVIR and VDIR).
- Pacing occurs at the programmed Lower Rate for all non-rate responsive modes (including VVIR and VDIR).

On the ECG, noise reversion may be difficult to distinguish from loss of sensing, but Marker Channel recordings will show refractory sense markers when noise reversion occurs.

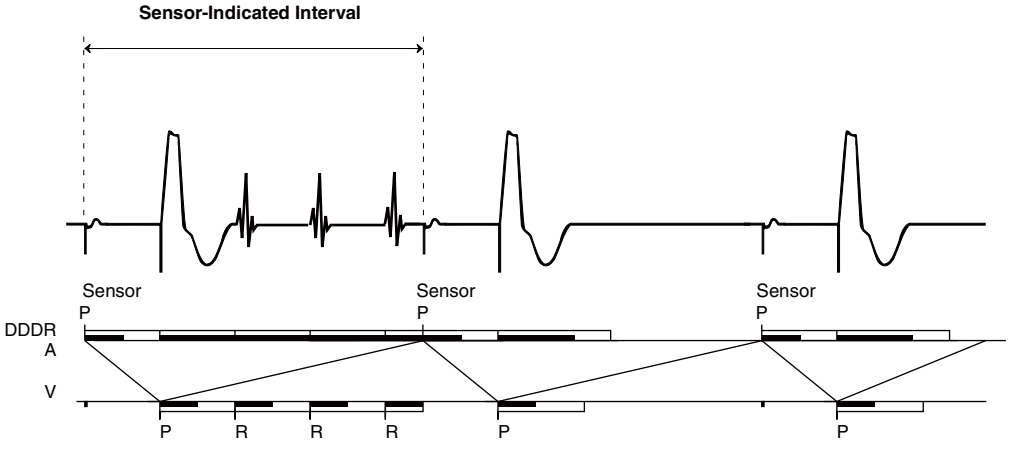


Figure 3-14. Example of noise reversion in DDDR at sensor-indicated rate.

Note: If an atrial refractory sensed event occurs, the pacemaker does not restart the refractory period. However, an atrial refractory sensed event will start a short blanking period of 50 to 100 ms depending on the signal strength and duration of the atrial event.

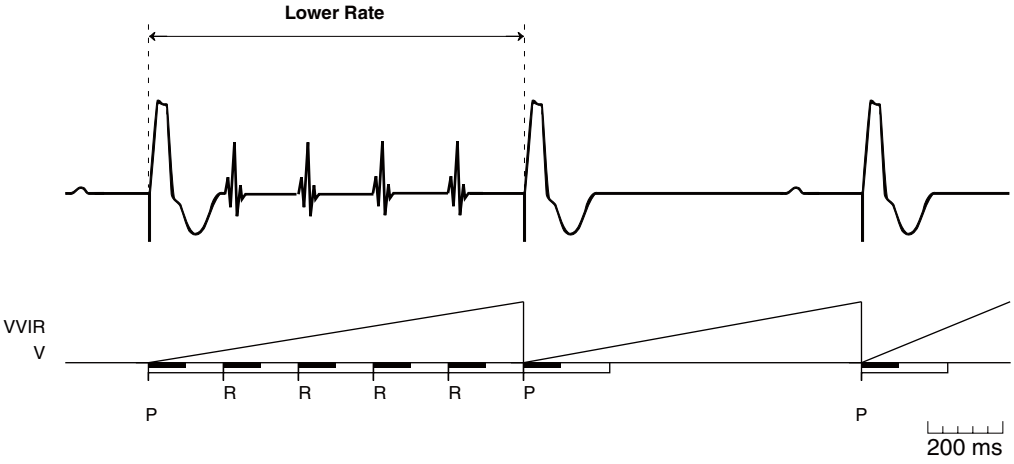


Figure 3-15. Example of noise reversion in VVIR at lower rate.

Preventing noise sensing

Noise reversion may be caused by electromagnetic interference (EMI), myopotentials, excessively high output settings, or low sensitivity settings. When it has been identified, noise reversion usually can be reduced or eliminated by one of the following actions:

- Reprogram sensitivity to a less sensitive setting (higher numerical value) or program Sensing Assurance to On, to monitor and if necessary, adjust the sensitivity value. Refer to “Sensing Assurance and diagnostic” on page 118.
- Reprogram sensing polarity to bipolar polarity (if available).
- Reduce the amplitude and/or pulse width in the same or opposite chamber.
- Program Capture Management to Adaptive to monitor capture thresholds, and, if necessary, adjust amplitude and pulse width values. Refer to “Capture Management and diagnostic” on page 98.
- Remove patient from EMI environment.

High rate atrial tracking

Overview

When the pacemaker is operating in the DDDR, DDD, and VDD modes, the fastest atrial rate the pacemaker can track is determined by the total atrial refractory period (TARP), which is the sum of the SAV and the PVARP. Pacemaker behavior at high atrial rates in these modes is determined by the relationship between the TARP and the interval corresponding to the Upper Tracking Rate. In the DDDR mode, the interval corresponding to the Upper Sensor Rate also must be considered.

2:1 block

When the intrinsic atrial interval is shorter than the TARP, some atrial events will fall in the PVARP and not be tracked. At the rate where this first occurs, ventricular tracking occurs only on alternate beats, and 2:1 block ensues. When the pacemaker is operating in the DDD and VDD modes, the ventricular pacing rate drops precipitously.

- When sensor-varied PVARP or automatic PVARP is selected, the 2:1 block rate may occur at a higher rate during activity due to shortening of the PVARP and the SAV (automatic PVARP only), thus increasing atrial tracking.
- When Rate Adaptive AV operation is selected, the SAV shortens at high atrial rates, shortening the TARP and raising the 2:1 block rate.
- When the 2:1 block rate is less than the Upper Tracking Rate, the Upper Tracking Rate cannot be achieved.
- When the pacemaker is operating in DDDR mode, pacing at the sensor-indicated rate may prevent a precipitous rate drop at the 2:1 block point when activity is present.
- For patients with a documented propensity for prolonged or sustained atrial fibrillation or flutter, the clinician can select Upper Tracking Rate, SAV, and PVARP values that induce 2:1 block at a desired rate (2:1 block rate = 60,000/TARP). Alternatives for controlling rates in these patients include use of the Mode Switch feature and DDIR mode pacing.
- When the pacemaker is operating in the DDDR mode, atrial competition may occur if the Upper Sensor Rate exceeds the 2:1 block rate.

Pacemaker Wenckebach

When the 2:1 block rate exceeds the programmed Upper Tracking Rate, pacemaker Wenckebach may occur. When the intrinsic rate exceeds the Upper Tracking Rate, a pacing stimulus at the expiration of the SAV would violate the upper tracking rate. The pacemaker therefore extends the SAV until the upper tracking rate interval expires. Subsequent SAVs require greater extension, until an atrial event falls in the PVARP and is not tracked.

- When the pacemaker is operating in the DDDR, DDD, and VDD modes, the result is normally a fixed ratio between atrial and ventricular rates (3:2, 4:3, and so forth).
- When the pacemaker is operating in the DDDR mode, the pacemaker Wenckebach rate may be smoothed by sensor-driven ventricular pacing, thereby overriding the fixed ratio.

Figure 3-16 shows how pacemaker Wenckebach operation occurs in the DDDR, DDD, or VDD modes.

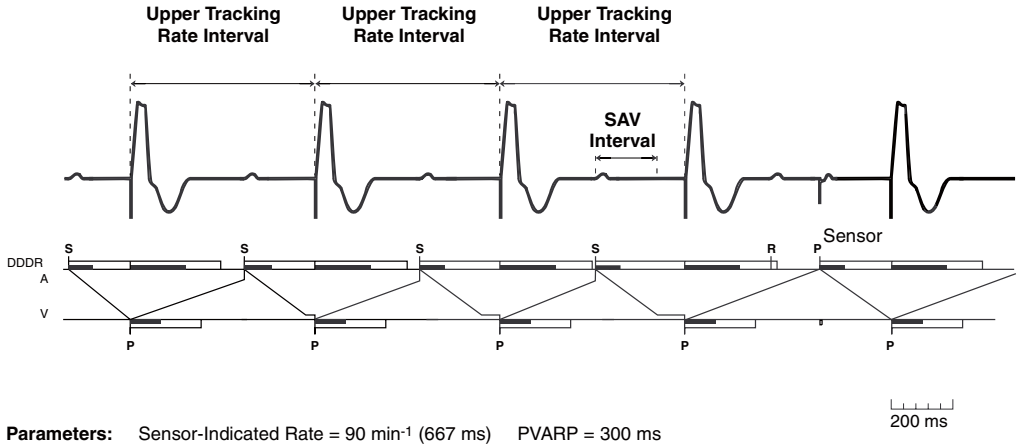


Figure 3-16. Example of pacemaker Wenckebach operation

High rate operation in the DDDR mode

Table 3-1 summarizes how the total atrial refractory period (TARP), the Upper Tracking Rate (UTR) interval, and the Upper Sensor Rate (USR) interval may interact at high atrial rates when the pacemaker is operating in the DDDR mode.

Table 3-1. Upper rates interaction with TARP

Relationship Between TARP and Upper Rate Intervals	Wenckebach Before 2:1 Block	Achieve Upper Tracking Rate	Potential Atrial Competition
TARP > both USR and UTR intervals	no	no	yes[a]
USR interval > TARP > UTR interval	no	no	no
USR interval > UTR interval > TARP	yes	yes	no
UTR interval > both USR interval and TARP	yes	yes	yes[a]

[a] Unless the Non-Competitive Atrial Pacing is On, see “Non-competitive atrial pacing” on page 148.

Lead/cardiac tissue interface 4

Implant Detection

Overview

Implant Detection is a 30-minute period, beginning at lead connection, during which the pacemaker verifies that each lead has been connected by measuring lead impedance. After 30 minutes of continuous lead connection, the pacemaker completes Implant Detection and activates the following features (see Figure 4-1):

- Operating polarity (automatic configuration occurs during Implant Detection)
- MVP operations including conduction checks and mode changes
- Adaptive sensitivity settings (Sensing Assurance)
- Rate responsive pacing, including adaptive rate profile optimization (Rate Profile Optimization)
- Adaptive ventricular output settings for threshold management (Capture Management)
- Diagnostic data collection

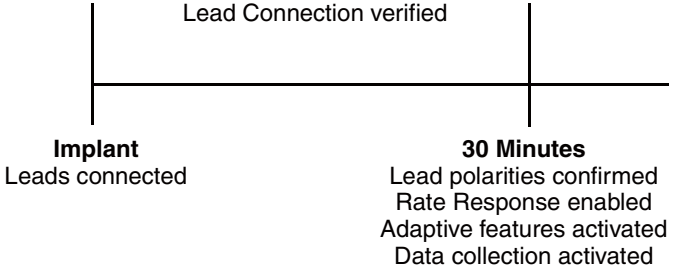


Figure 4-1. Implant Detection period

Implant Detection is available in all pacing modes and is turned on at shipment.

Note: Search AV+ initializes 60 min after Implant Detection is complete.

Note: Automatic polarity configuration does not occur during Implant Detection if the Lead Monitor parameter is programmed to Monitor Only before implant. Automatic configuration will take place if Lead Monitor is programmed to Adaptive before implant or remains set to its shipping setting of Configure.

Verifying lead connection during Implant Detection

At the time of lead connection, the pacemaker begins verifying that each lead is present by measuring the impedance of each pacing pulse. When a pace is delivered, the pacemaker determines if the impedance is within the acceptable range, which is programmable between 200 to 4000[1] ohms for both bipolar and unipolar configurations.

- High impedance paces cause Implant Detection to reset.
- Low impedance paces (and continuous sensing) are considered acceptable for the purpose of determining lead connection and configuring polarity.

Automatic polarity configuration

Overview

During Implant Detection, bipolar pacemakers automatically configure pacing and sensing polarities through the Lead Monitor feature. Bipolar pacemakers are shipped with the Atrial and Ventricular Lead Monitor set to Configure, enabling automatic polarity determination shortly after lead connection.

Unipolar-only pacemakers are configured to unipolar pacing and sensing polarity at the time of manufacture and remain unipolar during the operational life of the pacemaker.

[1] The acceptable maximum impedance limit for a valid lead (bipolar or unipolar) can be changed by programming the Notify If > (Greater Than) parameter, which is part of the Lead Monitor and is found under the programmed lead polarities. The minimum impedance limit of 200 ohms is nonprogrammable.

Measuring lead impedance during configuration

Bipolar pacemakers, using either bipolar or unipolar leads, automatically configure pacing and sensing polarities by measuring the impedance of each pace during the configuration period. (Lead Monitor must be set to Configure or Adaptive. See “Lead Monitor” on page 94.) Impedance measurement during configuration is as follows:

- The pacemaker issues a bipolar pace and immediately checks the pace for high impedance.
  - If the pace is within range, it is considered an acceptable bipolar pace.
  - If high impedance is found, the pacemaker immediately follows the bipolar pace with a backup unipolar pace.
- If a unipolar backup pace is issued, the pacemaker checks it for high impedance.
  - If the pace is within range, it is considered an acceptable unipolar pace.
  - If high impedance is found, the pacemaker assumes a lead is not attached and restarts Implant Detection.

Notes:

- During polarity configuration, the pacemaker also detects low impedance paces but does not follow them with unipolar backup paces. To avoid possible loss-of-capture due to continuous low impedance pacing, the pacemaker sets unipolar polarity when 3 of 16 paces are detected as low impedance during the first phase of configuration (see “Initial Configuration Phase” on page 91).
- If the pacemaker assumes a lead is not present (a high impedance unipolar pace is detected) in one chamber of a dual chamber pacemaker, Implant Detection will restart.

How polarities are automatically configured

Atrial and ventricular lead polarities are configured independently in dual chamber bipolar models, with the exception of pacemakers in the VDD Series, which have fixed bipolar atrial sensing only.

Operating pacing and sensing polarities for bipolar pacemakers are configured automatically in two phases during Implant Detection. (See Figure 4-2.) During these phases the pacemaker continues to measure impedance as described above.

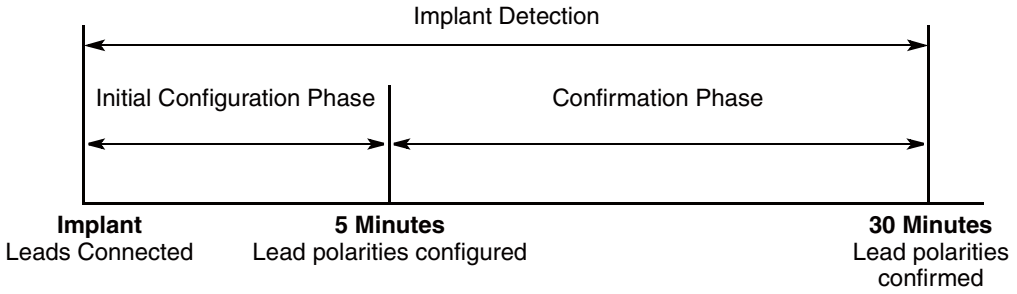


Figure 4-2. Automatic configuration of bipolar models

Initial Configuration Phase – The pacemaker sets lead polarities five minutes after lead connection unless a high impedance unipolar pace has reset Implant Detection, a prevalence of low impedance bipolar paces has set unipolar pacing, or if continuous sensing has occurred.

The pacemaker sets initial polarities as follows:

- The pacemaker delivers three asynchronous paces at magnet rate.
- If at least two of the three paces are determined to be bipolar, the pacemaker remains set to bipolar polarity (with backup unipolar paces) for the Confirmation Phase.
- If at least two of the three paces are determined to be unipolar, the pacemaker sets polarity to unipolar. Unipolar polarity becomes the operating polarity for pacing and sensing, and no Confirmation Phase is required.

  Note: If one of the asynchronous paces in a given chamber is a high impedance unipolar pace, the pacemaker restarts Implant Detection in both chambers. Polarity configuration restarts only in the affected chamber, however.

Confirmation Phase – Twenty-five minutes after initial configuration, the pacemaker confirms final operating polarity for leads configured bipolar in the Initial Configuration Phase. During this 25-minute Confirmation Phase, the pacemaker measures the lead for high and low impedance paces. If 8 of 16 paces (or the programmed number of paces out of sixteen) are out of range, the lead will automatically be reconfigured to unipolar polarity.

At the end of twenty-five minutes, operating polarity for leads detected as bipolar during the Initial Configuration Phase is determined as follows:

- The pacemaker delivers three asynchronous paces at magnet rate.
- If at least two of the three paces are determined to be bipolar, the pacemaker sets operating polarity to bipolar (or Adaptive operation if Lead Monitor was programmed to Adaptive prior to implant). See “Lead Monitor” on page 94.
- If at least two of the three paces are determined to be unipolar, the pacemaker sets operating pace and sense polarities to unipolar.

  Note: If a high impedance unipolar pace occurs in a given chamber at any time during the 25-minute Confirmation Phase, the pacemaker restarts Implant Detection in both chambers. Polarity configuration restarts only in the affected chamber, however.

Leads configured unipolar during the Initial Configuration Phase continue to operate in the unipolar configuration. If bipolar polarity switches to unipolar during the Confirmation Phase, the operating polarity remains unipolar with no additional confirmation through asynchronous pacing.

Warning: If, at implant, the setscrews, both tip and ring, for a 3.2 mm connector pacemaker are not properly engaged and all electrical contacts are not sealed, leakage between the tip and ring contacts may occur. Such leakage may cause the pacemaker to falsely identify a unipolar lead as bipolar, resulting in a loss of output. The same result could occur for all bipolar models if the electrical contacts were not properly sealed when using lead extenders or adaptors.

When automatic configuration is complete

Thirty minutes after lead connection, Implant Detection and automatic configuration are complete. If, after this time period, the leads are detached and lead polarity type is changed, automatic configuration and Implant Detection do not restart automatically at reinsertion. The clinician must reprogram Implant Detection to On/Restart, which automatically resets Lead Monitor to Configure.

The Lead Monitor feature (see “Lead Monitor” on page 94) monitors and reports on lead stability when Implant Detection and automatic configuration are complete. It is automatically set by the pacemaker as follows:

- Bipolar models are shipped with Lead Monitor set to Configure. However, after Implant Detection ends, Lead Monitor is automatically set to Monitor Only for bipolar and unipolar configurations.
- Bipolar models with Lead Monitor programmed to Adaptive before implant are set to Adaptive if polarity was determined to be bipolar. If polarity for these models was determined to be unipolar, they are set to Monitor Only.
- Unipolar models are shipped with Lead Monitor set to Monitor Only and continue to operate at that setting both during and after Implant Detection.

Manually setting polarities

To manually program atrial or ventricular lead polarities at implant, the clinician first must “turn off” the Configure setting under Lead Monitor by choosing the Monitor Only setting instead. Implant Detection still provides the 30-minute detection period, followed by automatic feature and diagnostics activation, when the pacemaker is programmed manually.

Programming interactions

- Programming Implant Detection to Off /Complete before completion of the 30-minute automatic polarity configuration period requires the clinician to manually program Lead Monitor and polarities. The pacemaker's automatic features are activated when Implant Detection is turned off.
- Manually programming Implant Detection to On/Restart restarts lead detection, polarity configuration (Lead Monitor is set to Configure), and automatic feature activation.
- Initiating a programming session at any time during Implant Detection causes Implant Detection to be restarted.
- If a dual chamber pacemaker is programmed to a single chamber mode, only one lead is configured. If the mode is reprogrammed to a dual chamber mode, the clinician will need to change the Lead Monitor from Configure to Monitor Only or Adaptive for the unconfigured lead, and then program pace and sense polarity for it manually.

Lead Monitor

Overview

The Lead Monitor feature measures lead impedances during the life of the pacemaker. When programmed to do so, Lead Monitor also enables the pacemaker to switch bipolar pacing and sensing to unipolar when bipolar lead integrity is in doubt. It also controls automatic configuration of lead polarities at implant. Lead Monitor is available in all pacing modes.

Caution: If the Lead Monitor detects out-of-range lead impedance, investigate lead integrity more thoroughly.

How lead monitoring works

The Lead Monitor feature monitors lead impedance of paced chambers, as defined by the mode, by measuring the impedance of each pacing pulse to see if it falls within the programmed impedance range for a stable lead.

The three programmable values under Atrial or Ventricular Lead Monitor are as follows:

- **Configure** - provides automatic configuration of polarity (see “How polarities are automatically configured” on page 91).
- **Adaptive**
  - monitors bipolar paces for high impedance and provides unipolar backup paces when high impedance is detected.
  - switches pacing and sensing polarity from bipolar to unipolar when the pacemaker detects a prevalence of high or low impedance paces (see Monitor Sensitivity parameter in Table 4-1). The Lead Monitor setting changes to Monitor Only when polarity switches.
  - provides automatic polarity configuration when selected prior to implant.
- **Monitor Only** - monitors either unipolar or bipolar paces to determine if they are out of range but does not switch polarity when an out-of-range lead is indicated.

Lead Monitor is activated at lead connection, and it is automatically set to its operating value of Monitor Only or Adaptive at the end of Implant Detection. See “When automatic configuration is complete” on page 93.

When Lead Monitor is set to Adaptive or Monitor Only and a lead is determined to be out of range, the pacemaker issues a lead warning that appears on the programmer screen at the next interrogation.

Lead Monitor programmable parameters – The programmable parameters for the Lead Monitor feature are shown below.

Table 4-1. Programmable parameters for Lead Monitor

General Parameters	Meaning
Atrial Lead Monitor	Monitors lead impedance in the atrium; option to provide unipolar backup paces and to switch from bipolar to unipolar polarity for an out-of-range lead; provides automatic configuration of polarity at implant.
Ventricular Lead Monitor	Monitors lead impedance in the ventricle; option to provide unipolar backup paces and to switch from bipolar to unipolar polarity for an out-of-range lead; provides automatic configuration of polarity at implant.
Notify If < (Less Than)	Nonprogrammable minimum boundary for acceptable atrial and ventricular bipolar lead impedance. Fixed at 200 ohms.
Notify If > (Greater Than)	Maximum boundary for acceptable atrial and ventricular bipolar lead impedance.
Monitor Sensitivity	Number of high or low impedance paces out of 16 that define an out-of-range lead on each channel.

Lead Monitor should not be programmed to Adaptive for patients with implantable defibrillators. When a prevalence of out-of-range lead impedance paces is detected, the monitor automatically reprograms the selected lead(s) to unipolar polarity. Pacing in the unipolar configuration may cause the defibrillator either to provoke inappropriate therapy or to withhold appropriate therapy.

Lead impedance data

Lead impedance data is recorded automatically.

Automatic Lead Impedance (Chronic Lead Trend)

The automatic Lead Impedance diagnostic data is based on measurements taken every three hours for each chamber that is being paced. The maximum, average, and minimum lead impedances are recorded every seven days for the most recent 14 months.

The following data is continuously updated:

- Initial impedance (recorded at implant or when Chronic Lead Trend is cleared)
- Lifetime minimum impedance (recorded since implant)
- Lifetime maximum impedance (recorded since implant)
- High impedance paces
- Low impedance paces

If the maximum number of high impedance paces or low impedance paces is reached, that value will remain until the data is cleared. All other diagnostic data collection will continue.

Note: To avoid high output pacing, Chronic Lead Trend data collection can be programmed to Off. The outputs are increased to make lead impedance measurements every 3 hours.

Clearing Lead Impedance data

Automatic (Chronic) Lead Impedance Trend data is retained by the pacemaker unless you use the Clear Data function on the programmer. Note that the data should be cleared only when a lead is replaced. Be sure to save the session data or print the trend report before ending the patient session.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information about collecting and displaying lead impedance trends.

Capture Management and diagnostic

Overview

When Capture Management is enabled, the pacemaker automatically monitors pacing thresholds at periodic intervals. Once the threshold is determined, the pacemaker determines a target output based on the programmable safety margin and programmable minimum amplitude.

- If programmed to Adaptive, the pacemaker reprograms outputs toward the target.
- If programmed to Monitor Only, the pacemaker does not reprogram outputs.

Caution: Epicardial leads have not been determined appropriate for use with the Ventricular Capture Management feature. Program Ventricular Capture Management to Off if implanting an epicardial lead.

Note: The pacemaker enables Capture Management once Implant Detection is completed.

Note: In the event of partial or complete lead dislodgment, Capture Management may not prevent loss-of-capture.

Ventricular Capture Management (VCM)

At programmable intervals, the pacemaker performs a ventricular pacing threshold search to determine the ventricular threshold, which is the combination of minimum amplitude and minimum pulse width that consistently results in capture of the ventricular myocardium.

Atrial Capture Management (ACM)

At programmable intervals, the pacemaker performs an atrial pacing threshold search to determine the atrial amplitude threshold, which is the minimum amplitude that consistently results in capture of the atrial myocardium.

Initiating the pacing threshold search

Scheduling the search – A pacing threshold search is initiated according to the schedule programmed by the clinician. The Capture Test Frequency parameter under Capture Management allows the clinician to schedule the search at fixed time intervals. (Refer to Table E-5 on page E-307 for the programmable time intervals for the pacing threshold search.) The clinician can also program the Day At Rest value that allows the pacemaker to determine when to run the search.

If a pacing threshold search is scheduled to occur once per Day At Rest, the pacemaker tries to initiate the first pacing threshold search 12 hours after Implant Detection is complete. It then runs subsequent searches at 24-hour intervals from the time of the last successfully completed search.

If a search cannot be completed, the pacemaker retries after 30 minutes.

Programmable Capture Management parameters

Capture Management can be programmed to Adaptive, Monitor Only, or Off. When Capture Management is programmed to Adaptive, the parameters in Table 4-2 are used to control Capture Management operation. They can also be programmed for diagnostic use when Capture Management is programmed to Monitor Only.

Table 4-2. Programmable parameters for Capture Management

General parameters	Meaning
Amplitude Margin	The safety margin applied to the pacing threshold search results for Amplitude.
Minimum Adapted Amplitude	The lower limit to which the operating Amplitude can be adapted.
Capture Test Frequency	Determines how often the pacing threshold search will be initiated.
V. Acute Phase Days Remaining	Time in days during which output settings can be adapted both upward and downward, but not below the permanently programmed ventricular outputs.

Table 4-2. Programmable parameters for Capture Management

General parameters	Meaning
A. Acute Phase Days Remaining	Time in days during which output settings can be adapted both upward and downward, but not below the permanently programmed atrial outputs.
V. Sensing During Search	The polarity used for ventricular sensing during ventricular pacing threshold searches. See “Preventing undersensing of ventricular evoked response events during the search” on page 107.

Ventricular Capture Management (VCM)

Checking for stable rhythm – Before a pacing threshold search can be initiated, the pacemaker determines if the patient is pacing or sensing at a low rate. A low rate is desirable during the pacing threshold search to reduce the risk of competition from forced pacing with fast intrinsic rhythms. To make the determination, the pacemaker looks for intrinsic or rate related events indicating:

- Out of eight measured V-V intervals no more than two are faster than:
  - 100 min^{-1} if the upper sensor rate and upper tracking rate are $\geq$ 135 min^{-1}
  - 95 min^{-1} if the upper sensor rate and upper tracking rate are $\geq$ 125 min^{-1}
  - 90 min^{-1} if the upper sensor rate and upper tracking rate are $<$ 125 min^{-1}
- the sensor rate, checked at the end of the eight intervals, is at or below the ADL rate.
- in dual chamber modes, at least one valid AV interval (AS-VS, AS-VP, AP-VS, AP-VP) occurred during the eight measured intervals.

The pacemaker also looks for automatic feature interaction indicating:

- Rate Drop Response is not in an intervention state.
- Mode Switch is not changing between a tracking and a nontracking mode.
- Battery measurements

- Atrial Preference Pacing
- Sleep function

If the stable rhythm check is successful, the pacing threshold search is initiated. If any of the criteria for the stable rhythm check is not met, the pacemaker defers the pacing threshold search until the next scheduled search period. See “Scheduling the search” on page 99.

The ventricular pacing threshold search

The pacemaker performs the pacing threshold search at a given Amplitude and Pulse Width setting through a series of support cycles and test paces. Each series has three sets of support cycles, with each set followed by a test pace and an automatic backup pace (see Figure 4-3).

- The *support cycles* are pacing cycles at the programmed Amplitude and Pulse Width that may or may not include ventricular paced events. The pacing threshold search begins with the support cycles.
- A *test pace* follows each set of support cycles and is delivered at a test Amplitude or Pulse Width. Amplitude and Pulse Width settings above the threshold cause capture of the myocardium; settings below the threshold result in loss-of-capture.
- A *backup pace* automatically follows each test pace regardless of capture or loss-of-capture for that pace. It is delivered 110 ms after the test pace at the programmed Amplitude and a 1.0-ms Pulse Width setting.

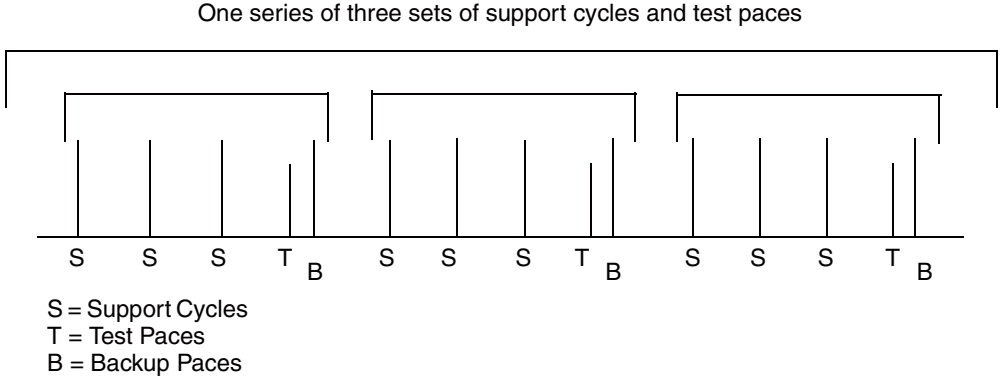


Figure 4-3. Pacing threshold search

The pacemaker may use one to three of the test paces in a series to determine if a particular Amplitude or Pulse Width is above or below the patient's stimulation threshold.

- When the first of the three test paces indicates capture (CAP), or the last two test paces indicate capture following loss-of-capture (LOC) on the first pace, the series is determined to be above the threshold. See Table 4-3.
- When two of the three test paces indicate loss-of-capture, the series is determined to be below the threshold. See Table 4-3.

Table 4-3. Above/below threshold determination

Series of 3 test paces	Results
CAP[a]	Above threshold
LOC[b], CAP, CAP	Above threshold
LOC, LOC	Below threshold
LOC, CAP, LOC	Below threshold

[a] CAP = capture

[b] LOC = loss-of-capture

Not all test paces qualify for use in the determination series. If a test pace meets abort criteria (see "When the pacing threshold search aborts" on page 106), the pace is ignored, the Amplitude and Pulse Width remain the same, and the next test pace is used in the determination series instead. For example, if a ventricular intrinsic sense inhibits the test pace during the test cycle, that intended pace will be ignored and not evaluated for capture.

If a support pace meets abort criteria, e.g., a ventricular safety pace occurs on a support pace, the pace is counted in the support/test cycle, but causes the next test pace to be ignored. The test pace following the ignored test pace remains at the Amplitude and Pulse Width and is used in the determination series.

Modifying Amplitude and Pulse Width during the search – When modifying first Amplitude and then Pulse Width during the pacing threshold search, the pacemaker is looking for two points that lie on the strength duration curve. These points define the boundary between settings that capture the myocardium and those that do not.

Amplitude modification operates as follows:

1. The test Amplitude is set at the last Amplitude result from the previous pacing threshold search or at 0.75 V if no previous search has been done. Pulse Width is set at 0.4 ms.
2. The pacemaker initiates a series of support cycles and test paces to determine whether the Amplitude setting is above or below the patient's stimulation threshold.
3. If the test Amplitude is above the patient's threshold, the pacemaker will reduce it by one setting and repeat the test series. The process of reducing the Amplitude setting and retesting continues until a point below the patient's threshold is found, indicating loss-of-capture.
4. The pacemaker then increments and retests the Amplitude one setting at a time until the setting is above the patient's stimulation threshold for three consecutive test series, indicating capture is recovered. The setting at which capture is recovered is called the amplitude threshold.

Pulse Width modification operates as follows:

1. The test Pulse Width is set at the last Pulse Width setting from the previous search or at 0.21 ms if no previous search has been done. Amplitude is set at two times the amplitude threshold determined during the Amplitude search. The upper Pulse Width limit for the test pulse is 0.4 ms.
2. The pacemaker performs the actions detailed in steps 2 through 4 for Amplitude modification above, but for Pulse Width. The Pulse Width setting that is in operation when capture is recovered at two times the amplitude threshold is designated the pulse width threshold.

If the clinician uses the in-office Capture Management test, the programmer uses the amplitude threshold and pulse width threshold to construct a strength duration curve. (See Figure 4-4.)

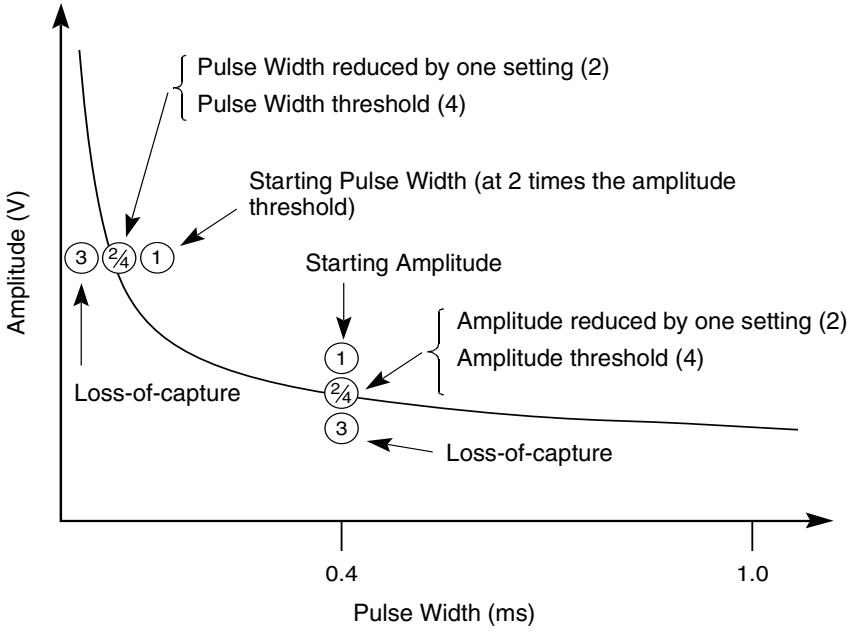


Figure 4-4. Modifying Amplitude and Pulse Width

Pacing therapy during the search – During a pacing threshold search, the pacemaker must provide ventricular test paces (which may affect normal pacing operation). To ensure ventricular pacing, if necessary, the pacemaker may adapt timing in both tracking and nontracking modes.

Note: If an MVP mode is programmed (AAIR<=>DDDR or AAI<=>DDD), the capture management sets the pacing mode to DDDR or DDD and suspends MVP mode changes for the duration of the pacing threshold search.

When operating in tracking modes:

- The pacemaker shortens the AV interval for each support cycle and test pace based on calculations using the shortest AV interval measured during the stable rhythm check.
- The test pace is always followed by a backup pace after 110 ms.
- PVARP is fixed at 350 ms for **support cycles**, but PVARP, PVAB, and the ventricular refractory period are timed from the backup pace on **test paces**.

- Ventricular Safety Pacing is disabled on test pace cycles.

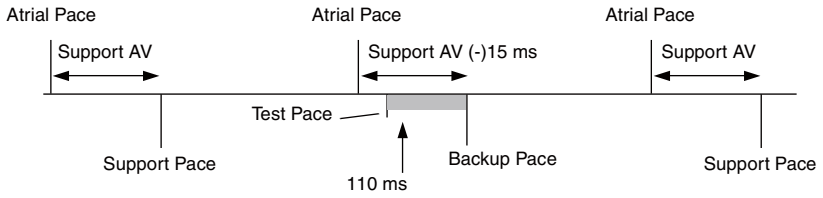


Figure 4-5. Rate modulation in DDD/tracking modes

When operating in nontracking modes:

- The lower rate is not changed on support cycles.
- the lower rate on test paces is set to the fastest V-V interval seen on any support cycle or seen during the stable rhythm check plus 15 min^{-1} or minus 150 ms, whichever results in a faster rate.

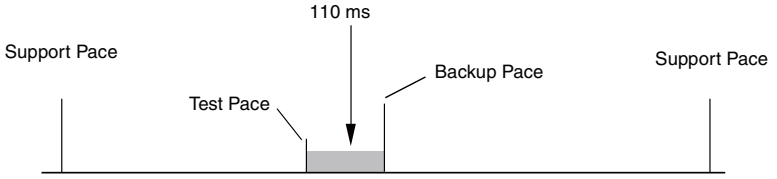


Figure 4-6. Rate modulation in nontracking modes

Because the pacing threshold search operates as the highest priority feature in control of pacing cycle parameters, the following pacing features are disabled during the search:

- Sensing Assurance
- Rate Drop Response detection
- AV modulation (Search AV+, Rate Adaptive AV)
- NCAP operation
- Lead Monitor
- Auto PVARP and sensor-varied PVARP operations
- Ventricular Safety Pacing on test paces
- Atrial Preference Pacing
- Sinus Preference

When the pacing threshold search aborts – Sometimes the pacing threshold search cannot be performed as scheduled. The pacemaker ensures that false events will not influence the determination of capture and loss-of-capture during the search by aborting the search immediately when the following occur:

- The sensor rate is greater than the ADL rate.
- Mode Switch occurs.

The pacemaker allows the following to occur several times before aborting the search:

- Upper tracking rate extension on a test pace.
- Nonrefractory ventricular senses in a tracking mode.
- V-V rate greater than 90 to 100 min^{-1} on support cycles, depending on the value of the upper sensor rate and upper tracking rate (see “Checking for stable rhythm” on page 100).
- Ventricular Safety Pacing during the support cycles.
- Consecutive ventricular refractory events.

Other conditions can also cause the pacing threshold search to abort:

- Pacemaker RRT/ERI or low battery is detected.
- Noise reversion is detected.
- Initiation of a programming or transtelephonic session.
- Capture is not determined during the entire search, indicating possible high thresholds.
- Loss-of-capture does not occur during the entire search, indicating a possible lead problem or undetected intrinsic events.

When a pacing threshold search cannot be completed, the pacemaker will automatically initiate another search within 30 minutes (or within 15 minutes, if the Capture Test Frequency parameter is programmed for every 15 minutes). See “Scheduling the search” on page 99. If four search attempts abort during one test period, however, the pacing threshold test is suspended until the next test period.

When the pacing threshold search aborts, a message indicating why the search could not be performed is stored in the Capture Management Detail diagnostic (if enabled).

Preventing undersensing of ventricular evoked response events during the search – To minimize the likelihood of undersensing of ventricular evoked response events during a pacing threshold search, the clinician can program the V. Sensing During Search parameter to Adaptive, if the Ventricular Sense Polarity parameter is set to Bipolar. Then, when an out-of-range measurement (see Figure 4-8) occurs, the pacing threshold search will be automatically repeated, using the Unipolar sensing setting.

If the second search is successful, the out-of-range measurement is ignored. If the second search results in another out-of-range measurement, outputs will remain at 5 V and 1 ms.

If the V. Sensing During Search parameter is set to Bipolar or Unipolar, ventricular sensing during the pacing threshold search will be done at that setting.

Automatic ventricular output adaptation

Capture Management can be programmed (Adaptive setting) to provide automatic adaptation of ventricular Amplitude and Pulse Width based on pacing threshold search results. Following each search, the pacemaker creates a target output by applying a programmable safety margin (Amplitude Margin parameter) to the amplitude threshold determined during the search. The pacemaker's calculation for the target is always rounded up to the next programmable setting. The pacemaker then adapts outputs toward this target.

Adaptation can take place only within an output range that is defined by a programmable lower limit (Minimum Adapted Amplitude parameter) and the upper threshold limit of 5.0 V and 1.0 ms. The minimum pulse width for ventricular capture management is 0.4 ms.

- Amplitude is adapted only when a pacing threshold search is successful; otherwise, it remains as programmed.

- If the operating Amplitude is below the target, it is immediately adapted to the target. (See Figure 4-7.)

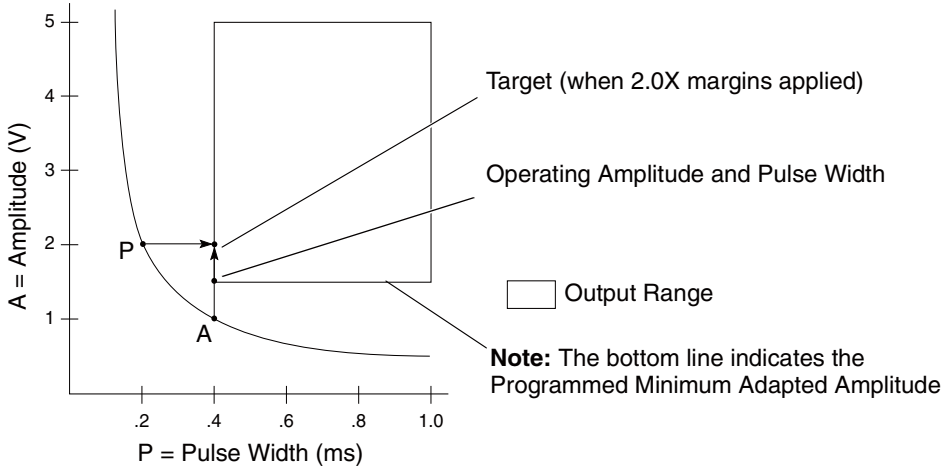


Figure 4-7. Adapting outputs upward to the target

- If the operating Amplitude is above the target, the pacemaker adapts the Amplitude downward one programmable setting per successful pacing threshold search. If the target is below the programmed minimum output limit, the adaptation stops at the minimum limit.
- A High Threshold Condition warning is issued if the amplitude threshold is greater than 2.5 V. The pacemaker responds by adapting to an Amplitude of 5.0 V and Pulse Width of 1.0 ms.
- If the amplitude threshold multiplied by the safety margin indicates an amplitude target greater than 5.0 V, the pacemaker responds by adapting to the highest possible Capture Management settings, an Amplitude of 5.0 V and Pulse Width of 1.0 ms. (See Figure 4-8.)

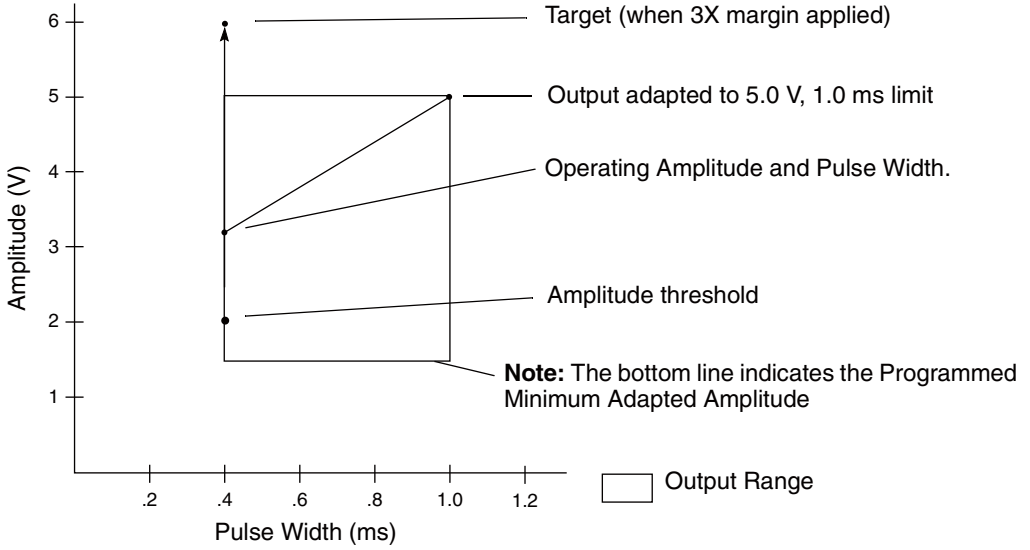


Figure 4-8. Limiting high thresholds

Considerations when programming parameters

In a small percentage of patients, the following conditions can influence thresholds measured by Capture Management and can lead to possible symptoms:

Lead fixation – With poor lead fixation, modulations in pacing timing and rate can influence thresholds.

Intrinsic event rejection – In rare instances, combinations of morphology and rhythm may result in a low threshold measurement. This may occur if the pacing threshold search is unable to differentiate between myocardial contractions caused by the pacing pulse and those caused by physiologic means.

Evoked response detection – In rare instances, the pacemaker may not detect the electronic waveform created by the contracting myocardium immediately following a pacing pulse. In such instances, a high threshold measurement may result. See “Preventing undersensing of ventricular evoked response events during the search” on page 107.

The Capture Management Threshold Test and manual threshold measurements provide data that can help in programming the parameters that control outputs (see “Programmable Capture Management parameters” on page 99).

Programming interactions

Warning: Capture Management will not program ventricular outputs above 5.0 V or 1.0 ms. If the patient needs a pacing output higher than 5.0 V or 1.0 ms, program Amplitude and Pulse Width manually.

The pacemaker must be programmed to a mode that permits pacing and sensing in the ventricle (but not VVT mode) in order to use the Ventricular Capture Management feature.

Atrial Capture Management (ACM)

Checking for stable rhythm – Before a pacing threshold search can be initiated, the pacemaker determines if the patient is pacing or sensing at a low rate. A low rate is desirable during the pacing threshold search to reduce the risk of competition from forced pacing with fast intrinsic rhythms. A Pacing Threshold Search (PTS) is performed when a stable atrial rhythm is observed for eight pacing cycles and the sensor rate is less than the ADL rate.

- ACM does not operate during Mode Switch episodes.
- ACM operates in DDDR and DDD modes.[1]
- The sensed atrial rate must not be faster than 87 min^{-1}.
- The paced atrial rate must be slower than 90 min^{-1}.

The atrial pacing threshold search

Conducting the search – The pacemaker performs the pacing threshold search through a series of support cycles followed by a test pace applied at a slightly faster rate.

[1] If the device is programmed to an MVP mode (AAIR<=>DDDR or AAI<=>DDD), the pacemaker changes the mode to DDDR or DDD during ACM operations.

- Beginning at one setting below the last measured value (or at 0.75 V if no previous search has been done), the amplitude is reduced in one setting decrements at 0.4 ms pulse width until loss-of-capture is detected. When two of the three test paces indicate loss-of-capture, the series is determined to be below the threshold.
- The pacemaker then increments and retests the amplitude one setting at a time until the setting is above the patient's stimulation threshold for three consecutive test series, indicating capture is recovered. The setting at which capture is recovered is called the amplitude threshold. The threshold criteria are shown in Table 4-4.

Table 4-4. Above/below threshold determination for a single test series

Series of up to 3 test paces	Results
CAP, CAP[a]	Above threshold
LOC[b], CAP, CAP	Above threshold
LOC, LOC	Below threshold
CAP, LOC, CAP	Above threshold
LOC, CAP, LOC	Below threshold

[a] CAP = capture

[b] LOC = loss-of-capture

Not all test paces qualify for use in the determination series. If sensed events surrounding the test pace meet abort criteria, the pace is ignored, the Amplitude remains the same, and the next test pace is used in the determination series instead. If a support cycle meets abort criteria, the previous set of support cycles is discarded, and a new set of support cycles is started.

Atrial Capture Management (ACM) observes the timing of sensed P and R waves (not evoked response) to evaluate capture.

ACM automatically selects one of two methods for evaluating atrial capture, based on the patient's rhythm at the time of the PTS. If the patient has a stable sinus rhythm, the device selects the Atrial Chamber Reset (ACR) method. Otherwise, the device selects the AV Conduction (AVC) method.

Atrial Chamber Reset (ACR) Method

Atrial Chamber Reset runs during stable sinus rhythm. It evaluates capture by observing the response of the intrinsic rhythm to the atrial test pace. If the test pace does not capture, the sinus node is not reset, and an atrial refractory sensed event (AR) is observed after the test pace. If no AR is observed within the AV interval, ACR concludes that the test pace captured the myocardium. (See Figure 4-9.)

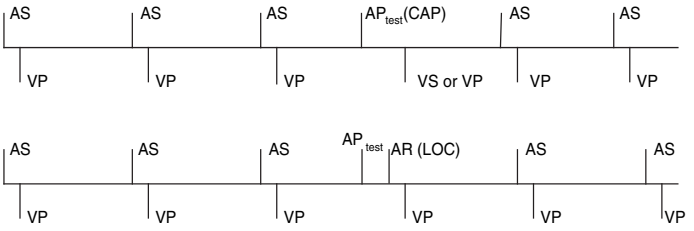


Figure 4-9. Atrial Chamber Reset test method

Atrial-Ventricular Conduction (AVC) Method

Atrial-Ventricular Conduction method runs when stable 1:1 AV conduction is observed with atrial pacing. The atrial pacing rate is increased by 15 min^{-1} (but no faster than 101 min^{-1}) and the AV interval is lengthened to try to achieve a stable AP-VS rhythm.

AVC evaluates capture by observing the conducted ventricular response to the atrial test pace. Each atrial test pace is followed by a backup pace at programmed amplitude and a 1.0 ms pulse width to maintain rhythm stability during the test. If a conducted VS event is observed at approximately the expected AP-VS interval following the atrial test pace, AVC concludes that the test pace captured the myocardium. (See Figure 4-10.)

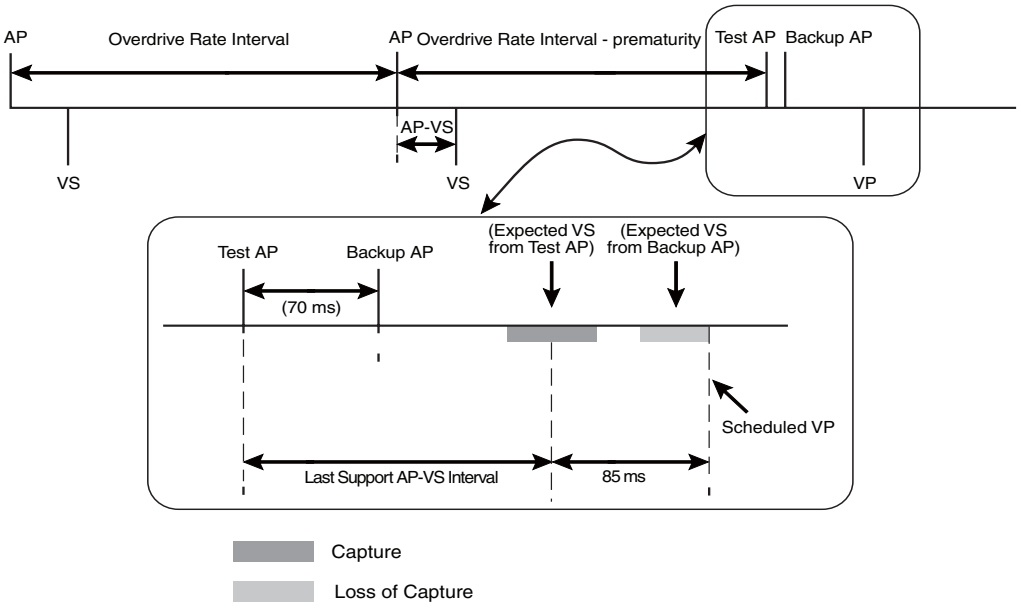


Figure 4-10. Atrial-Ventricular Conduction test method

Pacing therapy during the search
Because the pacing threshold search operates as the highest priority feature in control of pacing cycle parameters, the following pacing features are disabled during the search:

- Sensing Assurance
- Rate Drop Response detection
- AV modulation (Search AV+, Rate Adaptive AV)
- Blanked Flutter Search
- Lead Monitor
- Lower rate modulation (APP, Sinus Preference, Conducted AF Response)

Note: If an MVP mode is programmed (AAIR<=>DDDR or AAI<=>DDD), the capture management sets the pacing mode to DDDR or DDD and suspends MVP mode changes for the duration of the pacing threshold search.

When the pacing threshold search aborts – Sometimes the pacing threshold search cannot be performed as scheduled. The pacemaker ensures that false events do not influence the determination of capture and loss-of-capture during the search by aborting the search immediately when the following occur:

- Fast atrial rate (>87 min^{-1} with ACR, >100 min^{-1} with AVC)
- Ventricular pacing (AVC)
- Undesirable cardiac events (PVCs, PACs)
- Mode Switch occurs.

The pacemaker allows the following to occur several times before aborting the search:

- fast or variable intrinsic rate or ectopic events
- slow intrinsic rate[1] and a lack of AV conduction
- Variable AV conduction time
- Unexpected sensed events before or after the test pace
- Ventricular Safety Pacing

Other conditions can also cause the pacing threshold search to abort:

- Pacemaker RRT/ERI or low battery is detected.
- Initiation of a programming or transtelephonic session occurs.
- Capture is not determined during the entire search, indicating possible high thresholds.
- Loss-of-capture does not occur during the entire search, indicating undetected intrinsic events.

Automatic atrial threshold adaptation

Capture Management can be programmed (Adaptive setting) to provide automatic adaptation of atrial amplitude based on pacing threshold search results.

The pacemaker applies the programmable amplitude safety margin to the amplitude threshold value measured at a 0.4 ms pulse width to determine the target amplitude. If the operating amplitude is above the target, the pacemaker adapts the amplitude down toward the target in one-step decrements. If the operating amplitude is below the target, the amplitude is immediately adapted to the target.

[1] Turning the Sleep Function to On may allow ACM to run with slower intrinsic rates.

- Outputs are not adapted below the programmable minimum amplitude. During the programmable Acute Phase following implant detection, outputs are not adapted below the programmed outputs or the default shipping settings (3.5 V, 0.4 ms).
- A High Threshold Warning is issued if the amplitude threshold is greater than 2.5 V. The pacemaker responds by adapting to an Amplitude of 5.0 V and Pulse Width of 1.0 ms.
- A High Threshold warning is issued if the target amplitude is greater than 5.0 V and outputs are adapted to 5.0 V and 1.0 ms (See Figure 4-11).

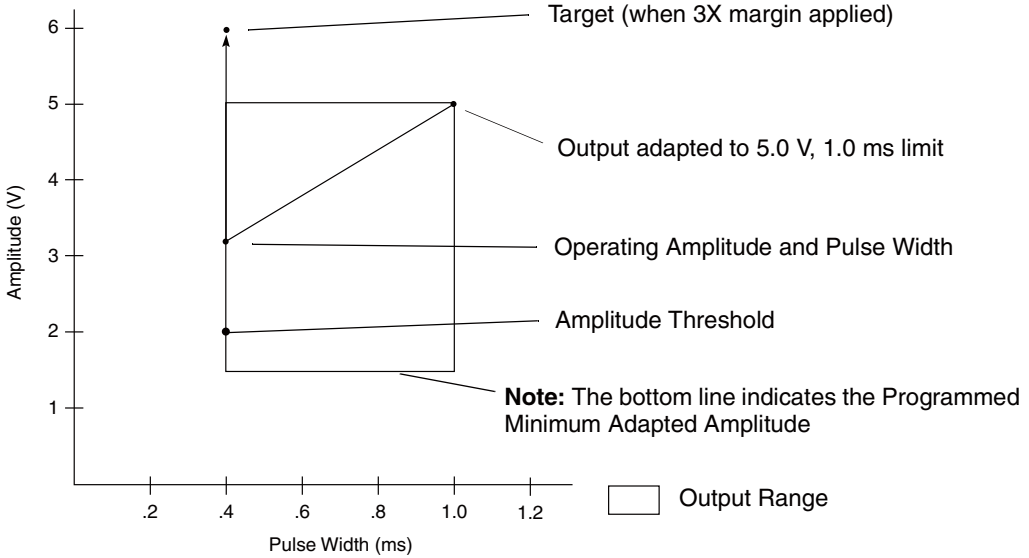


Figure 4-11. Limiting high atrial thresholds

Programming interactions

Warning: Capture Management will not program atrial outputs above 5.0 V or 1.0 ms. If the patient needs a pacing output higher than 5.0 V or 1.0 ms, program Amplitude and Pulse Width manually.

The pacemaker must be programmed to DDDR, DDD, AAIR<=>DDDR, or AAI<=>DDD mode in order to use the Atrial Capture Management feature.

Recording Capture Management data

Programming Capture Management also initiates automatic data collection. In addition, you may collect detailed information about every Capture Management search.

Summary Capture Management data

The automatic Capture Management trend records pacing threshold history. Every 7 days, the pacemaker collects the following Capture Management data automatically for 14 months:

- Maximum Threshold
- Average Threshold
- Maximum Amplitude
- Type of Capture Management search (Adaptive or Monitor Only)

Figure 4-12 shows a typical summary Capture Management trend.

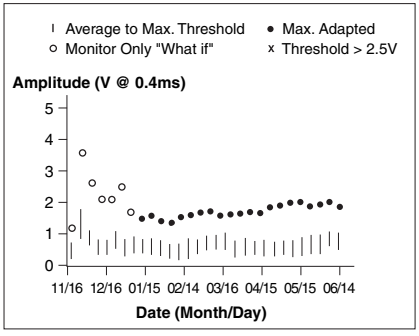


Figure 4-12. Summary Capture Management data

Detail Capture Management data

Capture Management Detail data provides a record of the pacing threshold, pulse width, and amplitude in the selected chamber. For the most recent 668 ventricular or 359 atrial Capture Management searches, the pacemaker records the following information for the selected chamber:

- Date and Time
- Threshold Amplitude
- Threshold Pulse Width (VCM only)
- Method of Search (ACM only)
- Adapted or Monitor Only (suggested) Amplitude (with programmed margin applied)
- Adapted or Monitor Only (suggested) Ventricular Pulse Width

A beat-to-beat trend for the most recent Capture Management search is available. Recording stops if more than 1000 events occur during the search. Clinicians have the option to record an EGM (atrial, ventricular, or summed EGM). Figure 4-13 shows an example of a detailed Capture Management trend.

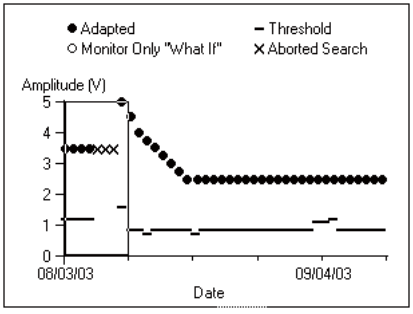


Figure 4-13. Detail Capture Management trend

The data collected can be displayed or printed from the Data icon.

Clearing Capture Management data

Automatic Capture Management Trend data can be cleared from the Clear Data screen by selecting the option to clear lead impedance trend data for the respective chamber. However, the clinician-selected Capture Management Detail data is cleared automatically one hour after the end of a programming session.

Also, you can select the option to clear data immediately. Be sure to save the session data or print the report before ending the patient session.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information about collecting and displaying Capture Management data.

Sensing Assurance and diagnostic

Overview

The Sensing Assurance feature automatically adjusts atrial and ventricular sensitivities within defined limits. At the completion of Implant Detection, the pacemaker enables Sensing Assurance and begins monitoring the peak amplitude of sensed signals. In response to monitoring, the pacemaker automatically increases or decreases Sensitivity to maintain an adequate sensing margin with respect to the patient's sensed P and R waves.

Monitoring sensitivity thresholds

The pacemaker monitors each nonrefractory sensed event (AS or VS) by measuring the ratio of the peak amplitude of the P or R wave to the Sensitivity setting. The pacemaker then compares the measured sensing margin to a target sensing margin.

Sensing Assurance provides the following target sensing margins:

- Atrial bipolar sensing: 4:1 ratio to 5.6:1 ratio
- Atrial unipolar sensing: 2.8:1 ratio to 4:1 ratio
- Ventricular (unipolar or bipolar) sensing: 2.8:1 ratio to 4:1 ratio

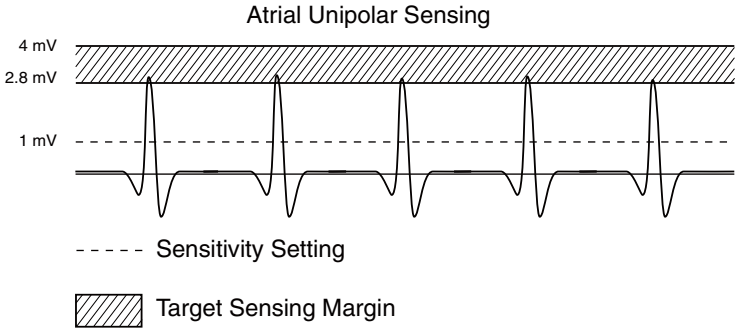


Figure 4-14. Maintaining a sensing margin of 3:1

Qualifying sensed events

When monitoring nonrefractory sensed events, the pacemaker checks each event to see if it qualifies for use in determining Sensitivity threshold adjustments. Events are disqualified when:

- The pacemaker is monitoring a high level of continuous interference
- A second event occurs in either chamber within 40 ms after a sensed event

Adjusting sensing thresholds

To adjust sensing thresholds, the pacemaker keeps a record of many sensed events. Non-PVC, nonrefractory senses that fall below the target sensing margin (low events) are assigned a negative value, and those that are above the target sensing margin (high events) are assigned a positive value. When the accumulated value of the events exceeds the upper or lower limits of a counter, the pacemaker will adjust the sensitivity by one setting:

- Many low events indicate an adjustment of one setting to a more sensitive (smaller numerical) setting.
- Many high events indicate an adjustment of one setting to a less sensitive (larger numerical) setting.

At least 17 low events are required to cause an adjustment to the next more sensitive setting, and 36 high events are required to cause an adjustment to the next less sensitive setting.

Adjustments occur more gradually if a mixture of low and high events are occurring or if paced events are intermingled with sensed events. If fewer than 60% of events are high (or low), or if the pace to sense ratio is greater than 5:1, no sensitivity adjustment is made.

Pacemaker-defined PVCs will cause ventricular sensitivity adjustments that are slower than those for non-PVC, non-refractory senses.

Adjustments during periods of infrequent sensing

The pacemaker maintains a long-term running average of the sensitivity adjustments. During periods when the pacing percentage is near 100%, the pacemaker may adjust the thresholds toward the long-term average. If persistent undersensing or persistent noise reversion pacing (due to continuous interference) is occurring, the pacemaker will adjust the threshold toward the long-term average.

Sensitivity in the VDD mode will be increased if there is an absence of atrial sensing for several pacing cycles.

Threshold adjustment limits for Sensing Assurance

Automatic Sensitivity adjustments are restricted to the following ranges of settings:

Table 4-5. Restricted Sensing Assurance settings

Sensing type	Lower limit	Upper limit
Atrial		
Bipolar[a]	0.18 mV	0.5 mV
VDD mode	0.18 mV	0.35 mV
Unipolar	0.5 mV	1.4 mV
Ventricular		
Bipolar and unipolar	2.0 mV	5.6 mV

[a] For SR Series and S Series bipolar models the lower limit is 0.25 mV.

Programming considerations

While Sensing Assurance is On, the clinician cannot manually program a lower or higher Sensitivity setting than those shown in Table 4-5.

Ventricular Safety Pacing (VSP) must be programmed On for ventricular Sensing Assurance operation.

Sensing Assurance will not adjust Sensitivity during temporary operation.

Sensing Assurance will adjust Sensitivity only if the programmed mode allows both sensing and pacing in a chamber, with the exceptions that adjustments are allowed in the VDD, AAI<=>DDD, and AAIR<=>DDDR modes, and they are not allowed in the AAT/VVT modes.

While Sensing Assurance is designed to adapt sensitivity margins in response to changes in sensed event amplitudes, Sensing Assurance may not eliminate all sources of oversensing.

Recording Sensing Assurance data

Programming Sensing Assurance to On also initiates automatic data collection.

Summary Sensing Assurance data

Automatic Sensitivity Trend data indicates the performance of the Sensing Assurance feature. Every seven days, the pacemaker records the following information for both chambers:

- Minimum sensitivity
- Maximum sensitivity
- Whether Sensitivity adjustments reach the upper limit (least sensitive) or the lower limit (most sensitive)

Figure 4-15 shows typical summary Sensing Assurance data

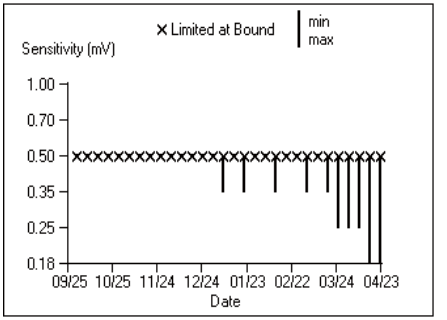


Figure 4-15. Summary Sensing Assurance data

Clearing Sensing Assurance data

Summary and Detailed Sensing Assurance data is normally cleared by the pacemaker one hour after a programming session.

Also, you can select the option to clear data immediately. Be sure to print the report before ending the patient session.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information about collecting and displaying Sensing Assurance data.

Manually selecting pacing parameters

Overview

Pacing output settings should be adequate to guarantee reliable capture, but not so high as to inappropriately deplete the pacemaker battery. Whether selecting pacing outputs at implant or follow-up, the same considerations apply:

- Select pacing polarity for leads (only if manual programming is desired).
- Determine stimulation thresholds.
- Select appropriate outputs (pulse width and amplitude).

Manually selecting pacing polarity

Atrial and ventricular pacing polarities can be manually programmed for each chamber when used with bipolar leads.

Bipolar pacing polarity – The lead tip is the active electrode; the lead ring is the common electrode. Bipolar pacing is less likely to produce muscle stimulation, but it produces smaller pacing artifacts on the ECG.

Unipolar pacing polarity – The lead tip is the active electrode; the noninsulated pacemaker case is the common electrode. Unipolar pacing produces large pacing artifacts that aid in ECG interpretation. However, it is more likely to cause muscle stimulation, especially at high pacing amplitudes.

Muscle stimulation with unipolar pacing

Under certain circumstances, e.g., high output settings, pacemaker-induced muscle stimulation may occur at the pocket site with the unipolar-only models and bipolar models programmed to unipolar pacing. Pacemaker-induced muscle stimulation may be effectively controlled and/or eliminated by programming Pulse Width to a narrower setting or programming a lower Amplitude.

Bipolar pacing polarity confirmation

Before programming from unipolar to bipolar pacing, the programmer verifies the presence of a bipolar lead by testing lead impedance for each lead. Testing is done under magnet operation for four seconds at an Amplitude of 5.0 V and a Pulse Width of 1.0 ms if the programmed settings are at or below this level. If the programmed settings are above these values, the measurement will be made at the programmed settings.

- If bipolar lead impedance is between 200 ohms and the programmed maximum impedance level (not to exceed 4000 ohms), a bipolar lead is assumed to be present.
- If bipolar lead impedance is outside this range, a unipolar lead is assumed to be present. The programmer displays a warning that the test failed, and pacing polarity remains set to unipolar. This interlock feature may be overridden to force lead pacing polarity to bipolar.

Warning: Overriding the bipolar verification prompt with bipolar polarity when a unipolar lead is connected **results in no pacing output**.

Determining stimulation threshold at implant

At implant, use a pacing system analyzer to determine threshold values for capture. Refer to the manual for the pacing system analyzer for detailed instructions.

Verifying stimulation threshold at follow-up

Medtronic programmers provide both automatic and manual threshold tests for determining the patient's stimulation threshold at follow-up. Stimulation threshold resolution is determined by the available increments of amplitude and pulse width.

The Strength-Duration test constructs a strength-duration graph that shows the amplitude safety margin.

The Capture Management test provides ventricular pacing thresholds that are automatically determined by the pacemaker through the Capture Management feature.

Selecting output parameters

Generally, to provide an adequate safety margin, select a pacing voltage twice the chronic stimulation threshold voltage for a given pulse width. For most patients, pacing outputs are the major contributor to battery depletion.

- To maximize battery longevity, select the lowest amplitude and pulse width settings that provide at least a 2:1 voltage safety margin.
- When amplitudes greater than 2.5 V are required during the maturation phase of the lead(s), threshold(s) and output setting(s) should be carefully reevaluated at the first follow-up.

Notes:

- Amplitudes of 5.0, 5.5, 6.0, and 7.5 V substantially reduce expected battery longevity. These amplitudes should be limited to short-term uses such as "Emergency" settings and electrophysiologic studies or long-term uses for specific indications such as exit block.

- High output pacing at 7.5 V may affect ECG or intracardiac electrogram (EGM) waveform quality and potentially cause crosstalk or self-inhibition.

For further information

Refer to “Projected service life” on page 266 for further information on pacemaker longevity under various pacing scenarios. Refer to “Programmable modes and parameters” on page 300 for further information on amplitude and pulse width parameter settings. Refer to “Crosstalk” on page 318 for further information on crosstalk or self-inhibition.

Manually selecting sensing parameters

Overview

Sensitivity determines the minimum intracardiac signal that the pacemaker can detect when intrinsic atrial or ventricular events occur. Whether selecting sensing parameters at implant or verifying sensing at follow-up, the same considerations apply:

- Select sensing polarity for leads (only if manual programming is desired).
- Determine sensing thresholds.
- Select appropriate sensitivity settings.

Manually selecting sensing polarity

Atrial and ventricular sensing polarities can be manually programmed for each chamber when used with bipolar leads.

Bipolar sensing polarity – The lead tip and lead ring electrode are the poles of the sensing circuit. Because bipolar sensing is more localized, it reduces the likelihood of sensing myopotentials and electromagnetic interference. It may also permit sensitivity to be programmed to a more sensitive setting.

Unipolar sensing polarity – The lead tip and noninsulated pacemaker case are the sensing electrodes. Unipolar sensing may allow sensing of smaller intrinsic signals than does bipolar sensing and therefore, can be selected when intrinsic cardiac signals are difficult to detect with bipolar sensing. Oversensing due to myopotentials is more common with unipolar sensing than with bipolar sensing.

Bipolar sensing polarity confirmation

Before programming from unipolar to bipolar sensing, the programmer verifies the presence of a bipolar lead by testing impedance for each lead. Testing is done under magnet operation for four seconds at an Amplitude of 5.0 V and a Pulse Width of 1.0 ms if the programmed settings are at or below this level. If the programmed settings are above these values, the measurement will be made at the programmed settings.

- If bipolar lead impedance is between 200 ohms and the programmed maximum impedance level (not to exceed 4000 ohms), a bipolar lead is assumed to be present.
- If bipolar lead impedance is outside this range, a unipolar lead is assumed to be present. The programmer warns that the test failed, and sensing polarity remains set to unipolar. This interlock feature may be overridden and lead sensing polarity forced to bipolar.

Determining sensing threshold(s) at implant

At implant, use Medtronic pacing system analyzer to determine sensing threshold values for the pacemaker. Refer to the manual for the pacing system analyzer for detailed instructions.

Before connecting a bipolar lead, measure the sensing potentials in the unipolar and the bipolar configurations. Adequate intracardiac signal should be present in both configurations to ensure proper sensing in either.

Verifying sensing threshold(s) at follow-up

Intracardiac signal amplitudes decrease during the lead maturation process. Medtronic programmers provide an automatic sensitivity test that allows the follow-up clinician to verify a patient's sensitivity settings. The automatic test measures the amplitude of sensed P or R waves on the atrial or ventricular channel. The test provides the sensitivity setting just above and below the point at which P waves or R waves are sensed.

Selecting sensitivity settings

Atrial and Ventricular Sensitivity are independently programmable. In general, a 2:1 to 3:1 sensitivity safety margin (threshold sensitivity value divided by 2 or 3) is adequate for newly implanted or chronic leads. For example, an atrial sensitivity of 1.0 mV should be satisfactory for intrinsic atrial signals between 2.0 mV and 3.0 mV.

- Always perform an atrial sensing test to determine the appropriate atrial sensitivity setting.
- Excessively sensitive (low) settings can cause some or all of the following problems:
  - oversensing due to electromagnetic interference (EMI), myopotentials, T waves, or crosstalk
  - undersensing due to overloading of the sensing circuit
  - noise reversion operation
- Atrial Sensitivity with bipolar sensing polarity allows 0.18 mV, 0.25 mV, and 0.35 mV atrial sensitivity settings. To prevent oversensing of muscle noise or electromagnetic interference, unipolar sensing is limited to values no less than 0.5 mV.

- Ventricular Sensitivity at 1.0 mV or 1.4 mV with wide atrial pulse widths or high atrial amplitudes may result in ventricular safety pacing (if On) with some lead systems at high sensor-driven pacing rates. Reprogramming Ventricular Sensitivity to a less sensitive setting (higher numerical value) is one option under such circumstances. Other options include programming a longer ventricular blanking period.

Effects of myopotentials during unipolar pacing

Myopotentials could affect the operation of the unipolar-only models and bipolar models programmed to unipolar sensing, especially with atrial sensitivity settings of 0.5 through 1.0 mV and ventricular sensitivity setting of 1.0 and 1.4 mV.

Myopotentials sensed on the atrial channel outside of the total atrial refractory period (SAV + PVARP) start sensed AV intervals in the DDDR, DDD, and VDD modes.

Continuous myopotentials cause reversion to **asynchronous operation** when sensed in the refractory period:

- on the ventricular channel at intervals less than the ventricular refractory period in the DDDR, DDD, DDIR, DDI, DVIR, DVI, VDD, VVIR, VDIR, VVI, VDI, and VVT modes
- on the atrial channel at intervals less than the atrial refractory period in the AAIR, ADIR, AAI, ADI, and AAT modes

In the VVIR and VDIR modes, the resulting asynchronous pacing occurs at the Lower Rate, otherwise such asynchronous pacing occurs at the sensor-indicated rate for rate response modes or the Lower Rate for nonrate response modes.

For further information

In the manual for the pacing system analyzer, refer to sensitivity threshold test procedures. Refer to “Noise reversion” on page 81 for a description of noise reversion operation. Refer to “Programmable modes and parameters” on page 300 for sensitivity parameter settings.

Transtelephonic follow-up features

Overview

When using transtelephonic monitoring, the clinician can do the following:

- Verify capture with the Threshold Margin Test (TMT)
- Enhance communication with transtelephonic equipment by means of the Transtelephonic Monitor feature

The Threshold Margin Test (TMT)

Applying the magnet over the pacemaker initiates a Threshold Margin Test (TMT). During transtelephonic monitoring, the TMT provides a check for loss-of-capture at reduced amplitudes. The TMT may indicate that loss-of-capture is possible but cannot verify that the safety margin is adequate.

In single chamber atrial or ventricular modes, the VDD mode, or dual chamber modes at RRT/ERI, TMT reduces amplitude in the pertinent paced chamber while pacing at a rate of 100 min^{-1}.

Threshold Margin Test operation

As Figure 4-16 shows, a dual chamber pacemaker delivers three asynchronous AV sequential pulses at a rate of 100 min^{-1} with a paced AV interval of 100 ms. The first two sequences of pulses are delivered at the programmed Amplitude. The third sequence is delivered at a 20% reduction of the programmed Amplitude. At the completion of the TMT, pacing is forced to a rate of 85 min^{-1} in the magnet mode. If RRT/ERI or an electrical reset has occurred, pacing is forced to 65 min^{-1} in the magnet mode.

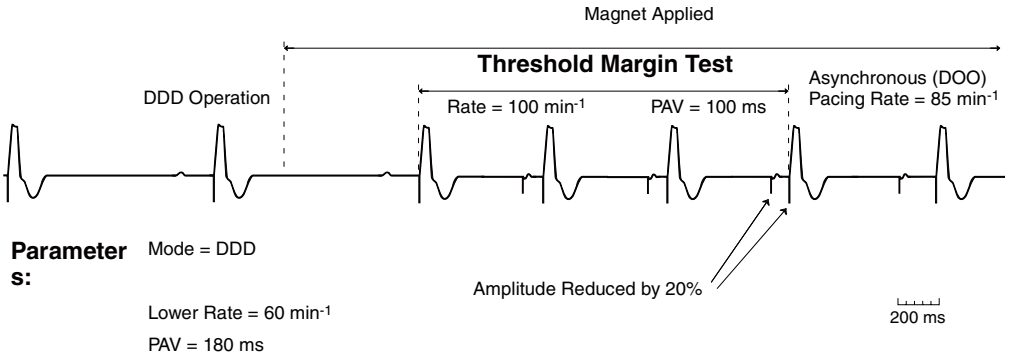


Figure 4-16. TMT operation

Warning: A loss-of-capture at a 20% reduction in amplitude indicates that the stimulation safety margin is inadequate. As soon as possible, reevaluate the patient's threshold and reprogram outputs for a 2:1 stimulation safety margin. Imminent loss of ventricular capture for a pacemaker-dependent patient may constitute an emergency situation.

Note: If follow-up is performed with the programming head, the clinician must perform a Magnet test in order to obtain a TMT. Placing the programming head over the pacemaker **does not** initiate a TMT.

Enhanced Transtelephonic Monitoring

The Transtelephonic Monitor is a programmable On or Off feature intended for use with remote pacemaker monitoring services. Programming the feature Off does not affect conventional transtelephonic monitoring.

When the Transtelephonic Monitor is On, the pacemaker delays the Threshold Margin Test for five seconds upon magnet application to enhance communication with transtelephonic equipment. If the pacing polarity is programmed to bipolar, it is temporarily set to unipolar to provide improved ECG artifact detection for the remote monitoring equipment. The programmed polarity is restored when the magnet is removed.

When Transtelephonic Monitor is Off, the Threshold Margin Test is not delayed upon magnet application, and conventional transtelephonic monitoring can occur.

Warning: Programming Transtelephonic Monitor On is contraindicated for patients with an implantable defibrillator. When it is programmed On, pacing polarity is temporarily set to unipolar when the magnet is applied over the pacemaker. Pacing in the unipolar configuration may cause the defibrillator either to provoke inappropriate therapy or to withhold appropriate therapy.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for programming instructions regarding Transtelephonic Monitor.

Special therapy options 5

Mode Switch and diagnostic

Overview

Mode Switch is a programmable On or Off feature designed to prevent the tracking of paroxysmal atrial tachycardias when the pacemaker is operating in the DDDR, DDD, and VDD modes. Mode Switch has a programmable Detect Rate that specifies when to switch modes and a Detect Duration setting to screen out short tachycardia episodes. It also has a programmable Blanked Flutter Search setting to switch modes if 2:1 blanking of a rapid atrial arrhythmia is detected.

Note: Mode Switch is not recommended for patients known to have chronic refractory atrial tachyarrhythmias, such as atrial tachycardia, atrial fibrillation, or atrial flutter.

When the pacemaker detects an atrial tachyarrhythmia, it switches from the programmed atrial tracking mode to a non-atrial tracking mode and remains in this mode until the atrial tachyarrhythmia ceases. Then the pacemaker switches back to the atrial tracking mode (see Table 5-1), unless Post Mode Switch Overdrive Pacing (PMOP) has been programmed.

Table 5-1. Mode switching modes

Atrial tracking mode		Non-Atrial tracking mode
DDDR	⇄	DDIR
DDD	⇄	DDIR
VDD	⇄	VDIR
AAIR<=>DDDR	⇄	DDIR
AAI<=>DDD	⇄	DDIR

Operation with other pacemaker functions

Managed Ventricular Pacing (MVP) – Mode Switch can be programmed concurrently with MVP in the AAIR<=>DDDR and AAI<=>DDD modes. During atrial tachyarrhythmias, the pacemaker switches to DDIR pacing regardless of the current operating MVP mode.

Post Mode Switch Overdrive Pacing (PMOP) – PMOP is available when the pacemaker is operating in DDDR and DDD modes. PMOP allows Mode Switch to provide extended DDIR pacing at a higher rate after the atrial arrhythmia subsides. In PMOP, after the programmed Overdrive Period (at a programmed Overdrive Rate) has elapsed, the pacemaker returns to tracking the atrium in DDDR or DDD mode, as originally programmed.

How atrial tachyarrhythmia is defined

The pacemaker defines an atrial tachyarrhythmia based on the programmable Detect Rate and Detect Duration:

Detect Rate – The rates above which pacemaker-defined atrial tachyarrhythmia starts. Note that ventricular tracking is limited by the Upper Tracking Rate or the total atrial refractory period, even when the atrial rate rises above the Detect Rate.

Detect Duration – The minimum duration (in seconds) that the atrial tachyarrhythmia must persist above the Detect Rate before the rate is considered tachyarrhythmic.

How atrial tachyarrhythmia is detected

When the A–A rate exceeds the Detect Rate and is sustained for the Detect Duration, the pacemaker assumes that atrial tachyarrhythmia is in progress.

In monitoring for rapid atrial rates, the pacemaker monitors for rapid consecutive A–A intervals. If the Blanked Flutter Search parameter is On, the pacemaker also monitors for A–A intervals that may indicate 2:1 blanking of atrial events.

1. The pacemaker first monitors for any four of the last seven consecutive A–A intervals that are shorter than the detect rate interval. These include all A–A intervals except AS–AP and AR–AP intervals and AP–AR–AP sequences, which are classified as far-field R waves.
2. If no rapid A–A intervals are detected (as described in Step 1) and Blanked Flutter Search is On, the pacemaker next monitors for eight consecutive A–A intervals
   – that are less than twice the total atrial blanking period (which is the SAV + PVAB) and

– where one half of the A–A interval is less than the detect rate interval

If these criteria are met, the pacemaker will extend PVARP and the VA interval to uncover any blanked AS events. If an A-A interval shorter than the detect rate interval is detected, 2:1 sensing of an atrial tachyarrhythmia is assumed. Otherwise, the pacemaker resumes monitoring for 2:1 sensing of atrial tachyarrhythmias in 90 seconds.

3. Once rapid consecutive A–A intervals are detected or 2:1 blanking of atrial events is detected, the Detect Duration delay timer is started. The pacemaker will not switch modes until this timer expires.

   To meet the Detect Duration delay, the pacemaker monitors that every eighth A–A interval is less than the detect rate interval. Once the Detect Duration timer expires, the pacemaker switches modes.

Switching to non-atrial tracking mode

When an atrial tachyarrhythmia is detected, the pacemaker switches to the appropriate non-atrial tracking mode, as shown in Table 5-1. To avoid an abrupt drop in the ventricular rate, it smoothly reduces the pacing rate from the atrial synchronous rate to the sensor-indicated rate over several pacing cycles.

After the rate transition is completed, the pacemaker continues sensor-driven pacing in the ventricle, operating in the non-atrial tracking mode until the atrial tachyarrhythmia ceases (see Figure 5-1 and Figure 5-2).

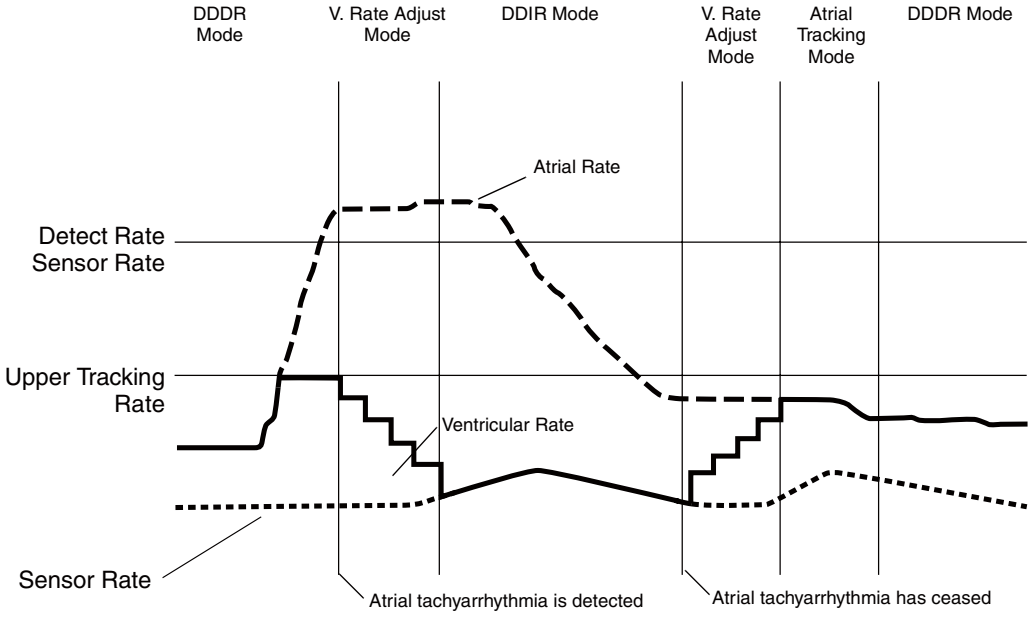


Figure 5-1. DDDR mode switching operation (without PMOP)

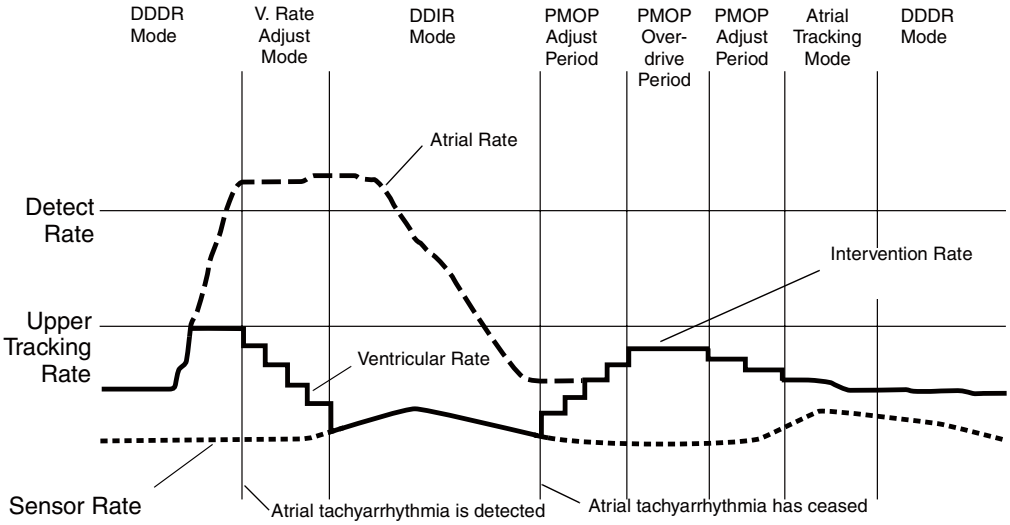


Figure 5-2. DDDR mode switching operation (with PMOP)

Switching back to atrial tracking mode

When the last seven A-A intervals are longer than the upper tracking rate interval or when five consecutive atrial paces occur, the pacemaker assumes atrial tachyarrhythmia has ceased and begins to switch back to the programmed atrial tracking mode (DDDR, DDD, or VDD). See Figure 5-1.

DDDR and DDD modes

When DDDR or DDD mode is programmed, abrupt changes in ventricular rate are avoided by smoothly varying the pacing rate during mode switches.

PMOP not programmed – If PMOP is not programmed, after the atrial tachyarrhythmia ends, the pacing rate is smoothly varied until the rate corresponds to the intrinsic atrial rate. Then the pacemaker switches to the programmed atrial tracking mode.

PMOP programmed – If PMOP is programmed, after the atrial tachyarrhythmia ends, the pacing rate is smoothly modulated until the programmed Overdrive Rate is reached. The pacemaker maintains the Overdrive Rate in DDIR mode for a programmed duration (Overdrive Period). When the Overdrive Period expires, the rate is gradually modulated until the Lower Rate or Sensor Rate is reached, and then the pacemaker switches back to the programmed atrial tracking mode.

VDD mode
If VDD mode is programmed, after the atrial tachyarrhythmia ends, the pacemaker immediately switches from VDIR back to VDD.

Mode switching interruption

The typical mode switching sequence may be interrupted by either of these two occurrences:

- The atrial tachyarrhythmia episode ceases before the pacemaker completes the rate transition to the appropriate non-atrial tracking mode.
- The atrial tachyarrhythmia episode ceases briefly but resumes before the atrial tracking mode is restored.

In either case, the pacemaker responds by adjusting the rate transition in the appropriate direction. The criteria for switching to the atrial tracking mode are unaffected.

Programming restrictions

When Mode Switch is On, several rates, timing intervals, and pacing therapies are limited to certain values as follows:

Mode Switch Detect Rate – The Mode Switch Detect Rate must be at least 10 min^{-1} greater than the Upper Tracking Rate and the Upper Sensor Rate.

PMOP Overdrive Rate – When Mode Switch is On and the PMOP Overdrive Period is set to any value, the PMOP Overdrive Rate is limited to a value greater than the Lower Rate but lower than the Upper Tracking Rate.

Rate Drop Response – Rate Drop Response is disabled for mode switching from DDD mode or AAI<=>DDD mode.

PVAB – The PVAB period is limited to a maximum of 200 ms.

SAV and PAV intervals – The SAV and PAV intervals are limited to a maximum of 350 ms. When SAV or PAV are programmed above 310 ms or Search AV+ allows the SAV interval to extend greater than 310 ms, the pacemaker issues a warning to indicate that mode switch can be delayed or prevented.

Sensor-varied PVARP – Sensor-varied PVARP is not allowed for DDDR and DDD mode switching.

Recording Mode Switch episode data

Programming Mode Switch therapy parameters also initiates automatic data collection of summary data for up to 16 atrial high rate episodes that are based on mode switch criteria. When a pacemaker is programmed for mode switch therapy, the Atrial Arrhythmia diagnostic identifies atrial high rate episodes, based on the parameters defined for mode switch therapy. In addition to the automatic data collection of summary high rate data, the pacemaker can collect detailed data for as many as 16 atrial high rate episodes, including EGM data for as many as 8 of these episodes.

The collected data can be displayed or printed from the Data icon.

Automatic summary mode switch data

The High Rate diagnostic automatically records the number of atrial arrhythmia episodes that were detected during the collection period and the percentage of time spent in atrial high rate. The High Rate diagnostic also records the following summary data for each episode.

- Date and time of episode
- Duration
- Maximum atrial and ventricular rate
- Average ventricular rate during episode
- Sensor rate
- Whether there is additional EGM or Trend data available

If the High Rate Collection Method is programmed by the clinician to Rolling, it also records the summary information above for the first, fastest (highest rate), and longest atrial high rate episodes plus the 13 most recent mode switch episodes. If the Collection Method is set to Frozen, summary data for the first 16 atrial high rate episodes in the collection period are recorded.

Detailed mode switch data

More detailed data about mode switch episodes can be collected when the High Rate Detail diagnostic is chosen as the clinician-selected diagnostic. This diagnostic collects detailed data from up to 16 high rate episodes (either 16 atrial high rate episodes, 16 ventricular high rate episodes, or 8 episodes of each type). For each episode, the diagnostic shows paced and sensed events on a trend (beat-to-beat) graph. Figure 5-3 shows a typical mode switch episode rate trend.

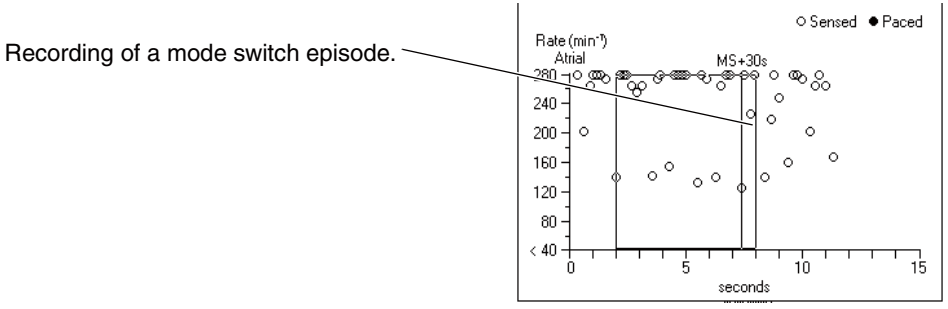


Figure 5-3. Mode switch episode rate trend

The High Rate Detail diagnostic also collects EGM data for 1, 2, 4, or 8 high rate episodes, for atrial, ventricular, or both atrial and ventricular episodes, depending upon clinician selections.

The clinician-selected Collection Type (Rolling or Frozen) parameter determines which episodes are used for collecting the high rate detail data. For more information about the High Rate Detail diagnostic, see “High Rate Episodes” on page 206.

Clearing mode switch episode data

Summary and detailed mode switch episode data is normally cleared by the pacemaker one hour after a programming session.

You can clear data immediately, using the Data Collection Setup/Clear menu option. Be sure to save the session data or print the report before ending the patient session.

Managed Ventricular Pacing (MVP)

The MVP modes promote intrinsic conduction by reducing unnecessary right ventricular pacing. These modes provide atrial-based pacing with ventricular backup. If AV conduction is lost, the pacemaker switches to DDDR or DDD mode. Periodic conduction checks are performed, and if AV conduction resumes, the pacemaker switches back to AAIR or AAI mode.

Programming guidelines

Review the following information related to programming MVP modes.

Selecting MVP modes – On the mode selection screen, the MVP modes are programmed by selecting AAIR<=>DDDR or AAI<=>DDD.

Status display – On the programmer status bar the current operating mode is displayed, as follows:

- In AAIR<=>DDDR mode, either AAIR+ or DDDR is displayed.
- In AAI<=>DDD mode, either AAI+ or DDD is displayed.

In each case, the atrial mode is followed by a “+” symbol to indicate that backup ventricular pacing is available.

V-V cycle variations – Depending on the patient’s intrinsic rhythm and conduction, MVP allows V-V cycle variations and occasional pauses of up to twice the lower rate interval. See Figure 5-4 and Figure 5-6.

PAV and SAV – For MVP modes, it is not necessary to program longer PAV and SAV values to promote intrinsic AV conduction. PAV and SAV apply only when loss of AV conduction is detected.

Lower Rate programming – Upon abrupt loss of AV conduction, prior to switching to DDDR or DDD mode, ventricular pacing support can be as low as one-half the programmed Lower Rate for two consecutive intervals. For patients with sinus bradycardia or frequent loss of AV conduction, program the Lower Rate to 50 min^{-1} or higher.

Complete heart block – For patients with complete heart block, the pacemaker will drop one beat every 16 hours (AV conduction check). See Figure 5-6. If this is undesirable, permanent DDDR or DDD modes may be more appropriate.

Long PR intervals – For patients with long PR intervals, the pacemaker will remain in the AAIR or AAI mode. Permanent DDDR or DDD modes may be more appropriate for patients with symptomatic first-degree AV block.

Programming restrictions

Search AV+ – Search AV+ is not pertinent and cannot be enabled if the pacemaker is programmed to an MVP mode.

Lower Rate and Sleep Rate – The Lower Rate and Sleep Rate parameters must be set to 35 min^{-1} or greater when the pacemaker is programmed to an MVP mode.

Sinus Preference – Sinus Preference cannot be enabled if the programmed mode is AAIR<=>DDDR. Sinus Preference is only available if the programmed pacing mode is DDDR.

Rate Drop Response – Rate Drop Response can be enabled in AAI<=>DDD mode but not in AAIR<=>DDDR mode.

How MVP operates

The MVP modes, AAIR<=>DDDR and AAI<=>DDD, provide AAIR or AAI mode pacing while monitoring AV conduction. For persistent loss of AV conduction, the pacemaker switches to DDDR or DDD mode. If AV conduction resumes, the pacemaker switches back to AAIR or AAI mode.

For transient loss of AV conduction, the pacemaker remains in the AAIR or AAI mode and provides a backup ventricular pace in response to an A-A interval that is missing a ventricular sense.

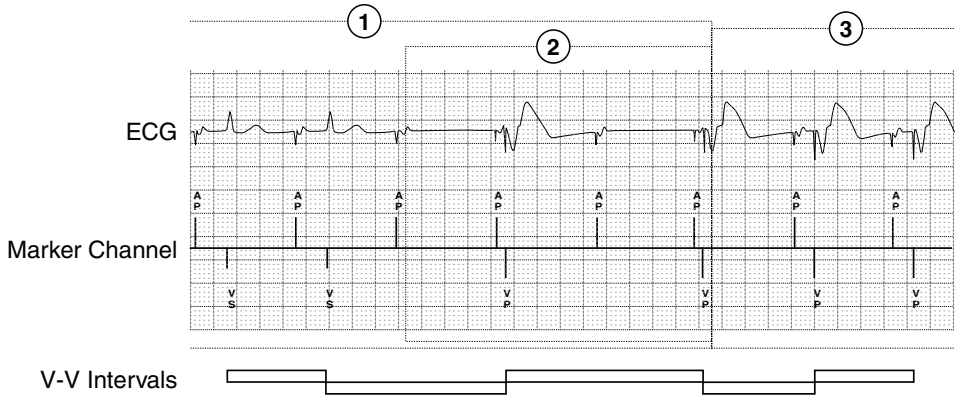
If two of the four most recent nonrefractory A-A intervals are missing a ventricular event, the pacemaker identifies a persistent loss of AV conduction and switches to the DDDR or DDD mode (Figure 5-4).

When MVP is operating in DDDR or DDD mode, the pacemaker operates as follows:

- All programmable parameters associated with DDDR or DDD mode apply.
- The pacemaker performs periodic one-cycle checks for AV conduction and the opportunity to resume AAIR or AAI therapy. See Figure 5-5 and Figure 5-6.
- The first check for AV conduction occurs after 1 min. Subsequent checks occur at progressively longer intervals (2, 4, 8 … min) up to 16 hours and then occur every 16 hours thereafter.

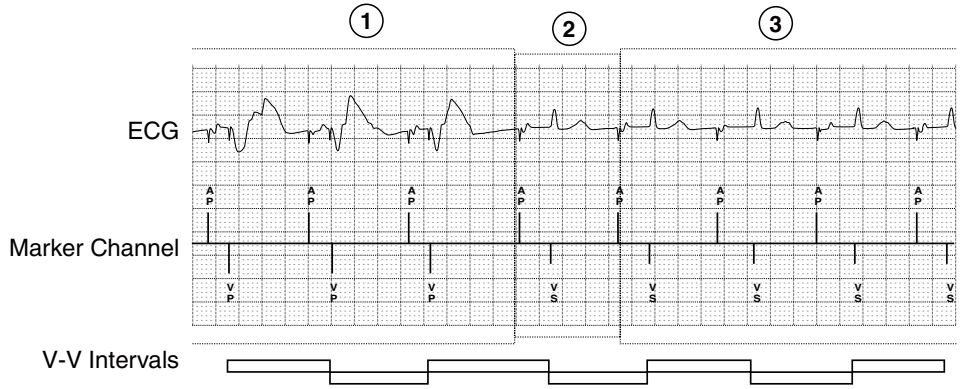
When MVP is operating in AAIR or AAI mode, the pacemaker operates as follows:

- Only programmable parameters associated with AAIR or AAI mode apply.
- Ventricular backup paces occur following A-A intervals without a valid ventricular sense. The backup paces are timed 80 ms after the A-A escape interval. A ventricular sense that occurs within 80 ms after the A-A interval is considered invalid and does not inhibit the backup pace.
- Atrial pacing is inhibited and new VA escape intervals are started in response to PVCs and PVC runs after the A-A interval.



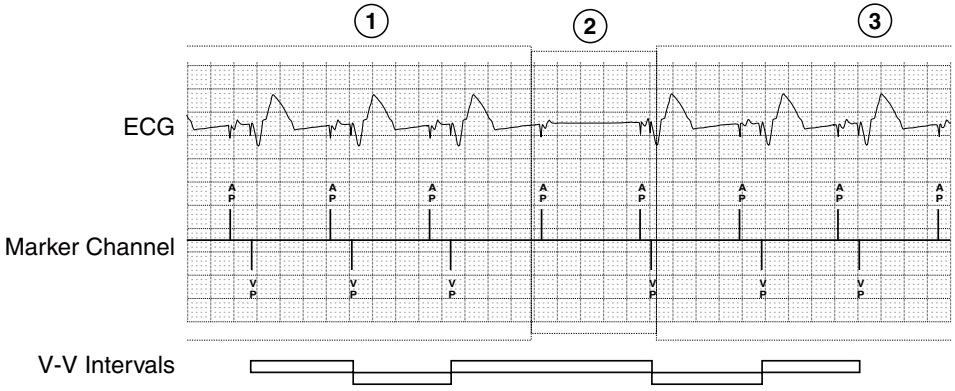
1 The pacemaker operates in AAIR mode.
2 At the onset of AV block, the pacemaker supplies ventricular backup paces.
3 The pacemaker switches to DDDR mode.

Figure 5-4. Switching from AAIR mode to DDDR mode



1 The pacemaker operates in DDDR mode.
2 The pacemaker performs an AV conduction check. AV conduction is detected.
3 The pacemaker switches to AAIR mode.

Figure 5-5. Switching from DDDR mode to AAIR mode



1 Remaining in DDDR mode after an AV conduction check

2 The pacemaker performs an AV conduction check. AV conduction is not detected.

3 The pacemaker continues to operate in DDDR mode.

Figure 5-6. Remaining in DDDR mode after an AV conduction check

Interaction with other pacemaker functions

Mode Switch – If Mode Switch is enabled, it continues to operate by switching to DDIR during AT/AF episodes.

Atrial Refractory Period (ARP) – While operating in AAIR or AAI mode, the Atrial Refractory Period (ARP) varies as a function of the current heart rate. ARP is 75% of the cardiac cycle length, up to a maximum of 600 ms.

Temporary MVP suspension – Several features suspend MVP mode changes and set the pacing mode to DDDR or DDD until their operations are complete:

- Rate Drop Response, while delivering a rate drop intervention therapy
- Lead Monitor, while waiting to gather at least one ventricular lead impedance measurement per day, which requires a ventricular pace
- Capture Management, while the pacemaker performs threshold searches

- Magnet Mode

Blanking Period – While operating in the AAIR or AAI mode, the pacemaker blanking will be 100 ms in the atrial chamber following an atrial pace or sense, 80 ms in the ventricle following an atrial pace, and 100 ms in the Ventricle following a ventricular pace or sense. Other blanking periods, such as PVAB are programmable.

Conducted AF Response

Conducted AF Response is designed to regularize the ventricular rate during AF. The pacemaker modifies the pacing rate on a beat-by-beat basis to pace close to the mean intrinsic ventricular rate. Long pauses are eliminated, thereby reducing the ventricular rate irregularity.

When programmed “On”, Conducted AF Response is activated by a Mode Switch episode (from DDDR, DDD, AAIR<=>DDDR, or AAI<=>DDD modes) or is active continuously (in DDIR, VDIR, or VVIR modes).

Note: This feature was named Ventricular Response Pacing in previous pacemakers.

How Conducted AF Response is defined

The programmable parameters below define Conducted AF Response operation.

Table 5-2. Defining Conducted AF Response operation

Parameter	Description
Conducted AF Response	On; Off
Maximum Rate	Sets a limit on the ventricular pacing rate.

Programming restrictions

Search AV+ – Conducted AF Response cannot be enabled concurrently with Search AV+ when the programmed pacing mode is DDIR or VDIR.

Interactions with other pacemaker features

Rate Response Pacing – Conducted AF Response will not cause the pacing rate to be slower than the rate response sensor-indicated rate, or faster than the programmable maximum response rate.

For more information

See “Ventricular Rate Histogram During Atrial Arrhythmias” on page 213.

Non-competitive atrial pacing

Overview

Non-Competitive Atrial Pacing (NCAP) is intended to prevent triggering of atrial tachycardias by an atrial pacing stimulus that falls within the atrium’s relative refractory period. This feature is available when the pacemaker is operating in the DDDR and DDD modes.

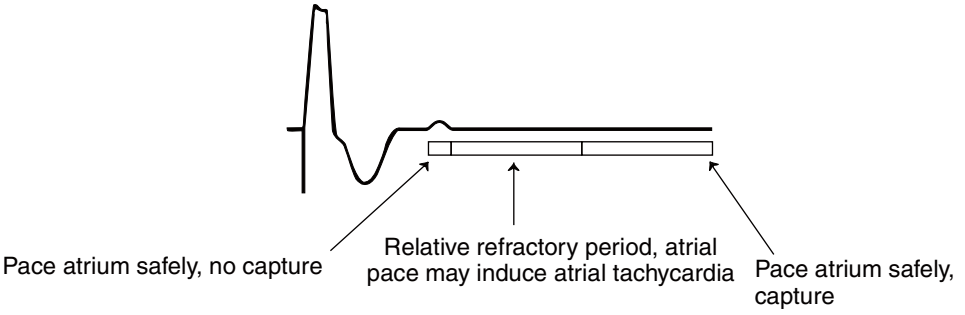


Figure 5-7. The atrium’s relative refractory period

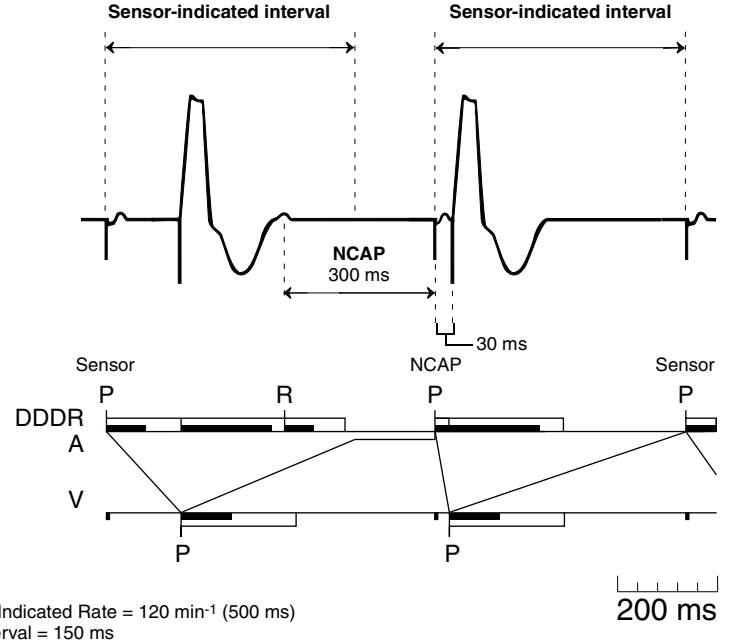
How NCAP affects atrial timing

When NCAP is programmed to On, a refractory sensed atrial event falling in the PVARP starts a 300 ms NCAP period, during which no atrial pacing may occur:

- If a sensor-driven or lower rate pacing stimulus is scheduled to occur during the NCAP period, the VA interval is extended until the NCAP period expires.
- If no pacing stimulus is scheduled to occur during the NCAP period, timing is unaffected; pacing occurs at the end of the VA interval unless inhibited.
- An atrial refractory sensed event occurring during the NCAP period starts a new NCAP period.

How NCAP affects ventricular timing

When an atrial pacing stimulus is delayed by the NCAP operation, the pacemaker attempts to maintain a stable ventricular rate by shortening the PAV interval that follows. It will not, however, shorten the PAV interval to less than 30 ms. When a relatively high Lower Rate and long PVARP are programmed, NCAP operation may result in ventricular pacing slightly below the Lower Rate.



Parameters: Sensor-Indicated Rate = 120 min^{-1} (500 ms)
PAV Interval = 150 ms
PVARP Interval = 230 ms
Post-Ventricular Atrial Blanking (PVAB) = 180 ms
Ventricular Refractory Period = 230 ms

Figure 5-8. Non-Competitive Atrial Pacing Operation

NCAP availability

The Non-Competitive Atrial Pacing is available when the pacemaker is operating in the DDDR and DDD modes. Its availability is also dependent on the following:

- When Mode Switch is programmed On, NCAP operations are temporarily disabled if the pacemaker mode switches to the non-atrial tracking mode. The NCAP feature is reenabled upon return to the atrial tracking mode.
- Even when NCAP is programmed Off, the NCAP operation is invoked automatically for cycles on which PMT Intervention or PVC Response operations occur.

For further information

Refer to “Mode Switch and diagnostic” on page 134, “PMT intervention” on page 150, and “PVC Response” on page 153 for more information on these therapy features.

PMT intervention

Overview

A Pacemaker-Mediated Tachycardia (PMT) may occur when retrograde P waves (due to a loss of AV synchrony) are sensed and tracked in an atrial tracking mode. PMT Intervention provides an automatic way for the pacemaker to detect and interrupt pacemaker-defined PMTs.

To ensure that retrograde P waves (rather than fast intrinsic rates) are being tracked, the pacemaker verifies that the sensor rate is at a moderate rate or less before intervening. This feature is available when the pacemaker is operating in the DDDR, DDD, and VDD modes.

Caution: Even with the feature turned On, PMTs may still require clinical intervention such as pacemaker reprogramming, magnet application, drug therapy, or lead evaluation.

How the pacemaker defines PMT

The pacemaker assumes that a PMT may be present when it detects a ninth ventricular pace following eight consecutive VA intervals that meet all of the following conditions:

- Duration less than 400 ms
- Start with a ventricular paced event
- End with an atrial sensed event

Sensor corroboration before intervening

On the eighth consecutive VA interval, the pacemaker verifies that retrograde P waves are being tracked, and not a fast intrinsic atrial rate, by checking the rate of the activity sensor.

- If the sensor rate is at or below the ADL Rate, a pacemaker-defined PMT episode is assumed to be present, and therapy intervention will ensue.
- If the sensor rate is above the ADL Rate, a rapid sinus rate is assumed to be present, and no therapy intervention will ensue.
- The pacemaker will continue to monitor each series of eight consecutive VA intervals and the sensor rate.

PMT therapy intervention

When a pacemaker-defined PMT is detected, the pacemaker intervenes, forcing a 400-ms PVARP after the ninth paced ventricular event (see Figure 5-9). If a PMT is indeed in progress, the extended PVARP ensures that the next atrial sensed event within 400 ms will be refractory. By interrupting atrial tracking for one cycle, the PMT may be stopped.

Note: A sinus tachycardia could cause PMT therapy intervention, resulting in a single P wave falling in the PVARP and, therefore, not being tracked by the pacemaker.

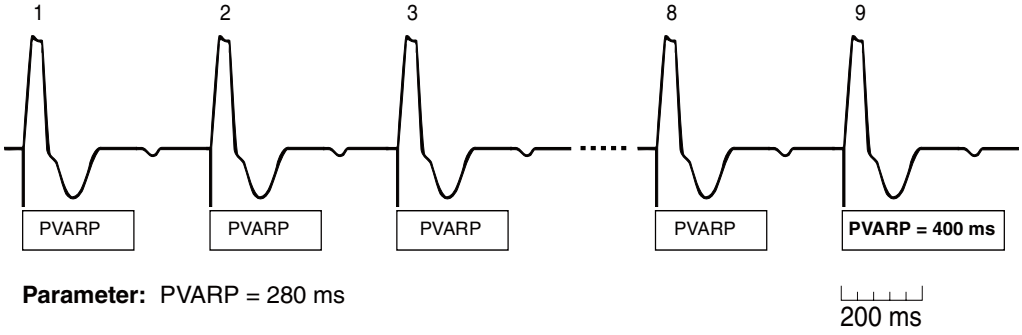


Figure 5-9. PMT Intervention

Automatic therapy suspension

After therapy intervention, PMT Intervention is automatically suspended for 90 seconds. This prevents unnecessary intervention in the presence of fast intrinsic atrial rates.

Interactions with other features

The PMT Intervention feature interacts with other pacemaker features in the following ways:

- Non-Competitive Atrial Pacing (NCAP) is automatically enabled for one cycle after the ninth ventricular pace of a pacemaker-defined PMT episode. The NCAP feature may shorten the ensuing PAV to maintain a stable ventricular rate.
- If Mode Switch is On, PMT Intervention is temporarily disabled if the pacemaker switches to the non-atrial tracking mode. It is reenabled upon return to the atrial tracking mode.

Patient intervention for PMT

When sensor-varied PVARP is active, the patient can often terminate a PMT simply by resting quietly, causing the sensor-indicated rate to drop and the PVARP to extend. When PVARP becomes longer than the retrograde time, the PMT may terminate.

For further information

Refer to “Non-competitive atrial pacing” on page 148 and “Mode Switch and diagnostic” on page 134 for more information on these therapies.

PVC Response

Overview

The Premature Ventricular Contraction (PVC) Response feature is available when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, and VDD modes. The feature, which is programmable On or Off, is intended for the following purposes:

Operation in DDDR, DDD, and VDD modes – PVC Response is intended to prevent tracking of retrograde P waves generated by PVCs. This response helps prevent initiation of pacemaker-mediated tachycardia.

Operation in DDIR and DDI modes – PVC Response prevents inhibition of atrial pacing that can result from retrograde P waves generated by PVCs.

How the pacemaker defines a PVC

The pacemaker defines a PVC as any ventricular sensed event (refractory or nonrefractory) that follows a ventricular event (pace, refractory sense, or non-refractory sense) without an intervening atrial event (pace, refractory sense, or non-refractory sense). In the VDD mode, a ventricular paced event delivered at the Lower Rate and not preceded by an atrial sensed event is also considered a PVC.

Extending PVARP

When PVC Response is On, a pacemaker-defined PVC starts an extended PVARP of 400 ms if the programmed value or the operating value is less than 400 ms (sensor-varied PVARP or automatic PVARP). This extended PVARP causes retrograde P waves within 400 ms to be identified as refractory sensed events.

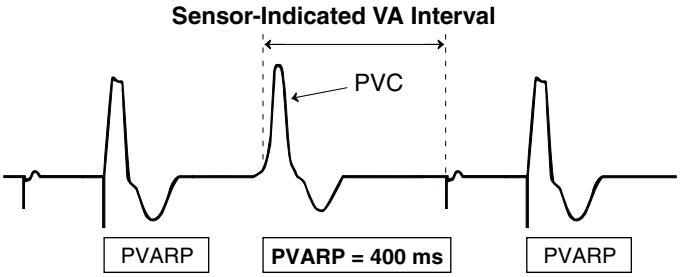


Figure 5-10. PVC response operation

Interaction with other features

PVC Response interacts with other pacemaker features as follows:

- The PVC Response feature always enables Non-Competitive Atrial Pacing (NCAP) for one cycle when NCAP is programmed Off. This occurs even when the PVARP extension occurs.
- If Mode Switching is On, PVC Response is temporarily disabled when the pacemaker switches to the non-atrial tracking mode. It is reenabled upon return to the atrial tracking mode.

PVCs automatically counted

The pacemaker automatically counts PVCs and runs of two or more consecutive PVCs. Both counts are included in the automatic Heart Rate Histogram diagnostic report.

Note: Pacemaker-defined PVCs do not necessarily correspond to physiological PVCs. For example, atrial undersensing or ventricular oversensing may result in two consecutive ventricular senses with no intervening atrial event. If high PVC counts occur, the cause should be further investigated before any therapeutic decision is made.

For further information

Refer to “Non-competitive atrial pacing” on page 148 and “Mode Switch and diagnostic” on page 134 for more information on these therapies. For information on the automatic Heart Rate Histogram diagnostic, refer to “Heart Rate Histograms” on page 200.

Ventricular Safety Pacing

Overview

Ventricular Safety Pacing (VSP) can be programmed to On or Off and is intended to prevent ventricular asystole due to inappropriate inhibition of ventricular pacing. Such inhibition may be caused by crosstalk or ventricular oversensing. The feature is available when the pacemaker is operating in the DDDR, DDD, DDIR, DDI, DVIR, and DVI modes.

- Crosstalk occurs when the ventricular lead senses atrial stimuli. When crosstalk occurs, the pacemaker may interpret the atrial paced event as a ventricular depolarization and inappropriately fail to pace the ventricle.
- Frequent VSP may be caused by a loss of atrial sensing.

Warning: VSP should always be programmed to On for pacemaker-dependent patients.

How VSP operates

When VSP is operating, a ventricular sense within 110 ms after an atrial pacing pulse results in a ventricular pacing pulse at 110 ms or at the PAV interval, whichever expires first. If the sensed event was, in fact, a ventricular depolarization, the ventricular pacing pulse at 110 ms falls harmlessly into the absolute refractory period of the ventricle.

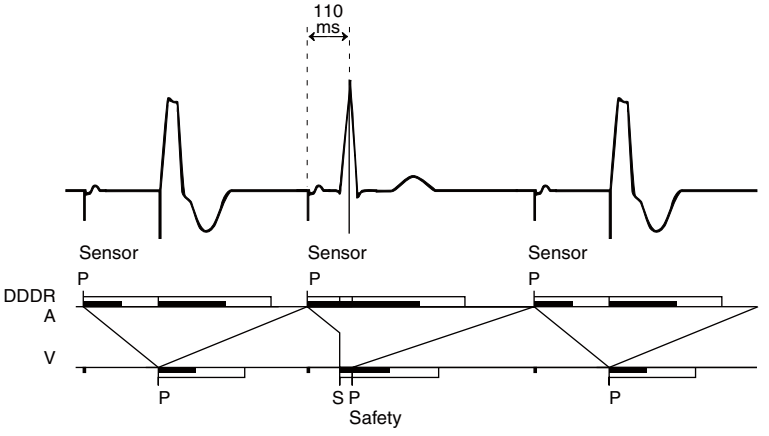


Figure 5-11. Ventricular Safety Pacing (VSP)

Sinus Preference

Overview

The Sinus Preference feature is intended to improve cardiac hemodynamics, primarily at lower rates, by providing preference to sinus activation of the heart over sensor-driven pacing. This occurs when the sinus rate and sensor-indicated rate are nearly the same. The feature permits a slower intrinsic escape rate by occasionally searching for the sinus rate below the sensor-indicated rate or when intrinsic atrial events are tracked (sinus breakthrough). This feature is available when the pacemaker is programmed to the DDDR mode.

How Sinus Preference is defined

Sinus Preference operation permits the sensor-driven pacing rate to gradually drop to a lower escape rate. If the sinus rate is not present at the *lower escape rate* for eight paced beats, the rate is gradually raised back to the sensor-indicated pacing rate. The operation is repeated for the next *scheduled time*. The two italicized terms represent the two programmable parameters below.

Table 5-3. Defining Sinus Preference operation

Parameter	Description
Sinus Preference Zone	The maximum drop in rate from the sensor-indicated rate while searching for or tracking the sinus rate. **Note:** The difference between the sensor-indicated rate and Sinus Preference Zone is held constant as the sensor rate varies.
Search Interval	The amount of time between sinus search operations.

Programming restrictions

Atrial Preference Pacing – Atrial Preference Pacing and Sinus Preference cannot be enabled concurrently.

MVP mode – Sinus Preference cannot be enabled if the programmed mode is AAIR<=>DDDR. Sinus Preference is only available if the programmed pacing mode is DDDR.

How Sinus Preference operates

Sinus Preference operates in two modalities: sinus search operation and sinus breakthrough operation.

During **sinus search** operation, the pacemaker searches for a sinus rate that is slightly below the sensor-indicated rate. When the Search Interval expires, the pacemaker gradually drops the pacing rate until the sinus rate is sensed or until the rate drops to the Sinus Preference Zone limit.

- If the sinus rate is sensed, ventricular rate is tracked to the sinus rate.
- If no sinus rate is present in the Sinus Preference Zone, the pacemaker paces at the Sinus Preference Zone limit for eight beats, whereupon rate is gradually increased to the sensor-indicated rate.

At the end of the Sinus Preference episode, the search interval is restarted and once the interval expires, the sinus search operation is repeated.

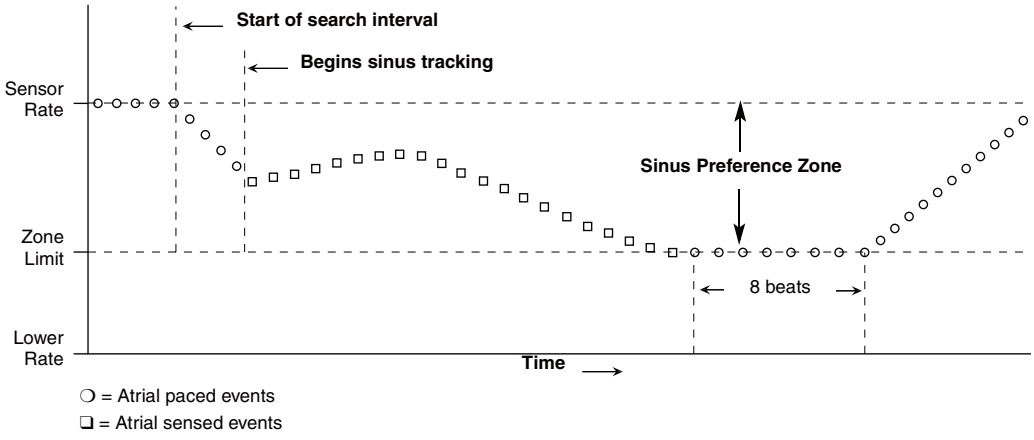


Figure 5-12. Example of Sinus Search operation

During **sinus breakthrough** operation, the pacemaker tracks the sinus rate to a rate that is below the sensor-indicated rate. The pacemaker can track the sinus rate down to the Sinus Preference Zone limit, but never below the Lower Rate.

Once the sinus rate falls below the Sinus Preference Zone limit, the pacemaker paces at this rate for eight beats, whereupon, the rate is gradually increased to the sensor-indicated rate.

Note that even though the search interval does not start the sinus breakthrough operation, the search interval is reset once sinus breakthrough tracking ends.

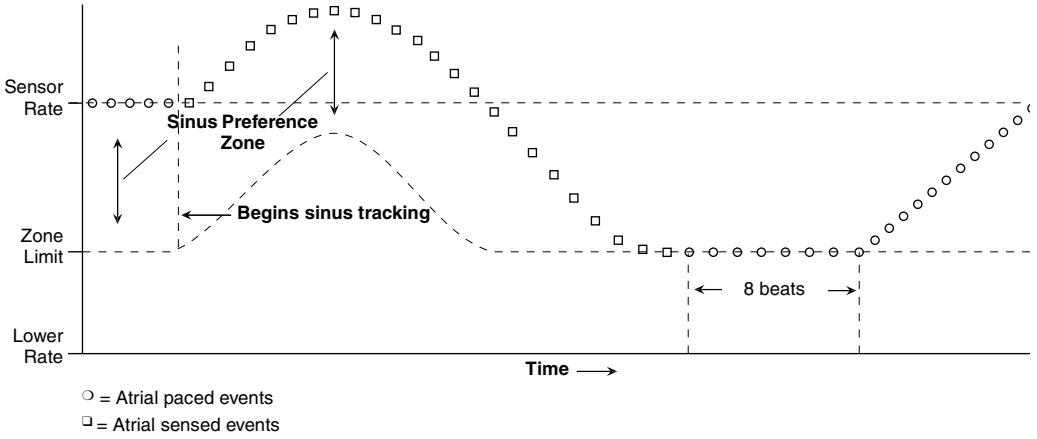


Figure 5-13. Example of Sinus Breakthrough operation

Interaction with other features

If Mode Switch is On, Sinus Preference is temporarily disabled when the pacemaker switches to the non-atrial tracking mode. It is enabled once the pacemaker returns to the atrial tracking mode.

For further information

Refer to “Mode Switch and diagnostic” on page 134 for more information on mode switching.

Atrial Preference Pacing

Overview

Atrial Preference Pacing is designed to reduce the incidence of atrial tachyarrhythmias by providing rate-variable continuous pacing, closely matched to the intrinsic sinus rate whenever it exceeds the sensor-indicated rate.

How Atrial Preference Pacing is defined

Atrial Preference Pacing gradually accelerates until atrial pacing replaces intrinsic atrial activation. After a programmable period of 100% atrial pacing, the pacemaker gradually decreases to match the sinus rate more closely. The next sinus beat reinitiates preference pacing.

Table 5-4. Defining Atrial Preference Pacing operation

Parameter	Description
A. Preference Pacing	On; Off
Maximum Rate	Sets a maximum rate for Atrial Preference Pacing.
Interval Decrement	In response to an atrial sensed event, the atrial pacing interval decreases by this value, per beat, to accelerate the pacing rate.
Search Beats	After this number of consecutive paces, the atrial rate decelerates in search of sinus activation.

Programming guidelines

Review the following information before programming Atrial Preference Pacing.

Pacemaker service life – When Atrial Preference Pacing is enabled, the pacemaker tends to provide a higher ratio of paced to sensed events, which may decrease the service life of the pacemaker.

Interval Decrement parameter – When choosing a value for the Interval Decrement parameter, be aware of these considerations:

- A larger value (for example, 100 ms) provides a more aggressive response to a sinus rate increase. This means that Atrial Preference Pacing occurs more often, more quickly, and lasts longer than with a smaller Interval Decrement value.
- A smaller value decreases the response to isolated PACs and sinus variability near the lower (or sensor) rate. Atrial Preference Pacing reacts more slowly to a sustained rate increase.

Programming restrictions

Review the following information before programming Atrial Preference Pacing.

Single Chamber Hysteresis – Atrial Preference Pacing and Single Chamber Hysteresis cannot be enabled concurrently.

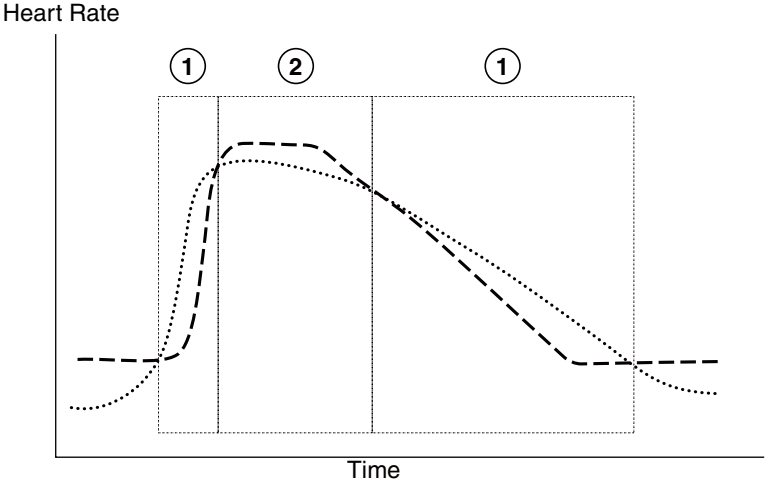
Sleep Function – Atrial Preference Pacing and the Sleep Function cannot be enabled concurrently.

Sinus Preference – Atrial Preference Pacing and Sinus Preference cannot be enabled concurrently.

Rate Drop Response – Atrial Preference Pacing and Rate Drop Response cannot be enabled concurrently.

How Atrial Preference Pacing operates

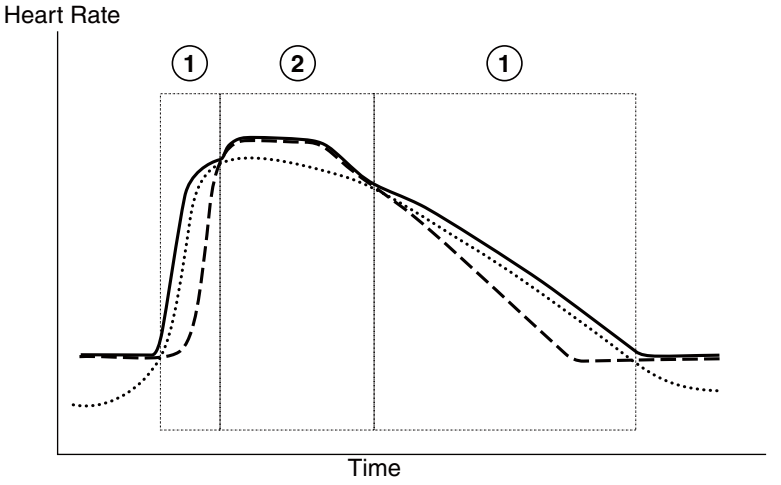
Atrial Preference Pacing is available when the pacemaker is operating in the DDDR, DDD, AAIR, or AAI modes. When Atrial Preference Pacing is enabled, the pacemaker responds to changes in the atrial rate by accelerating its pacing rate until a steady paced rhythm, slightly faster than the intrinsic rate, is obtained. Compare Figure 5-14 and Figure 5-15.



1 Intrinsic activation when the sinus rate exceeds the sensor-indicated rate.

2 Atrial pacing at the sensor-indicated rate when that rate exceeds the sinus rate.

Figure 5-14. DDDR operation without Atrial Preference Pacing



1 Atrial pacing slightly faster than the sinus rate when the sinus rate exceeds the sensor-indicated rate.

2 Atrial pacing at the sensor-indicated rate when that rate exceeds the sinus rate.

Figure 5-15. DDDR operation with Atrial Preference Pacing

On every nonrefractory atrial sensed event, the pacemaker shortens its pacing escape interval by the programmed Interval Decrement value, accelerating the pacing rate. If the next atrial event is another nonrefractory sensed event, the pacing interval is again decremented.

This progression continues until the pacing rate exceeds the intrinsic rate, resulting in an atrial paced rhythm; however, the programmed Maximum Rate value provides a rate limit for Atrial Preference Pacing.

When the number of consecutive paced atrial events reaches the programmed Search Beats value, the pacemaker adds 20 ms to the pacing escape interval, slowing the pacing rate. After the same number of consecutive paces at the new rate, the escape interval is again extended.

This progression continues until one of the following conditions occurs:

- The pacing rate reaches the Lower Rate.
- The pacing rate reaches the sensor-indicated rate.
- Pacing is interrupted by intrinsic atrial activity.

At the next nonrefractory atrial sensed event or when any atrial sensed event occurs during the deceleration, rate acceleration under Atrial Preference Pacing resumes as described above.

Interaction with other features

Mode Switch – Atrial Preference Pacing is suspended during mode switching (including PMOP).

Non-Competitive Atrial Pacing (NCAP) – The NCAP feature may delay an atrial pace that results from Atrial Preference Pacing.

Capture Management – Atrial Preference Pacing will not increase the pacing rate if an atrial sense occurs during either ACM or VCM).

Rate Drop Response and diagnostic

Overview

Rate Drop Response (RDR) is intended to provide backup pacing and prevent associated symptoms in patients who experience occasional episodes of significant drop in heart rate (e.g., syncope from cardioinhibitory and mixed forms of carotid sinus syndrome).

When a rate drop episode is detected, the pacemaker intervenes with an elevated rate for a brief period of time. RDR can be set to intervene following a drop in heart rate which meets programmed criteria, Lower Rate pacing occurs, or both. RDR is available only in the AAI<=>DDD, DDD and DDI modes.

How the pacemaker intervenes

When a drop of a specified size below a specified rate is detected or a drop to the Lower Rate is detected, the pacemaker intervenes by pacing at a programmed Intervention Rate for a programmed Intervention Duration:

- When the Intervention Duration expires, the pacemaker slowly reduces the pacing rate by approximately 5 min^{-1} steps per minute until the intrinsic rate is sensed or the Lower Rate is reached, whichever is higher.
- When the intervention cycle ends, standard operations for the programmed mode resumes.

Note that the intervention cycle may be terminated at any time by the occurrence of three consecutive nonrefractory sensed atrial events.

How the drop detection option defines a specified rate drop

A pacemaker-defined RDR rate drop is when the sensed or paced ventricular rate drops by the programmed Drop Size or more to below the programmed Drop Rate within the programmed Detection Window (see Figure 5-16).

Note: Episodes with variability in the presyncope rate are detected by RDR as long as the rate drop meets the Drop Size and Detection Window criteria.

If the intrinsic ventricular rate drops too slowly to meet the RDR detection criteria, the pacemaker paces at the Lower Rate if the intrinsic rate drops below the Lower Rate.

RDR can also be set to intervene when the rate drops below the Lower Rate by programming RDR to Both.

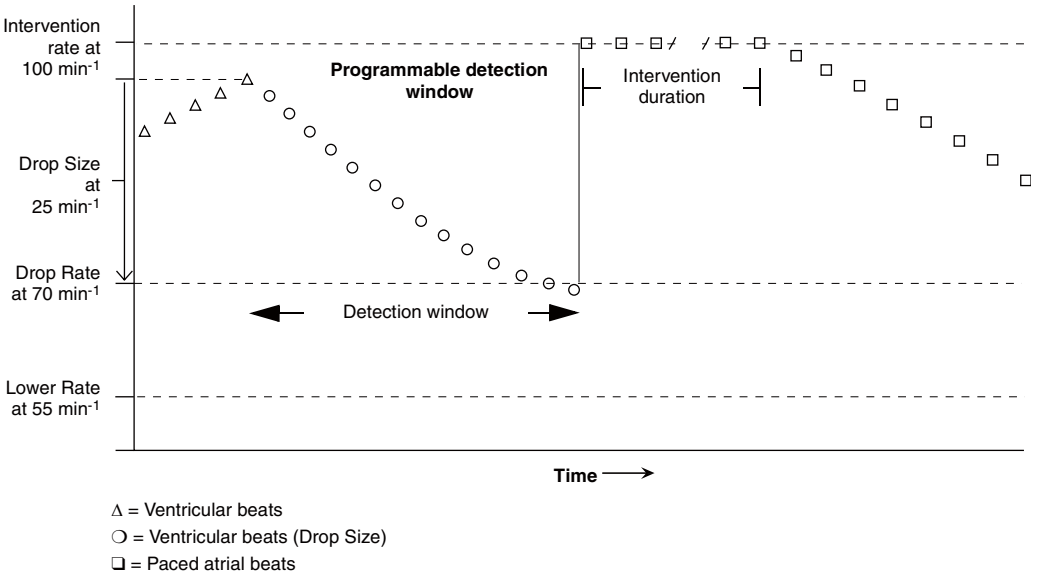


Figure 5-16. RDR intervention (drop detection at specified rate in DDD mode)

How the low rate detection operates

A pacemaker-defined RDR episode at the Lower Rate is when the heart rate drops to the Lower Rate and the atrium or ventricle is paced at the Lower Rate for a consecutive number of Detection Beats (see Figure 5-17).

Note that detecting a low rate RDR episode in the ventricle is applicable to the DDI mode only.

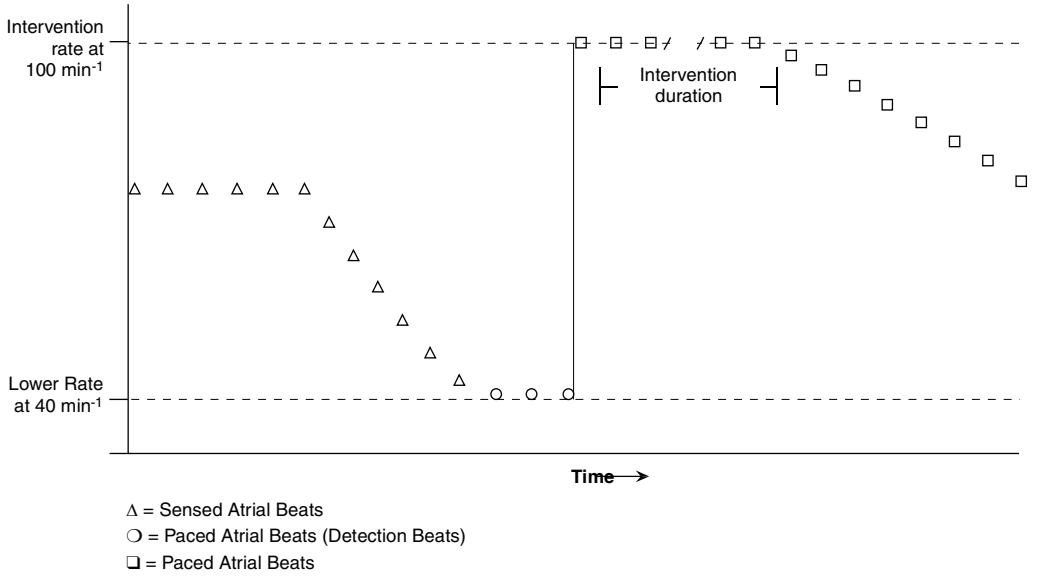


Figure 5-17. RDR intervention (low rate detection in DDD mode)

Programming guidelines

DDD and DDI modes – RDR therapy is typically used in the DDI mode for patients with intact AV conduction. RDR is used in the DDD mode for patients with complete or transient AV block during rate drop episodes.

AV intervals – Program the Paced AV interval to 150 ms for a therapeutic paced AV delay during RDR therapy intervention. While RDR therapy intervention is not in progress, intrinsic activation of the ventricles should be accomplished by using either MVP mode, or DDD mode with Search AV+ enabled.

Drop detect operation – For predictable rate drops, configure RDR to the shortest rate drop profile before syncope occurs by programming Drop Detection:

- Set Lower Rate below the normal sinus rate at rest.
- Set Drop Rate above the rate where syncope occurs.
- Set Drop Size at the shortest observed rate drop prior to syncope.

- Set Detection Window long enough to detect the slowest expected rate drop.

Low rate detect operation – For unpredictable rate drops, configure RDR to lower rate detection by programming Low Rate Detection:

- Set Lower Rate below the normal sinus rate at rest. Be sure to consider the patient's heart rate during sleep. See "Sleep Function" on page 171.
- Set Detection Beats to the desired number of paced beats (at the lower rate) to confirm the low rate episode.

Both operations – For a mix of predictable and unpredictable rate drops, configure RDR to both operations by programming Both. Select values for Drop Rate, Drop Size, Detection Window, Lower Rate, and Detection Beats as indicated above.

Therapy intervention – Set the Intervention Rate at a sufficient rate and the Intervention Duration to a long enough duration to prevent syncope and/or minimize associated symptoms.

Sleep Function – Program the Sleep Function On if undesirable symptoms occur (due to RDR intervention) while the patient sleeps. RDR is temporarily disabled during sleep times when the Sleep Function is active.

Note: Patients that are prone to rate drop episodes during sleep times should not have the Sleep Function On so RDR can intervene, if necessary.

Programming restrictions

Rate Drop Response subordinate parameters – The Drop Rate cannot be less than the programmed Lower Rate. The Intervention Rate cannot be greater than the programmed Upper Tracking Rate and must be greater than the programmed Lower Rate.

Capture Management – When both Capture Management and RDR are operating, RDR will be suspended during the pacing threshold search. Programming Capture Management to search for pacing thresholds at night can mitigate the interaction.

Mode Switch – Mode Switch is unavailable when RDR is programmed On.

Rate Adaptive AV, Sensor-Varied, and Automatic PVARP – Rate Adaptive AV, sensor-varied PVARP, and automatic PVARP are unavailable when RDR is programmed on.

Atrial Preference Pacing – Rate Drop Response and Atrial Preference Pacing cannot be enabled concurrently.

Recording of Rate Drop Episodes

Programming Rate Drop Response therapy parameters automatically initiates recording of episode summary data. You may also select to record detailed information about the first episode and the four most recent episodes.

Summary of Rate Drop Episodes

The Rate Drop Response Episodes diagnostic records a summary of both low rate detect and specified drop detect episodes. Specifically, it collects the following for the first and the nine most recent episodes:

- Type of episode
- Date and time
- Rate that resulted in a RDR intervention

It also counts both types of episodes up to a maximum of 255 for each episode type.

The data can be displayed and printed from the Data icon.

Detail Rate Drop Episode data

The clinician selected Rate Drop Response Detail diagnostic records a detailed beat-to-beat rate trend of cardiac events proceeding Rate Drop Response intervention. Episodes are defined by the programmed Rate Drop Response therapy parameters. A beat-to-beat trend is collected for the first and the four most recent episodes. Each trend can have a maximum of 680 events and is frozen when the detection criteria are met. Figure 5-18 shows a typical detail rate drop response trend.

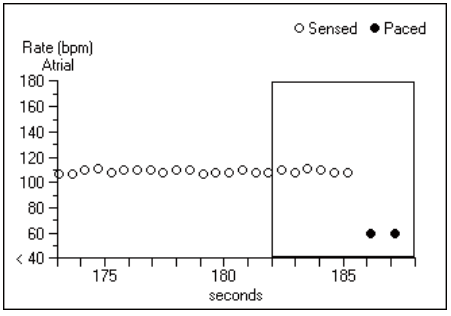


Figure 5-18. Detail Rate Drop Response trend

Data can be displayed and printed from the Data icon.

Clearing Rate Drop Episode data

Rate Drop Episode data is normally cleared by the pacemaker one hour after a programming session.

You can select the option to clear data immediately. Be sure to save the session data or print the episode report before ending the patient session.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for diagnostic retrieval instructions.

Sleep Function

Overview

The Sleep Function suspends the programmed Lower Rate and replaces it with a Sleep Rate (slower than the Lower Rate) during a specified sleep period. The slower pacing rate during the sleep period is intended to reduce the paced rhythm during sleep. This feature is available in all pacing modes.

How the Sleep Function works

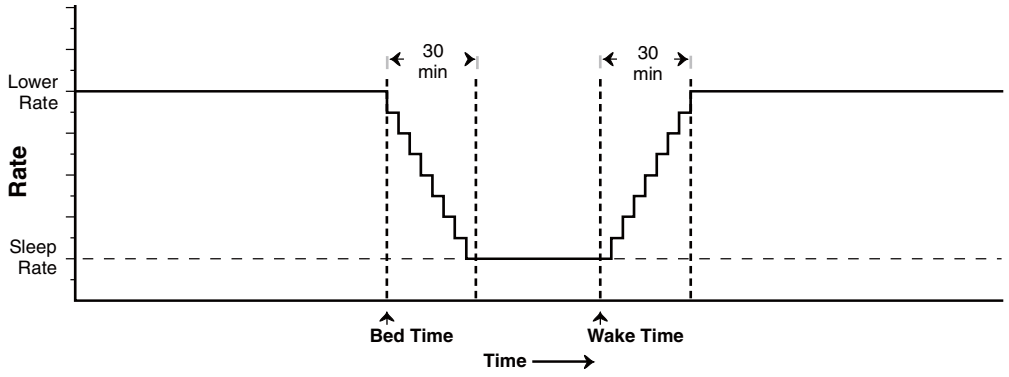


Figure 5-19. Sleep Function operation

The Sleep Function is controlled by three programmable parameters: Bed Time, Wake Time, and Sleep Rate. The Sleep Function works as follows:

1. During the 30 minutes following the programmed Bed Time, the pacemaker gradually reduces the operating rest rate from the Lower Rate to the Sleep Rate.
2. The Sleep Rate remains in effect as the operating rest rate until the programmed Wake Time.
3. During the 30 minutes following the programmed Wake Time, the pacemaker gradually raises the operating rest rate from the Sleep Rate to the Lower Rate.

Notes:

- To ensure that the Bed Time and Wake Time parameters are accurate, keep your programmer set to the correct time.
- Bed Time and Wake Time values are defined in a 12-hour format.

In rate responsive modes, the sensor-indicated rate drops to the Sleep Rate, but increases as usual in the presence of sensor-indicated activity.

Interrupting the Sleep Function

Applying a magnet or the programming head over the pacemaker during the sleep period causes the pacemaker to abandon Sleep operation and restores the programmed Lower Rate. The Sleep Function resumes at the next scheduled Bed Time.

Programming considerations

When setting Bed Time and Wake Time, consider time zone changes resulting from travel, daylight savings time, and variations in the patient's sleep patterns (such as variable work shifts). Bed Time and Wake Time must differ by at least one hour.

When Sleep Function is active, Rate Drop Response therapy intervention is temporarily disabled.

Programming restrictions

Atrial Preference Pacing – Atrial Preference Pacing and Sleep Function cannot be enabled concurrently.

Evaluating Sleep Function operation

The clinician selected Custom Rate Trend or automatic Heart Rate Histogram diagnostics may be used to evaluate the operation of the Sleep Function. Refer to "Custom Rate Trend" on page 216 and "Heart Rate Histograms" on page 200.

Single Chamber Hysteresis

Overview

Single Chamber Hysteresis lets the pacemaker track an intrinsic rhythm below the programmed Lower Rate. This prevents the pacemaker from overriding slow but appropriate intrinsic rhythms that may develop during extended periods of inactivity such as sleep. Hysteresis is programmed to a rate below the Lower Rate. The feature, which is programmed to a Hysteresis Rate or Off, is available in AAI, ADI, VVI, VDI, AAT, and VVT modes.

How hysteresis works

When the Single Chamber Hysteresis Rate is programmed, a sensed event temporarily suspends the Lower Rate, and the pacemaker determines its escape rate from the hysteresis rate instead. As long as the intrinsic rate remains above the hysteresis rate, pacing is inhibited. The first occurrence of an escape pace at the Hysteresis Rate suspends hysteresis operations and reestablishes the Lower Rate as the escape rate.

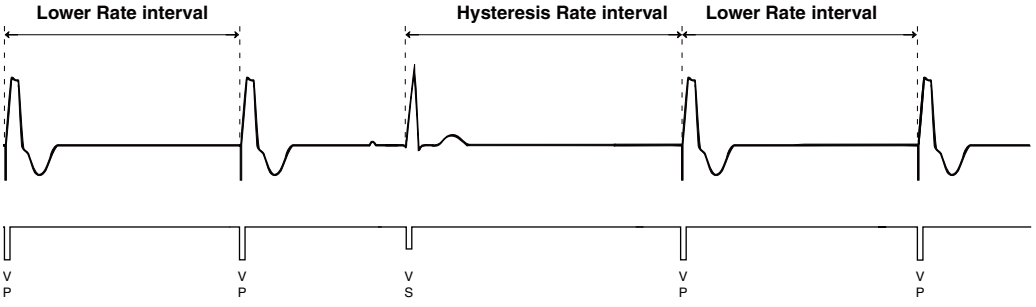


Figure 5-20. Single chamber hysteresis operation

Programming considerations

Hysteresis is intended for patients with a predominately normal sinus rhythm without ventricular irritability. Some patients may experience undesirable cardiac arrhythmias near the Hysteresis Rate (such as bigeminal beats). Therefore, verify adequate cardiac support at the Hysteresis Rate before programming. The difference between the Hysteresis Rate and the Lower Rate is typically not greater than 30 min^{-1}.

Programming restrictions

Atrial Preference Pacing – Atrial Preference Pacing and Single Chamber Hysteresis cannot be enabled concurrently.

Interactions with other pacemaker functions

Sleep Function – Hysteresis is inoperative when the Sleep Function is operating and if the Sleep Rate is programmed to a rate equal to or lower than the Hysteresis Rate.

Telemetry data 6

Establishing telemetry

Telemetry is established by placing the programming head over the implant site and moving the head along the axis as shown in Figure 6-1.

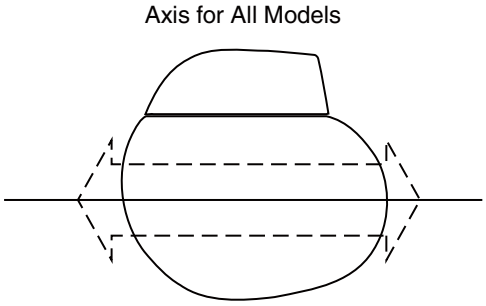


Figure 6-1. Positioning the programming head

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for instructions on positioning and using the programming head.

Parameter summary

Overview

When interrogated by the programmer, the pacemaker telemeters the programmed parameter settings along with battery status and device identification. Some features enable the pacemaker to alter previously programmed values (see “Possible variation from programmed values” on page 177).

Parameters reported

The programmer reports only parameters pertinent to the programmed mode. Depending on the programmed mode, the telemetered parameters and pacemaker data may include:

- Mode
- Pacing rates
- AV intervals
- Refractory periods
- Blanking periods
- Pulse amplitudes
- Pulse widths
- Sensitivities
- Polarities
- Rate Response features
- Therapy features
- Device identification
- Serial number
- Battery / lead values

Possible variation from programmed values

In general, parameters will be set to their values from the previous programming session. Exceptions are as follows:

Rate Profile Optimization – If programmed On, rate response parameters can change each day, as described in “Rate response” on page 36.

Lead Monitor – Bipolar polarities can revert to backup unipolar polarities if an out-of-range lead is detected, as described in “Lead Monitor” on page 94.

Capture Management – The pacemaker can check for atrial and ventricular capture. If enabled, it can adjust the amplitude and pulse width, as described in “Capture Management and diagnostic” on page 98.

Sensing Assurance – If this feature is active, the pacemaker can change the sensitivity for one or both leads to track changes in the sensed amplitude. Refer to “Sensing Assurance and diagnostic” on page 118.

Search AV+ – If the pacemaker does not observe intrinsic ventricular activation during its periodic searches over the course of a week, it turns off the Search AV+ feature.

Electrical Reset – If the pacemaker has undergone a full or partial electrical reset, the reported parameters will differ from their previously programmed settings, as described in “Electrical reset” on page 191.

Recommended Replacement Time (RRT/ERI) – If RRT/ERI is set, the reported parameters will be the RRT/ERI values, as described in “Recommended Replacement Time (RRT/ERI)” on page 193.

Note: If one of the AV Therapies (e.g., Search AV+) is active, the pacemaker can change the *operating values* (not the *programmed values*) of SAV and PAV.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for instructions on retrieving pacemaker parameters and data.

Patient information

Overview

The pacemaker can store information about the patient. After an interrogation, you can display and print this data from the programmer by selecting the Patient Information option under the Patient icon.

This information can be revised and reprogrammed during a patient session. In addition, it can be used to generate a warning message (for example, if Transtelephonic Monitoring is programmed for a patient having an implanted defibrillator).

Parameters reported

The types of patient data stored in the pacemaker are as follows:

- **Notes**
- **Patient Identification**
  - Name
  - Age
  - I.D. Number
  - Chart Number
- **Indications for Implant**

  The History window allows you to program the clinical conditions that are made available to TherapyGuide (see page 179).
- **Atrial and Ventricular Leads Implanted**
  - Lead Manufacturer
  - Lead Model
  - Lead Serial Number
  - Lead Implant Date
- **Device Implanted**
  - Serial Number
  - Implant Date
- **Physician information**
  - Name
  - Phone No.

Using TherapyGuide to select parameter values

Caution: TherapyGuide does not replace a physician's expert judgment. The physician's knowledge of the patient's medical condition goes beyond the set of inputs presented to TherapyGuide. The physician is free to accept, reject, or modify any of the suggested parameter values.

TherapyGuide offers a simple clinically-focused method for a clinician to obtain suggested parameter values. At implant or an early follow-up appointment, the clinician enters information about the patient's clinical conditions. Based on those inputs the programmer suggests parameter values. The suggestions are based on clinical studies, literature, current practice, and the consensus of physicians.

Table 6-1 shows an example of how programming suggestions are determined by combinations of clinical conditions. The programmable features (and certain clinical conditions) shown in the table do not apply to all pacemaker models. To learn which of the following features apply, refer to the Implant Manual for that pacemaker.

Table 6-1. Example of how programming suggestions are determined

Programming suggestions	Clinical conditions
Mode/Mode Switch	Atrial Status AV Conduction Reflex Syncope Lead Chamber
Rate Response	Heart Failure Age Activity Level Reflex Syncope
Lower Rate	Atrial Status Age Reflex Syncope
Upper Tracking Rate	Age
AV intervals (including RAAV and Search AV+)	Atrial Status AV Conduction
Atrial Preference Pacing and Post Mode Switch Overdrive Pacing	Atrial Status Reflex Syncope
Rate Drop Response	Atrial Status Reflex Syncope

From the TherapyGuide window, You can perform the following functions:

- Select the clinical conditions that describe your patient.
- Get Suggestions, and program the parameters that TherapyGuide makes pending to pacemaker memory.

- View a Rationale window, and learn what parameter settings are suggested by specific clinical conditions.

The clinical conditions can be printed from the Patient Information screen. They are also included in the Initial Interrogation report and in the Save to Disk file.

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for more information about using TherapyGuide.

Battery and lead information

Overview

The pacemaker can telemeter measured and calculated values for battery parameters, pacing outputs, and leads to the programmer. This data may be used both for routine assessment of pacing system performance and for evaluating suspected problems.

Telemetered data

The battery and atrial and ventricular lead data are as follows:

- **Battery status:**
  - Message “OK” or “Replace Pacer”
  - Date of Implant
  - Estimated Time to Replacement (years or months)
  - Voltage (V)
  - Current (μA)
  - Impedance (ohms)
- **Atrial and/or ventricular outputs and leads:**
  - Pulse Width (ms)
  - Amplitude (V)
  - Output Energy (μJ)
  - Measured Current (mA)
  - Measured Impedance (ohms)
  - Pace Polarity (unipolar/bipolar)

Conditions and variance in measurements

Measurement conditions – When the pacemaker measures lead information, it temporarily sets Amplitudes to 5.0 V, Pulse Widths to 1.0 ms, Rate to 100 min^{-1}, and AV interval to 100 ms for several beats.

Battery measurements – As the battery is depleted, the measured battery voltage gradually drops, and the battery impedance gradually increases.

Chronic Lead Impedance Trend

The automatic diagnostic Chronic Lead Impedance Trend tracks changes in lead data. Significant changes in chronic lead data could indicate a lead dislodgment or fracture.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for instructions on retrieving battery and lead data.

Marker Channel telemetry

Overview

Marker Channel telemetry provides simple depictions of paced and sensed events that aid in evaluating pacemaker timing and operations. These annotations are most useful when used in conjunction with a simultaneous ECG and/or EGM. Marker Channel telemetry is available in all modes.

Standard Marker Channel telemetry

When Extended Markers is programmed as Standard, telemetry provides annotated vertical markers of paced, sensed, and refractory sensed events. Atrial markers and ventricular markers have distinctive placements and heights to denote the type of event marked.

Marker Channel telemetry can be used to identify which ECG events are treated as paced or sensed events by the pacemaker and to measure timing intervals, as shown in Table 6-2.

Table 6-2. Marker Channel annotations

AP	-	Atrial pace
AS	-	Atrial sense
AR	-	Atrial sense in refractory
VP	-	Ventricular pace
VS	-	Ventricular sense
VR	-	Ventricular sense in refractory
TP	-	Triggered pace (AAT and VVT pacing mode)
MS	-	Mode switch (switch to non-atrial tracking mode and back to atrial tracking mode)
ER	-	Error marker (flags a marker signal that could not be decoded)

Therapy Trace telemetry

When Extended Markers is programmed to Therapy Trace, telemetry provides information when certain therapy features modify timing intervals. The standard Marker Channel annotations appear on-screen, but the added Therapy Trace markers can be used with a special external monitor to evaluate the operation of pacemaker features. They include:

- A/V Sense Margin markers
- Lead Monitor markers
- Capture Management markers

Note that Therapy Trace markers are not available when temporary parameters are in effect.

Intracardiac electrograms

Overview

The pacemaker can be configured to telemeter intracardiac electrograms (EGM). An intracardiac EGM is a real-time waveform of cardiac activity as detected by one or both leads. Depending on the programmed Mode and Telemetry Mode, the EGM options are:

- Atrial EGM
- Ventricular EGM
- Dual EGM
- Summed EGM

The programming head must be held in place over the pacemaker while telemetering EGMs. To inhibit pacing and display intrinsic events only on the Intracardiac EGM, enable the programmer Inhibit function.

Warning: Use caution when using the programmer to inhibit pacing. The patient is without pacing support when pacing is inhibited.

Intracardiac electrogram recording

Pacing stimuli are not detected by the Intracardiac EGM circuitry, but the programmer inserts simulated pacing pulses in the appropriate locations on the Intracardiac EGM recording accompanied by Marker Channel annotation. The Intracardiac EGM can be displayed on the programmer or printed as shown in Figure 6-2.

Note: The simulated pacing pulses on the Intracardiac EGM should not be interpreted as representing the actual amplitude of paced events. Use an ECG to determine such events.

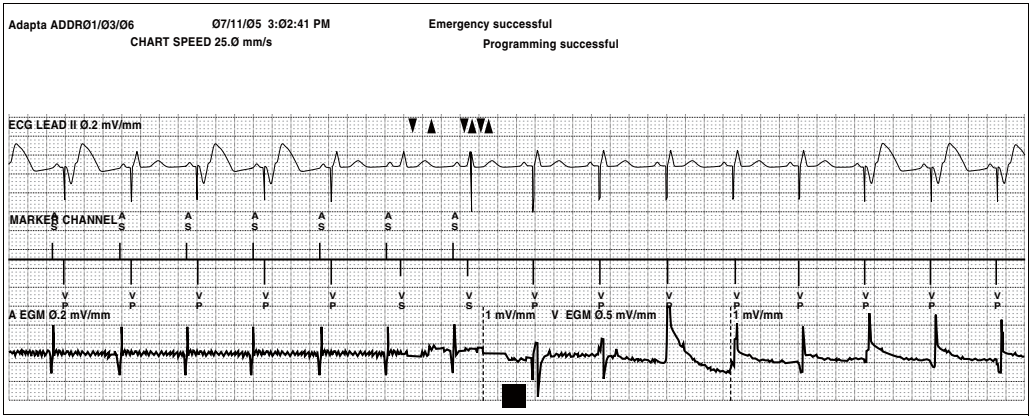


Figure 6-2. Intracardiac electrogram with Marker Channel recordings

Uses for the Intracardiac Electrogram

The Intracardiac Electrogram shows intracardiac waveforms and event timing as the pacemaker sees them. It may be used as follows:

- Atrial and ventricular waveforms may be evaluated for the following:
  - Relative amplitude of intrinsic signals
  - Myopotentials or electromagnetic interference (EMI)
  - Loss of atrial capture
  - Retrograde P waves
  - Retrograde conduction time (Summed or Dual EGM)
  - AV conduction time (Summed or Dual EGM)
  - Supraventricular tachycardias
- Timing intervals may be evaluated as follows:
  - Appropriate Paced AV and Sensed AV parameters may be determined by measuring AV conduction times.
  - Appropriate Post-Ventricular Atrial Refractory Period (PVARP) in the DDDR, DDD, DDIR, DDI, and VDD modes may be determined by measuring retrograde conduction times.

Note: Do not use absolute intracardiac amplitudes measured from the Intracardiac EGM to assess the programmed Sensitivity. Test for sensing thresholds instead.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for additional information on accessing Intracardiac Electrograms.

Extended Telemetry

Overview

Extended Telemetry is a programmable On or Off feature intended for frequent patient monitoring in the programmed mode during a 48-hour period.

- When Extended Telemetry is On, the pacemaker continuously transmits an EGM with marker telemetry regardless of whether the programming head is applied or not.
- Extended Telemetry is automatically programmed Off by the pacemaker after 48 hours. (A programmer command can terminate the feature before automatic shutoff.)

Extended Telemetry options

When Extended Telemetry is On, one of the following extended telemetry types may be selected for automatic transmission:

- Marker Channel annotations (Standard markers)
- Therapy Trace markers

For a description of these marker types, refer to “Marker Channel telemetry” on page 182.

Additional battery drain

Because Extended Telemetry continuously transmits an EGM, it significantly increases pacemaker battery current drain.

- Generally, longevity will be reduced by approximately one day for each day that Extended Telemetry is On.
- Extended Telemetry should not be used when Recommended Replacement Time (RRT/ERI) is set.

Miscellaneous operations 7

Magnet Mode operation

Overview

When the programming head is placed over the pacemaker, Magnet Mode is automatically cancelled and the programmed mode is maintained.

Magnet Mode operations begin in two ways:

- When you run Magnet test with the programmer.
- If a transtelephonic magnet is placed over the pacemaker (closing the magnetic reed switch).

A Threshold Margin Test (TMT) automatically occurs when Magnet mode starts. The Transtelephonic Monitor feature, if programmed On, enhances the communication of transtelephonic information.

Magnet Mode operation

When initiating the Magnet Mode, the pacemaker switches to an asynchronous mode and paces at the magnet rate.

- Magnet Modes are as follows: DOO in modes with dual chamber pacing, VOO in the VDD mode, and VOO/AOO in single chamber modes.
- Magnet rate for normal operation is 85 min^{-1} for all modes.
- Magnet rate is 65 min^{-1} when Recommended Replacement Time (RRT/ERI) is set or a full electrical reset has occurred.

Note: For the purpose of determining Magnet Modes, the AAI<=>DDD and AAIR<=>DDDR modes are considered dual chamber modes.

Magnet Mode remains in effect as long as the Magnet Test is operating or the transtelephonic magnet is over the pacemaker. When the Magnet test is stopped or the transtelephonic magnet is removed, the pacemaker resumes programmed operation within 2 seconds.

Note: When Emergency VVI pacing is active, the pacemaker automatically starts Magnet Mode operation for the first application of the programming head, and it remains in Magnet Mode until the programming head is removed.

Threshold Margin Test

The pacemaker performs a Threshold Margin Test (TMT) when Magnet mode starts to allow a check for loss-of-capture. A TMT is performed at 100 min^{-1} with the amplitude reduced by 20% on the third pulse.

Warning: A loss-of-capture at a 20% reduction in amplitude indicates that the stimulation safety margin is inadequate. As soon as possible, reevaluate the patient's threshold and reprogram outputs for a 2:1 stimulation safety margin. Imminent loss of ventricular capture for a pacemaker-dependent patient may constitute an emergency situation.

Transtelephonic Monitor feature

The Transtelephonic Monitor feature, if programmed On, enhances the communication of transtelephonic information by delaying the TMT for five seconds upon application of the magnet. Programming the feature Off does not affect conventional transtelephonic monitoring.

Special operation with Extended Telemetry

When the Extended Telemetry feature is On, the pacemaker responds to the programming head or magnet application by sending telemetry data, as described in "Extended Telemetry" on page 186.

For further information

"Transtelephonic follow-up features" on page 129 provides a detailed discussion of the transtelephonic follow-up features:

- Threshold Margin Test
- Extended Telemetry

Temporary programming

Overview

Pacing mode and certain other parameters may be programmed temporarily for diagnostic purposes or to test their effects on pacing operations prior to programming. Programmed settings are restored automatically when the programming head is removed or the telemetry link is broken.

Temporarily programmable parameters

Six pacing parameters may be programmed temporarily:

- Mode
- Rate
- Pulse Amplitudes
- Pulse Widths
- Sensitivities
- AV Intervals

Note: Available temporary parameter values are dependent on the programmed mode and, if a test is in progress, the type of test. “Temporary parameters” on page 313 lists detailed temporary parameter values.

Temporary refractory period settings

During Temporary test operation, refractory periods for dual and single chamber modes remain set to the programmed values, except for the following conditions:

- For temporary single chamber modes programmed at rates above 180 min^{-1}, the refractory period is set to 150 ms.
- For temporary DDD and VDD modes (if the programmed mode is dual chamber), PVARP programmed as Auto or Varied is temporarily set to 340 ms.

Note that Atrial Blanking is temporarily set to 100 ms for single chamber atrial modes and dual chamber modes.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for additional information on temporary programmable parameters.

Electrical reset

Overview

An electrical reset is a device-activated safety feature that can reset device parameters to values that provide basic device functionality. These basic parameters are considered safe for the vast majority of patients. Pacing remains active during a reset condition.

An electrical reset may occur when the device is exposed to extreme conditions, such as cold temperatures (before implant); intense, direct x-ray exposure; electrocautery; or external defibrillation.

Two types of electrical reset are possible:

Partial reset – Polarity, pacing mode, rates, and certain other parameters are preserved.

Full reset – Pacing resumes in the VVI mode at 65 min^{-1} with reset parameters.

The programmer detects and reports any reset condition when the pacemaker is interrogated. A full reset also may be inferred when the ECG shows VVI pacing at 65 min^{-1} and the battery is not depleted. In this case, Recommended Replacement Time (RRT/ERI) is not set.

Partial electrical reset

If a partial electrical reset occurs, the pacemaker automatically preserves the following parameters to their programmed states:

- Pacing Mode
- Pacing and Sensing Polarities
- Lower Rate, Upper Tracking Rate, and Upper Sensor Rate
- Amplitudes, Pulse Widths, and Capture Management operation
- Sensitivities and Sensing Assurance operation
- Mode Switch selection
- Rate Profile Optimization
- Implant Detection
- Lead Monitor selection
- RAAV and Search AV+ operation
- PVARP setting
- RRT/ERI status
- Other therapy features

All other parameters are changed to their electrical reset values, as described in Section B.

Full electrical reset

If a full electrical reset occurs, all programmed values are lost and set to electrical reset values. Refer to “Electrical reset settings” on page 251 for parameter values. When power is restored, the pacemaker is initially set to the VVI mode at 65 min^{-1}.

While pacing in the VVI mode, the pacemaker automatically restarts the implant detection sequence. Optionally, the pacemaker can be manually programmed by first using the programmer’s reset command.

Note: If after interrogating the pacemaker a message appears on the programmer screen or printout indicating the date/time memory has been altered or the model has changed to SES01(Adapta, Versa, Sensia) or RES01 (Relia), contact your Medtronic representative for further information.

Recommended Replacement Time (RRT/ERI)

Overview

The Recommended Replacement Time (RRT/ERI) is reported upon interrogation with the programmer when the pacemaker battery is nearly depleted. When the RRT/ERI is set, the pacemaker is automatically reprogrammed to a distinctive set of parameters (VVI mode at 65 min^{-1}).

Basis for setting RRT/ERI

RRT/ERI is set when the battery voltage drops below a certain limit and remains there. The RRT/ERI criteria for the pacemaker are listed in “Recommended Replacement Time (RRT/ERI)” on page 282. When RRT/ERI is set, diagnostic data collection is suspended, but data previously collected is retained in the pacemaker’s memory.

Note: Exposing the pacemaker to extreme cold temperatures can inadvertently set RRT/ERI. Usually, the pacemaker can reset an RRT/ERI caused by cold temperatures when it is warmed to room temperature. If the pacemaker does not reset the RRT/ERI during warm-up, use the programmer reset command to reset it.

Caution: When RRT/ERI is set and verified, the pacemaker must be replaced within three months. For details, refer to “Prolonged service period” on page 282.

RRT/ERI verification

When the programmer detects that RRT/ERI is set, it displays a message. A programmer command can be used to reset the RRT/ERI. First a stress test is performed to determine the battery’s condition. If the battery fails the stress test, the programmer does not reset RRT/ERI. Because RRT/ERI is set only after multiple voltage measurements, it is unlikely to be set prematurely, except when the device is exposed to cold temperatures for extended periods.

Emergency pacing

Emergency pacing provides VVI pacing at 70 min^{-1} at high output settings in emergency situations for pacemaker-dependent patients. Refer to “Emergency settings” on page 263 for more information.

Diagnostics 8

Introduction to diagnostics

Diagnostics provide data to evaluate the patient's intrinsic rhythm and the pacemaker's operation. The pacemaker offers two types of diagnostics to aid in this evaluation:

- Diagnostics that run in the background automatically.
- Clinician-selected diagnostics of which only one can be active at a time.

Most of the diagnostics are available in all pacing modes, while some are pertinent only to dual chamber modes or certain therapy features. Four diagnostic modes are also available: ADIR, ADI, VDIR, and VDI. These modes offer the opportunity to record events in the non-paced chamber.

The pacemaker automatically clears diagnostic data one hour after a patient session and then restarts data collection of the background diagnostics and the one clinician-selected diagnostic.

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information about displaying diagnostic data and which diagnostic data is available for each model.

Automatic diagnostics

The automatic diagnostics consist of summary data collection types that run continuously in the background of normal pacing operation. These diagnostics monitor intrinsic and paced events, lead integrity, and certain therapy episodes. In most cases, the diagnostics are fully automatic and require no intervention by the clinician, although a few have programmable options. Listed below are brief summaries of the automatic diagnostics and sections of the manual that provide detailed information about each diagnostic.

Heart Rate Histograms – Collects short and long term heart rate and percent-paced data of the atrium and ventricle. See “Heart Rate Histograms” on page 200.

AV Conduction Histograms – Collects short and long term AV conduction sequences. See “AV Conduction Histograms” on page 202.

Search AV+ Histograms – Collects conduction sequences resulting from the Search AV+ function. See “Automatic Search AV+ Histogram” on page 72.

Sensor Indicated Rate Profile – Automatically collects sensor rate data for the programmed rate responsive mode. See “Sensor Indicated Rate Profile” on page 205.

High Rate Episodes – Collects summary data about atrial and ventricular high rate episodes. If the pacemaker is programmed for mode switch therapy, the atrial high rate episode data collected are based on mode switch criteria. Otherwise, the atrial high rate episodes are based on criteria defined specifically for collection of atrial high rate data. See “High Rate Episodes” on page 206.

Atrial Arrhythmia Trend – Collects data indicating how much time in each day of the collection period that the patient spent in atrial arrhythmia episodes. See “Atrial Arrhythmia Trend” on page 214.

Ventricular Rate Histogram During Atrial Arrhythmias – Collects data about ventricular rates during atrial arrhythmia episodes, to show how successfully ventricular rate is being controlled. See “Ventricular Rate Histogram During Atrial Arrhythmias” on page 213.

Atrial Arrhythmia Durations – Collects data about the duration of atrial arrhythmia episodes and shows (on the Initial Interrogation Report) the number of episodes that occurred in each of eight categories, based on duration lengths. See “Atrial Arrhythmia Durations” on page 216.

Lead Impedance – Collects long-term lead impedance trend and performance data. Lead impedance trend data is collected every 7 days for the most recent 14 months and performance data is continually collected until it is manually cleared. See “Automatic Lead Impedance (Chronic Lead Trend)” on page 97.

Rate Drop Response Episodes – Collects basic data on rate drops and rate drop response therapy intervention. See “Summary of Rate Drop Episodes” on page 169.

Capture Management Trend – Collects threshold, pulse width, and amplitude data every 7 days for the most recent 14 months. See “Summary Capture Management data” on page 116.

Sensitivity Trend – Collects data about the operation of the Sensing Assurance feature every seven days. See “Summary Sensing Assurance data” on page 121.

Key Parameter History – Records key parameter values for the last eight programming sessions. See “Key Parameter History” on page 219.

Clinician-selected diagnostics

The clinician-selected diagnostics consist of programmable types that collect detailed data on specific intrinsic episodes, patient symptoms, and lead and rate trends. Some of the clinician-selected diagnostics provide more detailed data to an equivalent automatic diagnostic. Only one clinician-selected diagnostic can be active at a time. Listed below is a brief summary of each of the clinician-selected diagnostics.

High Rate Detail – Collects rate trend (beat-to-beat) data from up to 16 atrial or ventricular high rate episodes, or from up to 8 high rate episodes of each type. This diagnostic also collects EGM data for one or more episodes. These diagnostics correspond to and supplement the data collected in the automatic high rate episodes diagnostic. If the pacemaker is programmed for automatic mode switch therapy, atrial high rate episodes collected are based on the therapy parameters for mode switching. See “Programmable data collection” on page 208 and “Detailed mode switch data” on page 141.

Atrial Capture Management Detail – Records the atrial pacing threshold for every capture management search. Data can include an electrogram. See “Detail Capture Management data” on page 117.

Ventricular Capture Management Detail – Records the ventricular pacing threshold for every capture management search. Data can include an electrogram. See “Detail Capture Management data” on page 117.

Rate Drop Response Detail – Collects detailed data on rate drop response therapy in the DDD, DDI, or AAI <=> DDD modes. A rate trend for the first and the four most recent episodes is available. It supplements the automatic Rate Drop Response episodes diagnostic. See “Detail Rate Drop Episode data” on page 170.

Custom Rate Trend – Collects heart rate and percent-paced trends over a beat-to-beat, 1-hour, or 24-hour period. See “Custom Rate Trend” on page 216.

Battery and lead data

The pacemaker reports the status of battery voltage, estimated time to replacement, and other parameters. It also reports the status of atrial and ventricular lead impedance, polarity, and other parameters. Refer to “Telemetry data” on page 175 for more information.

Suspending and clearing of data

The pacemaker automatically suspends all diagnostic data collection while the programming head or magnet is applied to the pacemaker.

Note: If a magnet has been applied, data collection resumes when the magnet is removed. Applying a magnet does not clear diagnostic data.

Interrogating the pacemaker automatically clears diagnostic data one hour after the end of the programming session unless you select the option to clear data immediately. Data collection resumes after the clearing of diagnostic data.

Note: Automatic chronic trend diagnostic data (Atrial Lead Trend, Ventricular Lead Trend, and Atrial Arrhythmia Trend) can be cleared from the Clear Data screen. Clearing the Ventricular Chronic Lead Trend also clears the automatically collected Ventricular Capture Management trend. Clearing the Atrial Chronic Lead Trend also clears the Atrial Capture Management trend. The Sensor Indicated Rate Profile is only cleared when programming certain rate response parameters or another rate responsive mode.

When the Recommended Replacement Time (RRT/ERI) is tripped, all diagnostic data collection is suspended. At RRT/ERI, the previously collected diagnostic data are retained. When a partial or full electrical reset occurs, all diagnostic data is lost.

Heart Rate Histograms

The Heart Rate Histogram shows the range of the patient's heart rate (to a resolution of 10 min^{-1}) recorded since the last patient session and the relative percentage of heart beats distributed over that range. This histogram is intended as an aid for evaluating rate response parameter settings and chronotropic incompetence.

This example shows typical data for a long-term ventricular heart rate histogram.

The graph shows the percentage of all sensed and paced events in each rate range.

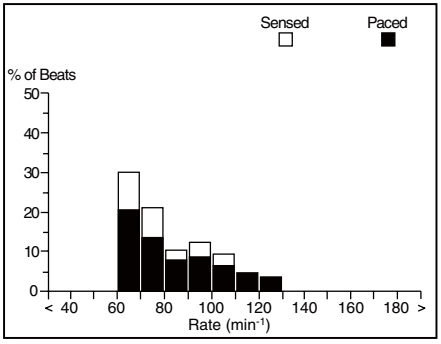


Figure 8-1. Ventricular Heart Rate Histogram

Automatic data collection

The Heart Rate Histograms can be displayed for two intervals of data collection:

- Short term heart rate histograms represent data collected over the last 3 to 6 days.
- Long term heart rate histograms represent data collected since the last follow-up.

Heart Rate Histograms show what percentage of the rate events counted during the monitoring period fall into each 10 min^{-1} segment in the range of 40 min^{-1} to 180 min^{-1}. (The "< 40" min^{-1} group also includes events occurring below 40 min^{-1}; the "180 >" min^{-1} group also includes events occurring above 180 min^{-1}.) Each 10 min^{-1} event group is coded to show the percentage of paced events and the percentage of sensed events. See Figure 8-1.

Both atrial and ventricular histograms display the pertinent programmed parameter settings. Ventricular histograms also display the recorded number of single PVCs and PVC runs. Atrial histograms display the number of PAC runs.

Event counters

Histograms have the following ventricular or atrial information in dual chamber modes (including VDD, VDIR, VDI, ADIR, and ADI modes):

Premature Ventricular Contraction (PVC) – Counts pacemaker-defined PVCs (a VS event following a ventricular event with no intervening atrial event) and runs of two or more consecutive PVCs with no intervening atrial event.

Premature Atrial Contraction (PAC) – Counts pacemaker-defined PAC (an AS event following an atrial event with no intervening ventricular event) runs of two or more consecutive PACs with no intervening ventricular event.

Note: Counting ceases when any counter reaches its maximum count, but this is unlikely since each counter can store several years of data.

Retrieving the atrial and ventricular rate histograms

If data were collected during device operation in a dual chamber mode (including ADIR, ADI, VDIR, VDI, and VDD modes), both atrial and ventricular histograms can be viewed by selecting the Histogram field at the top of the display.

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information on collecting rate histogram data.

AV Conduction Histograms

The AV Conduction Histogram diagnostic counts and collects paced and sensed AV conduction sequences. The diagnostic classifies specific types of AV sequences by rate range and the percentage of the total AV sequences counted in dual chamber modes. The pacemaker automatically collects the histogram data without any programming by the clinician. The AV Conduction Histogram is intended for purposes such as the following:

- To determine whether programmed PAV and SAV intervals are promoting or inhibiting AV conduction in sick sinus syndrome patients, and the rates where transitions occurs.
- To determine at what upper rates the programmed Rate Adaptive AV operation limits AV conduction.

This example shows short-term AV histogram data.

The graph shows the percentage of all AV sequences (AS-VS, AS-VP, AP-VS AP-VP) in each rate range.

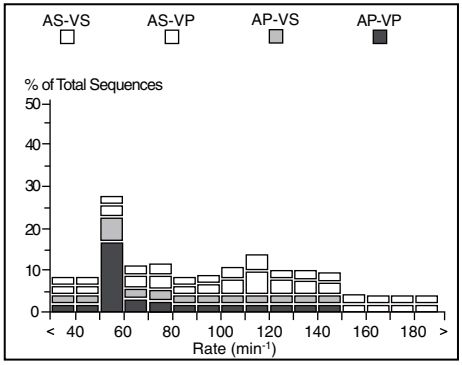


Figure 8-2. Example of AV conduction histogram data

Automatic data collection

The diagnostic collects all AV sequences between 40 and 180 min^{-1} and classifies AV sequences by rate range and sequence type (bin). Events below 40 min^{-1} are counted in the lowest event group; rates above 180 min^{-1} are counted in the highest event group. The sequence type categories are as follows:

- AS-VS, AS-VP, AP-VS, and AP-VP (dual chamber modes, including MVP modes)
- AS-VS and AS-VP (VDD, VDIR, and VDI modes)
- AS-VS and AP-VS (ADIR and ADI modes)

Atrial and ventricular refractory sensed events are not counted. Ventricular safety paced events are counted as atrial paced to ventricular paced events (AP-VP).

There are two types of AV Conduction Histograms collected:

Short Term AV Conduction Histogram – Contains the last three-to-six days of rate range data and sequence types.

Long Term AV Conduction Histogram – Contains the summation of rate range data and sequence types since the last programming session.

The collection period for the AV conduction histogram is indicated by the starting and ending date when the data is interrogated. Once any rate bin is full, data collection stops, but this is unlikely since the device can collect several years of data.

Total events

The percentages of the types of AV event sequences are indicated as follows:

- Dual chamber modes (including MVP modes): AS-VS, AS-VP, AP-VS, and AP-VP
- VDD, VDIR, and VDI modes: AS-VS and AS-VP
- ADIR and ADI modes: AS-VS and AP-VS

Note: Counting ceases when any counter reaches its maximum count but this is unlikely since each counter can store several years of data.

Retrieving the AV Conduction Histogram

When an interrogation of the pacemaker is performed, the programmer retrieves the histogram data and presents the short-term and long-term histograms on rate distribution profile graphs. For each rate range, the percentage of AV sequences in each category is presented. The diagnostic information can be displayed from the Graphs and Tables screen.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information on collecting AV conduction histogram data.

Search AV+ Histogram

The Search AV+ feature is intended to promote intrinsic ventricular activation in patients with intact or intermittent AV conduction and prevent inappropriate therapy in patients without conduction. Search AV+ is available when the pacemaker is programmed to the DDDR, DDD, DDIR, DDI, DVIR, DVI, or VDD mode. The pacemaker searches for the patient's intrinsic AV conduction time and adjusts the SAV and PAV intervals either longer or shorter to promote intrinsic activation of the ventricles. When Rate Adaptive AV is active, the pacemaker also adjusts the SAV and PAV intervals relative to the rate adaptive values. If the pacemaker does not observe intrinsic ventricular activation during its periodic searches over the course of a week, it turns off the Search AV+ feature. For more information on Search AV+, see "Search AV+ and diagnostic" on page 69.

This diagnostic is intended to show the amount of ventricular sensing which is due to the extension of the AV interval by Search AV+.

Automatic data collection

The Search AV+ Histogram data is automatically collected when Search AV+ is programmed On. This histogram shows the percentage of A-VS, VS from Search, and A-VP intervals versus rate.

Search AV+ Histogram data can be displayed from the Graphs and Tables screen.

This example shows Search AV+ histogram data.

The graph shows the percentage of all AV sequences (A-VS, VS from Search, A-VP) in each rate range.

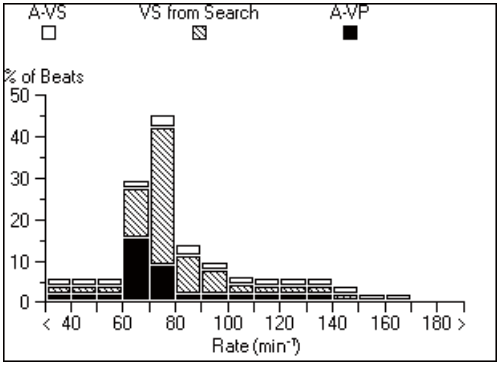


Figure 8-3. Example of Search AV+ histogram data

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information on collecting Search AV+ Histogram data.

Sensor Indicated Rate Profile

The Sensor Indicated Rate Profile records sensor rates regardless of the programmed mode and classifies them by rate ranges. The pacemaker automatically collects the data without any programming by the clinician. This diagnostic is intended for evaluating the Rate Profile Optimization feature.

This example shows a typical sensor indicated rate profile graph.

The percentage of time in each rate range is shown.

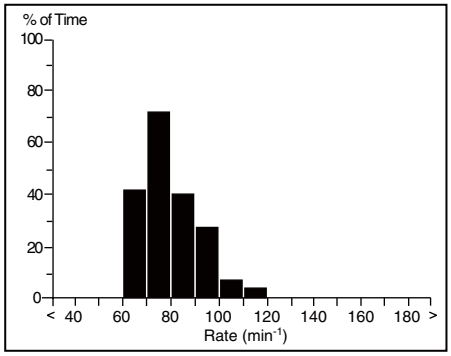


Figure 8-4. Sensor Indicated Rate Profile data

Automatic data collection

The diagnostic records the sensor-indicated rate every two seconds. Rates are recorded in rate groups (bins) between the rates of 40 and 180 min^{-1}. Rates below 40 min^{-1} are counted in the lowest rate group; rates above 180 min^{-1} are counted in the highest rate group.

Note: Sensor Indicated Rate Profile data is normally retained by the pacemaker, regardless of any other diagnostic programming. The data is only cleared when reprogramming rate response parameters or another rate responsive mode.

Retrieving the Sensor Rate Profile

When an interrogation of the pacemaker is performed, the programmer retrieves the profile data and presents a chronic rate profile graph. The report can be displayed from the Graphs and Tables screen.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for information on collecting Sensor Indicated Rate Profile data.

High Rate Episodes

The High Rate Episodes diagnostics are used to detect episodes of atrial or ventricular tachycardia, and to record summary and detailed data that are useful in the assessment of these episodes.

Automatic data collection

The automatic High Rate Episodes diagnostics automatically record two types of summary data: data for the overall collection period (see “Collection period summary data” on page 206) and data for up to 32 specific high rate episodes (see “Specific High Rate Episode data” on page 207). In addition, detailed data for some of these high rate episodes can also be collected, if the High Rate Detail diagnostic is chosen as the clinician-selected diagnostic (see “Programmable data collection” on page 208).

Collection period summary data

Automatically-collected high rate data includes the following summary data for the entire collection period:

- A count of all atrial and ventricular high rate episodes that occurred during the collection period.
- Percentage of time during the collection period spent in atrial high rate.
- Number of premature atrial contraction runs.
- Number of premature ventricular contractions, both singles and runs.

Specific High Rate Episode data

For up to 16 atrial high rate episodes and up to 16 ventricular high rate episodes, the pacemaker automatically records the data listed below, using a programmable data collection type (either rolling or frozen):

- Date, time, and duration of each episode.
- Maximum atrial and ventricular rate during the episode.
- Average ventricular rate.
- Sensor rate when the high rate was detected (displayed only in reports).
- Whether EGM or trend data was collected for each episode.

Data collection period and collection capacity

The collection period for the high rate episodes is indicated by the starting date and ending date when the pacemaker is interrogated. The maximum number of high rate episodes the pacemaker will count is 16,777,215 atrial episodes and 16,777,215 ventricular episodes. Once a limit is reached, the count for that episode type is frozen.

Definition of high rate episodes

If the pacemaker is programmed for mode switch therapy, atrial high rate episodes are defined by the therapy parameters for mode switch therapy (see “Mode Switch and diagnostic” on page 134). If the pacemaker is not programmed for mode switch therapy, atrial high rate episodes are defined by criteria selected by the clinician on the Data Collection/Setup screen. Ventricular high rate criteria are defined on the Data Collection/Setup screen.

Note: For atrial high rate episodes, the initial interrogation report and the High Rate Episode diagnostic screens indicate if the episodes are based upon mode switch criteria.

Rolling or frozen data collection

Either rolling or frozen data collection can be selected for recording summary data for high rate episodes. This clinician selection applies to data collection for both atrial and ventricular high rate episodes. With rolling data collection, the first, fastest, longest, and most recent 13 episodes of each type that have occurred since the data collection was reset are recorded. With frozen data collection, the first 16 high rate episodes of each type during the collection period are recorded.

Supraventricular tachycardia episode filter

The pacemaker can be programmed to filter out detection of conducted supraventricular tachycardia episodes and thus improve detection of true episodes of ventricular tachycardia, using the SVT Filter. The filter removes ventricular high rate episodes that are detected during mode switch episodes, and is effective only when mode switch therapy is enabled. Clinicians can set this filter on the Data Collection Setup screen.

Programmable data collection

The High Rate Detail diagnostic allows clinicians to program the pacemaker to collect more detailed onset and termination data for some of the atrial and/or ventricular high rate episodes for which summary data was automatically collected. Detailed data consists of the following:

- Marker Channel and beat-to-beat data for up to 16 atrial or ventricular episodes, or up to 8 episodes of each type
- EGM data for an allocated number of episodes

Marker Channel data

This data represents detailed rate trend from the onset of a atrial high rate episode, based on mode switch (MS) therapy criteria.

"Seconds" indicates when each sensed and paced event occurred.

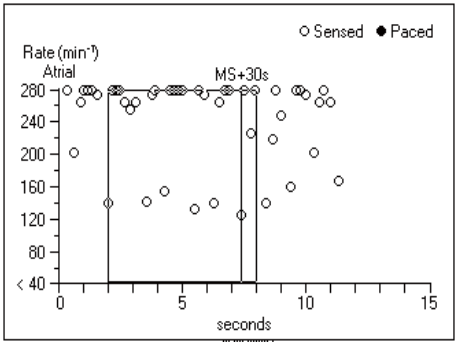


Figure 8-5. Atrial high rate detailed episode data

For each high rate episode for which detailed data is collected, this diagnostic collects Marker Channel and beat-to-beat (see Figure 8-5) data for the following:

- Up to 40 pre-onset events
- Up to 20 post-onset events
- Up to 10 pre-termination events

Pre-onset data and pre-termination data are temporarily stored in rolling buffers and collected as detailed data only after the detection or termination criteria are met (see "Detection criteria" on page 211). For any high rate episode, the number of post-onset and pre-termination events for which data is collected depends upon the duration of the episode. For episodes of short duration, the post-onset data and pre-termination data may overlap.

When the High Rate Detail diagnostic is selected, Marker Channel or beat-to-beat trend data are collected for up to either 16 atrial high rate episodes or 16 ventricular high rate episodes, or for 8 episodes of each type (as described in Table 8-1).

Table 8-1. Marker Channel data collection

Collection type	High rate collection type	Episodes collected
Frozen	AHR only	First 16
	VHR only	First 16
	VHR and AHR	First 8 AHR and first 8 VHR
Rolling	AHR only	First 1 + last 13
	VHR only	First 1 + last 13
	VHR and AHR	Last 8 AHR and last 8 VHR

EGM data

The specific data collected for High Rate Detail is controlled by these diagnostic parameters:

- High Rate Type: AHR, VHR, or both
- EGM Type: AEGM, VEGM, Summed, or Off
- EGM Allocation: how many episodes with EGM collection and how the EGM is aligned relative to the episode onset
- Pre-detection Timeout: the time limit in which pre-onset EGM can be collected

For single-chamber pacemakers, High Rate Detail data is available for the paced chamber.

Each choice for EGM Allocation represents a number of episodes and the number of seconds of pre-onset and post-onset EGM to be collected for each episode. If High Rate Type set to AHR&VHR, the number of episodes is split evenly between atrial episodes and ventricular episodes.

Note: If EGM data is being collected for an AHR or VHR episode while an episode of the other type occurs, no EGM data is collected for the second episode.

Refer to “Clinician-selectable diagnostics” on page 292 for EGM Allocation values related to the settings of High Rate Type and Collection Method. These values are presented in three sections of “Clinician-selectable diagnostics” on page 292: one section for Adapta and Versa models, one section for Sensia models, and one section for Relia models.

Note: If Rolling collection is programmed and several episodes of one type occur before episodes of the other type occur, EGM collection for the first type will use all allocated EGM storage until the other episode type occurs. For example, if an allocation of 4 EGM episodes is programmed and both AHR and VHR High Rate Types are selected, an occurrence of 4 consecutive VHR episodes results in EGM collection for all 4 VHR episodes. If any AHR episodes subsequently occur, EGM data for the first 2 AHR episodes replaces the EGM data of the oldest 2 VHR episodes. Thereafter, EGM data are allocated equally between the 2 triggers.

EGM can be collected with a programmable Pre-detection Timeout of 1 to 12 weeks, in 1-week increments, or of 14 to 24 weeks, in 2-week increments. If episodes occur before the programmable timeout, pre-onset and post-onset EGM can be collected. If episodes occur after the programmable timeout, only post-onset EGM can be collected.

Note: If pre-onset EGM and Rolling collection are programmed, and the EGM Pre-detection Timeout expires, EGM collection will occur for an extra episode. For example, if EGM Allocation is programmed to “4 for 4/4 secs”, the user would go from 4 episodes with EGM (prior to the timeout) to 5 episodes with EGM (after the timeout).

How high rate episodes are defined

The automatic and clinician-selected capabilities of the diagnostics can be programmed to collect summary and detailed data about specific ventricular high rate episodes and atrial high rate episodes. Detection and termination criteria for these episodes are described in the following paragraphs.

Detection criteria

Clinician-defined atrial high rate episodes – Begin when, during a specified number of seconds (A. Detection Duration), 4 of 7 atrial intervals are shorter than a specified duration (A. Min. Detection Rate).

Mode Switch defined atrial high rate episodes – Begin when the pacemaker's Mode Switch therapy switches from a tracking mode to a non-tracking mode. The programmable parameter Collection Delay After Mode Switch allows the collection diagnostic to ignore mode switch episodes of very short durations (0-60 seconds).

Ventricular high rate episodes – Begin when a specified number of sequential heart beats (V. Events to Detect) exceeds a specified rate (V. Min. Detection Rate). If the clinician has set the SVT Filter to On, ventricular high rate detection criteria are disabled during Mode Switch episodes.

Termination criteria

Clinician-defined atrial high rate episodes – Terminate when a specified number of consecutive atrial intervals (A. Events to Terminate) is longer than a specified rate (Atrial Termination Rate).

Mode Switch defined atrial high rate episodes – Terminate when the pacemaker's Mode Switch therapy switches from a non-tracking mode back to a tracking mode (Mode Switch therapy ends).

Ventricular high rate episodes – Terminate when a specified number of consecutive ventricular intervals (V. Events to Terminate) is longer than a specified rate (Ventricular Termination Rate).

Limitation to detect high rate atrial events

In the DDDR, DDD, DDIR, DDI, VDD, VDIR, and VDI modes, atrial sensing is blanked for a programmable interval (the Post-Ventricular Atrial Blanking period) following any ventricular event. Detection of atrial high rate episodes in these modes may be inhibited by blanking and may result in a periodic rate drop on the diagnostic report.

Retrieving atrial and ventricular high rate diagnostics

When a full interrogation of the pacemaker is performed, the programmer retrieves the automatic diagnostic data and clinician-selected diagnostic data (if previously programmed). The data can be displayed from the Graphs and Tables screen or from the Observations box on the Quick Look II screen.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for programming and collecting the automatic high rate episodes data and the clinician-selected high rate detail diagnostic.

Ventricular Rate Histogram During Atrial Arrhythmias

This histogram shows a profile of ventricular rates recorded during the atrial high rate episodes that have been recorded since the last patient session. This information can show how well ventricular rate is being controlled during atrial arrhythmias and for evaluating the Conducted AF Response function. For more information, see “Conducted AF Response” on page 147.

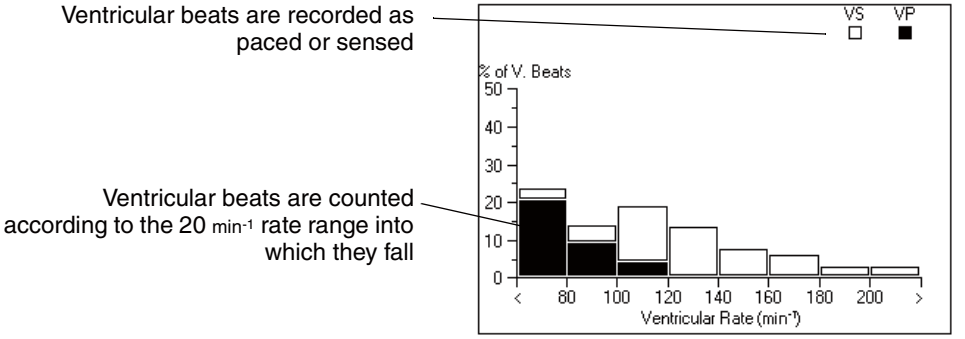


Figure 8-6. Ventricular Rate Histogram During Atrial Arrhythmias

Automatic data collection

During atrial arrhythmias, the pacemaker collects both atrial and ventricular rate data. This histogram shows what percent of the total number ventricular beats counted during these episodes fall into each of eight 20 min^{-1} rate groups in the measured rate range. The beats within each rate group are coded to show the proportion of paced and sensed beats.

Information included with the histogram lists the pertinent programmed parameter settings and summary information about the recorded arrhythmias during which the ventricular rate information was recorded.

Refractory Sense Setup option

Data collection can be set to include or exclude refractory senses (events sensed during the refractory period). Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.

Retrieving Ventricular Rate Histogram During Arrhythmias

When an interrogation of the pacemaker is performed, the programmer retrieves the automatic diagnostic data and clinician-selected diagnostic data (if previously programmed). The data can be displayed from the Graphs and Tables screen or by selecting the QuickLink [>>] button next to AT/AF on the Quick Look II screen.

Atrial Arrhythmia Trend

The Atrial Arrhythmia Trend diagnostic shows a log of how much time each day the patient spends in atrial arrhythmias. Collected over a period of weeks or months, this information indicates when there is an upward or downward trend in these episodes.

Daily measurements of the length of time high rate episodes have been detected

If mode switch therapy is enabled, mode switch criteria define the arrhythmias. Otherwise, atrial high rate (AHR) detection criteria are used.

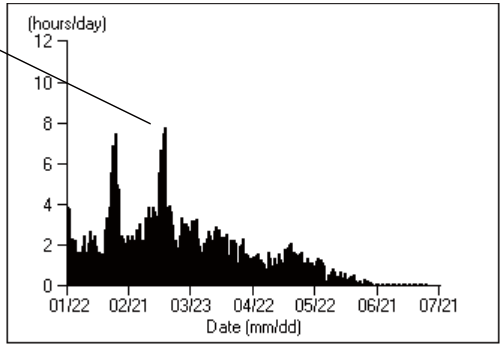


Figure 8-7. Atrial Arrhythmia Rate Trend

Automatic data collection

This display is a graph of daily measurements showing the times when the pacemaker detects atrial arrhythmias. Included with the trend display is the time period covered by the accumulated data, the pertinent programmed parameter settings, and the date of the last follow-up (patient) session.

The Atrial Arrhythmia Trend can show up to 6 months of collected data and is a rolling trend that continues to update. An option lets you clear the accumulated data if desired. Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.

Retrieving Atrial Arrhythmia Trend diagnostics

When an interrogation of the pacemaker is performed, the programmer retrieves the automatic diagnostic data and clinician-selected diagnostic data (if previously programmed). The data can be displayed from the Graphs and Tables screen or by selecting the QuickLink [>>] button next to AT/AF on the Quick Look II screen.

Atrial Arrhythmia Durations

The Atrial Arrhythmia Durations diagnostic collects data about the duration of episodes of atrial arrhythmia and counts the number of episodes that occurred for each of eight categories, based on episode durations (see the sample data in Table 8-2). This data is displayed in the Initial Interrogation Report only. When a pacemaker is programmed for mode switch therapy, this diagnostic collects atrial high rate data based on the criteria for mode switch therapy (not upon the delay criteria used to filter out brief mode switch episodes, in the Atrial Arrhythmia diagnostic).

Table 8-2. Atrial Arrhythmia Durations

Duration	Count
=>72 hr	2
24 hr - <72 hr	1
12 hr - <24 hr	0
4 hr - <12 hr	0
1 hr - <4 hr	12
10 min - <1 hr	50
1 min - <10 min	65
<1 min	390

Custom Rate Trend

Custom Rate Trend is a clinician-selected diagnostic that records heart rate data as a function of time and classifies the rates by percent paced out of the total beats counted. It is intended for patient and pacemaker assessment tasks such as the following:

- Assessing chronotropic incompetence
- Evaluating programmed rate response parameters

This shows a typical 24-hour detailed rate trend.

Data is collected as percent paced.

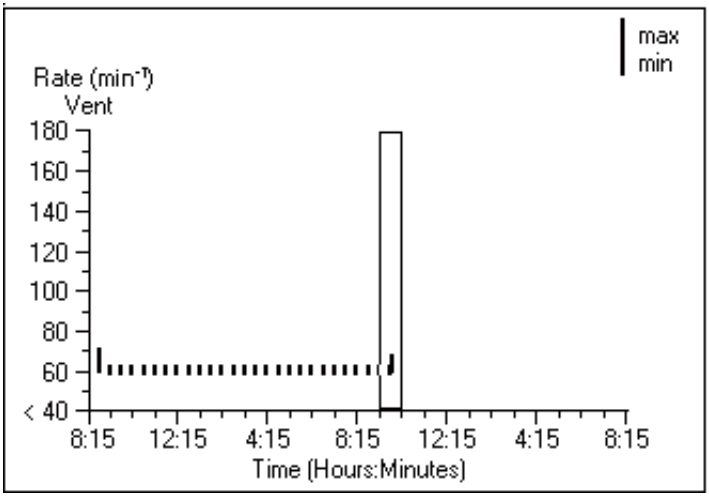


Figure 8-8. 24-Hour Rate Trend Detailed Data

Data collection

The diagnostic collects paced, sensed, and optionally, refractory sensed atrial and/or ventricular rates over a beat-to-beat, 1-hour, or 24-hour period. Data collection resolution depends on the sampling period. The diagnostic collects:

- Percent paced information and classifies by percent paced ranges.
- Ventricular safety paced events as paced events.

Programmable data collection options

The following programmable options control how the Custom Rate Trend diagnostic collects data:

Table 8-3. Programmable options for Custom Rate Trend diagnostic

Parameter	Meaning
Duration	Rate sampling occurs on either:
	Every beat-to-beat (paced and sensed)
	Every 2 seconds over a 1-hour period
	Every 60 seconds over a 24-hour period
Include Refractory Senses?	Determines whether refractory sensed events are counted.
Collection	The Frozen method collects data for the programmed Duration and then stops. The Rolling method collects data continuously, overwriting the oldest data.

Retrieving Custom Rate Trend

When a full interrogation of the pacemaker is performed, the programmer retrieves the diagnostic data and presents a trend graph. The data can be displayed from the Graphs and Tables screen.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for further information on programming the Custom Rate Trend diagnostic and collecting its data.

Key Parameter History

Key Parameter History provides a record of programmed values. Information is collected automatically.

Automatic parameter value recording

Values for the 8 most recent programming sessions are recorded for the following parameters:

- Mode
- Mode Switch
- Lower Rate
- ADL Rate
- Upper Tracking Rate
- Upper Sensor Rate
- Paced AV Interval (PAV)
- Sensed AV Interval (SAV)
- Atrial Amplitude
- Atrial Pulse Width
- Atrial Sensitivity
- Ventricular Amplitude
- Ventricular Pulse Width
- Ventricular Sensitivity

Retrieving Key Parameter History information

When an interrogation of the pacemaker is performed, the programmer retrieves Key Parameter History information. Information is displayed from the Patient icon.

For further information

Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide* for more information about displaying and printing Key Parameter History information.

Troubleshooting the pacing system 9

Troubleshooting strategy

Overview

When troubleshooting pacemaker problems, consider both electrical problems and the effect of various parameter settings on cardiac hemodynamics. Determining the nature of the troubleshooting problem is the first step toward solving it. The following questions may help pinpoint the type of problem:

- Is the pacing system operating per design?
- Is this operation appropriate for this patient?

The answer to the first question helps determine whether the patient has a conduction disorder or the pacemaker has an electrical problem. The answer to the second question helps assess the hemodynamic appropriateness of the pacemaker's settings. For example, when a DDD pacemaker tracks an atrial tachycardia, it is operating as it was intended to perform. While its electrical function is appropriate, the hemodynamic result may not be appropriate (for example, if the patient also has angina).

While troubleshooting may sometimes be challenging, the steps in the troubleshooting process are simple, and they are the same for each type of problem:

1. Define the problem.
2. Identify the cause of the problem.
3. Correct the problem.

Troubleshooting electrical problems

Defining electrical problems

When investigating an electrical problem, the clinician will need data from a wide variety of sources, including the following:

Patient data – Determine the patient's medical history, especially the underlying cardiac rhythm.

Pacemaker data – Determine the device model and serial number and, especially, its RRT/ERI characteristics.

Lead data – Determine the lead type and serial number and, most importantly, the impedance data on each lead.

Note: Much of this data may be available under Patient Information or Key Parameter History, both stored in the pacemaker. Refer to "Patient information" on page 178.

Identifying the cause of an electrical problem

Electrical problems have only six potential causes. Pinpointing the actual cause, however, is sometimes difficult. During the problem-identification phase of troubleshooting, one should consider not only the surface ECG, but also the Intracardiac Electrograms and Marker Channel recordings.

The six causes of electrical problems are as follows:

Undersensing – If the pacemaker fails to reset or start timing operations when P or R waves are apparent on the surface ECG, undersensing is the likely cause. If undersensing is occurring, Marker Channel telemetry will fail to display appropriate sense markers (AS, AR, VS, and VR). One possible cause would be inappropriate programming of the sensitivity setting(s). Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.

Oversensing – If the pacemaker resets or starts timing intervals when no P or R waves are apparent on the surface ECG, oversensing is the likely cause. If so, Marker Channel telemetry will display inappropriate sense markers. A sensitivity setting programmed to a very low number might be the cause. Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.

Noncapture – When pacing occurs with no evidence of a depolarization after each pacing artifact/spike on the surface ECG, loss-of-capture has occurred. Investigate the output settings. Are the amplitude and pulse width settings adequate to consistently capture cardiac tissue? When capture is lost, a threshold test may be used to determine appropriate output settings. Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.

No Output – If pacing artifacts do not appear on the ECG, even though Marker Channel telemetry shows pacing markers (AP or VP), output to the cardiac tissue may be compromised. If pacing stimuli are not being delivered (digitized ECGs sometimes miss pacing artifacts), a lead wire fracture or a faulty lead connection might be the source of the problem. Determine the lead impedance and compare to values from previous follow-up sessions.

Altered Parameter – If the pacing mode or other parameters differ from what appears on the latest entry in the patient's record (e.g., the pacemaker is in the VVI mode), battery depletion or full electrical reset might be the cause. In addition, many parameters can be changed by pacemaker features. Refer to "Possible variation from programmed values" on page 177.

Undesirable Side Effects – This category covers a broad range of situations. For example, a patient's pectoralis muscle might be stimulated at the programmed pacing rate due to high amplitude output(s) with a unipolar pacemaker. Or, another patient might have all the classic symptoms of pacemaker syndrome, due to retrograde P waves that may occur with the loss of AV synchrony.

Correcting an electrical problem

Four types of solutions apply to electrical problems, two non-invasive and two invasive:

Reprogramming – For example, pocket stimulation can occur with unipolar pacing. It may be necessary to program the device to bipolar pacing.

Changing the patient's medication or diet – Some anti-arrhythmic drugs, for example, may alter the patient's stimulation threshold. Diet may alter the patient's electrolyte balance, having a direct effect on the stimulation threshold.

Repositioning the lead – If a lead slips out of position, it may be impossible to pace and/or sense consistently. If this is confirmed, the lead must be repositioned or replaced.

Replacing the lead or the pacemaker – If the lead wire is fractured or the battery is depleted, there is no other recourse than to replace one or both.

Troubleshooting hemodynamic problems

Defining a hemodynamic problem

When investigating a hemodynamic problem, data will be needed from many sources, including:

Patient Data – Determine the patient's condition and daily routine. Is the patient active or relatively sedentary? Is the patient on drug therapy? If the problem is activity-related, what is the patient doing when the problem occurs, and what are the symptoms?

Pacemaker Data – Determine the device's model and serial number, its diagnostic capabilities, and its programmed settings.

Note: Much of this data may be available under Patient Information or Key Parameter History, both stored in the pacemaker. Refer to "Patient information" on page 178.

Identifying the cause of a hemodynamic problem

Identifying the cause of a hemodynamic problem can be challenging. Diagnostic features, however, simplify the evaluation of such problems by providing current and long-term information about pacemaker settings and function. The three most common causes of hemodynamic problems are listed below:

Pacemaker syndrome – This occurs when pacemaker mode or parameter settings result in a loss of AV synchrony. Most commonly, the problem is related to an inappropriate AV interval, but it may also result from premature onset of 2:1 block or loss of atrial capture or sensing. Use of the AV Conduction Histogram (see "AV Conduction Histograms" on page 202), Atrial Intracardiac Electrogram, or the Marker Channel recording can help determine the exact cause.

Inappropriate rate response – This may result when programmed rate response settings do not match the patient's activity needs—especially if Rate Profile Optimization is Off. Review Heart Rate Histograms and Sensor Indicated Rate Profile and/or perform a simple Exercise Test to verify rate response settings. (Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.) To validate and fine-tune the patient's rate response prescription, the pacemaker offers several diagnostic tools, including Rate Histograms and Custom Rate Trends. Refer to "Heart Rate Histograms" on page 200.

Changes in patient condition – A common example is the development of chronic atrial flutter or fibrillation post-implant. If the clinician suspects this condition, the pacemaker's High Rate Episodes diagnostic can provide information on atrial tachycardias that are sensed, including the rates at which they occur and the number of occurrences. Refer to "High Rate Episodes" on page 206.

Correcting a hemodynamic problem

Solutions to hemodynamic problems are invariably non-invasive.

Change the patient's medication – In patients with intermittent atrial tachycardias, drug therapy can reduce the frequency of SVTs.

Reprogram – In dual chamber modes, if the patient experiences intermittent sudden atrial tachycardia, it may be necessary to program the Mode Switch feature On. The High Rate Episodes diagnostic can provide information on the duration and time of each episode along with the maximum atrial rate. Refer to "High Rate Episodes" on page 206.

Alter rate response settings – A patient who feels light-headed while walking up a flight of stairs may have a rate response setting that is not responsive enough. A possible solution may be to change the patient's ADL Rate or target rate profile used by Rate Profile Optimization by changing the ADL Response setting. The Exercise test can be used to monitor and fine-tune the rate response prescription. Refer to the *Adapta/Versa/Sensia/Relia Pacemaker Programming Guide*.

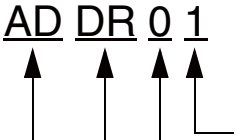
Appendices

Pacemaker description

A

Model number designator

Adapta/Versa/Sensia/Relia pacemakers have four model number attributes that define the model family, the pacing capability, battery type, and lead type.



Lead connector type

1 – IS–1 Bipolar or unipolar leads, setscrew for tip electrodes

3 – 3.2 mm low profile bipolar leads or IS–1 bipolar or unipolar leads, setscrews for tip and ring electrodes

6 – 6 mm or 5 mm unipolar leads, setscrews for tip electrodes, parylene coating on backside of case

Physical size and battery type

0 – Midsize, Sigma 263 battery (two lead systems), Small size, Sigma 213 battery (one lead systems, VDD device)

S – Small size, Sigma 213 battery

L – Large size, Sigma 303 battery

Primary pacing mode capability

DR – DDDR mode

D – DDD mode

VDD – VDD mode

SR – AAIR and VVIR modes

S – AAI and VVI modes

Model Family

AD – Adapta

VE – Versa

SE – Sensia

RE – Relia

Radiopaque codes

A standard X-ray displays the pacemaker's radiopaque code block as black characters on a white background. This code identifies the pacemaker model (see Table A-1).

Table A-1 Radiopaque codes

Model number	Radiopaque code
ADDR01	PWB
ADDR03	PWB
ADDR06	PWB
ADDRS1	PWB
ADDRL1	PWB
ADD01	PWB
ADVDD01	PWB
ADSR01	PWB
ADSR03	PWB
ADSR06	PWB
VEDR01	PWH or PWB
SEDR01	PWL or PWB
SEDRL1	PWL or PWB
SED01	PWL or PWB
SESR01	PWL or PWB
SES01	PWL or PWB
REDR01	PWB
RED01	PWB
RESR01	PWB
RES01	PWB
REVDD01	PWB

Physical dimensions

Table A-2 Physical dimensions

Model number	Height (mm)	Length (mm)	Width (mm)	Mass (g)	Volume (cc)
ADDR01	44.7	47.9	7.5	27.1	12.1
ADDR03	46.7	47.9	7.5	28.1	13.0
ADDR06	50.3	47.9	7.5	28.5	14.2
ADDRS1	44.7	42.9	7.5	23.6	11.1
ADDRL1	45.4	52.3	7.5	31.3	13.1
ADD01	44.7	47.9	7.5	27.1	12.1
ADVDD01	44.7	42.9	7.5	23.6	11.1
ADSR01	40.2	42.9	7.5	21.5	9.7
ADSR03	42.9	42.9	7.5	22.5	10.5
ADSR06	43.3	42.9	7.5	22.5	11.0
VEDR01	44.7	47.9	7.5	27.1	12.1
SEDR01	44.7	47.9	7.5	27.1	12.1
SEDRL1	45.4	52.3	7.5	31.3	13.1
SED01	44.7	47.9	7.5	27.1	12.1
SESR01	40.2	42.9	7.5	21.5	9.7
SES01	40.2	42.9	7.5	21.5	9.7
REDR01	44.7	47.9	7.5	27.1	12.1
RED01	44.7	47.9	7.5	27.1	12.1
RESR01	40.2	42.9	7.5	21.5	9.7
RES01	40.2	42.9	7.5	21.5	9.7
REVDD01	44.7	42.9	7.5	23.6	11.1

Connector dimensions

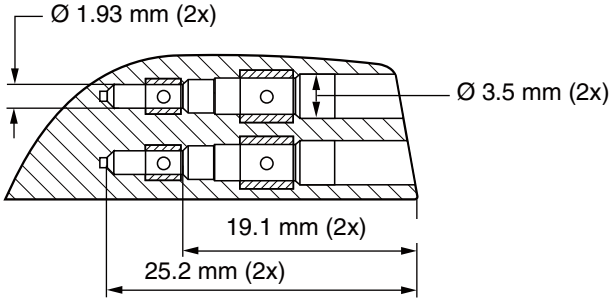


Figure A-1. ADDR01, ADDRL1, ADD01, VEDR01, SEDR01, SEDRL1, SED01, REDR01, RED01 IS–1[1] connector dimensions

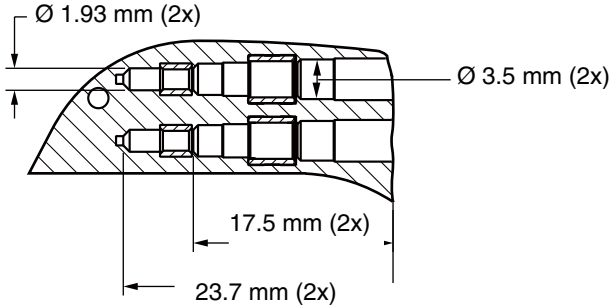


Figure A-2. ADDRS1, ADVDD01, REVDD01 IS–1[1] connector dimensions

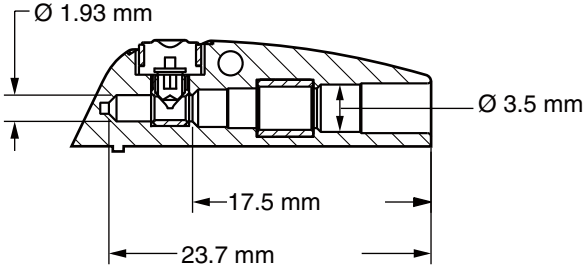


Figure A-3. ADSR01, SESR01, SES01, RESR01, RES01 IS–1[1] connector dimensions

[1] IS–1 refers to an International Connector Standard (See Document No. ISO 5841-3; 1992) whereby pacemakers and leads so designated are assured of meeting the electrical and mechanical parameters specified in the IS-1 international standard.

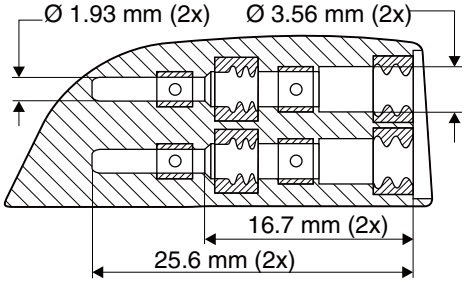


Figure A-4. ADDR03 3.2 mm connector dimensions

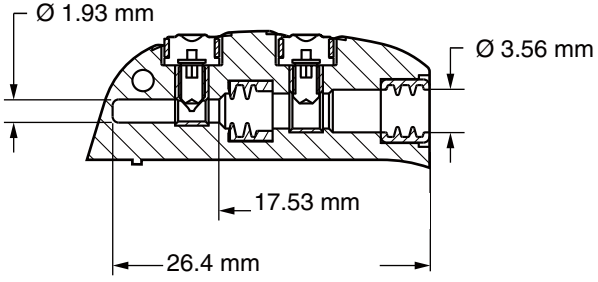


Figure A-5. ADSR03 3.2 mm connector dimensions

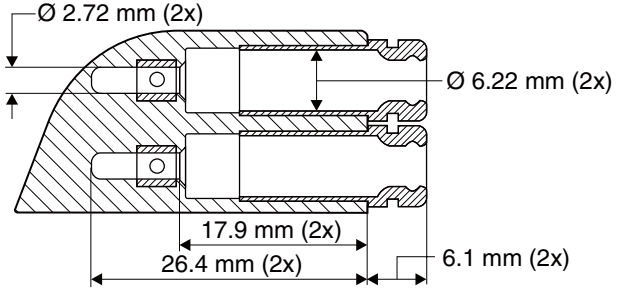


Figure A-6. ADDR06 5/6 mm connector dimensions

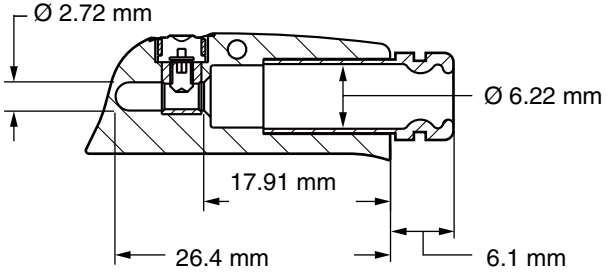


Figure A-7. ADSR06 5/6 mm connector dimensions

Preset parameter settings

B

Shipping and nominal settings

Shipping parameter settings and Medtronic nominal parameter settings shown in Table B-1 through Table B-11.

Notes:

- Specifications in this section are categorized by mode prefixes contained in the model number (for example, DR Series). Parameters shown can apply to a model in that series, provided that the pacemaker was manufactured with the feature. To find applicable features for a specific model, refer to the Implant Manual for that pacemaker.
- “Unchanged” indicates that the programmed setting is unaffected by nominal programming or an electrical reset event. “Adaptive” indicates that the parameter is adapted during operation.
- The shipping parameters for some features are not applied until the 30-minute Implant Detection period is complete.

Table B-1 Mode and rates

Parameter	Series	Shipping settings	Nominal settings
Mode	DR Series	Adapta: AAIR<=>DDDR Versa, Sensia, Relia: DDDR	Adapta: AAIR<=>DDDR Versa, Sensia, Relia: DDDR
	D Series	Adapta: AAI<=>DDD Versa, Sensia, Relia: DDD	Adapta: AAI<=>DDD Versa, Sensia, Relia: DDD
	VDD Series	VDD	VDD
	SR Series	VVIR	VVIR
	S Series	VVI	VVI
Mode Switch	DR Series, D Series	On	On
	VDD Series	Off	Off
Detect Rate	DR Series, D Series, VDD Series	175 min^{-1}	175 min^{-1}
Detect Duration	DR Series, D Series, VDD Series	No Delay	No Delay
Blanked Flutter Search	DR Series, D Series, VDD Series	On	On
Lower Rate	DR Series, D Series, SR Series, S Series	60 min^{-1}	60 min^{-1}
	VDD Series	50 min^{-1}	50 min^{-1}

Table B-1 Mode and rates (continued)

Parameter	Series	Shipping settings	Nominal settings
Upper Tracking Rate	DR Series, D Series, VDD Series	130 min^{-1}	130 min^{-1}
Upper Sensor Rate	DR Series, D Series, VDD Series, SR Series	130 min^{-1}	130 min^{-1}

Table B-2 Rate Response

Parameter	Series	Shipping settings	Nominal settings
ADL Rate	DR Series, D Series, VDD Series, SR Series	95 min^{-1}	95 min^{-1}
Rate Profile Optimization	DR Series, D Series, VDD Series, SR Series	On	On
ADL Response	DR Series, D Series, VDD Series, SR Series	3	3
Exertion Response	DR Series, D Series, VDD Series, SR Series	3	3
ADL Setpoint	DR Series, D Series, VDD Series, SR Series	15	Unchanged
UR Setpoint	DR Series, D Series, VDD Series, SR Series	40	Unchanged
Activity Threshold	DR Series, D Series, VDD Series, SR Series	Medium/Low	Unchanged

Table B-2 Rate Response (continued)

Parameter	Series	Shipping settings	Nominal settings
Acceleration	DR Series, D Series, VDD Series, SR Series	30 s	Unchanged
Deceleration	DR Series, D Series, VDD Series, SR Series	Exercise	Unchanged

Table B-3 Atrial Lead[a]

Parameter	Series	Shipping settings	Nominal settings
Amplitude[b,c]	DR Series, D Series	3.5 V (Adaptive)	3.5 V (Adaptive[d])
	SR Series, S Series	—	—
Pulse Width[c]	DR Series, D Series	0.4 ms (Adaptive)	0.4 ms (Adaptive[d])
	SR Series, S Series	—	—
Sensitivity	DR Series, D Series	0.5 mV (Adaptive)	0.5 mV (Adaptive[d])
	SR Series, S Series	0.5 mV (Adaptive)	2.80 mV (Adaptive)
	VDD Series	0.25 mV (Adaptive)	0.25 mV (Adaptive)
Sensing Assurance	Adapta, Versa, Sensia	On	On
Pacing Polarity	DR Series, D Series, SR Series, S Series	Configure or Unipolar[e]	Unchanged
Sensing Polarity	DR Series, D Series, SR Series, S Series	Configure or Unipolar[e]	Unchanged
	VDD Series	Bipolar	Bipolar

Table B-3 Atrial Lead[a] (continued)

Parameter	Series	Shipping settings	Nominal settings
Lead Monitor	DR Series, D Series, SR Series, S Series	Configure or Monitor Only[e]	Unchanged
Notify if < (less than)		200 Ohms	200 Ohms
Notify if > (greater than)		4000 Ohms	4000 Ohms
Monitor Sensitivity		8	8

[a] Applies to SR Series and S Series when set on atrial mode.

[b] Tolerance for amplitudes from 0.5 V through 6.0 V is ± 10%, and for 7.5 V is -20/+0%. Tolerances are based on 37°C and a 500-ohm load. Amplitude is determined 200 microseconds after the leading edge of the pace.

[c] For the SR Series and S Series models, the shipping and nominal modes are ventricular. Atrial amplitude and pulse width have no shipping or nominal values.

[d] Value from which adaptive adjustment begins when nominals are programmed.

[e] Applies to unipolar only models (indicated by a “6” in the last digit of the model number).

Table B-4 Ventricular Lead[a]

Parameter	Series	Shipping settings	Nominal settings
Amplitude[b]	All	3.5 V (Adaptive)	3.5 V (Adaptive[c])
Pulse Width	All	0.4 ms (Adaptive)	0.4 ms (Adaptive[c])
Sensitivity	All	2.8 mV (Adaptive)	2.8 mV (Adaptive[c])
Sensing Assurance	Adapta, Versa, Sensia	On	On
Pacing Polarity	DR Series, SR Series, S Series	Configure or Unipolar[d]	Unchanged
	D Series, VDD Series	Configure	Unchanged
Sensing Polarity	DR Series, SR Series, S Series	Configure or Unipolar[d]	Unchanged
	D Series, VDD Series	Configure	Unchanged
Lead Monitor	DR Series, SR Series, S Series	Configure or Monitor Only[d]	Unchanged
	D Series, VDD Series	Configure	Unchanged
Notify if < (less than)		200 Ohms	200 Ohms
Notify if > (greater than)		4000 Ohms	4000 Ohms
Monitor Sensitivity		8	8

[a] Applies to SR Series and S Series when set on ventricular mode.

[b] Tolerance for amplitudes from 0.5 V through 6.0 V is ± 10%, and for 7.5 V is -20/+0%. Tolerances are based on 37°C and a 500-ohm load. Amplitude is determined 200 microseconds after the leading edge of the pace.

[c] Value from which adaptive adjustment begins when nominals are programmed.

[d] Applies to unipolar only models (indicated by a “6” in the last digit of the model number).

Table B-5 Ventricular Capture Management

Parameter	Series	Shipping settings	Nominal settings
Ventricular Capture Management	All	Adaptive	Adaptive
Amplitude Margin	All	2x (times)	2x (times)
Minimum Adapted Amplitude	All	2.0 V	2.0 V
Capture Test Frequency	All	Day at Rest	Day at Rest
Capture Test Time	All	None	None
Acute Phase Days Remaining	All	112 days	Unchanged
V. Sensing during Search	All	Adaptive[a]	Adaptive

[a] Unipolar only models (indicated by a “6” in the last digit of the model number) are set to “Unipolar.”

Table B-6 Atrial Capture Management

Parameter	Series	Shipping settings	Nominal settings
Atrial Capture Management	DR Series, D Series	Adaptive	Adaptive
Amplitude Margin		2x (times)	2x (times)
Minimum Adapted Amplitude		1.5 V	1.5 V
Capture Test Frequency		Day at …	Day at …
Capture Test Time		1 AM	1 AM
Acute Phase Days Remaining		112 days	Unchanged

Table B-7 Intrinsic Activation and AV Intervals

Parameter	Series	Shipping settings	Nominal settings
Paced AV (PAV)	DR Series, D Series	150 ms	150 ms[a]
Sensed AV (SAV)	DR Series, D Series, VDD Series	120 ms	120 ms[a]
RAAV	DR Series, D Series, VDD Series	Off	Off
Start Rate		80 min^{-1}	80 min^{-1}
Stop Rate		120 min^{-1}	120 min^{-1}
Maximum Offset		- 40 ms	- 40 ms
Search AV+	DR Series, D Series, VDD Series	On	On
Max Increase to AV		170 ms	170 ms
Sinus Preference	DR Series	On	On
Sinus Preference Zone		10 min^{-1}	10 min^{-1}
Search Interval		10 min	10 min

[a] Value from which adaptive adjustment begins when nominals are programmed.

Table B-8 Refractory / Blanking

Parameter	Series	Shipping settings	Nominal settings
PVARP	DR Series, D Series, VDD Series	Auto	Auto
Minimum PVARP		250 ms	250 ms
PVAB	DR Series, D Series, VDD Series	180 ms	180 ms
Ventricular Refractory Period	DR Series, D Series, VDD Series	230 ms	230 ms
	SR Series, S Series	330 ms	330 ms
Ventricular Blanking (after atrial pace) (PVAB)	DR Series, D Series	28 ms	28 ms
Atrial Refractory Period[a]	DR Series, D Series	250 ms	250 ms
	SR Series, S Series	—	250 ms
Atrial Blanking Period[a]	DR Series, D Series	180 ms	180 ms
	SR Series, S Series	—	180 ms

[a] Atrial modes only

Table B-9 Additional Features

Parameter	Series	Shipping settings	Nominal settings
Sleep Function	All	Off	Off
Sleep Rate	All	50 min^{-1}	50 min^{-1}
Bed Time	All	10:00 PM	10:00 PM
Wake Time	All	8:00 AM	8:00 AM
Non-Competitive Atrial Pacing	DR Series, D Series	On	On
Single Chamber Hysteresis	All	Off	Unchanged
Rate Drop Response	DR Series, D Series		
Detection Type		Off	Off
Intervention Rate		100 min^{-1}	100 min^{-1}
Intervention Duration		2 min	2 min
Detection Beats		2 beats	2 beats
Drop Rate		50 min^{-1}	50 min^{-1}
Drop Size		25 min^{-1}	25 min^{-1}
Detection Window		25 s	25 s
PMT Intervention	DR Series, D Series, VDD Series	Off	Off
PVC Response	DR Series, D Series, VDD Series	On	On
Ventricular Safety Pacing	DR Series, D Series	On	On
Implant Detection	All	On / Restart	Unchanged

Table B-10 Interventions

Parameter	Series	Shipping settings	Nominal settings
Post Mode Switch Pacing	DR Series, D Series	Off	Off
Overdrive Rate	DR Series, D Series	80 min	80 min
Overdrive Period	DR Series, D Series	10 min^{-1}	10 min^{-1}
Atrial Preference Pacing	DR Series, D Series	Off	Off
Maximum Rate		100 min^{-1}	100 min^{-1}
Interval Decrement		30 ms	30 ms
Search Beats		20	20
Conducted AF Response[a]	DR Series, D Series, VDD Series, SR Series	Off	Off
Maximum Rate		110 min^{-1}	110 min^{-1}

[a] This feature was named Ventricular Response Pacing in previous pacemakers.

Table B-11 Telemetry Features

Parameter	Series	Shipping settings	Nominal settings
Transtelephonic Monitor	All	Off	Unchanged
Extended Telemetry	All	Off	Unchanged
Extended Marker	All	Standard	Unchanged

Electrical reset settings

Parameter settings for a partial electrical reset and a full electrical reset are shown in Table B-12 through Table B-22.

Notes:

- Specifications in this section are categorized by mode prefixes contained in the model number (for example, DR Series). Parameters shown can apply to a model in that series, provided that the pacemaker was manufactured with the feature. To find applicable features for a specific model, refer to the Implant Manual for that pacemaker.
- “Unchanged” indicates that the programmed setting is unaffected by nominal programming or an electrical reset event. “Adaptive” indicates that the parameter is adapted during operation.
- The shipping parameters for some features are not applied until the 30-minute Implant Detection period is complete.
- After certain serious device errors, the pacemaker will recover as a model SES01 (Adapta, Versa, Sensia) or RES01 (Relia). If this occurs, contact your Medtronic representative immediately.

Table B-12 Mode and rates

Parameter	Series	Partial reset settings	Full reset settings
Mode	All	Unchanged	VVI
Mode Switch	DR Series, D Series, VDD Series	Unchanged	Off
Detect Rate	DR Series, D Series, VDD Series	175 min^{-1}	175 min^{-1}
Detect Duration	DR Series, D Series, VDD Series	No Delay	No Delay
Blanked Flutter Search	DR Series, D Series, VDD Series	Unchanged	On
Lower Rate	All	Unchanged	65 min^{-1}
Upper Tracking Rate	DR Series, D Series, VDD Series	Unchanged	120 min^{-1}
Upper Sensor Rate	DR Series, D Series, VDD Series, SR Series	Unchanged	120 min^{-1}

Table B-13 Rate Response

Parameter	Series	Partial reset settings	Full reset settings
ADL Rate	DR Series, D Series, VDD Series, SR Series	Unchanged	95 min^{-1}
Rate Profile Optimization	DR Series, D Series, VDD Series, SR Series	Unchanged	Off
ADL Response	DR Series, D Series, VDD Series, SR Series	3	3
Exertion Response	DR Series, D Series, VDD Series, SR Series	3	3
ADL Setpoint	DR Series, D Series, VDD Series, SR Series	15	15
UR Setpoint	DR Series, D Series, VDD Series, SR Series	40	407
Activity Threshold	DR Series, D Series, VDD Series, SR Series	Medium/Low	Medium/Low

Table B-13 Rate Response (continued)

Parameter	Series	Partial reset settings	Full reset settings
Acceleration	DR Series, D Series, VDD Series, SR Series	30 s	30 s
Deceleration	DR Series, D Series, VDD Series, SR Series	Exercise	Exercise

Table B-14 Atrial Lead[a]

Parameter	Series	Partial reset settings	Full reset settings
Amplitude	DR Series, D Series	Unchanged	5.0 V
	SR Series, S Series	Unchanged	—
Pulse Width	DR Series, D Series	Unchanged	0.4 ms
	SR Series, S Series	Unchanged	—
Sensitivity	DR Series, D Series	Unchanged	0.5 mV
	SR Series, S Series	Unchanged	2.80 mV
	VDD Series	Unchanged	0.25 mV
Sensing Assurance	All	Unchanged	Off
Pacing Polarity	DR Series, D Series, SR Series, S Series	Unchanged	Configure[b] or Unipolar[c]
Sensing Polarity	DR Series, D Series, SR Series, S Series	Unchanged	Configure[b] or Unipolar[c]
	VDD Series	Bipolar	Bipolar

Table B-14 Atrial Lead[a] (continued)

Parameter	Series	Partial reset settings	Full reset settings
Lead Monitor	DR Series, SR Series, S Series	Unchanged	Configure or Monitor Only[c]
	D Series	Unchanged	Configure[b]
Notify if < (less than)		200 Ohms	200 Ohms
Notify if > (greater than)		4000 Ohms	4000 Ohms
Monitor Sensitivity		8	8

[a] Applies to SR Series and S Series when set on atrial mode.

[b] Bipolar models revert to Implant Detection during which polarity is automatically configured.

[c] Applies to unipolar only models (indicated by a “6” in the last digit of the model number).

Table B-15 Ventricular Lead[a]

Parameter	Series	Partial reset settings	Full reset settings
Amplitude	All	Unchanged	5.0 V
Pulse Width	All	Unchanged	0.4 ms
Sensitivity	All	Unchanged	2.8 mV
Sensing Assurance	All	Unchanged	Off
Pacing Polarity	DR Series, SR Series, S Series	Unchanged	Configure[b] or Unipolar[c]
	D Series, VDD Series	Unchanged	Configure
Sensing Polarity	DR Series, SR Series, S Series	Unchanged	Configure[b] or Unipolar[c]
	D Series, VDD Series	Unchanged	Configure
Lead Monitor	DR Series, SR Series, S Series	Unchanged	Configure or Monitor Only[d]
	D Series, VDD Series	Unchanged	Configure
Notify if < (less than)		200 Ohms	200 Ohms
Notify if > (greater than)		4000 Ohms	4000 Ohms
Monitor Sensitivity		8	8

[a] Applies to SR Series and S Series when set on ventricular mode.

[b] Bipolar models revert to Implant Detection during which polarity is automatically configured.

[c] Applies to unipolar only models (indicated by a “6” in the last digit of the model number).

[d] Unipolar-only models are set to a fixed value of Monitor Only.

Table B-16 Ventricular Capture Management

Parameter	Series	Partial reset settings	Full reset settings
Ventricular Capture Management	All	Unchanged	Off
Amplitude Margin	All	Unchanged	2x (times)
Minimum Adapted Amplitude	All	Unchanged	2.0 V
Capture Test Frequency	All	Day at Rest[a]	Day at Rest
Capture Test Time	All	None[a]	None
Acute Phase Days Remaining	All	112 days	112 days
V. Sensing during Search[b]	All	Adaptive	Adaptive

[a] If values differ from nominal, the Capture Test Time will be set to occur every Day at… 12 hours after electrical reset time.

[b] Unipolar only models (indicated by a “6” in the last digit of the model number) are set to “Unipolar.”

Table B-17 Atrial Capture Management

Parameter	Series	Partial reset settings	Full reset settings
Atrial Capture Management	DR Series, D Series	Unchanged	Off
Amplitude Margin		Unchanged	2x (times)
Minimum Adapted Amplitude		Unchanged	1.5 V
Capture Test Frequency		Day at …	Day at …
Capture Test Time		1 AM	1 AM
Acute Phase Days Remaining		Unchanged	112 days

Table B-18 Intrinsic Activation and AV Intervals

Parameter	Series	Partial reset settings	Full reset settings
Paced AV (PAV)	DR Series, D Series	150 ms[a]	150 ms
Sensed AV (SAV)	DR Series, D Series, VDD Series	120 ms[a]	120 ms
RAAV	DR Series, D Series, VDD Series	Unchanged	Off
Start Rate		80 min^{-1}	80 min^{-1}
Stop Rate		120 min^{-1}	120 min^{-1}
Maximum Offset		- 40 ms	- 40 ms
Search AV+	DR Series, D Series, VDD Series	Unchanged	Off
Max Increase to AV		Unchanged	110 ms
Sinus Preference	DR Series	Unchanged	Off
Sinus Preference Zone		10 min^{-1}	10 min^{-1}
Search Interval		10 min	10 min

[a] Reset value from which adaptive adjustment begins if Search AV+ is On at a partial reset.

Table B-19 Refractory / Blanking

Parameter	Series	Partial reset settings	Full reset settings
PVARP	DR Series, D Series, VDD Series	Unchanged	310 ms[a]
Minimum PVARP		Unchanged	None
PVAB	DR Series, D Series, VDD Series	180 ms	180 ms
Ventricular Refractory Period	DR Series, D Series, VDD Series	230 ms	230 ms
	SR Series, S Series	330 ms	330 ms
Ventricular Blanking (after atrial pace) (PVAB)	DR Series, D Series	28 ms	28 ms
Atrial Refractory Period[b]	DR Series, D Series	Unchanged	310 ms
	SR Series, S Series	400 ms	330 ms
Atrial Blanking Period[b]	DR Series, D Series, SR Series, S Series	180 ms	180 ms

[a] PVARP previously set to sensor-varied (varied) or automatic (auto) is disabled at a full electrical reset.

[b] Atrial modes only.

Table B-20 Additional Features

Parameter	Series	Partial reset settings	Full reset settings
Sleep Function	All	Off	Off
Sleep Rate	All	50 min^{-1}	50 min^{-1}
Bed Time	All	10:00 PM	10:00 PM
Wake Time	All	8:00 AM	8:00 AM
Non-Competitive Atrial Pacing	DR Series, D Series	Unchanged	Off
Single Chamber Hysteresis	All	Unchanged	Off
Rate Drop Response	DR Series, D Series		
Detection Type		Unchanged	Off
Intervention Rate		Unchanged	100 min^{-1}
Intervention Duration		Unchanged	2 min
Detection Beats		2 beats	2 beats
Drop Rate		Unchanged	50 min^{-1}
Drop Size		25 min^{-1}	25 min^{-1}
Detection Window		25 s	25 s
PMT Intervention	DR Series, D Series, VDD Series	Unchanged	Off
PVC Response	DR Series, D Series, VDD Series	Unchanged	On
Ventricular Safety Pacing	DR Series, D Series	Unchanged	On
Implant Detection	All	Unchanged	On / Restart

Table B-21 Interventions

Parameter	Series	Partial reset settings	Full reset settings
Post Mode Switch Pacing	DR Series, D Series	Unchanged	Off
Overdrive Rate	DR Series, D Series	Unchanged	80 min
Overdrive Period	DR Series, D Series	Unchanged	10 min^{-1}
Atrial Preference Pacing	DR Series, D Series	Unchanged	Off
Maximum Rate		100 min^{-1}	100 min^{-1}
Interval Decrement		30 ms	30 ms
Search Beats		20	20
Conducted AF Response[a]	DR Series, D Series, VDD Series, SR Series	Unchanged	Off
Maximum Rate		110 min^{-1}	110 min^{-1}

[a] This feature was named Ventricular Response Pacing in previous pacemakers.

Table B-22 Telemetry Features

Parameter	Series	Partial reset settings	Full reset settings
Transtelephonic Monitor	All	Unchanged	Off
Extended Telemetry	All	Off	Off
Extended Marker	All	Standard	Standard

Emergency settings

Emergency pacing provides VVI pacing at high output settings in emergency situations for pacemaker-dependent patients. Table B-23 lists the emergency settings. The settings apply to all pacemakers.

Table B-23 Emergency settings

Parameter	Setting
Mode	VVI
Pacing Rate	70 min^{-1}
Ventricular	
Amplitude	7.5 V
Pulse Width	1.5 ms
Sensitivity	2.8 mV
Pacing Polarity	Unipolar
Sensing Polarity	Unipolar
Lead Monitor	Monitor Only
Ventricular Refractory Period	330 ms
Single Chamber Hysteresis	Off
Ventricular Capture Management	Off

Longevity projections

C

Projected service life

Refer to Table C-1 to locate the service life projections for an individual pacemaker model, based on the model number and serial number prefix. The serial number prefix of a pacemaker appears at the top of any report printed during a patient session. The serial number prefix also appears on the pacemaker box and on the pacemaker itself.

Projected service life is defined as the number of years from implant to Recommended Replacement Time (RRT/ERI). The operating conditions for these projections are listed in the projected service life tables. (Pacing at 100 min^{-1} represents pediatric operation.)

Note: These projections are based on calculations using deliverable battery capacity. These values are estimates of projections from implant to RRT/ERI and can help the clinician in understanding the effects of various pacing conditions on battery life. These values should not be interpreted as precise numbers.

Caution: When RRT/ERI is set, the pacemaker must be replaced within 3 months. The time and date when RRT/ERI was set is shown in the Observations window.

Table C-1 Identifying the tables for projected service life

Model	Serial number prefix	Longevity table	Serial number prefix	Longevity table
ADDR01	PWB	Table C-2	NWB	Table C-9
ADDR03	PWD	Table C-2	NWD	Table C-9
ADDR06	PWC	Table C-2	NWC	Table C-9
ADD01	PWF	Table C-2	NWF	Table C-9
ADDRS1	PWA	Table C-3	NWA	Table C-10
ADDRL1	PWE	Table C-4	NWE	Table C-11
ADSR01	PWM	Table C-5	NWM	Table C-12
ADSR03	PWP	Table C-5	NWP	Table C-12
ADSR06	PWN	Table C-5	NWN	Table C-12
SESR01	PWR	Table C-5	NWR	Table C-12
SES01	PWS	Table C-5	NWS	Table C-12
RESR01			NWU	Table C-12
RES01			NWV	Table C-12
ADVDD01	PWG	Table C-6	NWG	Table C-13
REVDD01			NWX	Table C-13
VEDR01	PWH	Table C-7	NWH	Table C-14
SEDR01	PWL	Table C-7	NWL	Table C-14
SED01	PWK	Table C-7	NWK	Table C-14
REDR01			NWT	Table C-14
RED01			NWW	Table C-14
SEDRL1	PWJ	Table C-8	NWJ	Table C-15

Projected service life: Models with serial number prefixes PWB, PWD, PWC, and PWF

Table C-2 ADDR01/03/06, ADD01 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.8	9.8
	2.5 V, 2.5 V		9.3	9.3
	3.5 V, 3.5 V		9.6	9.6
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.0	9.4
	2.5 V, 2.5 V		8.2	8.7
	3.5 V, 3.5 V		7.4	8.3
AAIR<=>DDDR or AAI<=>DDD (MVP modes), 50% atrial, 5% ventricular	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.4	9.6
	2.5 V, 2.5 V		8.7	9.0
	3.5 V, 3.5 V		8.3	8.9
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	8.2	8.9
	2.5 V, 2.5 V		7.4	8.2
	3.5 V, 3.5 V		6.0	7.3
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	9.0	----
	5.0 V, 5.0 V		8.9	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	6.5	----
	5.0 V, 5.0 V		3.5	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.4	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.7	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Model with serial number prefix PWA

Table C-3 ADDRS1 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	7.4	7.4
	2.5 V, 2.5 V		7.0	7.0
	3.5 V, 3.5 V		7.2	7.2
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	6.7	7.0
	2.5 V, 2.5 V		6.1	6.5
	3.5 V, 3.5 V		5.5	6.2
AAIR<=>DDDR or AAI<=>DDD (MVP modes), 50% atrial, 5% ventricular	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	7.1	7.2
	2.5 V, 2.5 V		6.5	6.7
	3.5 V, 3.5 V		6.2	6.6
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	6.1	6.7
	2.5 V, 2.5 V		5.5	6.1
	3.5 V, 3.5 V		4.3	5.4
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	6.7	----
	5.0 V, 5.0 V		6.6	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	4.8	----
	5.0 V, 5.0 V		2.4	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	1.6	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.1	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Model with serial number prefix PWE

Table C-4 ADDRL1 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.2	12.2
	2.5 V, 2.5 V		11.5	11.5
	3.5 V, 3.5 V		11.9	11.9
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	11.0	11.5
	2.5 V, 2.5 V		10.1	10.7
	3.5 V, 3.5 V		9.1	10.3
AAIR<=>DDDR or AAI<=>DDD (MVP modes), 50% atrial, 5% ventricular	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	11.6	11.9
	2.5 V, 2.5 V		10.7	11.1
	3.5 V, 3.5 V		10.2	11.0
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	10.1	11.0
	2.5 V, 2.5 V		9.1	10.1
	3.5 V, 3.5 V		7.4	9.0
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	11.1	----
	5.0 V, 5.0 V		10.9	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	8.0	----
	5.0 V, 5.0 V		4.1	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.6	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.7	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Models with serial number prefixes PWM, PWP, PWN, PWR, and PWS

Table C-5 ADSR01/03/06, SESR01, SES01 Projected service life from implant to RRT/ERI in years

Pacing	Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
SSIR or SSI, 0%	2.0 V	60 min^{-1}, 0.4 ms	9.0	9.0
	2.5 V		8.5	8.5
	3.5 V		8.8	8.8
SSIR or SSI, 50%	2.0 V	60 min^{-1}, 0.4 ms	8.4	8.7
	2.5 V		7.8	8.1
	3.5 V		7.4	8.0
SSIR or SSI, 100%	2.0 V	60 min^{-1}, 0.4 ms	7.9	8.4
	2.5 V		7.3	7.8
	3.5 V		6.4	7.4
SSIR or SSI, 0%	2.5 V	70 min^{-1}, 0.5 ms	8.3	----
	5.0 V		8.2	----
SSIR or SSI, 100%	2.5 V	70 min^{-1}, 0.5 ms	6.7	----
	5.0 V		4.1	----
SSIR or SSI, 100%	5.0 V	70 min^{-1}, 1.0 ms	2.9	----
SSIR or SSI, 100%	5.0 V	100 min^{-1}, 1.0 ms	2.2	----

Projected service life: Model with serial number prefix PWG

Table C-6 ADVDD01 Projected service life from implant to RRT/ERI in years

Pacing	Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
VDD, 0%	2.0 V	60 min^{-1}, 0.4 ms	7.4	7.4
	2.5 V		7.0	7.0
	3.5 V		7.2	7.2
VDD, 50%	2.0 V	60 min^{-1}, 0.4 ms	7.0	7.2
	2.5 V		6.6	6.8
	3.5 V		6.3	6.7
VDD, 100%	2.0 V	60 min^{-1}, 0.4 ms	6.6	7.0
	2.5 V		6.2	6.5
	3.5 V		5.5	6.2
VDD, 0%	2.5 V	70 min^{-1}, 0.5 ms	6.8	----
	5.0 V		6.7	----
VDD, 100%	2.5 V	70 min^{-1}, 0.5 ms	5.6	----
	5.0 V		3.6	----
VDD, 100%	5.0 V	70 min^{-1}, 1.0 ms	2.6	----
VDD, 100%	5.0 V	100 min^{-1}, 1.0 ms	2.0	----

Note: VDD longevity is calculated with the following conditions: Dual chamber device, DDD mode, 0.0 V amplitude in the atrium (atrial pacing disabled).

Projected service life: Models with serial number prefixes PWH, PWL, and PWK

Table C-7 VEDR01, SEDR01, SED01 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.8	9.8
	2.5 V, 2.5 V		9.3	9.3
	3.5 V, 3.5 V		9.6	9.6
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.0	9.4
	2.5 V, 2.5 V		8.2	8.7
	3.5 V, 3.5 V		7.4	8.3
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	8.2	8.9
	2.5 V, 2.5 V		7.4	8.2
	3.5 V, 3.5 V		6.0	7.3
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	9.0	----
	5.0 V, 5.0 V		8.9	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	6.5	----
	5.0 V, 5.0 V		3.5	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.4	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.7	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Model with serial number prefix PWJ

Table C-8 SEDRL1 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.2	12.2
	2.5 V, 2.5 V		11.5	11.5
	3.5 V, 3.5 V		11.9	11.9
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	11.0	11.5
	2.5 V, 2.5 V		10.1	10.7
	3.5 V, 3.5 V		9.1	10.3
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	10.1	11.0
	2.5 V, 2.5 V		9.1	10.1
	3.5 V, 3.5 V		7.4	9.0
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	11.1	----
	5.0 V, 5.0 V		10.9	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	8.0	----
	5.0 V, 5.0 V		4.1	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.6	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.7	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Models with serial number prefixes NWB, NWD, NWC, and NWF

Table C-9 ADDR01/03/06, ADD01 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.8	12.8
	2.5 V, 2.5 V		11.9	11.9
	3.5 V, 3.5 V		12.5	12.5
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	11.4	12.0
	2.5 V, 2.5 V		10.2	11.0
	3.5 V, 3.5 V		9.1	10.4
AAIR<=>DDDR or AAI<=>DDD (MVP modes), 50% atrial, 5% ventricular	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.1	12.4
	2.5 V, 2.5 V		10.9	11.4
	3.5 V, 3.5 V		10.4	11.3
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	10.2	11.3
	2.5 V, 2.5 V		9.0	10.2
	3.5 V, 3.5 V		7.1	8.9
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	11.8	----
	5.0 V, 5.0 V		11.5	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	7.9	----
	5.0 V, 5.0 V		3.8	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.5	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.8	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Model with serial number prefix NWA

Table C-10 ADDRS1 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.8	9.8
	2.5 V, 2.5 V		9.1	9.1
	3.5 V, 3.5 V		9.5	9.5
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	8.6	9.1
	2.5 V, 2.5 V		7.7	8.3
	3.5 V, 3.5 V		6.7	7.8
AAIR<=>DDDR or AAI<=>DDD (MVP modes), 50% atrial, 5% ventricular	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	9.2	9.4
	2.5 V, 2.5 V		8.3	8.6
	3.5 V, 3.5 V		7.8	8.5
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	7.7	8.5
	2.5 V, 2.5 V		6.7	7.7
	3.5 V, 3.5 V		5.2	6.6
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	8.9	----
	5.0 V, 5.0 V		8.8	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	5.9	----
	5.0 V, 5.0 V		2.7	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	1.8	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.2	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Model with serial number prefix NWE

Table C-11 ADDRL1 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	15.9	15.9
	2.5 V, 2.5 V		14.8	14.8
	3.5 V, 3.5 V		15.5	15.5
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	14.1	14.9
	2.5 V, 2.5 V		12.7	13.6
	3.5 V, 3.5 V		11.2	12.9
AAIR<=>DDDR or AAI<=>DDD (MVP modes), 50% atrial, 5% ventricular	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	14.9	15.4
	2.5 V, 2.5 V		13.5	14.1
	3.5 V, 3.5 V		12.8	13.9
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.6	14.0
	2.5 V, 2.5 V		11.1	12.6
	3.5 V, 3.5 V		8.7	11.0
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	14.6	----
	5.0 V, 5.0 V		14.3	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	9.7	----
	5.0 V, 5.0 V		4.6	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.8	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.9	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Models with serial number prefixes NWM, NWP, NWN, NWR, NWS, NWU, and NWV

Table C-12 ADSR01/03/06, SESR01, SES01, RESR01, RES01 Projected service life from implant to RRT/ERI in years

Pacing	Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
SSIR or SSI, 0%	2.0 V	60 min^{-1}, 0.4 ms	11.3	11.3
	2.5 V		10.4	10.4
	3.5 V		11.1	11.1
SSIR or SSI, 50%	2.0 V	60 min^{-1}, 0.4 ms	10.4	10.8
	2.5 V		9.5	9.9
	3.5 V		9.0	9.9
SSIR or SSI, 100%	2.0 V	60 min^{-1}, 0.4 ms	9.6	10.4
	2.5 V		8.7	9.5
	3.5 V		7.5	8.9
SSIR or SSI, 0%	2.5 V	70 min^{-1}, 0.5 ms	10.3	----
	5.0 V		10.2	----
SSIR or SSI, 100%	2.5 V	70 min^{-1}, 0.5 ms	8.0	----
	5.0 V		4.6	----
SSIR or SSI, 100%	5.0 V	70 min^{-1}, 1.0 ms	3.1	----
SSIR or SSI, 100%	5.0 V	100 min^{-1}, 1.0 ms	2.3	----

Projected service life: Models with serial number prefixes NWG and NWX

Table C-13 ADVDD01, REVDD01 Projected service life from implant to RRT/ERI in years

Pacing	Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
VDD, 0%	2.0 V	60 min^{-1}, 0.4 ms	9.8	9.8
	2.5 V		9.1	9.1
	3.5 V		9.5	9.5
VDD, 50%	2.0 V	60 min^{-1}, 0.4 ms	9.1	9.4
	2.5 V		8.4	8.7
	3.5 V		7.9	8.6
VDD, 100%	2.0 V	60 min^{-1}, 0.4 ms	8.5	9.0
	2.5 V		7.7	8.3
	3.5 V		6.8	7.9
VDD, 0%	2.5 V	70 min^{-1}, 0.5 ms	9.0	----
	5.0 V		8.8	----
VDD, 100%	2.5 V	70 min^{-1}, 0.5 ms	7.1	----
	5.0 V		4.3	----
VDD, 100%	5.0 V	70 min^{-1}, 1.0 ms	3.0	----
VDD, 100%	5.0 V	100 min^{-1}, 1.0 ms	2.2	----

Note: VDD longevity is calculated with the following conditions: Dual chamber device, DDD mode, 0.0 V amplitude in the atrium (atrial pacing disabled).

Projected service life: Models with serial number prefixes NWH, NWL, NWK, NWT, and NWW

Table C-14 VEDR01, SEDR01, SED01, REDR01, RED01 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.8	12.8
	2.5 V, 2.5 V		11.9	11.9
	3.5 V, 3.5 V		12.5	12.5
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	11.4	12.0
	2.5 V, 2.5 V		10.2	11.0
	3.5 V, 3.5 V		9.1	10.4
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	10.2	11.3
	2.5 V, 2.5 V		9.0	10.2
	3.5 V, 3.5 V		7.1	8.9
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	11.8	----
	5.0 V, 5.0 V		11.5	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	7.9	----
	5.0 V, 5.0 V		3.8	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.5	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.8	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Projected service life: Model with serial number prefix NWJ

Table C-15 SEDRL1 Projected service life from implant to RRT/ERI in years

Pacing	A Amplitude, V Amplitude	Rate, Pulse Width	Lead impedance	
			500 Ω	1000 Ω
			Longevity (years)	
DDDR or DDD, 0%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	15.9	15.9
	2.5 V, 2.5 V		14.8	14.8
	3.5 V, 3.5 V		15.5	15.5
DDDR or DDD, 50%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	14.1	14.9
	2.5 V, 2.5 V		12.7	13.6
	3.5 V, 3.5 V		11.2	12.9
DDDR or DDD, 100%	1.5 V, 2.0 V[a]	60 min^{-1}, 0.4 ms	12.6	14.0
	2.5 V, 2.5 V		11.1	12.6
	3.5 V, 3.5 V		8.7	11.0
DDDR or DDD, 0%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	14.6	----
	5.0 V, 5.0 V		14.3	----
DDDR or DDD, 100%	2.5 V, 2.5 V	70 min^{-1}, 0.5 ms	9.7	----
	5.0 V, 5.0 V		4.6	----
DDDR or DDD, 100%	5.0 V, 5.0 V	70 min^{-1}, 1.0 ms	2.8	----
DDDR or DDD, 100%	5.0 V, 5.0 V	100 min^{-1}, 1.0 ms	1.9	----

[a] For ACM the Minimum Adapted Amplitude is 1.5 V (nominal). For VCM the Minimum Adapted Amplitude is 2.0 V (nominal).

Prolonged service period

When the device reaches RRT/ERI, it automatically changes the mode and rate as shown in Table C-16.

At most programming settings, at least 95% of the pacemakers will achieve a prolonged service period of at least 3 months after RRT/ERI is set.

The 3 month prolonged service period between RRT/ERI and EOS assumes 100% pacing at the settings shown in Table C-16, RV Amplitude of 3.5 V, RV Pulse Width of 0.4 ms, and pacing load of 500 Ω. Reprogramming the pacing parameters may reduce the duration of the prolonged service period.

Recommended Replacement Time (RRT/ERI)

The Recommended Replacement Time (RRT/ERI) establishes the time when the physician should schedule replacement of the device as soon as possible.

RRT/ERI is set when the battery voltage drops below a certain limit. Listed below are the nonmagnet and magnet modes at RRT/ERI.

Table C-16 RRT/ERI conditions

Nonmagnet Mode	VVI mode at 65 min^{-1} rate
Magnet Mode	VOO mode at 65 min^{-1} rate
Telemetry	Replacement message on programmer
Battery/Lead Information	Replacement message and displayed battery voltage on programmer

From the point that the RRT/ERI is set, the pacemaker will operate at RRT/ERI conditions for approximately three months for typical pacemaker configurations during the normal operating life. At the end of three months, erratic pacing will ensue. The patient should be scheduled for immediate pacemaker replacement when the RRT/ERI is first found to be set.

Distinguishing RRT/ERI from full electrical reset

Unlike RRT/ERI, a full electrical reset puts the device initially in the VVI mode at 65 min^{-1} and then automatically restarts the initialization sequence of implant detection, as described in “Implant Detection” on page 88. Current devices are designed to be less susceptible to electrocautery, defibrillation, and so forth, than previous generation Medtronic devices, and only extreme electromagnetic disturbances can trigger a full electrical reset.

- If the full electrical reset condition exists and the RRT/ERI status is not set, reprogram the desired mode after the pacemaker completes the initialization sequence or use the programmer reset command to clear the reset condition and manually reprogram the pacemaker.
- If after interrogating the pacemaker a message appears on the programmer screen/printout indicating that the date/time memory has been altered or the model has changed to SES01, contact a Medtronic representative for further information.

Battery specifications

The three types of batteries used in Adapta/Versa/Sensia/Relia pacemakers are listed in the tables below. Note that the projected deliverable capacity is the estimated average capacity of the battery.

Table C-17 Battery specifications for Models ADDR01, ADDR03, ADDR06, ADD01

Type	Sigma 263 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	1.2 ampere-hour

Table C-18 Battery specifications for Model ADDRS1

Type	Sigma 213 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	0.83 ampere-hour

Table C-19 Battery specifications for Model ADDRL1

Type	Sigma 303 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	1.4 ampere-hour

Table C-20 Battery specifications for Models ADSR01, ADSR03, ADSR06, SESR01, SES01, RESR01, RES01

Type	Sigma 213 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	0.86 ampere-hour

Table C-21 Battery specifications for Model ADVDD01, REVDD01

Type	Sigma 213 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	0.86 ampere-hour

Table C-22 Battery specifications for Models VEDR01, SEDR01, SED01, REDR01, RED01

Type	Sigma 263 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	1.2 ampere-hour

Table C-23 Battery specifications for Model SEDRL1

Type	Sigma 303 Lithium-Iodine
Voltage	2.8 Volts
Projected deliverable capacity	1.4 ampere-hour

Telemetry and diagnostic values

D

Magnet Mode operations

Listed in Table D-1 are the Magnet Mode operations in dual and single chamber modes.

Note: For the purpose of this table, the AAI<=>DDD and AAIR<=>DDDR modes are considered dual chamber modes.

Table D-1 Magnet mode operations

Dual chamber modes	DOO mode at 85 min^{-1}
VDD mode	VOO mode at 85 min^{-1}
Single chamber modes	VOO/AOO mode at 85 min^{-1}

When the programming head is placed over the pacemaker, Magnet Mode is automatically cancelled and the programmed mode is maintained. Magnet Mode is established by placing the programming head over the pacemaker until the head light indicates telemetry is possible and starting the Magnet test.

Placing a transtelephonic magnet over the pacemaker and moving it along the axis will immediately start the Magnet Mode.

Figure D-1 shows the axis for all pacemaker models.

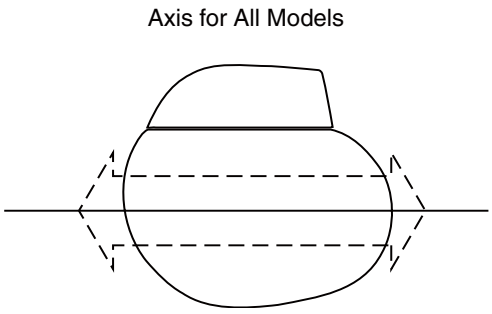


Figure D-1. Positioning the magnet or programming head

Telemetry functions

Telemetry functions include the following:

- Marker Channel and Extended Telemetry
- Electrograms—listed in Table D-2
- Battery and lead information—listed in Table D-3 and Table D-4
- Patient data telemetry

Marker Channel and extended telemetry

- Standard
- Therapy Trace

Electrograms (EGM)

Table D-2 Electrograms

Type of Electrogram[a]	Series
Intracardiac	
Atrial EGM	All[b]
Ventricular EGM	All[c]
Summed EGM	Dual-chamber models
Dual EGM	Dual-chamber models

[a] For single-chamber models (SR Series and S Series), EGM collection options are OFF and EGM.

[b] Applies to dual-chamber models and to single-chamber models that are set to atrial mode.

[c] Applies to dual-chamber models and to single-chamber models that are set to ventricular mode.

Battery and Lead Information

Table D-3 Battery information telemetry

Battery Status	Value	Tolerance[a]
Message	"OK" or "Replace Pacer"	
Voltage	Volts	± 10%
Current	μA	± 29%
Impedance	Ohms	± 10% (± 100 ohms)
Estimated Time to Replace	Years or Months	Compare with minimum, maximum values.

[a] Based on a 200 to 1250 ohm load at the time of manufacture until Recommended Replacement Time (RRT/ERI) is set.

Table D-4 Lead information telemetry[a]

Lead Status	Value	Tolerance[b]
Amplitude	Volts	± 10%
Pulse Width	ms	± 10 ms
Output Energy	μJ	± 45%
Measured Current	mA	± 35%
Measured Impedance	Ohms	± 20%
Pace Polarity	Unipolar/Bipolar	

[a] Lead information is identical for the atrial and ventricular chambers.

[b] Based on a 200 to 1250 ohm load at the time of manufacture until Recommended Replacement Time (RRT/ERI) is set.

Patient data

The types of patient data stored in the pacemaker are as follows:

- Notes
- Patient Identification
  - Name
  - Age
  - I.D. Number
  - Chart Number
- Indications for Implant

  The History window allows you to program the clinical conditions that are made available to TherapyGuide.
- Atrial and Ventricular Leads Implanted
  - Lead Manufacturer
  - Lead Model
  - Lead Serial Number
  - Lead Implant Date
- Device Implanted
  - Serial Number
  - Implant Date
- Physician Information
  - Name
  - Phone No.

The clinical conditions for Therapy Guide are programmed in device memory. See “Using TherapyGuide to select parameter values” on page 179.

Automatic diagnostics

The automatic diagnostics listed in Table D-5 are automatically collected by the pacemaker. Note that some of the diagnostics have programmable parameters that are accessed by selecting Data Collection Setup under the Data icon.

Note: The diagnostics in this section are categorized by mode prefixes contained in the model number (for example, DR Series). The diagnostic parameters shown can apply to a model in that series, provided that the pacemaker was manufactured with that diagnostic. To find applicable diagnostics for a specific model, refer to the Implant Manual for that pacemaker.

Table D-5 Automatic diagnostics

Parameter	Series	Settings
Heart Rate Histograms (Short and Long Term, Atrial and Ventricular)	All[a]	
Include Refractory Senses		Include, Exclude
AV Conduction Histograms (Short and Long Term)	DR Series, D Series, VDD Series	
Search AV+ Histogram	DR Series, D Series, VDD Series	
Sensor Indicated Rate Profile	DR Series, D Series, VDD Series, SR Series	
Atrial High Rate Episodes (Mode Switch On)	DR Series, D Series, VDD Series	
Collection Delay after Mode Switch		0, 1, 2 … 20, 25, 30 … 60 seconds
Collection Method		Frozen, Rolling
Atrial High Rate Episodes (Mode Switch Off)	All[b]	

Table D-5 Automatic diagnostics (continued)

Parameter	Series	Settings
Detection Rate		80, 85, 90 … 180, 200, 220, 240 … 320, 330, 350, 370, 380, 400 min^{-1}
Detection Duration[c]		1, 2, 3 … 20, 25, 30 … 50, 55, 60 sec
Termination Beats		5, 6, 7 … 20 beats
Collection Method[d]		Frozen, Rolling
Ventricular High Rate Episodes	All[b]	
Detection Rate		80, 85, 90 … 180, 200, 220, 240 … 320, 330, 350, 370, 380, 400 min^{-1}
Detection Duration[c]		2, 3, 4 … 198, 199, 200 beats
Termination Beats		5, 6, 7 … 20 beats
SVT Filter	DR Series, D Series, VDD Series	Off, On
Collection Method[d]		Frozen, Rolling
Atrial Arrhythmia Trend	DR Series, D Series, VDD Series, SR Series	
Atrial Arrhythmia Durations	DR Series, D Series, VDD Series, SR Series	
Ventricular Rate During Atrial Arrhythmias	DR Series, D Series, VDD Series	
Rate Drop Response Episodes	DR Series, D Series	Based on programmed therapy
Chronic Lead Trends	All	
Lead Monitor Counters	All	
Sensitivity Trends	All	Monitors chambers with Sensing Assurance
Capture Management Trend		Based on use of Capture Management

Table D-5 Automatic diagnostics (continued)

Parameter	Series	Settings
Atrial Capture Management	DR Series, D Series	
Ventricular Capture Management	All	
Key Parameter History	All	

[a] For single chamber models (SR Series and S Series), Heart Rate Histograms are available for the paced chamber. For all models, Heart Rate Histograms can be programmed to include or exclude refractory sensed events.

[b] For single chamber models (SR Series and S Series), High Rate Episode is available for the paced chamber.

[c] For single chamber models (SR Series and S Series), Detection Duration is 2 to 200 beats.

[d] Collection Method applies to Atrial High Rate Episodes and Ventricular High Rate Episodes.

Clinician-selectable diagnostics

Note: The diagnostics in this section are categorized by mode prefixes contained in the model number (for example, DR Series). The diagnostic parameters shown can apply to a model in that series, provided that the pacemaker was manufactured with that diagnostic. To find applicable diagnostics for a specific model, refer to the Implant Manual for that pacemaker.

The clinician-selected diagnostics listed in Table D-6 through Table D-9 are programmed by selecting Data Collection/Setup under the Data icon. Table D-6 lists the parameters for all clinician-selectable diagnostics except for High Rate Detail. To learn which set of parameters applies to a specific model, refer to the Implant Manual for that pacemaker.

The parameters settings for High Rate Detail diagnostics are presented in Table D-7 through Table D-9. Table D-7 applies to Adapta and Versa pacemakers, which collect 48 seconds of EGM. Table D-8 applies to Sensia pacemakers, which collect 24 seconds of EGM. Table D-9 applies to Relia pacemakers, which collect 16 seconds of EGM.

Notes:

- For each clinician-selectable diagnostic with EGM collection, there is an automatic diagnostic that collects corresponding trend data.

- The parameters settings for the automatic High Rate Episode diagnostics also apply to the corresponding clinician-selectable High Rate Detail diagnostics.

Table D-6 Common clinician-selectable diagnostics

Diagnostic and parameters	Series	Parameter settings
Custom Rate Trend	All	
Duration		Beat-to-Beat, 1 Hour, 24 hours
Collection Method		Frozen, Rolling
Include Refractory Senses?		Include, Exclude
Ventricular Capture Management Detail	All	
EGM Collection		Off, Atrial EGM, Ventricular EGM, Summed EGM[a]
Atrial Capture Management Detail	DR Series, D Series	
EGM Collection		Off, Atrial EGM, Ventricular EGM, Summed EGM
Rate Drop Response Detail	DR Series, D Series	
Include Refractory Senses?		Include, Exclude

[a] For single chamber models (SR Series and S Series), EGM Collection options are limited to OFF and EGM.

Table D-7 High Rate Detail for Adapta and Versa models

Diagnostic and parameters	Series	Parameter settings
High Rate Detail[a]	All[b]	
High Rate Type[c]		AHR and VHR, AHR, VHR
EGM Type		Off, Atrial EGM, Ventricular EGM, Summed EGM[d]

Table D-7 High Rate Detail for Adapta and Versa models (continued)

Diagnostic and parameters	Series	Parameter settings
Allocation (Collection Method[e] = Frozen, High Rate Type = AHR and VHR)		2 for 0/24, 2 for 24/0, 2 for 12/12, 4 for 0/12, 4 for 12/0, 4 for 6/6, 8 for 0/6, 8 for 6/0, 8 for 3/3 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e] = Frozen, High Rate Type = AHR only or VHR only)		1 for 0/48, 1 for 48/0, 1 for 24/24, 2 for 0/24, 2 for 24/0, 2 for 12/12, 4 for 0/12, 4 for 12/0, 4 for 6/6, 8 for 0/6, 8 for 6/0, 8 for 3/3 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e] = Rolling, High Rate Type = AHR and VHR)		2 for 16/0, 2 for 8/8, 2 for 0/24, 4 for 8/0, 4 for 4/4, 4 for 0/12, 8 for 4/0, 8 for 2/2, 8 for 0/6 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e]= Rolling, High Rate Type = AHR only or VHR only)		1 for 24/0, 1 for 12/12, 1 for 0/48, 2 for 16/0, 2 for 8/8, 2 for 0/24, 4 for 8/0, 4 for 4/4, 4 for 0/12, 8 for 4/0, 8 for 2/2, 8 for 0/6 (number of episodes for pre-onset seconds/post onset seconds collected)
Pre-detection Timeout		1, 2, 3 … 12, 14, 16 … 24 weeks

[a] High rate detection rate, detection duration, and termination criteria are set by parameters for the automatic diagnostic (Atrial High Rate Episodes or Ventricular High Rate Episodes - see page 290).

[b] For single chamber models (SR Series), High Rate Detail is available for the paced chamber.

[c] For single chamber models (SR Series), High Rate Type is not displayed.

[d] For single chamber models (SR Series), EGM Collection options are limited to OFF and EGM.

[e] Collection Method is set in either of the High Rate Episodes automatic diagnostics.

Table D-8 High Rate Detail for Sensia models

Diagnostic and parameters	Series	Parameter settings
High Rate Detail[a]	All[b]	
High Rate Type[c]		AHR and VHR, AHR, VHR
EGM Type		Off, Atrial EGM, Ventricular EGM, Summed EGM[d]
Allocation (Collection Method[e] = Frozen, High Rate Type = AHR and VHR)		2 for 12/0, 2 for 0/12, 2 for 6/6, 4 for 0/6, 4 for 6/0, 4 for 3/3 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e] = Frozen, High Rate Type = AHR only or VHR only)		1 for 0/24, 1 for 24/0, 1 for 12/12, 2 for 12/0, 2 for 0/12, 2 for 6/6, 4 for 0/6, 4 for 6/0, 4 for 3/3 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e] = Rolling, High Rate Type = AHR and VHR)		2 for 8/0, 2 for 4/4, 2 for 0/12, 4 for 4/0, 4 for 2/2, 4 for 0/6 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e] = Rolling, High Rate Type = AHR only or VHR only)		1 for 12/0, 1 for 6/6, 1 for 0/24, 2 for 8/0, 2 for 4/4, 2 for 0/12, 4 for 4/0, 4 for 2/2, 4 for 0/6 (number of episodes for pre-onset seconds/post onset seconds collected)
Pre-detection Timeout		1, 2, 3 … 12, 14, 16 … 24 weeks

[a] High rate detection rate, detection duration, and termination criteria are set by parameters for the automatic diagnostic (Atrial High Rate Episodes or Ventricular High Rate Episodes - see page 290).

[b] For single chamber models (SR Series and S Series), High Rate Detail is available for the paced chamber.

[c] For single chamber models (SR Series and S Series), High Rate Type is not displayed.

[d] For single chamber models (SR Series and S Series), EGM Collection options are limited to OFF and EGM.

[e] Collection Method is set in either of the High Rate Episodes automatic diagnostics.

Table D-9 High Rate Detail for Relia models
Table D-10.

Diagnostic and parameters	Series	Parameter settings
High Rate Detail[a]	All[b]	
High Rate Type[c]		AHR, VHR
EGM Type		Off, Atrial EGM, Ventricular EGM, Summed EGM[d]
Allocation (Collection Method[e] = Frozen, High Rate Type = AHR only or VHR only)		1 for 0/16, 1 for 16/0, 1 for 8/8, 2 for 0/8, 2 for 8/0, 2 for 4/4, 4 for 0/4, 4 for 4/0, 4 for 2/2 (number of episodes for pre-onset seconds/post onset seconds collected)
Allocation (Collection Method[e] = Rolling, High Rate Type = AHR only or VHR only)		1 for 8/0, 1 for 4/4, 1 for 0/8, 2 for 4/0, 2 for 2/2, 2 for 0/4, 4 for 2/0, 4 for 1/1, 4 for 0/2 (number of episodes for pre-onset seconds/post onset seconds collected)
Pre-detection Timeout		1, 2, 3 … 12, 14, 16 … 24 weeks

[a] High rate detection rate, detection duration, and termination criteria are set by parameters for the automatic diagnostic (Atrial High Rate Episodes or Ventricular High Rate Episodes - see page 290).

[b] For single chamber models (SR Series and S Series), High Rate Detail is available for the paced chamber.

[c] For single chamber models (SR Series and S Series), High Rate Type is not displayed.

[d] For single chamber models (SR Series and S Series), EGM Collection options are limited to OFF and EGM.

[e] Collection Method is set in either of the High Rate Episodes automatic diagnostics.

Cardiac event counters

Table D-11 Cardiac event counters

Type of counter	Series
Automatic Event Counters[a] (AS-VS, AS-VP, AP-VS, AP-VP)	All
Percent Paced Events	All
Percent Sensed Events	All
AV Conduction Events	DR Series, D Series, VDD Series
Premature Ventricular Contraction (PVC), singles and runs	DR Series, D Series, VDD Series
Premature Atrial Contraction (PAC), runs only	DR Series, D Series, VDD Series
Lead Performance	All

[a] For single-chamber pacing modes, the event counters are Paced and Sensed.

Parameter values and restrictions

E

Programmable modes and parameters

Parameter settings shown in the following tables show all the programmable parameters.

Note: Specifications in this section are categorized by mode prefixes contained in the model number (for example, DR Series). Parameters shown can apply to a model in that series, provided that the pacemaker was manufactured with the feature. To find applicable features for a specific model, refer to the Implant Manual for that pacemaker.

Caution: When programming Upper Tracking Rates of 190, 200, or 210 min^{-1}, be careful to ensure that these rates are appropriate for the patient. The Upper Tracking Rates of 190, 200, and 210 min^{-1} are intended primarily for use in pediatric patients.

Table E-1 Mode and rates

Parameter	Series	Settings	Tolerances	Notes
Mode	DR Series	AAIR<=>DDDR, DDDR, AAI<=>DDD, DDD, DDIR, DDI, DVIR, DVI, DOOR, DOO, VDD, VVIR, VDIR, VVI, VDI, VVT, VOOR, VOO, AAIR, ADIR, AAI, ADI, AAT, AOOR, AOO, ODO, OVO, OAO	None	
	D Series	AAI<=>DDD, DDD, VDD, DDI, DVI, DOO, VVI, VDI, VVT, VOO, AAI, ADI, AAT, AOO, ODO, OVO, OAO, VVIR, VOOR, AAIR, AOOR, VDIR, ADIR	None	
	VDD Series	VDD, VVIR, VDIR, VVI, VDI, VVT, VOOR, VOO, ODO, OVO, OAO	None	
	SR Series	VVIR, VVI, VVT, VOOR, VOO, AAIR, AAI, AAT, AOOR, AOO, OVO, OAO	None	
	S Series	VVI, VVT, VOO, AAI, AAT, AOO, OVO, OAO	None	
Mode Switch	DR Series, D Series, VDD Series	On, Off	None	

Table E-1 Mode and rates (continued)

Parameter	Series	Settings	Tolerances	Notes
Detect Rate	DR Series, D Series, VDD Series	120, 125, 130 … 200, 210, 220 min^{-1}	± 3 min^{-1}	
Detect Duration	DR Series, D Series, VDD Series	No Delay, 10, 20 … 60 sec	None	
Blanked Flutter Search	DR Series, D Series, VDD Series	On, Off	None	
Lower Rate	DR Series, D Series, VDD Series, SR Series	30, 35, 40 … 120 min^{-1} 125, 130, 135 … 170 min^{-1} (except 65 and 85 min^{-1})	± 1 min^{-1} ± 2 min^{-1}	
Lower Rate	S Series	30, 35, 40 … 120 min^{-1} 125, 130, 135 … 175 min^{-1} (except 65 and 85 min^{-1})	± 1 min^{-1} ± 2 min^{-1}	
Upper Tracking Rate[a,b]	DR Series, D Series, VDD Series	80, 90, 95 … 180, 190, 200, 210 min^{-1}	± 2 min^{-1}	
Upper Sensor Rate	DR Series, D Series, VDD Series, SR Series	80, 90, 95, 100 … 180 min^{-1}	± 2 min^{-1}	

[a] If the Upper Tracking Rate is set to 190 min^{-1} or higher, the atrial and ventricular Rate Limit is 227 min^{-1} (± 17 min^{-1}). Otherwise, the atrial and ventricular Rate Limit is 200 min^{-1} (± 20 min^{-1}).

[b] For Sensia and Relia models, the maximum Upper Tracking Rate is 180 min^{-1}.

Table E-2 Rate Response

Parameter	Series	Settings	Tolerances	Notes
ADL Rate	DR Series, D Series, VDD Series, SR Series	60, 65, 70 … 120 min^{-1} 125, 130, 135 … 175 min^{-1}	± 1 min^{-1} ± 2 min^{-1}	
Rate Profile Optimization	DR Series, D Series, VDD Series, SR Series	On, Off	None	
ADL Response	DR Series, D Series, VDD Series, SR Series	1, 2, 3, 4, 5	None	
Exertion Response	DR Series, D Series, VDD Series, SR Series	1, 2, 3, 4, 5	None	
ADL Setpoint	DR Series, D Series, VDD Series, SR Series	5, 6, 7 … 40, 42, 44, 46 … 80	None	Programmable from the Exercise test only
UR Setpoint	DR Series, D Series, VDD Series, SR Series	15, 16, 17 … 40, 42, 44, 46 … 80, 85, 90, 95 … 180	None	Programmable from the Exercise test only
Activity Threshold	DR Series, D Series, VDD Series, SR Series	Low, Medium/Low, Medium/High, High	None	

Table E-2 Rate Response (continued)

Parameter	Series	Settings	Tolerances	Notes
Acceleration	DR Series, D Series, VDD Series, SR Series	15 sec 30 sec 60 sec	+8, -2 sec +13, -3 sec +19, -3 sec	
Deceleration	DR Series, D Series, VDD Series, SR Series	2.5 min 5.0 min 10 min Exercise	+0.6, -0.2 min +1.1, -0.5 min +1.1, -1.0 min None	

Table E-3 Atrial Lead[a]

Parameter	Series	Settings	Tolerances	Notes
Amplitude[b] (with Atrial Capture Management)	DR Series, D Series	0.5, 0.75, 1.0 … 4.0, 4.5, 5.0 V	± 10%	0.625, 0.875, 1.125, 1.375, 1.625, and 1.875 V can be set by Capture Management. Values are displayed but are not selectable.
Amplitude[b] (without Atrial Capture Management)	DR Series, D Series, SR Series, S Series	0.5, 0.75, 1.0 … 4.0, 4.5, 5.0, 5.5, 6.0 V 7.5 V	± 10% +0/-20%	
Pulse Width (with Atrial Capture Management)	DR Series, D Series	0.12, 0.15 ms 0.21, 0.27, 0.34, 0.40, 0.46, 0.52, 0.64, 0.76, 1.00 ms	± 10 ms ± 25 ms	Settings lower than 0.40 ms can be programmed, but Capture Management adjusts them to 0.40 ms.
Pulse Width (without Atrial Capture Management)	DR Series, D Series, SR Series, S Series	0.12, 0.15 ms 0.21, 0.27, 0.34, 0.40, 0.46, 0.52, 0.64, 0.76, 1.00, 1.25, 1.50 ms	± 10 ms ± 25 ms	
Sensitivity	All	0.18[c], 0.25, 0.35 mV 0.5, 0.7, 1.0, 1.4, 2.0, 2.8, 4.0 mV	± 60% ± 40%	0.18, 0.25, 0.35 mV apply to bipolar atrial sensing only
Sensing Assurance	Adapta, Versa, Sensia	On, Off	None	
Pacing Polarity	DR Series, D Series, SR Series, S Series	Bipolar, Unipolar[d], Configure	None	Configure is displayed but is not selectable.

Table E-3 Atrial Lead[a] (continued)

Parameter	Series	Settings	Tolerances	Notes
Sensing Polarity	DR Series, D Series, SR Series, S Series	Bipolar, Unipolar[d], Configure	None	Configure is displayed but is not selectable.
	VDD Series	Bipolar	None	
Lead Monitor[e, f]	DR Series, D Series, SR Series, S Series	Configure, Monitor Only, Adaptive, Off	None	
Notify if < (less than)		200 ohms	None	nonprogrammable
Notify if > (greater than)		1000, 2000, 3000, 4000 ohms	None	
Monitor Sensitivity		2, 3, 4 … 16	None	

[a] Applies to SR Series and S Series when set on atrial mode.

[b] Tolerance for amplitudes from 0.5 V through 6.0 V is ± 10%, and for 7.5 V is -20/+0%. Tolerances are based on 37°C and a 500-ohm load. Amplitude is determined 200 microseconds after the leading edge of the pace.

[c] The atrial sensitivity value 0.18 mV does not apply to the SR Series and S Series models.

[d] Unipolar-only models are set to a fixed value of Unipolar.

[e] For single chamber models (SR Series and S Series), Lead Monitor is available only for the paced chamber.

[f] Unipolar-only models are set to a fixed value of Monitor Only.

Table E-4 Ventricular Lead[a]

Parameter	Series	Settings	Tolerances	Notes
Amplitude[b] (with Ventricular Capture Management)	All	0.5, 0.75, 1.0 … 4.0, 4.5, 5.0 V	± 10%	0.625, 0.875, 1.125, 1.375, 1.625, and 1.875 V can be set by Ventricular Capture Management. Values are displayed but are not selectable.
Amplitude[b] (without Ventricular Capture Management)	All	0.5, 0.75, 1.0 … 4.0, 4.5, 5.0, 5.5, 6.0 V 7.5 V	± 10% +0/-20%	
Pulse Width (with Ventricular Capture Management)	All	0.12, 0.15 ms 0.21, 0.27, 0.34, 0.40, 0.46, 0.52, 0.64, 0.76, 1.00 ms	± 10 ms ± 25 ms	Settings lower than 0.40 ms can be programmed, but Capture Management adjusts them to 0.40 ms.
Pulse Width (without Ventricular Capture Management)	All	0.12, 0.15 ms 0.21, 0.27, 0.34, 0.40, 0.46, 0.52, 0.64, 0.76, 1.00, 1.25, 1.50 ms	± 10 ms ± 25 ms	
Sensitivity	All	1.0, 1.4, 2.0, 2.8, 4.0, 5.6, 8.0, 11.2 mV	± 40%	
Sensing Assurance	Adapta, Versa, Sensia	On, Off	None	
Pacing Polarity	All	Bipolar, Unipolar[c], Configure	None	Configure is displayed but is not selectable.
Sensing Polarity	All	Bipolar, Unipolar[c], Configure	None	Configure is displayed but is not selectable.
Lead Monitor[d, e]	All	Configure, Monitor Only, Adaptive, Off		
Notify if < (less than)		200 ohms	None	nonprogrammable

Table E-4 Ventricular Lead[a] (continued)

Parameter	Series	Settings	Tolerances	Notes
Notify if > (greater than)		1000, 2000, 3000, 4000 ohms	None	
Monitor Sensitivity		2, 3, 4 … 16	None	

[a] Applies to SR Series and S Series when set on ventricular mode.

[b] Tolerance for amplitudes from 0.5 V through 6.0 V is ± 10%, and for 7.5 V is -20/+0%. Tolerances are based on 37°C and a 500-ohm load. Amplitude is determined 200 microseconds after the leading edge of the pace.

[c] Unipolar-only models are set to a fixed value of Unipolar.

[d] For single chamber models (SR Series and S Series), Lead Monitor is available only for the paced chamber.

[e] Unipolar-only models are set to a fixed value of Monitor Only.

Table E-5 Ventricular Capture Management

Parameter	Series	Settings	Tolerances	Notes
Ventricular Capture Management	All	Off, Monitor Only, Adaptive	None	
Amplitude Margin	All	1.5x, 2x, 2.5x, 3x, 4x (times)	None	
Minimum Adapted Amplitude	All	0.5, 0.75, 1.0 … 3.5 V	None	
Capture Test Frequency	All	15, 30 minutes 1, 2, 4, 8, 12 hours, Day at Rest, Day at …, 7 Days at …	None	For Day(s) at …, next parameter specifies the time of day.
Capture Test Time	All	12:00 AM, 1:00 AM … 11:00 PM	None	Applies only for Day(s) at … parameter.
Acute Phase Days Remaining[a]	All	Off, 7, 14 … 84,112, 140, 168, 196, 224, 252 days	None	
V. Sensing during Search	All	Unipolar[b], Bipolar, Adaptive	None	

[a] If the acute phase is completed, the time and date of completion are indicated below Acute Phase Days Remaining.

[b] Unipolar-only models are set to a fixed value of Unipolar.

Table E-6 Atrial Capture Management

Parameter	Series	Settings	Tolerances	Notes
Atrial Capture Management	DR Series, D Series	Off, Monitor Only, Adaptive	None	
Amplitude Margin		1.5x, 2x, 2.5x, 3x, 4x (times)	None	
Minimum Adapted Amplitude		0.5, 0.75, 1.0 … 3.5 V	None	
Capture Test Frequency		1, 2, 4, 8, 12 hours, Day at Rest, Day at …, 7 Days at …	None	For Day(s) at …, next parameter specifies the time of day.
Capture Test Time		12:00 AM, 1:00 AM … 11:00 PM	None	Applies only for Day(s) at … parameter.
Acute Phase Days Remaining[a]		Off, 7, 14 … 84,112, 140, 168, 196, 224, 252 days	None	

[a] If the acute phase is completed, the time and date of completion are indicated below Acute Phase Days Remaining.

Table E-7 Intrinsic Activation and AV Intervals

Parameter	Series	Settings	Tolerances	Notes
Paced AV (PAV)	DR Series, D Series	30, 40, 50 … 350 ms	± 4 ms	
Sensed AV (SAV)	DR Series, D Series, VDD Series	30, 40, 50 … 350 ms	+16/–4 ms	
RAAV	DR Series, D Series, VDD Series	On, Off	None	
Start Rate		50, 55, 60 … 175 min^{-1}	None	
Stop Rate		55, 60, 65 … 180 min^{-1}	None	
Maximum Offset		-10, -20, -30 … -300 ms	None	
Search AV+	DR Series, D Series, VDD Series	On, Off	None	
Max Increase to AV		10, 20, 30 … 250 ms	None	
Sinus Preference	DR Series	On, Off	None	
Sinus Preference Zone		3, 5, 10, 15, 20 min^{-1}	None	
Search Interval		5, 10, 20, 30 minutes	None	

Table E-8 Refractory / Blanking

Parameter	Series	Settings	Tolerances	Notes
PVARP	DR Series, D Series, VDD Series	Auto, Varied, 150, 160, 170 … 500 ms	± 9 ms	
Minimum PVARP		150, 160, 170 … 500 ms	± 9 ms	Auto PVARP only
PVAB	DR Series, D Series, VDD Series	130, 140, 150 … 350 ms	± 9 ms	Blanking for PVARP
Ventricular Refractory Period	All	150, 160, 170 … 500 ms	± 9 ms	
Ventricular Blanking Period	DR Series, D Series	20, 28, 36, 44 ms	+0/–15 ms	After atrial pace
Atrial Refractory Period	DR Series, D Series, SR Series, S Series	180, 190, 200 … 500 ms	± 9 ms	
Atrial Blanking Period	DR Series, D Series, SR Series, S Series	130, 140, 150 … 350 ms	± 9 ms	

Table E-9 Additional Features

Parameter	Series	Settings	Tolerances	Notes
Sleep Function	All	On, Off	None	
Sleep Rate	All	30, 35, 40 … 90 min^{-1} (except 65 and 85 min^{-1})	± 1 min^{-1}	
Bed Time	All	12:00 AM, 12:15 AM, 12:30 AM … 11:45 PM	± 10 min	
Wake Time	All	12:00 AM, 12:15 AM, 12:30 AM … 11:45 PM	± 10 min	
Non-Competitive Atrial Pacing	DR Series, D Series	On, Off	None	
Single Chamber Hysteresis	All	40, 50, 60 min^{-1}, Off	± 1 min^{-1}	
Rate Drop Response	DR Series, D Series			
Detection Type		Low Rate, Drop, Both, Off	None	
Intervention Rate		60, 70, 75 … 120 min^{-1} 125, 130, 135 … 180 min^{-1} (except 65 and 85 min^{-1})	± 1 min^{-1} ± 2 min^{-1}	
Intervention Duration		1, 2, 3 … 15 minutes	None	
Detection Beats		1, 2, 3 beats	None	
Drop Rate		30, 40, 50 … 100 min^{-1}	± 1 min^{-1}	
Drop Size		10, 15, 20 … 50 min^{-1}	± 2 min^{-1}	
Detection Window		10, 15, 20 … 30 seconds 1, 1.5, 2, 2.5 minutes	None	
PMT Intervention	DR Series, D Series, VDD Series	On, Off	None	
PVC Response	DR Series, D Series, VDD Series	On, Off	None	

Table E-9 Additional Features (continued)

Parameter	Series	Settings	Tolerances	Notes
Ventricular Safety Pacing	DR Series, D Series	On, Off	None	
Implant Detection	All	On/Restart, Off/Complete[a]	None	

[a] If Implant Detection is completed, the time and date of completion are indicated below the Off/Complete setting.

Table E-10 Interventions

Parameter	Series	Settings	Tolerances	Notes
Post Mode Switch Pacing	DR Series, D Series	On, Off	None	
Overdrive Rate		70, 75, 80, 90, 95, 100 … 120 min^{-1}, excluding 85 min^{-1} for magnet operation	None	
Overdrive Period		0.5, 1, 2, 3, 5, 10, 20, 30, 60, 90, 120 min	None	
Atrial Preference Pacing	DR Series, D Series	On, Off	None	
Maximum Rate		80, 90, 95, 100 … 150 min^{-1}	None	
Interval Decrement		30, 40, 50 … 100; 150 ms	None	
Search Beats		5, 10, 15, 20, 25, 50	None	
Conducted AF Response[a]	DR Series, D Series, VDD Series, SR Series	On, Off	None	Continuously in DDIR, VDIR or VVIR modes, or during mode switching
Maximum Rate		80, 85, 90, 95 … 130 min^{-1}	± 2 min^{-1}	

[a] This feature was named Ventricular Response Pacing in previous pacemakers.

Table E-11 Telemetry Features

Parameter	Series	Settings	Tolerances	Notes
Transtelephonic Monitor	All	On, Off	None	
Extended Telemetry	All	On, Off	None	
Extended Marker[a]	All	Standard, Therapy Trace	None	

[a] Therapy Trace markers cannot be displayed or printed on the programmer.

The following parameters are programmable only when a specific type of Warning or Indicator status is set. You can check Observations on the Quick Look II screen to learn if a status type is set.

Table E-12 Status (reset) parameters

Parameter	Series	Settings	Notes
Atrial Lead Status	DR Series, D Series, SR Series, S Series	Reset Indicator	A subparameter of either Atrial Polarity
Ventricular Lead Status	All	Reset Indicator	A subparameter of either Vent. Polarity
RRT/ERI or POR Reset	All	Reset	Listed under Additional Features

Table E-13 Temporary parameters

Parameter	Series	Settings	Tolerances	Notes
Chamber	All	Atrium, Ventricle	None	Setting determines available modes.
Mode	DR Series, D Series	DDD, DDI,DOO, VDD, VDI, VVI, VVT, VOO, AAI, ADI, AAT, AOO, ODO, OVO, OAO	None	Availability of modes is dependent on programmed mode.
	VDD Series	VDD, VDI, VVI, VVT, VOO, ODO, OVO, OAO	None	Availability of modes is dependent on programmed mode.

Table E-13 Temporary parameters (continued)

Parameter	Series	Settings	Tolerances	Notes
	SR Series, S Series	VVI, VVT, VOO, AAI, AAT, AOO, OVO, OAO	None	Availability of modes is dependent on programmed mode.
Lower Rate	All	30, 35, 40 … 120 min^{-1} (except 65 and 85 min^{-1}), 125, 130, 135 …180 min^{-1} 190, 200, 210 … 250 min^{-1} 260, 270, 280, 300, 310, 320, 330, 350, 370, 380, 400 min^{-1}	± 1 min^{-1} ± 2 min^{-1} ± 3 min^{-1} ± 5 min^{-1}	Rates above 180 min^{-1} are available by selecting the enable button.
Amplitude[a]	All	0.25, 0.375 … 2.0 V 2.25, 2.50, 2.75 … 4.0 V 4.5, 5.0, 5.5, 6.0 V 7.5 V	± 10% ± 10% ± 10% +0/-20%	
Pulse Width	All	0.03, 0.06, 0.09 … 0.15 ms 0.21, 0.27, 0.34, 0.40, 0.46, 0.52, 0.64, 0.76, 1.00, 1.25, 1.50 ms	± 10 msec ± 25 msec	
Atrial Sensitivity	All	0.18[b], 0.25, 0.35 mV[c] 0.5, 0.7, 1.0, 1.4, 2.0, 2.8, 4.0 mV	± 60% ± 40%	
Ventricular Sensitivity	All	1.0, 1.4, 2.0, 2.8, 4.0, 5.6, 8.0, 11.2 mV	± 40%	
AV Delay	DR Series, D Series, VDD Series	30, 40, 50 … 350 ms	± 4 ms	Selection sets PAV and SAV if pertinent to mode.

[a] The amplitude values in 0.125 V increments apply only to the Capture Management and Temporary tests.

[b] The sensitivity value 0.18 mV does not apply to the SR Series and S Series.

[c] The values of 0.18, 0.25, and 0.35 mV are not available for unipolar-only models.

Rate Response programming guidelines

For basic information about Rate Profile Optimization, refer to “Rate Profile Optimization operation” on page 39 and “Individualizing Rate Profile Optimization” on page 46.

To adjust Rate Response (via Optimization):

1. Verify that the three rates are appropriate for the patient. The Lower Rate should provide sufficient cardiac support at rest; the ADL Rate should be set for rate support during typical daily activities; and the Upper Sensor Rate should limit the rate during vigorous exercise.
2. If these rates are appropriate, the ADL Response and/or Exertion Response parameters can then be adjusted based on the guidelines in Table E-14 and Table E-15.

Note: The ADL Response setting tells Optimization the amount of time to target the sensor rate in the ADL rate range (rates at or near the ADL Rate). The Exertion Response setting tells Optimization the amount of time to target the sensor rate in the exertion rate range (rates at or near the Upper Sensor Rate).

Table E-14 ADL Response programming guidelines

Evaluating ADL rate response		ADL Response values		Targeted minutes per day sensor rate is in the ADL rate range
Rate Response too aggressive	→ Select lower number	1	→	8 minutes
		2	→	15 minutes
Rate Response too low	→ Select higher number	3	→	30 minutes
		4	→	60 minutes
		5	→	100 minutes

Table E-15 Exertion Response programming guidelines

Evaluating exertion rate response		Exertion Response values		Targeted minutes per week sensor rate is in the exertion rate range[a]
Rate Response too aggressive	→ Select lower number	1	→	21 minutes
		2	→	21 minutes
Rate Response too low	→ Select higher number[b]	3	→	21 minutes
		4	→	51 minutes
		5	→	101 minutes

[a] The exertion rate range extends from the rate in parentheses to a programmed Upper Sensor Rate of 130 min^{-1} or greater.

[b] If a higher Exertion Response value has not produced the desired rate response, increase the ADL Response value.

Implant information

F

Warnings

Device operation

Crosstalk – Crosstalk may cause the device to self-inhibit, which will result in no pacing. Program Ventricular Safety Pacing to On to prevent inhibition due to crosstalk.

Lead compatibility – Do not use another manufacturer's leads without demonstrated compatibility with Medtronic devices. If a lead is not compatible with a Medtronic device, the result may be undersensing of cardiac activity, failure to deliver necessary therapy, or a leaking or intermittent electrical connection.

Lead connection – Consider the following information when connecting the lead and the device:

- Cap abandoned leads to avoid transmitting electrical signals.
- Plug any unused lead ports to protect the device.
- Verify lead connections. Loose lead connections may result in inappropriate sensing and failure to deliver arrhythmia therapy.

Rate responsive modes – Do not program rate responsive modes for patients who cannot tolerate rates above the programmed Lower Rate. Rate responsive modes may cause discomfort for those patients.

Single chamber atrial modes – Do not use program single chamber atrial modes for patients with impaired AV nodal conduction. Ventricular pacing will not occur.

Pacemaker-dependent patients

Inhibit function – Use caution when using the programmer to inhibit pacing. The patient is without pacing support when pacing is inhibited.

Pacemaker-dependent patients – Always program Ventricular Safety Pacing (VSP) to On for pacemaker-dependent patients. Ventricular Safety Pacing prevents ventricular asystole due to inappropriate inhibition of ventricular pacing caused by oversensing.

Polarity override – Do not override the polarity verification prompt with bipolar polarity when a unipolar lead is connected. Overriding the polarity verification prompt results in no pacing output.

Threshold margin test (TMT) and loss-of-capture – Be aware that loss-of-capture during a TMT at a 20% reduction in amplitude indicates an inadequate stimulation safety margin.

Medical therapy hazards

Diathermy – People with metal implants such as pacemakers, implantable cardioverter defibrillators (ICDs), and accompanying leads should not receive diathermy treatment. The interaction between the implant and diathermy can cause tissue damage, fibrillation, or damage to the device components, which could result in serious injury, loss of therapy, and/or the need to reprogram or replace the device.

Electrosurgical cautery – Electrosurgical cautery may induce ventricular arrhythmias and fibrillation or may cause device malfunction or damage. If electrosurgical cautery cannot be avoided, observe the following precautions to minimize complications:

- Keep temporary pacing and defibrillation equipment available.
- Use a bipolar electrocautery system if possible.
- Use short, intermittent, and irregular bursts at the lowest clinically appropriate energy levels.
- Avoid direct contact with the implanted device or leads. If unipolar cautery is used, position the ground plate so the current pathway does not pass through or near the device and lead system. The current pathway should be a minimum of 15 cm (6 in) away from the device and lead system.
- Program the device to an asynchronous pacing mode for pacemaker-dependent patients.

External defibrillation – External defibrillation may damage the implanted device. External defibrillation may also temporarily or permanently elevate pacing thresholds or temporarily or permanently damage the myocardium at the electrode tissue interface. Current flow through the device and lead may be minimized by following these precautions:

- Use the lowest clinically appropriate defibrillation energy.
- Position the defibrillation patches or paddles a minimum of 15 cm (6 in) away from the device.
- Position the defibrillation patches or paddles perpendicular to the device and lead system.

If an external defibrillation is delivered within 15 cm (6 in) of the device, contact a Medtronic representative.

Medical treatment influencing device operation – The electrophysiological characteristics of a patient's heart can change over time, especially if the patient's medications have changed. As a result of the changes, programmed therapies may become ineffective and possibly dangerous to the patient.

Hospital and medical environments

External defibrillation equipment – Keep external defibrillation equipment nearby for immediate use whenever arrhythmias are possible or intentionally induced during device testing, implant procedures, or post implant testing.

External pacing instrument – Keep an external pacing instrument available for immediate use. When the lead is disconnected, pacemaker-dependent patients are without pacing support.

Precautions

Handling and storage instructions

Follow these guidelines when handling or storing the device.

Checking and opening the package – Before opening the sterile package tray, visually check for any signs of damage that might invalidate the sterility of the package contents.

If the package is damaged – The device packaging consists of an outer tray and inner tray. Do not use the device or accessories if the outer packaging tray is wet, punctured, opened, or damaged. Return the device to Medtronic because the integrity of the sterile packaging or the device functionality may be compromised. This device is not intended to be resterilized.

Dropped device – Do not implant the device if it has been dropped on a hard surface from a height of 30 cm (12 in) or more after it is removed from its packaging.

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

For single use only – Do not resterilize and reimplant an explanted device that has been contaminated by contact with body fluids.

Sterilization – Medtronic has sterilized the package contents with ethylene oxide before shipment. This device is for single use only and is not intended to be resterilized.

Device storage – Store the device in a clean area, away from magnets, kits containing magnets, and sources of electromagnetic interference. Exposing the device to magnets or electromagnetic interference may damage the device.

Temperature limits – Store and transport the package between -18 °C and +55 °C (0 °F and 131 °F). Electrical reset may occur at temperatures below -18 °C (0 °F). Device longevity may decrease and performance may be affected at temperatures above +55 °C (131 °F).

Device temperature – Allow the device to reach room temperature before it is programmed or implanted. Device temperature above or below room temperature may affect initial device function.

Explant and disposal

Consider the following information related to device explant and disposal:

- Explant the implantable device postmortem. In some countries, explanting battery-operated implantable devices is mandatory because of environmental concerns; please check the local regulations. In addition, if subjected to incineration or cremation temperatures, the device may explode.
- Medtronic implantable devices are intended for single use only. Do not resterilize and reimplant explanted devices.
- Please return explanted devices to Medtronic for analysis and disposal. See the back cover for mailing addresses.

Device operation

Accessories – Use this device only with accessories, parts subject to wear, and disposable items that have been tested to technical standards and found safe by an approved testing agency.

Atrial Capture Management – Atrial Capture Management does not program atrial outputs above 5.0 V or 1.0 ms. If the patient needs a pacing output higher than 5.0 V or 1.0 ms, manually program the Amplitude and Pulse Width. If a lead dislodges partially or completely, Atrial Capture Management may not prevent loss-of-capture.

Continuous myopotentials – Continuous myopotentials can cause reversion to asynchronous operation in unipolar pacing. Sensing of myopotentials is more likely to occur when sensitivity settings of 0.5 mV through 1.4 mV are programmed.

Device status indicators – If any of the device status indicators (examples include RRT/ERI and Electrical Reset) are displayed on the programmer after interrogating the device, inform a Medtronic representative immediately. If these device status indicators are displayed, therapies may not be available to the patient.

Electrical reset – Electrical reset can be caused by exposure to temperatures below –18 °C (0 °F) or strong electromagnetic fields. Advise patients to avoid strong electromagnetic fields. Observe temperature storage limits to avoid exposure of the device to cold temperatures. If a partial reset occurs, pacing resumes in the programmed mode with many of the programmed settings retained. If a full reset occurs, the device operates in VVI mode at 65 min^{-1}. Electrical reset is indicated by a programmer warning message that is displayed immediately upon interrogation. To restore the device to its previous operation, it must be reprogrammed. See the device implant manual for a complete list of preserved and changed partial and full reset parameters.

Epicardial leads – Epicardial leads have not been determined appropriate for use with the Ventricular Capture Management feature. Program Ventricular Capture Management to Off if implanting an epicardial lead.

Extended Upper Tracking Rate – When programming Upper Tracking Rates of 190, 200, or 210 min^{-1}, be careful to ensure that these rates are appropriate for the patient. The Upper Tracking Rates of 190, 200, and 210 min^{-1} are intended primarily for use in pediatric patients.

False bipolar pathway with unipolar lead – When implanting a unipolar lead, ensure that the tip and ring setscrews are properly engaged and that all electrical contacts are sealed to prevent electrical leakage between the tip and ring contacts. Electrical leakage may cause the device to inappropriately identify a unipolar lead as bipolar, resulting in loss of output.

Hex wrench – Do not use a blue-handled or right-angled hex wrench. These wrenches have torque capabilities greater than the lead connector can tolerate. The setscrews may be damaged by excessive torque.

Muscle stimulation – Muscle stimulation (for example, due to high-output unipolar pacing) may result in pacing at rates up to the Upper Sensor rate in rate responsive modes.

Pacing and sensing safety margins – Consider lead maturation when selecting pacing amplitudes, pacing pulse widths, and sensing levels. Loss of capture may occur if lead maturation is not considered when selecting settings.

PMT intervention – Even with the feature turned to On, PMTs may still require clinical intervention such as pacemaker reprogramming, magnet application, drug therapy, or lead evaluation.

Programmers – Use only Medtronic programmers and application software to communicate with the device. Programmers and software from other manufacturers are not compatible with Medtronic devices.

Shipping values – Do not use shipping values or nominal values for pacing amplitude and sensitivity without verifying that the values provide adequate safety margins for the patient.

Slow retrograde conduction – Slow retrograde conduction may induce pacemaker-mediated tachycardia (PMT) when the VA conduction time is greater than 400 ms. Programming PMT intervention may help prevent PMT when the VA conduction time is less than 400 ms.

Tip and ring contacts – When implanting a device, ensure that the tip and ring setscrews are properly engaged and all electrical contacts are sealed to prevent possible electrical leakage between the tip and ring contacts. Also, ensure that electrical contacts are sealed when using lead extenders or adaptors with bipolar models. Electrical leakage may cause a loss of output.

Twiddler's syndrome – Twiddler's syndrome, i.e., patient manipulation of the device after implant, may cause the pacing rate to increase temporarily if the pacemaker is programmed to a rate responsive mode.

Ventricular Capture Management – Ventricular Capture Management does not program ventricular outputs above 5.0 V or 1.0 ms. If the patient needs a pacing output higher than 5.0 V or 1.0 ms, manually program Amplitude and Pulse Width. If a lead dislodges partially or completely, Ventricular Capture Management may not prevent loss-of-capture.

Pacemaker-dependent patients

Diagnostic modes – Do not program diagnostic modes (ODO, OVO, and OAO) for pacemaker-dependent patients. Instead, use the programmer's inhibit function for brief interruption of outputs.

Medical therapy hazards

Co-implantation with an implantable cardioverter defibrillator (ICD) – An ICD may be implanted at the same time as an implantable pulse generator (IPG) with bipolar leads. Follow the implant instructions in the lead technical manual to place the lead. Observe the following precautions to avoid using pulse generator features that trigger unipolar polarity in patients with ICDs:

- Disable the IPG's Automatic Polarity Configuration feature, and manually program pacing lead polarities to bipolar configuration.
- Do not program the Lead Monitor to Adaptive because the monitor automatically reprograms the selected lead to unipolar polarity when an out-of-range lead impedance is detected.
- Do not program the Transtelephonic Monitor to On because the pacing polarity is temporarily set to unipolar when the magnet is applied.
- If a full electrical reset occurs, the IPG resets bipolar devices to the Implant Detection feature and to the Automatic Polarity Configuration feature.

Computed tomographic x-ray (CT scan) – If the patient undergoes a CT scan procedure and the device is not directly in the CT scan beam, the device is not affected.

If the device is directly in the CT scan beam, oversensing may occur for the duration of time the device is in the beam. Additionally, if the device is operating in a rate responsive pacing mode, a minor increase in pacing rate may occur during the CT scan procedure.

If the device will be in the beam for more than 4 s, take appropriate measures for the patient, such as enabling an asynchronous mode for pacemaker-dependent patients or enabling a nonpacing mode for nonpacemaker-dependent patients. These measures prevent false inhibition and false tracking. After completing the CT scan procedure, restore device parameters.

High-energy radiation – Do not direct high-energy radiation sources such as cobalt 60 or gamma radiation at the device. High-energy radiation may damage the device, however, the damage may not be immediately detectable. If a patient requires radiation therapy near the device, radiation exposure to the device should not exceed 500 rads. However, diagnostic x-ray and fluoroscopic radiation should not adversely affect the device.

Lithotripsy – Lithotripsy may permanently damage the device if the device is at the focal point of the lithotripter beam. If lithotripsy must be performed, take the following precautions:

- Keep the focal point of the lithotripter beam a minimum of 2.5 cm (1 in) away from the implanted device.
- For pacemaker-dependent patients, program the implanted device to an asynchronous pacing mode or to a single chamber mode without rate response before treatment.

Magnetic resonance imaging (MRI) – Do not use magnetic resonance imaging (MRI) on patients who have an implanted device. MRI can induce currents on implanted leads, potentially causing tissue damage and the induction of tachyarrhythmias. MRI may also cause damage to the device.

Radio frequency (RF) ablation – An RF ablation procedure may cause device malfunction or damage. Radio frequency ablation risks may be minimized by observing the following precautions:

- Keep temporary pacing and defibrillation equipment available.
- Avoid direct contact between the ablation catheter and the implanted system.
- Position the ground plate so the current pathway does not pass through or near the device and lead system. The current pathway should be a minimum of 15 cm (6 in) away from the device and lead system.
- Program the device to an asynchronous pacing mode for pacemaker-dependent patients.

Therapeutic ultrasound – Do not expose the device to therapeutic ultrasound. Therapeutic ultrasound may permanently damage the device.

Home and occupational environments

Cellular phones – This device contains a filter that prevents most cellular phone transmissions from interacting with device operation. To further minimize the possibility of interaction, observe these cautions:

- Maintain a minimum separation of 15 cm (6 in) between the device and the cellular phone, even if the cellular phone is not on.
- Maintain a minimum separation of 30 cm (12 in) between the device and any antenna transmitting above 3 W.
- Hold the cellular phone to the ear farthest from the device.

This device has been tested to the frequency ranges used by common cellular phone transmission technologies. Based on this testing, the device should not be affected by the normal operation of cellular phones using such technologies.

Electromagnetic interference (EMI) – Instruct patients to avoid devices that generate strong EMI. Electromagnetic interference may cause device malfunction or damage such as prevention of programming, detection, or therapy delivery. The patient should move away from the EMI source or turn off the source because this usually allows the device to return to its normal mode of operation. EMI may be emitted from these sources:

- high-voltage power lines
- communication equipment such as microwave transmitters, linear power amplifiers, or high-powered amateur transmitters
- commercial electrical equipment such as arc welders, induction furnaces, or resistance welders

Home appliances that are in good working order and properly grounded do not usually produce enough EMI to interfere with device operation. There are reports of temporary disturbances caused by electric hand tools or electric razors used directly over the implant site.

Electronic article surveillance (EAS) – Electronic article surveillance equipment, such as retail theft prevention systems, may interact with devices and result in inappropriate therapy delivery. Advise patients to walk directly through an EAS system and not remain near an EAS system longer than necessary.

Static magnetic fields – Patients should avoid equipment or situations where they would be exposed to static magnetic fields greater than 10 gauss or 1 mT. Static magnetic fields may cause the device to operate asynchronously. Sources of static magnetic fields include, but are not limited to, stereo speakers, bingo wands, extractor wands, magnetic badges, or magnetic therapy products.

Potential complications

The pacemaker/lead system may operate inappropriately or fail completely due to several potential complications. Note the following potential complications.

- Potential effects of premature battery depletion are decreased output voltage, no pacing output, loss-of-capture, Recommended Replacement Time (RRT/ERI), and eventual erratic pacing.
- Potential effects of pacemaker component(s) failure are loss of pacing output, pacing rate and other parameter changes, reversion to asynchronous mode, loss-of-capture, loss of programming capability, RRT/ERI, and erratic pacing.
- Potential effects of the activity sensor detecting muscle or mechanical stimulation may increase the pacing rate to levels higher than expected for a given patient activity. In addition, an open or shorted activity sensor may cause rate response pacing to cease operating.
- Potential effects of electromagnetic interference (EMI) on the pacemaker's circuitry are pacing output inhibition, reversion to asynchronous mode, pacing synchronized to the EMI source, and a partial or full electrical reset condition. EMI from electrocautery and defibrillation may cause pacing output inhibition, temporary pause in pacing, permanent loss of pacing output, reversion to asynchronous mode, pacing synchronized to the EMI source, set the RRT/ERI, and a partial or full electrical reset condition.

- Potential effects of poor connection of lead to pacemaker connector block are intermittent or continuous loss-of-capture, failure to sense properly or loss of sensing, crosstalk between leads, and inhibition of pacing.
- Reversed connection of the atrial and ventricular leads will result in improper pacing and sensing operations.
- Potential effects of displaced or fractured lead are intermittent or continuous loss-of-capture and/or sensing, and inhibition of pacing. Cardiac perforation may cause intermittent or continuous loss-of-capture and/or sensing, inhibition of pacing, cardiac tamponade, and muscle or nerve stimulation. Myocardial irritability at the time of lead insertion may cause fibrillation or flutter. Elevation of pacing thresholds may cause a loss-of-capture.

Replace a device

Warning: Keep an external pacing instrument available for immediate use. When the lead is disconnected, pacemaker-dependent patients are without pacing support.

Replace a device by performing the following steps.

1. Program the device to a non-rate responsive mode to avoid potential rate increases while handling the device.
2. Dissect the lead and the device free from the surgical pocket. Do not nick or breach the insulation.
3. Use a wrench to loosen the setscrews in the connector port.
4. Gently pull the lead out of the connector port.
5. Evaluate the condition of the lead. Replace the lead if electrical integrity is not acceptable or if the lead connector pin is pitted or corroded. Return the explanted lead to Medtronic for analysis and disposal.
6. Connect the lead to the replacement device.

   Note: A lead adaptor may be needed to connect the lead to the replacement device. Contact a Medtronic representative for questions about lead adaptor compatibility.
7. Evaluate stimulation thresholds and sensing potentials. Use the replacement device or an implant support instrument.
8. After confirming acceptable electrical measurements, place the device in the pocket. Suture the pocket incision closed.

9. Return the explanted device to Medtronic for analysis and disposal.

For further information

For further information on implanting pacemakers, consult the implant manual packaged with each device. For information on available adaptor kits, consult the Pacemaker and ICD Encyclopedia (a Medtronic publication). Refer to “Connector dimensions” on page 235 for the different types of pacemaker connectors.

Patient counseling information

Patient counseling information

The clinician may wish to discuss the following topics with the patient before discharge.

- Review the signs and symptoms that should be reported to the patient’s physician.
- Review instructions to the patient concerning physical activity.
- Advise the patient on the frequency of follow-up care.
- Inform the patient of cautions regarding sources of electromagnetic interference (EMI).
- Educate the patient about the consequences of device manipulation (Twiddler’s syndrome).

Device registration form

A device registration form is included with each device in the shipping package. The form serves as a permanent record of facts related to the implanted device. Return a completed copy of this form to Medtronic. Note that in some areas, the device package may not contain the registration form.

Establish a patient record

At the time of implant, document the patient's pacemaker programmed parameter settings for later reference. A patient record gives an accurate account of the patient's medical history at subsequent follow-ups when evaluating the pacemaker's performance.

The Patient Information and Key Parameter History reports can provide data for this patient record. These data contain demographic information on the patient and values for certain parameters for the last eight programming sessions, respectively. Refer to "Patient information" on page 178 for more information.

Note that the registration form should not serve this purpose since the form is intended for registering the patient and pacemaker with Medtronic.

Glossary

G

activity – 1) patient body motion as detected by the pacemaker's accelerometer in rate responsive modes. 2) type of rate responsive sensor that increases or decreases pacing rate in proportion to levels of detected patient body motion.

activities of daily living (ADL) – 1) the target rate which the patient's heart rate is expected to reach during moderate exercise. 2) the pacemaker's ADL Response setting that determines rate responsiveness in the ADL rate range.

acute phase – lead maturation period beginning at lead implantation during which myocardial stimulation thresholds begin at low voltages, rise, and decline to a plateau. The acute phase normally ends within 6 to 12 weeks post-implant when local tissue reaction to the lead subsides.

ADL rate range – rates at or near the ADL Rate that are achieved during moderate activities.

arrhythmia – any variation from the normal rhythm of the heartbeat; it may be an abnormality of either the rate, regularity, or site of impulse origination or the sequence of activation.

artifact – the pacemaker's electrical output recorded as a vertical spike on the electrocardiogram.

atrial kick – contribution of an atrial contraction to ventricular late end-diastolic filling volume and pressure.

Atrial Preference Pacing (APP) – This atrial rhythm management feature adapts the pacing rate to slightly higher than the intrinsic sinus rate.

atrial tracking – a pacing operation (in the DDDR, DDD, and VDD modes) in which the ventricles are paced in synchrony with sensed atrial events.

AV synchrony – the activation sequence of the heart in which the atria contract first and then, after an appropriate delay, the ventricles. Pacemakers which utilize the atrium for sensing and/or pacing are designed to replicate the heart's normal contraction sequence.

battery capacity – a battery's capability for current delivery, expressed in ampere hours, i.e., *current x time*. The battery capacity is one determinant of pacemaker longevity, along with current drain.

blanking – a time interval during which the pacemaker's sensing circuitry is turned off and no sensing can occur.

calibrate – a reference signal sent to an externally connected recorder or monitor used to facilitate the measurement of telemetered EGM or ECG tracings.

capture – Depolarization of the atria or ventricles by an electrical stimulus delivered by an artificial pacemaker.

capture test frequency – Capture Management operation that automatically performs ventricular and atrial pacing threshold measurements at programmed times. During measurement the pacemaker causes test paces to be delivered and monitors them for capture or loss-of-capture.

chronotropic incompetence – inability of the heart to vary its rate appropriately in response to exercise.

clipping – the truncation of displayed waveform peaks which can occur on the ECG/Markers/EGM screen when the selected amplitude scaling is set too high.

configuration – the programmable state for a pacemaker operation option. Specifically applies to polarity, i.e., unipolar or bipolar configuration.

confirmation – programmer display of message(s) to verify programming and storage of selected pacing parameter values after engaging the **PROGRAM** button.

crosstalk – in dual chamber pacemakers, the sensing of a pacing stimulus delivered in the opposite chamber, which results in undesirable pacemaker response, e.g., false inhibition or resetting of the refractory period.

current – in pacemakers, the continuing flow of electricity through the pacemaker circuit (especially through the lead conductor) as measured in milliamperes; high current is associated with high voltage, low current with low voltage. Current cannot be directly controlled, but can be indirectly controlled by altering the voltage or the resistance (impedance).

current drain – 1) depletion of electricity from the pacemaker battery measured in microjoules. Depletion is caused by the continuous low-level "self-discharge" from the battery; by pacing and sensing circuit efficiency; and by the following programmable factors under the control of the follow-up clinician: a) pacing rate; b) output voltage (amplitude); c) pulse duration (pulse width); d) percent of time pacing, and e) other programmable features. 2) one determinant of pacemaker longevity along with battery capacity. Current drain is inversely proportional to pacemaker longevity.

demand modes – any pacemaker mode which, after sensing a spontaneous depolarization, withholds its pacing stimulus.

electrical reset – automatic setting of pacing parameters to specific values upon pacemaker detection of a momentary interruption of electrical power to the pacemaker's control circuitry; can be either a partial or a full reset. **partial reset** - pacing mode, polarity, and certain other parameter settings are preserved; all other parameters are changed to their Electrical Reset values. **full reset** - pacing resumes in the VVI mode with all values changed to Electrical Reset values.

electrogram – in pacing, the recording of the cardiac waveforms as taken at the lead (electrode) site within the heart. Electrograms may be transmitted from implanted pacemakers by telemetry.

electromagnetic interference (EMI) – radiated or conducted energy - either electrical or magnetic - which can interfere with or disrupt the function of a pacemaker.

emergency – for the pacing system, programming [**EMERGENCY**] delivers maximal energy output in the VVI mode in an attempt to provide pacing support to the ventricle.
Note: Programming [**EMERGENCY**] for single chamber systems applied in the atrium results in emergency AAI pacing.

episode – usually applied to a series of cardiac events; here used to mean certain pacemaker-defined series of cardiac events such as PMT episodes, Rate Drop episodes, and Mode Switch episodes, which are reported via programmer automatic diagnostics.

escape interval – a pacemaker-defined time between a paced or sensed cardiac event and the subsequent scheduled pacing stimulus; the longest interval associated with the base pacing rate.

escape rate – a pacing rate which is a function of the "escape interval" (see above); the slowest pacing rate possible.

evoked response detection – the act of detecting the electronic waveform created by the contracting myocardium immediately following a pacing pulse.

exertion – the pacemaker's Exertion Response setting that determines rate responsiveness in the exertion rate range.

exertion rate range – rates at or near the Upper Sensor Rate that are achieved during vigorous exercise.

exit block – failure of a pacemaker to capture the heart because the patient's stimulation threshold exceeds the output of the pacemaker.

freeze – to stop and collect a portion of the patient's ECG trace.

fusion beat – an intrinsic depolarization that occurs coincidentally with a paced depolarization. The intrinsic and paced waveforms "fuse" on the ECG.

hysteresis – a pacing operation and programmable parameter that allows a longer escape interval after a sensed event, giving the heart a greater opportunity to beat on its own.

impedance – the total opposition that a circuit presents to current flow in the pacing system.

implant detection – period of time after pacemaker implant during which lead impedance is measured in order to verify lead connection and stability.

inhibit – a temporary function which causes the cessation of pacing output pulses.

interlock – a safety restriction in the pacemaker programmer software that aids in the choice of proper values, usually by initiating a screen message informing the user of important value interrelationships.

interrogate – a programmer command used to retrieve and display information about the status of the patient's pacing system.

intrinsic event rejection – the ability of the Capture Management pacing threshold search to differentiate between myocardial contractions caused by the pacing pulse and those caused by physiologic means.

lead fixation – contact between the lead electrode and the myocardial tissue.

longevity – duration of the normal service life of the pacemaker.

Marker Channel recording – a pacing system feature used to simplify ECG interpretation by identifying pacing and/or sensing operations.

mean atrial rate – a running average of the atrial rate that is continuously calculated by the pacemaker for use by the Rate Adaptive AV and automatic PVARP features. The average uses all A-A intervals except those beginning with either an atrial sense or atrial refractory sense and ending with an atrial pace.

MVP (Managed Ventricular Pacing) – MVP promotes intrinsic conduction by reducing unnecessary right ventricular pacing. MVP operates when the programmed mode is either AAIR<=>DDDR or AAI<=>DDD.

myopotential – a term used to describe electrical signals that originate in body muscles; these signals may be sensed by the pacemaker and falsely interpreted as cardiac depolarizations.

noise – any electromagnetic interference, myopotentials, or crosstalk detected by a pacemaker's sensing amplifier.

noise reversion – continuous restarting of the refractory period (and its blanking period) caused by continuous sensing at intervals less than the refractory period.

nominal – in pacing, the term describes a set of programmable parameter values considered reasonable for the majority of uncomplicated patients.

nonrefractory – describes atrial or ventricular events sensed outside of a refractory period (in dual chamber modes, outside of AV intervals and Post Ventricular Atrial Refractory Period; in single chamber modes outside of the Atrial Refractory Period or Ventricular Refractory Period).

oversensing – inappropriate sensing of noncardiac signals, e.g., myopotentials, electromagnetic interference, crosstalk, etc., which can cause inhibition of the pacemaker stimulus.

pacemaker-defined PVC (premature ventricular contraction) – any ventricular sensed event (refractory or nonrefractory) that follows a ventricular event (pace, refractory sense, or nonrefractory sense) without an intervening atrial event (pace, refractory sense, or nonrefractory sense).

pacemaker-mediated tachycardia (PMT) – a paced rhythm, usually rapid, which can occur with loss of AV synchrony. This rhythm begins with and is sustained by ventricular events which are conducted retrogradely (i.e., backwards) to the atria. The pacemaker senses this retrograde atrial depolarization, starts an AV interval, and then delivers a stimulus to the ventricle, causing a ventricular depolarization, which again is conducted retrogradely to the atria. The cycle repeats itself to produce tachycardia.

pacemaker syndrome – a collection of signs and symptoms (often described as dizziness and/or weakness) related to the adverse hemodynamic effects of ventricular pacing, usually attributed to the absence of synchrony between the atrial and ventricular contractions.

pacing cycles – a recurring set of events that consists of a paced or sensed atrial event followed by a paced or sensed ventricular event.

PMOP (Post Mode Switch Overdrive Pacing) – PMOP enables the pacemaker to provide extended DDIR (non-atrial tracking) pacing for a programmed duration and rate following a mode switch. For example, a patient can be paced at an Overdrive Rate of 80 min^{-1} for 10 minutes following a mode switch episode.

PMT – see “pacemaker-mediated tachycardia” earlier.

pseudofusion – a spontaneous cardiac depolarization with a superimposed stimulus. The pacing stimulus is delivered after the chamber has already spontaneously depolarized.

radiopaque ID – a small metallic plate (inside the pacemaker connector) bearing both the Medtronic logo and a code for identifying the pacemaker under fluoroscopy.

rate profile – 1) a historical rate profile of the sensor-indicated rate that rate response is adjusted from. 2) a desired target rate profile that rate response is adjusted toward.

real-time measurement – a pacing system function that presents measured and calculated data at the time of the clinician’s query via programmer telemetry.

retrograde conduction – the propagation of ventricular depolarization to the atria, also known as “VA conduction.”

safety margin – 1) the difference between the measured stimulation threshold and the programmed amplitude or the programmed pulse width. Output settings that produce a margin of twice the stimulation threshold are necessary because of threshold variability due to exercise, eating, sleeping, drug therapy, and other changes in cardiac condition. 2) **safety margin, output** - a ratio of the programmed output divided by the stimulation threshold to achieve adequate pacing voltage and duration to prevent loss-of-capture.

sensing threshold – the minimum signal strength (highest sensitivity setting) that allows continuous sensing of intrinsic depolarizations.

sensitivity – the degree to which a pacemaker's sense amplifiers are responsive to levels of electrical activity in the heart (or other electrical signals).

sensor-indicated rate – the pacing rate determined by the sensor-detected level of patient activity and on programmed rate response parameters; this rate is never greater than the Upper Sensor Rate or less than the operating Lower Rate.

status reset – a pacing system command which attempts to reset an electrical reset or the RRT/ERI status.

stimulation threshold – the minimum electrical stimulus needed to consistently capture the heart. It can be expressed in terms of amplitude (volts, milliampere), pulse width (milliseconds), and/or energy (microjoules).

strength-duration – refers to a curve that is a plot of at least two pacemaker stimulation threshold test results, each test defining the minimum amplitude (strength) and pulse width (duration) settings needed to capture the myocardium. The narrower the pulse width, the greater the voltage required to stimulate the heart, and vice versa. If values below the curve are programmed, loss-of-capture will occur. The Strength-Duration Test and the Capture Management Test provide a strength-duration curve.

target sensing margin – the desired sensing margin against which the pacemaker compares the P and R wave amplitudes of sensed events when making automatic Sensitivity adjustments. Used by the Sensing Assurance feature.

telemetry – the transmission of data from the pacemaker to the programmer and from the programmer to the pacemaker by radio waves. Information transmitted includes programmed status, real-time measurements, and diagnostic data.

temporary (settings) – parameters programmed for brief diagnostic purposes or to quickly test their effects on pacing operations prior to programming. Programmed settings are restored automatically when the programming head is removed or the telemetry link is broken.

test pace – A pace delivered at a given amplitude or pulse width during the pacing threshold search. The pacemaker evaluates the test pace for capture or loss-of-capture.

trigger – in pacing, to start a process, operation, or a collection of data.

triggered mode – a pacemaker mode that, upon detecting a spontaneous depolarization or other signal, delivers an electrical stimulus to the heart.

troubleshooting – a strategy and methodology for isolating and correcting problems with the pacing system.

2:1 block rate – the rate at which intrinsic atrial events are sensed as refractory in the TARP causing synchronization of ventricular pacing to every other atrial event. Determined by the total atrial refractory period (TARP: the sum of the SAV interval and the PVARP). The operation results in a ventricular rate one half as fast as the atrial rate.

undersensing – failure of the pacemaker to sense the P or R wave may cause the pacemaker to not withhold pacing output pulses.

value window – rectangular display listing specific programmable options for a selected parameter from a programmer screen.

Wenckebach operation – in dual chamber atrial tracking modes, an upper rate operation which limits the average ventricular pacing rate when intrinsic atrial rates rise above the Upper Tracking Rate. The pacemaker does this by gradually prolonging the pacemaker's AV interval until one atrial event falls into the PVARP and is not tracked. Since no AV interval is started by the refractory event, there will be no ventricular output synchronized to this atrial event.

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