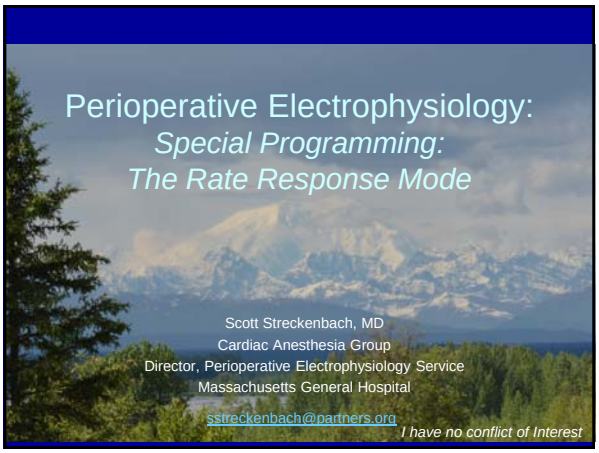

What do you need to know about the Rate Response Mode (RRM)?

1. Why patients need the RRM
2. How the RRM works
3. How to determine if the RRM is on
4. How to disable the RRM
5. How the RRM can affect patients in the perioperative period
6. How to manage the RRM in perioperative period

Rate Response Mode Definition

A pacemaker function which helps increase the paced heart rate during exercise for those patients with chronotropic incompetence

What is Chronotropic Incompetence?

Insufficient increase in HR during exercise or other activities of daily life which results in fatigue or SOB

Patients with Pacemakers and Response to Exercise

- Some patients with a pacemaker are able to respond appropriately to exercise because they have an intact sinus node and are in sinus rhythm
- Other patients with a pacemaker are not able to respond appropriately to exercise—pts with SA dysfunction, Atrial fibrillation or those with a pacer in a non-tracking pacing mode, e.g., VVI

Patients with a pacemaker and AV node disease?

- Sinus rate response to exercise is intact
- Pacer in a DDD mode can track the native sinus rate above the base pacing rate to respond to exercise
- Exercise leads to an increase in the sinus rate and the pacer follows 1:1 with ventricular pacing to keep up with demand
- Therefore patients with isolated AV node disease do not have CI

Patients with a pacemaker and Sinus Node Disease

- Exercise may not reliably increase the sinus rate sufficiently to meet exercise demand
- A DDD pacer will not necessarily be sufficient as the base pacing rate does not change on its own
- This patient is “chronotropically incompetent”

Patients with a pacemaker and in Atrial Fibrillation

- When a patient is in Afib, a tracking mode cannot be used, so the pacer must be changed to DDI or VVI
- Non-tracking modes have no way to increase the ventricular paced rate
- Pts with Afib are therefore also chronotropically incompetent

Patients with a Non-tracking Pacing Mode

- If the pacer is in a non-tracking mode, the LRL is fixed.
- An increase in the atrial rate cannot be translated into an increase in the ventricular paced rate

Summary of Patients with Chronotropic Incompetence

Underlying Issue	Response to Exercise
• Sick Sinus Syndrome	Chron Incomp
• A Fib with AV block	Chron Incomp
• DDI or VVI pacing mode	Chron Incomp

Why do Patients Need RRM?

- And it is for these patients with Chronotropic Incompetence that the RRM was developed

What do you need to know about the Rate Response Mode (RRM)?

1. Why patients need the RRM
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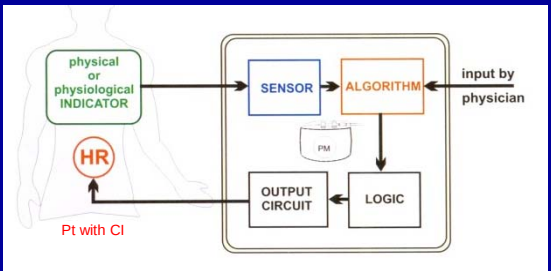
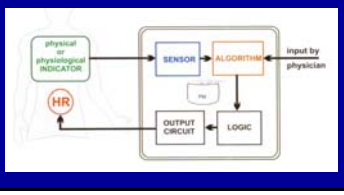
Rate Response Mode Overview



Cardiac Pacemakers, SS Barold et al

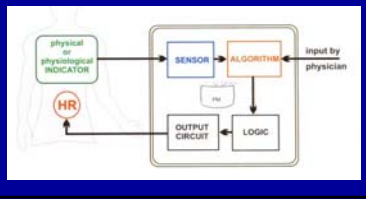
Physical or Physiologic Indicators

- Body Movement
- Minute Ventilation
- RV contractility



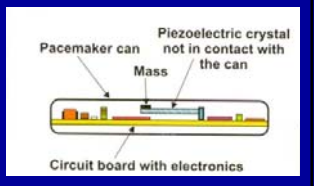
Rate Response Mode (RRM) Sensors

1. Accelerometer (body movement)
2. Transthoracic Impedance (min. ventilation)
3. Myocardial Impedance (vent. contractility)



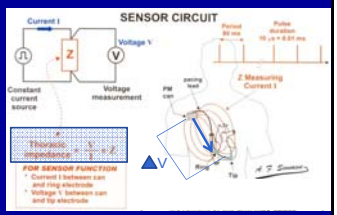
Accelerometer

- A piezoelectric crystal with a small mass is attached to the circuit board of the pacemaker
- Patient movement in the A-P dimension leads to movement of the mass which deforms the piezoelectric crystal which then creates a voltage
- The voltage is detected by the pacer control system



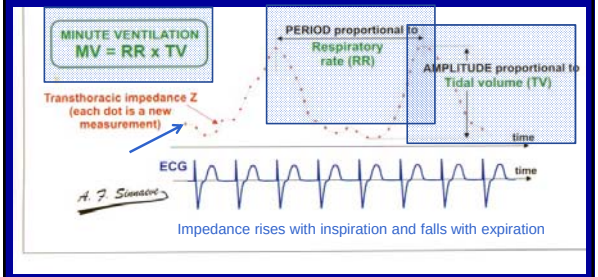
Transthoracic Impedance Sensor

- Transthoracic impedance sensors measure the change of impedance across the chest during patient ventilation
- Rapid, ultra-short and subthreshold current impulses are emitted from the pulse generator and detected by one of the electrodes
- The voltage difference is measured
- Using V=IR the Resistance (Impedance) is determined



* the current pulses I for impedance measurement are subthreshold, they have a low amplitude and are very short (pulse duration 5 to 15 µs)
* the measurement is frequently repeated (480 to 1200 times per minute)

Minute Ventilation Sensor

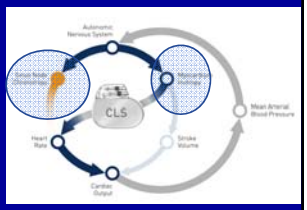


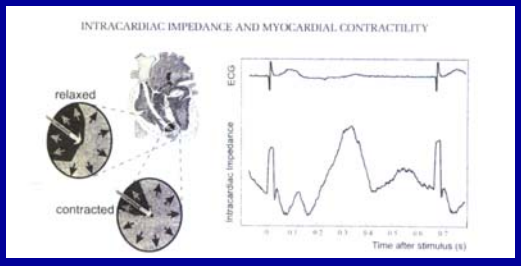
Increases in RR or TV can activate the sensor.

Cardiac Pacemakers, SS Barold et al

Ventricular Impedance Sensor

- When the ANS detects a need to increase CO, it stimulates the SA Node and increases contractility
- Sinus Node dysfunction prevents the SA node contribution to increase CO
- The body compensates by increasing contractility further
- The "extra contractility" can be estimated by measuring myocardial impedance change at the RV lead's distal electrode

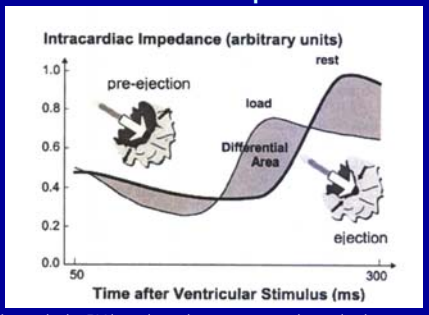




Myocardial Impedance (Z) = Measured V / Injected I

Osswald S, et al, PACE 2000; 23:1502-1508

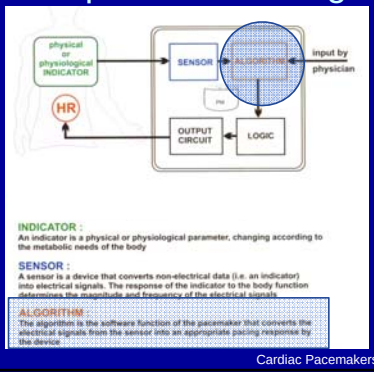
Ventricular Impedance



The change in the RV impedance between rest and exercise is represented by the gray area. This information is used to adjust the heart rate

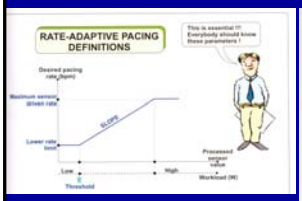
Griesbach L, et al, PACE 2003;26:1432-1437

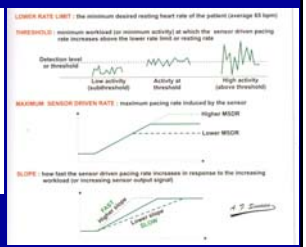
Rate Response Mode Algorithm



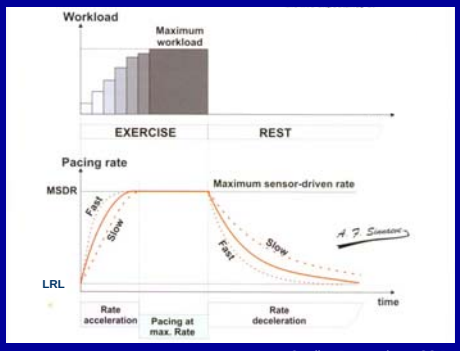
Cardiac Pacemakers, SS Barold et al

Rate Adaptive Definitions





Rate Response HR Change



Cardiac Pacemakers, SS Barold et al

Key Points of how the RRM works

- Pacers with an active RRM sense physiologic signals with one of three different sensors
- A physician adjusts the pacer algorithm that determines how the HR will respond to that stimulus
- The HR hopefully matches the demands of daily life and exercise

What do you need to Know?

- How the RRM works
- **How to determine if the RRM is on and what the settings are**
- How to disable the RRM
- How the RRM can affect patients in the perioperative period
- How to manage the RRM in perioperative period

How to Determine if the RRM is programmed ON

- If the active pacing mode has an "R" at the end, the RRM is ON
- Information about the RRM and whether or not it is activated can be found in 3 ways:
  - Cardiologist or EP's recent note
  - Programmer report
  - Programmer interrogation

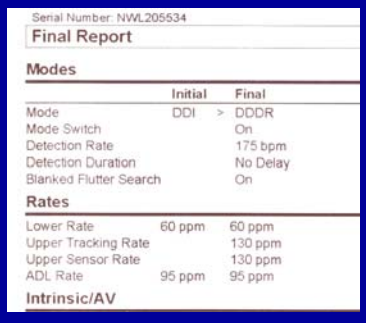
Rate Response Mode Company Specific Information

- Medtronic
- St Jude
- Boston Scientific
- Biotronik

Medtronic

- Essentially all Medtronic pacers and ICDs use an accelerometer sensor

Medtronic Programmer Report



Serial Number: NWL205534

Final Report

Modes

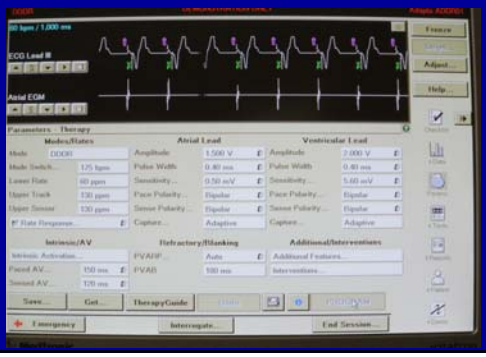
	Initial		Final
Mode	DDI	>	DDDR
Mode Switch			On
Detection Rate			175 bpm
Detection Duration			No Delay
Blanked Flutter Search			On

Rates

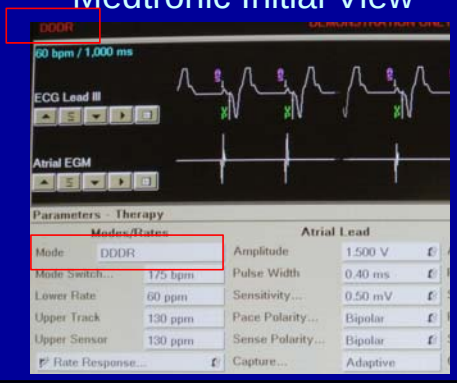
Lower Rate	60 ppm	60 ppm
Upper Tracking Rate		130 ppm
Upper Sensor Rate		130 ppm
ADL Rate	95 ppm	95 ppm

Intrinsic/AV

Medtronic Programmer: Initial View



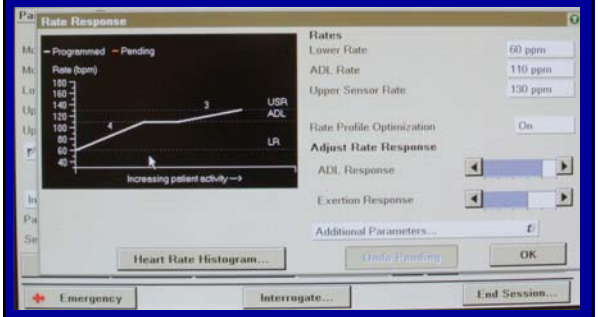
Medtronic Initial View



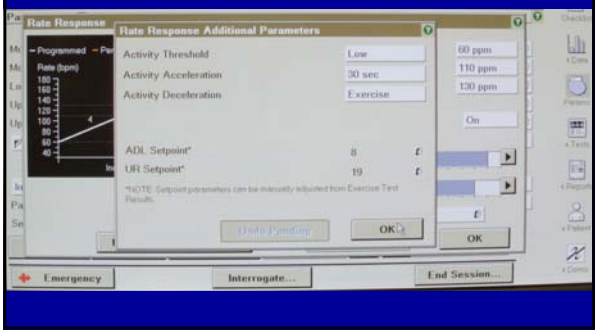
Medtronic RRM Specific Settings

Clicking on the Rate Response Box opens the specific settings area

Specific RRM Settings for Medtronic Devices



Specific RRM Settings for Medtronic Devices



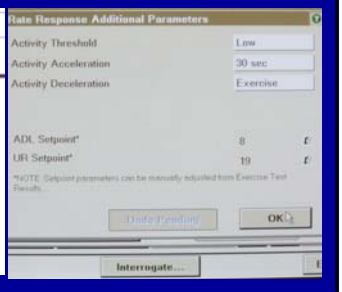
Medtronic Comparison

Final Report

Rate Response

Optimization	On
ADL Response	3
Exertion Response	3
ADLR Percent	2.0%
Activity Threshold	Medium/Low
Activity Acceleration	30 sec
Activity Deceleration	Exercise
High Rate Percent	0.2%
ADL Rate Setpoint	14
Upper Rate Setpoint	25

Programmer Report

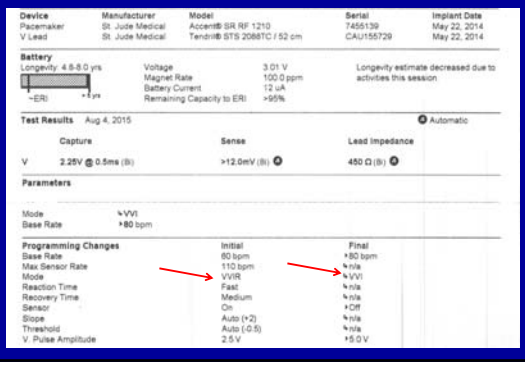


Programmer Screen

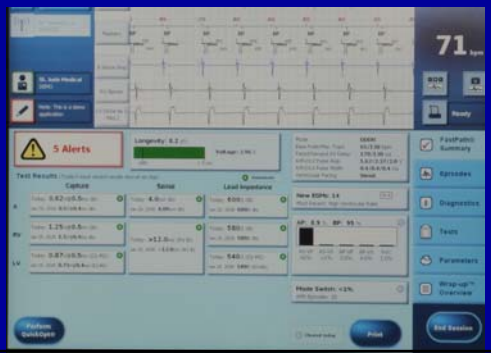
St Jude RRM

- St Jude utilizes accelerometer technology only

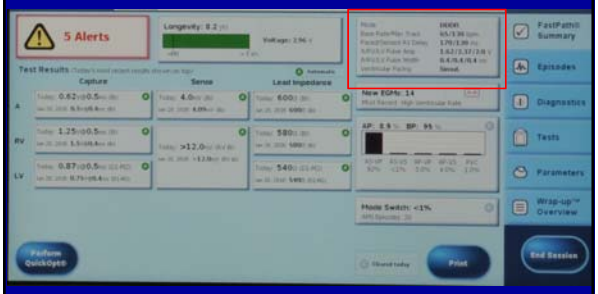
St Jude Programmer Report



St Jude Programmer



Specific Settings for St Jude RRM

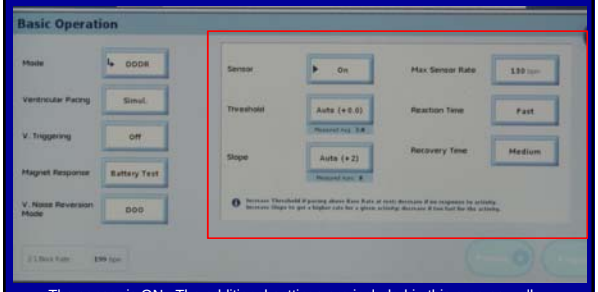


To get more information on the RRM settings click on the Mode Box or on the Parameters tab on the right

St Jude Brady Parameters

Click on the "Basic Operation" section to get the Mode Options and "Sensor" Settings

St Jude RRM Settings

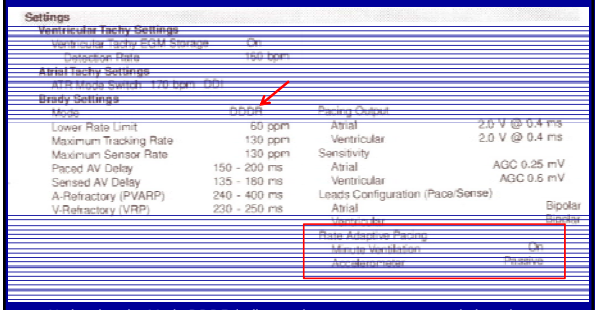


The sensor is ON. The additional settings are included in this area as well. Electrophysiologists adjust these settings to improve the pacing efficiency. Anesthesiologists will not need to modify these settings and should ensure they are not changed.

Boston Scientific RRM

- BS has three sensor options:
  - Minute Ventilation
  - Accelerometer
  - Combination

Boston Scientific RRM

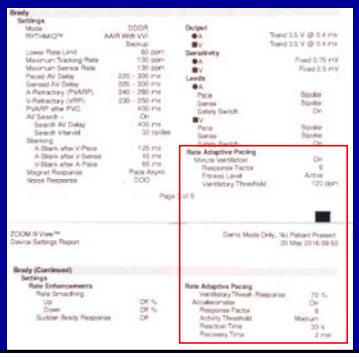


Notice that the Mode DDDR indicates that a rate response mode is active. In the Rate Adaptive Pacing section you can find out which sensor is active. Note the Minute Ventilation sensor is on, the accelerometer is passive (off).

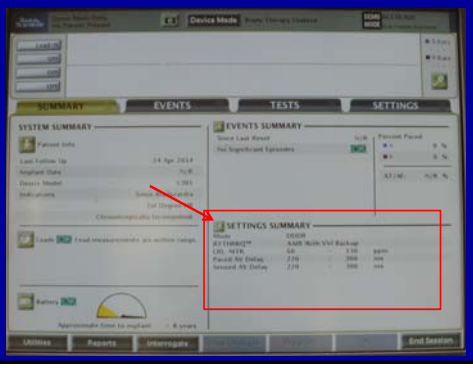
Bost Sci. Programmer Printout with Pacer in DDD mode

Note that both sensors are Passive

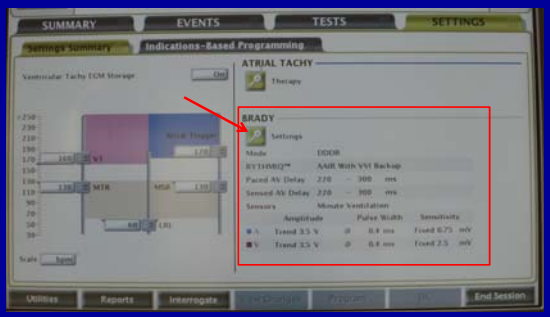
Boston Sci. Programmer Printout with both sensors on



Boston Scientific Programmer

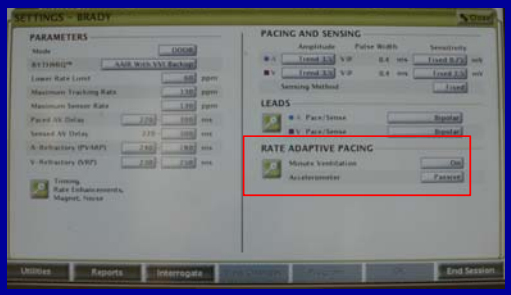


Boston Scientific Programmer

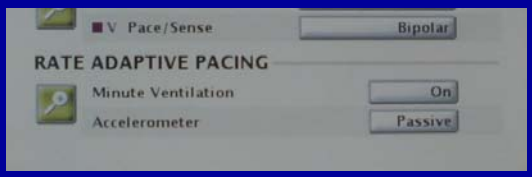


You can see that the mode indicates a RRM is ON. You also can see that the sensor is Minute Ventilation. To get more detail, click on the zoom box.

Minute Ventilation On

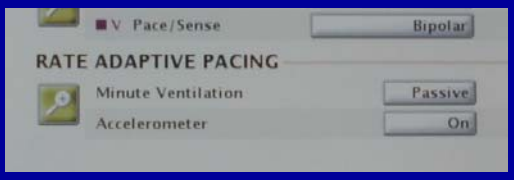


Minute Ventilation On

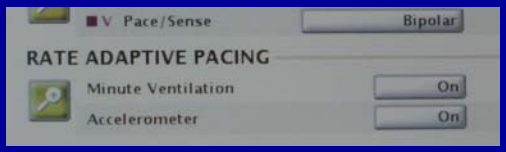


Notice that the Minute Ventilation is ON; the Accelerometer is PASSIVE.
For our purposes, PASSIVE is OFF.

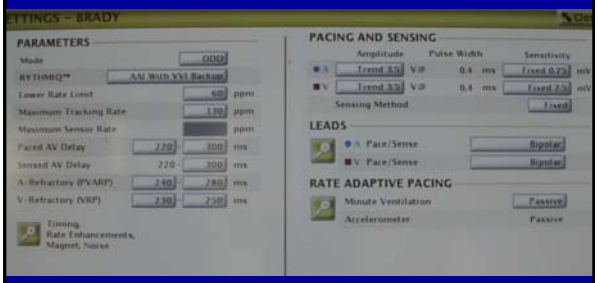
It could also be set as: Accelerometer On



or Both On

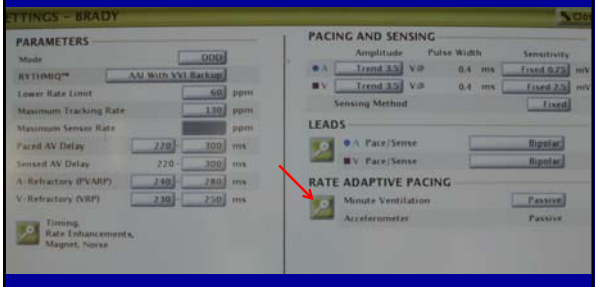


or Both Off--DDD

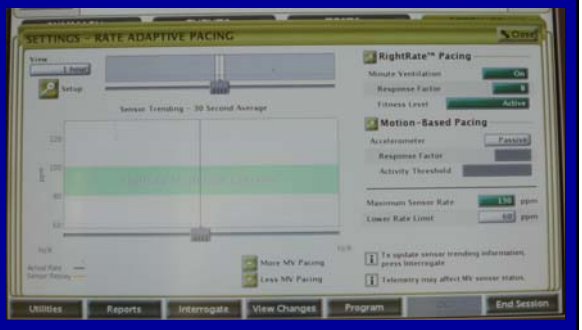


When the pacer is programmed in a DDD mode, both sensors will be Passive or Off.

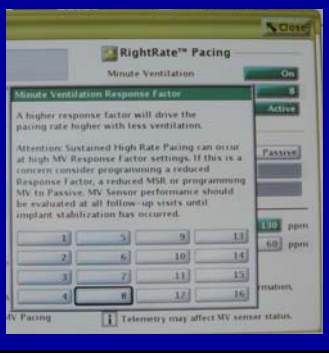
To Get More Information on the Specific RRM settings click on the Zoom Box



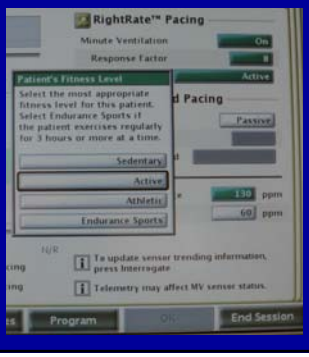
RRM Specific Settings



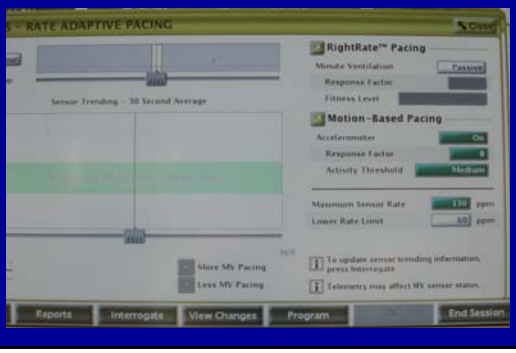
Minute Ventilation Settings



Minute Ventilation Settings



Accelerometer Specifics



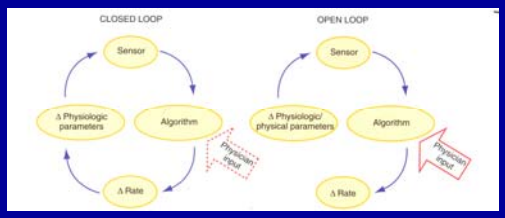
Biotronik RRM

- Biotronik has two types of sensors
  - Accelerometer (appears as DDDR)
  - Ventricular Impedance (appears as DDD-CLS)
    - "CLS" is closed loop stimulation algorithm

Biotronik Programmer Report DDDR

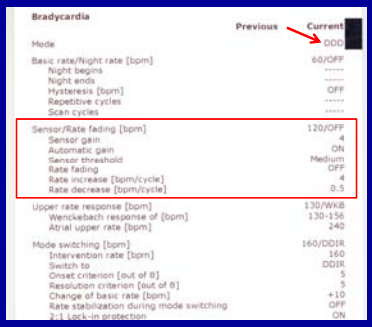
Biotronik Programmer Report DDD CLS

What does CLS mean?



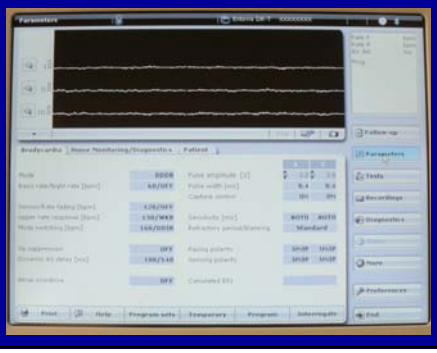
CLS=Closed Loop Stimulation

DDD Mode

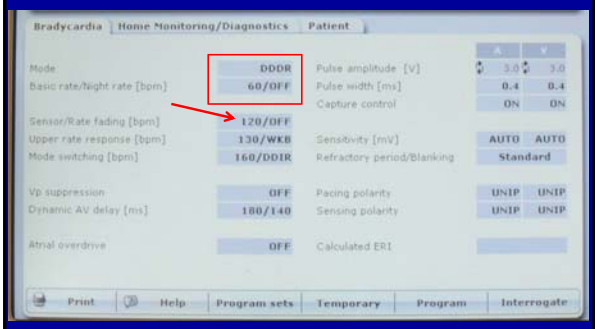


Even though the RRM is off, the settings for the RRM are listed in the programmer report

Biotronik RRM—DDDR Accelerometer

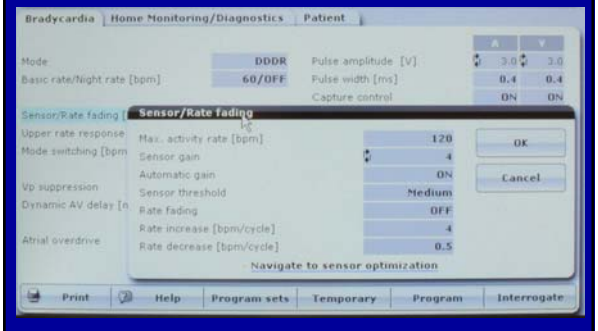


Biotronik RRM—DDDR Accelerometer

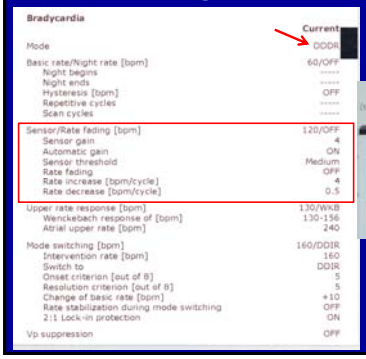


To see the specific Accelerometer Settings click on “Sensor/Rate Fading”

Patient Specific Settings--DDDR

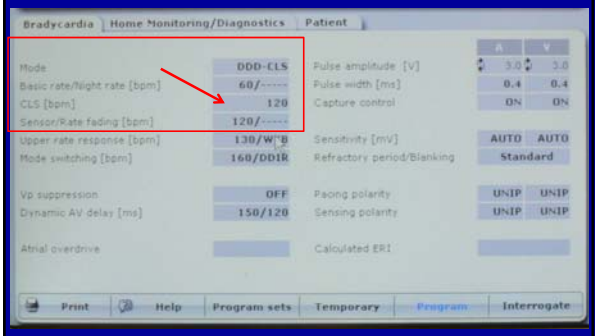


DDDR as seen on the Programmer Report



The specific settings from the programmer are listed in the programmer printout

Biotronik RRM--CLS



What do you need to Know?

- How the RRM works
- How to determine if the RRM is on and what the settings are
- **How to disable the RRM**
- How the RRM can affect patients in the perioperative period
- How to manage the RRM in perioperative period

How to Turn Off the RRM

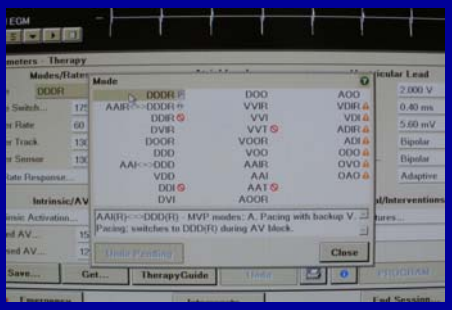
- You should know how to turn off the RRM modes of each of the 4 major manufacturers
  - Magnet--temporary
  - Programmer

How to Turn off RRM in Medtronic Devices

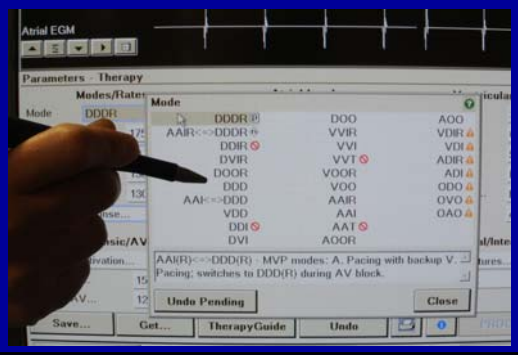
- Very simple
- Use the programmer to change the mode to one without the “R”

How to Turn off RRM in Medtronic Devices

How to Turn off RRM in Medtronic Devices



Select the Desired Mode

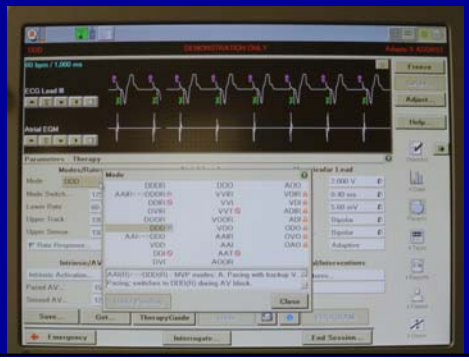


Click Program

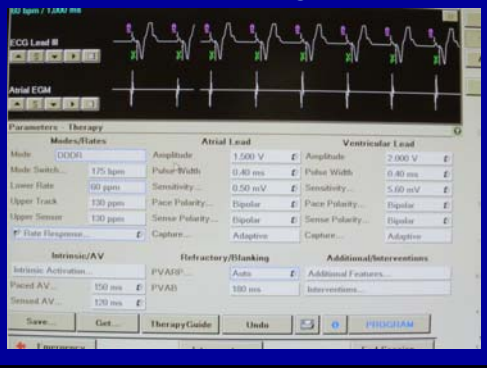
Confirm Change

To Resume Medtronic RRM

Click on DDDR



Click on Program

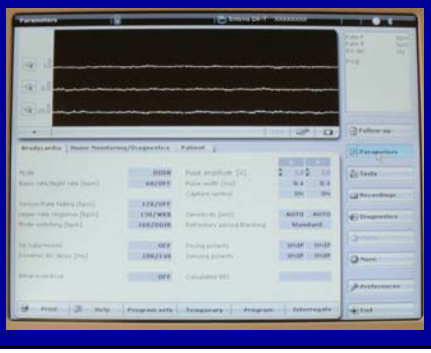


Rate Response is Back On

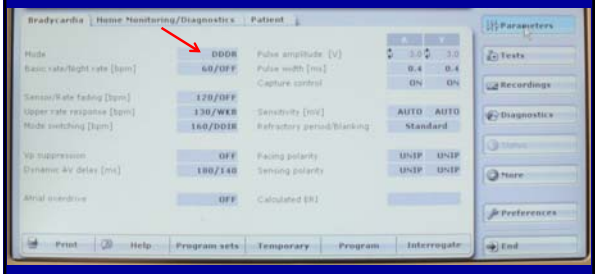
Summary Medtronic RRM

- Turning the Medtronic RRM off and on is very simple
  - When turning off the Medtronic RRM, the patient specific RRM settings are retained
  - When you turn the RRM on at the end of the case, the patient specific RRM settings will automatically resume

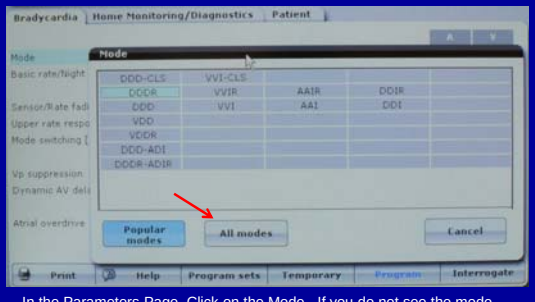
How to turn off the Biotronik RRM



How to turn off the Biotronik RRM

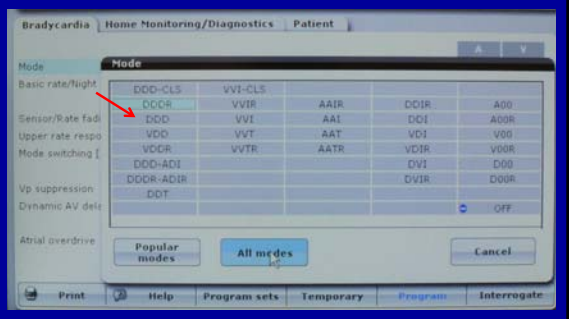


Biotronik

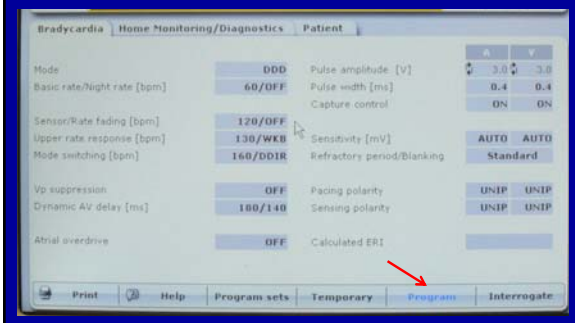


In the Parameters Page, Click on the Mode. If you do not see the mode you would like, click on ALL MODES

Select DDD



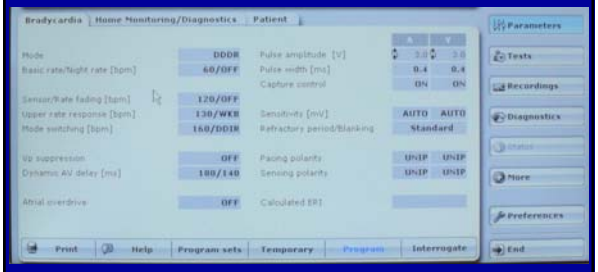
Click Program



Resume the Biotronik RRM

1. Open parameters page and click on the DDD mode to open the Mode Option Box
2. Click on DDDR
3. Click the blue Program box

Confirm DDDR mode



Key Biotronik Concept

- All the patient specific settings remain as they were before you turned the RRM off
- You do not have to go into the specific programming for the RRM to ensure that the patient specific settings are back to baseline

Biotronik Summary

- Rate response mode can appear as DDDR (VVIR etc) or DDD-CLS
- R represents an accelerometer
- CLS represents a ventricular impedance sensor
- Both are turned off simply by clicking on the present mode and choosing the pacing mode without the rate response mode and programming the change

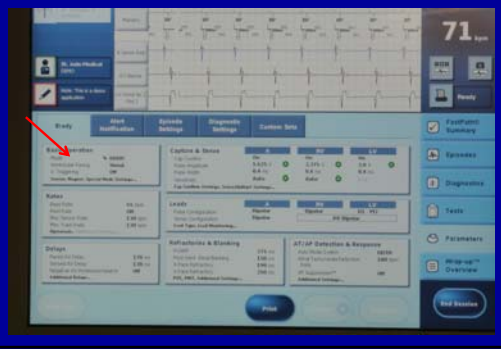
Biotronik Summary

- Like the Medtronic devices, when you turn the Biotronik RRM back on, the patient specific settings automatically resume

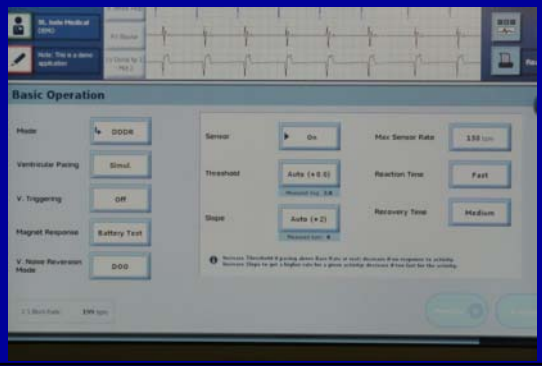
How to turn off the RRM in a St Jude Device

- Less intuitive than Medtronic and Biotronik
- Not so simple as just changing the pacing mode
- Must turn SENSOR to Passive

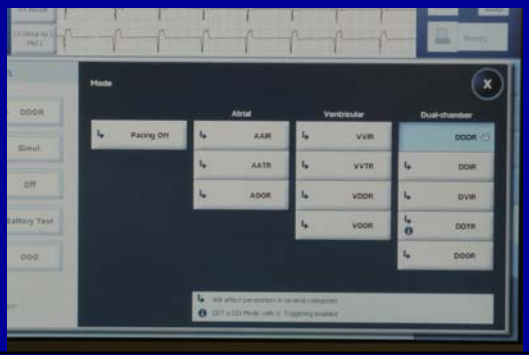
How to turn off the St Jude RRM



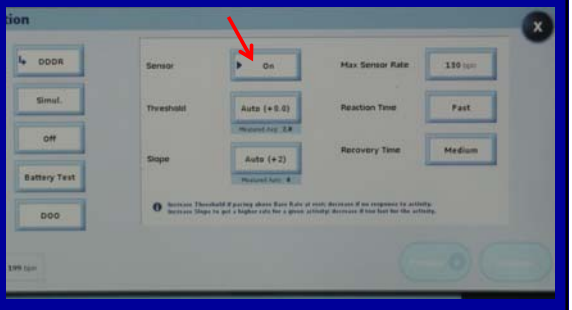
Intuition Says Click on Mode



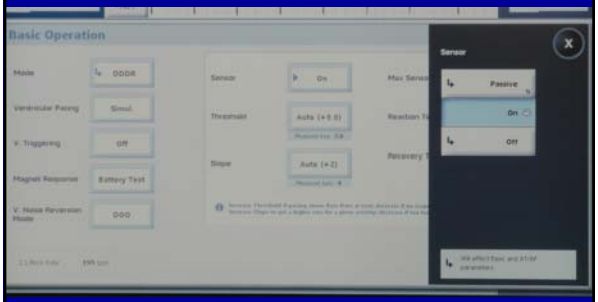
Note that all Modes have an R



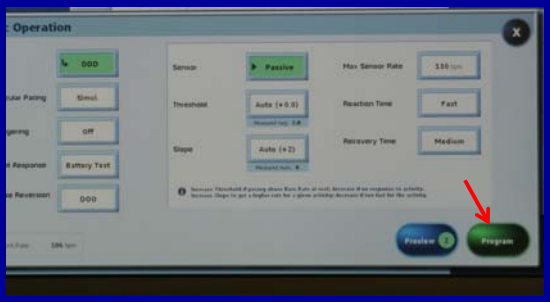
Must Click on Sensor



Turn to Passive to maintain patient-specific settings



Must Click Program to Activate the Change



Notice that the mode changes to DDD automatically.

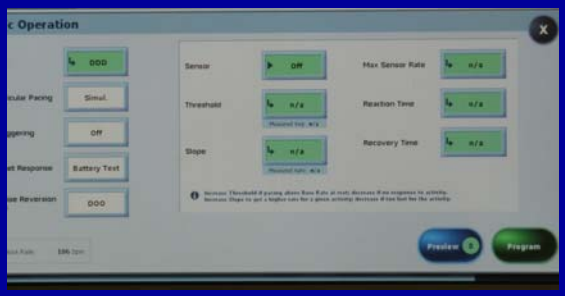
Programmer Report BEFORE turning RRM off

Basic Operation	
Mode	**DDDR**
Ventricular Pacing	Simul.
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	DOO
Sensor	**On**
Threshold (Measured Avg.)	Auto (+0.0) (2.0)
Slope (Measured Auto)	Auto (+2) (8)
Max Sensor Rate	130 bpm
Reaction Time	Fast
Recovery Time	Medium

St Jude Programmer Report after turning RRM to Passive

Basic Operation	
Mode	DDD
Ventricular Pacing	Simul.
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	DOO
Sensor	Passive
Threshold (Measured Avg.)	Auto (+0.0) (2.0)
Slope (Measured Auto)	Auto (+2) (8)
Max Sensor Rate	130 bpm
Reaction Time	Fast
Recovery Time	Medium

Example of Turning St Jude RRM Off

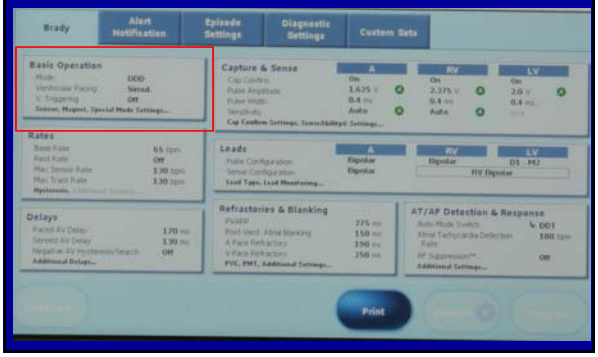


NEVER turn the RRM OFF—always use Passive instead

St Jude Programmer Report when turning RRM Off

Basic Operation	
Mode	DDD
Ventricular Pacing	Simul.
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	DOO
Sensor	Off
Rates	
Base Rate	65 bpm
Rest Rate	Off
Max Track Rate	130 bpm
Hysteresis Rate	Off
2:1 Block Rate	186 bpm

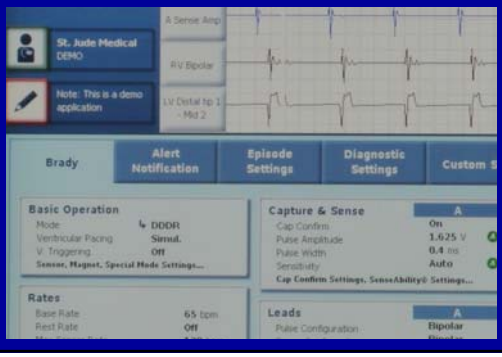
St Jude RRM now Passive/Off



Turning RRM Back On

- Follow same procedure and turn RRM ON from either Passive or Off
- Check to make sure the baseline patient specific settings have not changed
  - Passive—no change in parameters
  - Off—may see a change in parameters

RRM Active Again



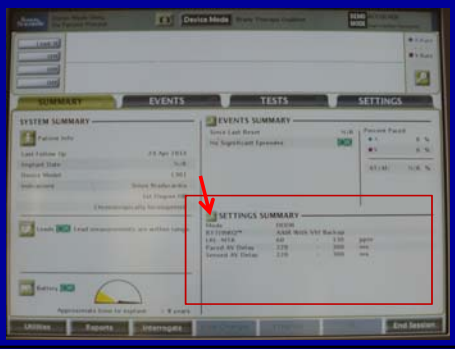
St Jude Summary

- Unlike the Medtronic and Biotronik devices, you have to actually change the RRM setting in a location separate from the mode settings.
- Choose the PASSIVE setting, not the OFF setting to inactivate the RRM
- Reactivation of the RRM is easy
- Confirm that the patient-specific settings have not changed

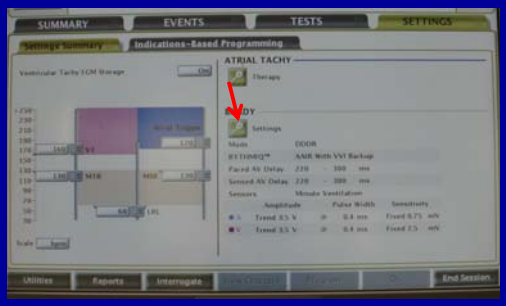
How to turn off the Boston Scientific RRM

- Boston Scientific has two sensors and three possible sensor programming options

How to turn off the Boston Scientific RRM

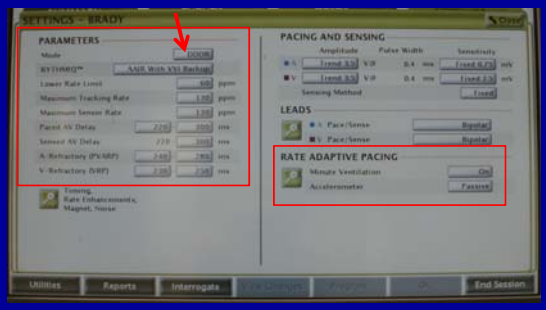


How to turn off the Boston Scientific RRM



The rate limits are on the left—LRL, MTR, MSR, Mode Switch rate
On the right you see the mode again as DDDR—click on magnifying glass again

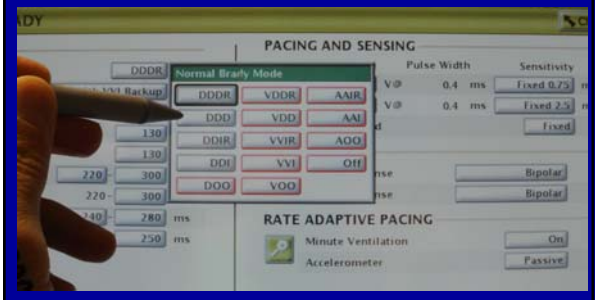
How to turn off the Boston Scientific RRM



Now you can see the mode with a box around it; note the Rate Adaptive Pacing section
Click on the DDDR box to open Mode Options

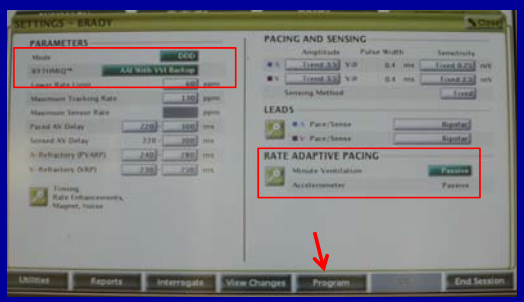
How to turn off the Boston Scientific RRM

How to turn off the Boston Scientific RRM



Click on the DDD mode to inactivate the RRM

How to turn off the Boston Scientific RRM



Note the change in the Modes and the change from Min Vent on to Min Vent Passive
All changed boxes are GREEN—you must push program to activate the change

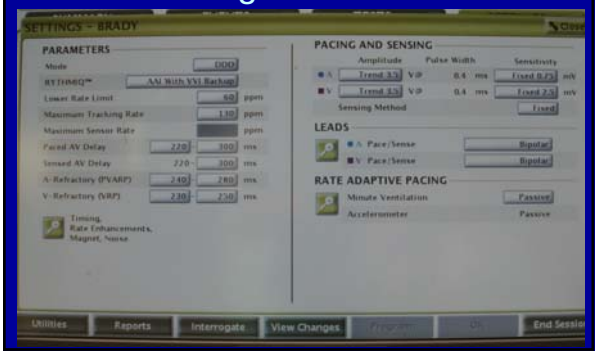
How to turn off the Boston Scientific RRM

You have two options to program your changes: click on screen as seen here

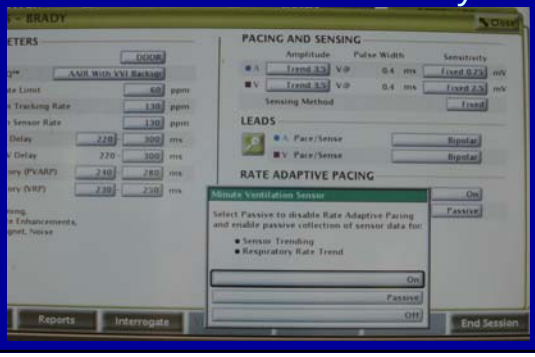
How to turn off the Boston Scientific RRM

You have two options to program your changes: click on lower panel of programmer

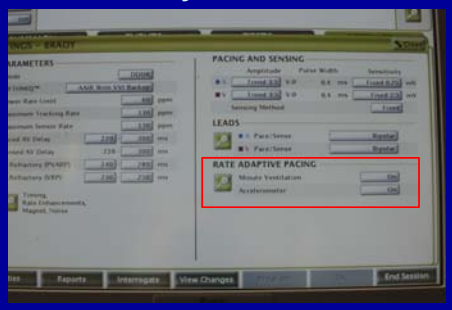
Confirm that RRM "Off" by seeing DDD mode



Can also convert the Min Ven Sensor to Passive Directly

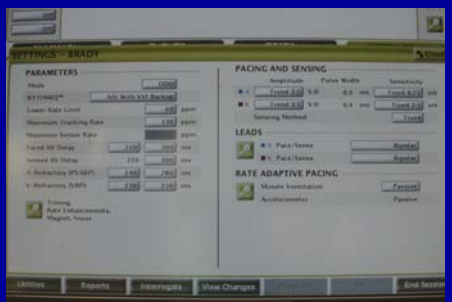


Tricky Situation



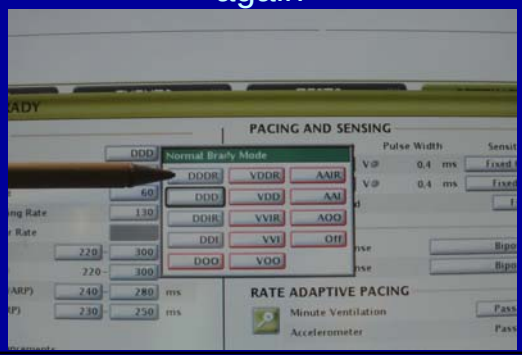
If Min Ven and Acceler are on, and you turn off the RRM, you have to be vigilant when reactivating the RRM—Min Vent will come on, but the accel may not.

Bost Sci RRM turned off now with RRMs in Passive mode

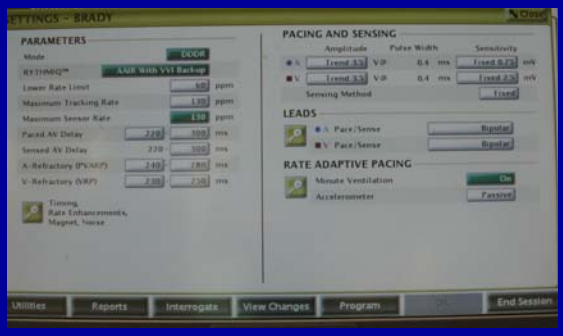


By converting the pacing mode from DDDR to DDD using the MODE option, MV and Accel. both convert to PASSIVE

Post op, you choose DDDR again



Note that the Accelerometer is still Passive



Key Concept

- Pacer and ICD programming is not always intuitive.
- Always print the baseline settings before making any programming changes
- Always make sure the post-op settings are the same as the pre-op settings if you make any programming changes

When turning off RRM make sure to use the passive option if available so as to not lose the baseline settings

What do you need to Know?

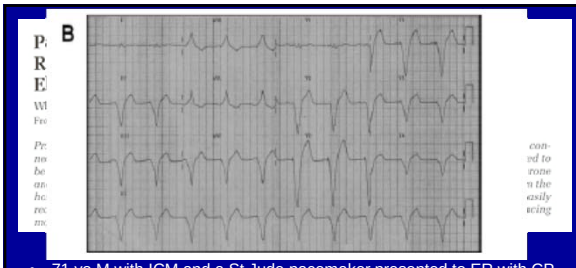
- How the RRM works
- How to determine if the RRM is on
- How to disable the RRM
- **How the RRM can affect patients in the perioperative period**
- **How to manage the RRM in perioperative period**

Accelerometers and Anesthesia

- Environmental interference can cause unwanted HR increases:
  - Succinylcholine fasciculations
  - Shaking the patient during prepping
  - Electrocautery
  - Post op shivering

Minute Ventilation Sensors and Anesthesia

- Increased RR or TV can produce a substantial increase in paced HR
- Electrocautery may provoke changes in the impedance and thus increase the pacer to the upper rate limit
- Respiratory monitoring systems in the ICU or recovery room can accelerate the paced HR



- 71 yo M with ICM and a St Jude pacemaker presented to ER with CP
- Connected to EKG monitor in ER and he subsequently developed WCT at 130—conscious and feeling OK, BP 120/70
- IV amio→hypotension→amio, mg, sotalol, 11 shocks
- BP unrecordable—> Epi→transferred to tertiary center
- Arrived in stable paced rhythm at 70 bpm, intubated and unconscious

PACE 2006;29:438-40

Ventricular Impedance Sensors (Biotronik CLS) and Anesthesia

- According to company technicians and reps, we do not have to be concerned about electrocautery negatively impacting the CLS (ventricular impedance) sensor
- I think it is therefore safe to not change the mode (e. g., from DDD-CLS to DDD) during surgery
- Nevertheless, maintain vigilance

What do you need to Know?

- How the RRM works
- How to determine if the RRM is on
- How to disable the RRM
- **How the RRM can affect patients in the perioperative period**
- **How to manage the RRM in perioperative period**

Rate Response Mode Recommendations

- Intrathoracic impedance (minute ventilation) sensors should be suspended for all surgery
- Accelerometers should be suspended if the surgery is in the High Risk Zone (above the waist)
- Ventricular impedance sensor (Biotronik CLS) can remain on

Rate Response Mode Recommendations

- If the rate response mode is not turned off, the heart rate may increase transiently due to:
  - Increased patient motion or manipulation of the pacer or ICD
  - Increased ventilation
  - Electrocautery

Special Consideration for Boston Scientific Devices

- If the patient has a Boston Scientific pacer or ICD and the mode indicates a RRM is active, you must find out which of the two sensors is/are active before you can determine how to manage the device

Case Example
Pt having Pelvic Surgery

Impression & Recommendations:

Problem # 1: PACEMAKER, PERMANENT - BSCI ADVANTIO DUAL (ICD-V45.01) (ICD10-Z95.0) normal pacemaker function with today. Patient continues to be pacemaker dependent. Atrial and ventricular output today were decreased to 2.0 volts. Patient we'll continue to follow him in the device clinic. Return to clinic in 6 months.

Medications Added to Medication List This Visit:
1) Ofloxacin 0.3 % Soln (Ofloxacin) ... [patient not taking] 6 drops left ear twice daily for 7-10 days.

Pacemaker/Defibrillator Device Interrogation
EKG with and without magnet on file.
Chief Complaint: device check

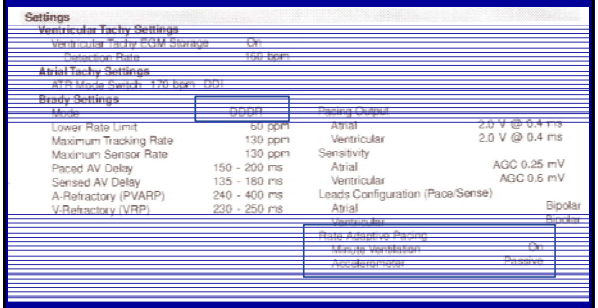
Device Information
Manufacturer: Boston Scientific
Device Type: pacemaker
Mode: DDDR
Model Name: Advantio
Model #: K083 DR - 182126
Atrial Lead #: 4136 29457940 Guidant
RV Lead #: 4137 29467684 Guidant
Indication: AV block

Battery Status

Lead Characteristics
P Wave: 4.0 mV
Atrial (V @ ms): V @ 0.4ms0.6
Atrial: 772 Ohms

The patient has a Boston Scientific Pacemaker in the DDDR mode. Given that the procedure is below the waist, one might consider leaving the pacing mode unchanged

Boston Scientific Adventio Pacer



Settings

Ventricular Tachy Settings
Ventricular Tachy RSM Storage On
Detection Rate 156 bpm

Atrial Tachy Settings
AT/F Mode Switch: 176 bpm DDI

Brady Settings
Mode DDDR
Lower Rate Limit 60 ppm
Maximum Tracking Rate 130 ppm
Maximum Sensor Rate 130 ppm
Paced AV Delay 150 - 200 ms
Sensed AV Delay 135 - 180 ms
A-Refractory (PVARP) 240 - 400 ms
V-Refractory (VRP) 230 - 250 ms

Pacing Output
Atrial 2.0 V @ 0.4 ms
Ventricular 2.0 V @ 0.4 ms
Sensitivity
Atrial AGC 0.25 mV
Ventricular AGC 0.6 mV
Leads Configuration (Pace/Sense)
Atrial Bipolar
Ventricular Bipolar
Rate Adaptive Pacing
Minute Ventilation On
Accelerometer Passive

By checking the settings with a programmer, you note that a Min Vent sensor is on You would be well to have the RRM turned off by converting to a DDD mode instead.

Summary 1/4

1. Pts who are chronotropically incompetent depend on the RRM
2. There are three different sensors
3. You may determine which sensor is active by getting a programmer report or using a programmer to interrogate the device

Summary 2/4

1. Medtronic and St Jude only have accelerometers
2. Boston Scientific has accelerometers and minute ventilations sensors
3. Biotronik has accelerometers and ventricular impedance sensors (CLS)

Summary 3/4

1. A Magnet inhibits the RRM in pacemakers
2. A Magnet does not inhibit the RRM in ICDs
3. A Programmer can always turn off the RRM

Summary 4/4

1. Suspend Min Ventilation RRM on all cases
2. Suspend Accelerometer RRM if in HRZ
3. If you leave rate response on, HR will likely increase in response to:
   - Increased patient motion/pressure on pacer
   - Increased ventilation rate
   - Electrocautery

THE END