Perioperative Electrophysiology:
Perioperative Management of Pacemakers

Timing Cycles

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I have no conflict of Interest

What have you Studied so far?

- Pacemaker Anatomy
- Pacemaker "Physiology"
- Pacemaker Capture
- Pacemaker Sensing

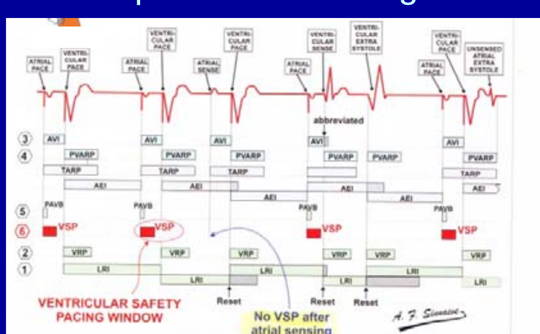
Timing Cycles

- What is the Goal?
  - To make sure that you understand as much as possible about the various timing cycles so that you will be ready to study the clinically relevant Pacemaker modes in the next lecture

Timing Cycles

- Rates
- Intervals
- Periods

Interpret This Electrogram



Barold, Cardiac Pacemakers and Resync. P. 101

15 Key Timing Cycles to Understand

1. Lower Rate Limit (base rate)
2. Lower Rate Interval (LRI)
3. A-V Interval (AVI)
4. Atrial Escape Interval (AEI)
5. Atrial Blanking Period

15 Key Timing Cycles to Understand

6. Atrial Refractory Period (ARP)
7. Ventricular Blanking Period (VB)
8. Ventricular Refractory Period (VRP)
9. Post-Ventricular Atrial Blanking Period (PVAB)
10. Post-Ventricular Atrial Refractory Period (PVARP)

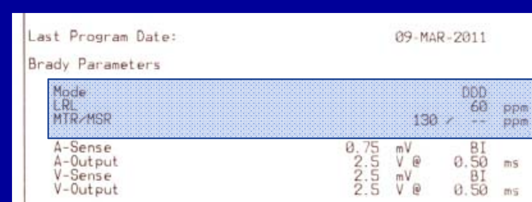
15 Key Timing Cycles to Understand

11. Post-Atrial Ventricular Blanking Period (PAVB)
12. Crosstalk Detection Window (CDW)
13. Total Atrial Refractory Period (TARP)
14. Upper Rate Interval (URI)
15. Maximum Tracking Rate (MTR)

1. Lower Rate Limit

- The base pacing rate:
  - Asynchronous pacers—always pace at this rate
  - Demand pacers—pace at this rate if intrinsic rhythm is below the base rate
- Described in beats per minute
  - 60 beats per minute

Lower Rate Limit Example



Lower Rate Limit Example

2. Lower Rate Interval

- The time between one sensed or paced event and the next paced event
- Determined by the programmed lower rate limit
- Described in msec

Rate to Interval Conversion

- Rates are described as beats per minute
- Intervals are described as msec per beat

How does one convert Rate to an Interval?

Step 1: Convert Rate to beats/msec

$$\text{Rate} = \frac{\text{beats}}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{secs}} \times \frac{1\ \text{sec}}{1000\ \text{msec}} = \text{beats/60,000 msec}$$

Example: Assume rate = 60 bpm
= 60 beats/60,000 msec
= 1 beat/1000 msec

Key Concept

The interval is the inverse of the rate

How does one convert Rate to an Interval?

Step 2: Take the reciprocal of the rate

RATE		INTERVAL
1 beat/1000 msec	→	1000 msec/beat

Rate to Interval Calculation

To convert a programmed rate [pulse per minute (ppm)] to a timing interval, perform the following operation:

$$\text{time interval (msec)} = \frac{60{,}000\ \text{msec/min}}{\text{programmed rate (ppm)}}$$

Moses, A Practical Guide to Pacing Appendix II

Interval Calculation

- Assume the pacemaker's rate is set at 75 bpm. How much time should elapse between one beat and the next? In other words, what is the interval?

Example

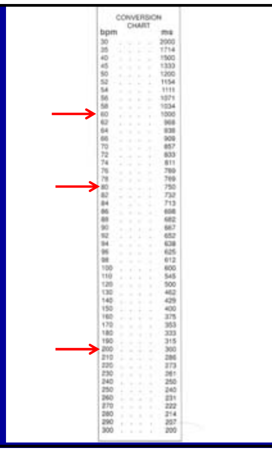
- If rate=75 bpm:

$$\text{Interval} = \frac{60{,}000 \text{ msec}}{75 \text{ beats}}$$

Interval = 800 msec

Example

- If the Heart Rate at which VF is detected is 180, what is the R-R interval at which VF is detected?
- Interval = 60,000 msec/180 beats
  = 333 msec
- Thus an R-R interval of 333 is bad!



CONVERSION CHART

bpm	ms
30	2000
35	1714
40	1500
45	1333
50	1200
52	1154
54	1111
56	1071
58	1034
60	1000
62	968
64	938
66	909
70	857
72	833
74	811
76	789
78	769
80	750
82	732
84	713
86	698
88	682
90	667
92	652
94	638
96	625
98	612
100	600
110	545
120	500
130	462
140	429
150	400
160	375
170	353
180	333
190	315
200	300
210	286
220	273
230	261
240	250
250	240
260	231
270	222
280	214
290	207
300	200

This conversion chart lists the interval associated with paced rates from 30 to 300

Moses, A Practical Guide to Pacing, p. 204

Take Home Message

- Normal rhythms have longer intervals
  - 60 bpm 1000 msec
  - 75 bpm 800 msec
  - 100 bpm 600 msec
- Arrhythmias have shorter intervals
  - 150 bpm 400 msec
  - 200 bpm 300 msec

Interval to Rate Conversion

- What if you know the interval between two paced beats and you want to determine what the paced rate is?

$$\text{programmed rate (ppm)} = \frac{60{,}000 \text{ msec/min}}{\text{time interval (msec)}}$$

Moses, A Practical Guide to Pacing Appendix II

Interval to Rate Conversion

- If the Lower Rate Interval is 800 msec, what is the Lower Rate in beats per minute?

$$\text{Rate} = \frac{60{,}000 \text{ msec/min}}{800 \text{ msec/beat}}$$

$$= 75 \text{ beats/min}$$

“Programmed” vs “Derived” Intervals

- Programmed Intervals
  – Lower Rate Limit (LRL) interval
  – AV Interval (AVI)
- Derived Intervals
  – Atrial Escape Interval (AEI)

Interval Abbreviations

- “P” Intrinsic atrial depolarization
- “R” Intrinsic vent. depolarization
- “A” Atrial paced event
- “V” Ventricular paced event

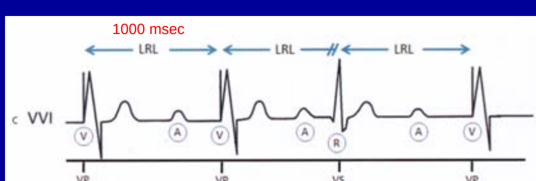
Interval Examples

- A-R: A-pace, spontaneous QRS
- P-V Spontaneous P followed by V-pace
- A-V A-V paced
- P-R Spontaneous P-QRS

2. Lower Rate Interval

- The time in msec between one sensed or paced event and the next paced event
- Reciprocal of the programmed lower rate limit

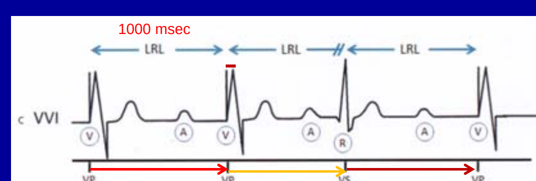
2. Lower Rate Interval Example



- The pacing mode is VVI—the LRL represents the lower rate interval.
  – If lower rate set at 60, the LR interval will be 1000 msec

Ellenbogen, Clinical Cardiac Pacing, Defib, and Resync. 4th ed

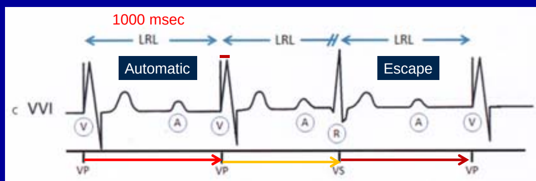
2. Lower Rate Interval Example



- Three separate intervals:
  1. VP-VP—full 1000 msec
  2. VP-VS—less than 1000 msec
  3. VS-VP—slightly less than 1000 msec

Ellenbogen, Clinical Cardiac Pacing, Defib, and Resync. 4th ed

2. Lower Rate Interval Example

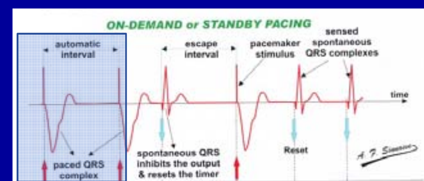


- Three separate intervals:
  1. VP-VP—full 1000 msec
  2. VP-VS—less than 1000 msec
  3. VS-VP—slightly less than 1000 msec

Ellenbogen, Clinical Cardiac Pacing, Defib, and Resync. 4th ed

Automatic Interval

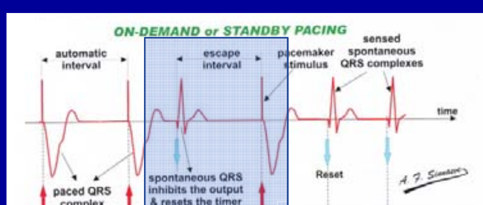
- The time between two paced beats when the pacer is pacing at the lower rate limit
- If LRL is 60, the Automatic interval is 1000 msec



Barold, Cardiac Pacemakers and Resynch.

Escape Interval

- Escape Interval—the period, measured in milliseconds, between a sensed cardiac event and the next pacemaker output pulse

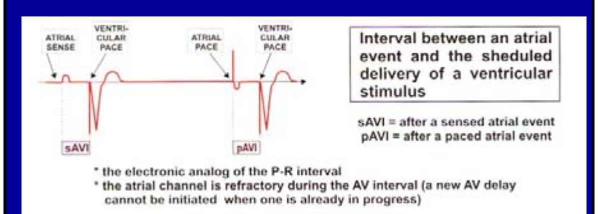


Barold, Cardiac Pacemakers and Resynch.

3. AV Interval

- The interval between an atrial event (sensed or paced) and the paced ventricular event
- Represents the P-R interval
- A programmed interval
- Usually 160-240 msec

3. AV Interval



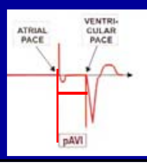
Barold, Cardiac Pacemakers and Resynch.

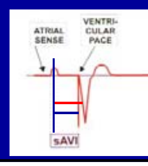
Why are there 2 AVIs?

- With both AVIs, we want the functional atrial kick to occur a given # of msec before the VP event
- The pAVI starts as soon as the AP event occurs
- The sAVI starts later, not until the atrial depolarization is already moving into the atrial tissue where the lead is
- To ensure that the same amount of time elapses between the functional atrial kick, the sAVI is set shorter by approx 30-50 sec

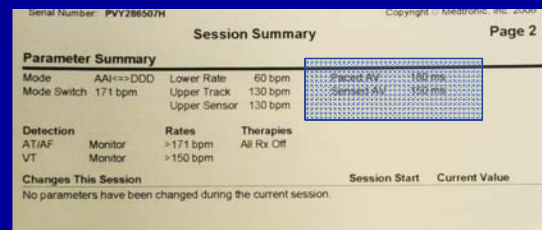
Paced AVI vs Sensed AVI

- The Paced AV interval (pAVI) will usually be programmed approximately 30-50 msec longer than a Sensed AV interval (sAVI)
  - This compensates for the fact that the pAVI timing circuit (stopwatch) starts as soon as the atrium is paced—this happens 30-50 msec before the atrial depolarization is sensed by the atrial pacing electrodes





Two AV Intervals



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Session Summary — Page 2

Parameter Summary

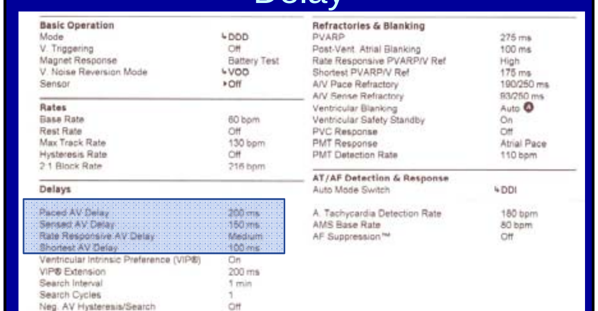
Mode	AAI<=>DDD	Lower Rate	60 bpm	Paced AV	180 ms
Mode Switch	171 bpm	Upper Track	130 bpm	Sensed AV	150 ms
		Upper Sensor	130 bpm		

Detection		Rates	Therapies
AT/AF	Monitor	>171 bpm	All Rx Off
VT	Monitor	>150 bpm	

Changes This Session — Session Start — Current Value

No parameters have been changed during the current session.

Paced AV Delay vs Sensed AV Delay

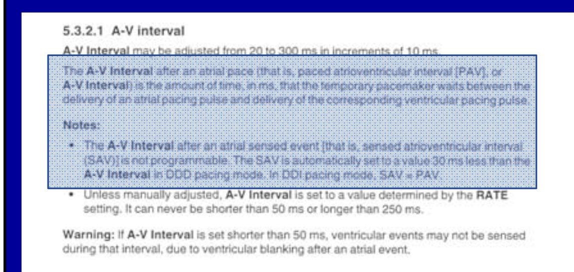


Basic Operation	
Mode	DDD
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	VOO
Sensor	Off
Rates	
Base Rate	60 bpm
Rest Rate	Off
Max Track Rate	130 bpm
Hysteresis Rate	Off
2:1 Block Rate	216 bpm
Delays	
Paced AV Delay	200 ms
Sensed AV Delay	150 ms
Rate Responsive AV Delay	Medium
Shortest AV Delay	100 ms
Ventricular Intrinsic Preference (VIP®)	On
VIP® Extension	200 ms
Search Interval	1 min
Search Cycles	1
Neg. AV Hysteresis/Search	Off

Refractories & Blanking	
PVARP	275 ms
Post-Vent. Atrial Blanking	100 ms
Rate Responsive PVARP/V Ref	High
Shortest PVARP/V Ref	175 ms
A/V Pace Refractory	190/250 ms
A/V Sense Refractory	93/250 ms
Ventricular Blanking	Auto
Ventricular Safety Standby	On
PVC Response	Off
PMT Response	Atrial Pace
PMT Detection Rate	110 bpm
AT/AF Detection & Response	
Auto Mode Switch	DDI
A. Tachycardia Detection Rate	180 bpm
AMS Base Rate	80 bpm
AF Suppression™	Off

What is Rate Responsive AV Delay?

Medtronic Temp Pacer 5392



5.3.2.1 A-V interval

A-V Interval may be adjusted from 20 to 300 ms in increments of 10 ms.

The **A-V Interval** after an atrial pace (that is, paced atrioventricular interval [PAV], or **A-V Interval**) is the amount of time, in ms, that the temporary pacemaker waits between the delivery of an atrial pacing pulse and delivery of the corresponding ventricular pacing pulse.

Notes:

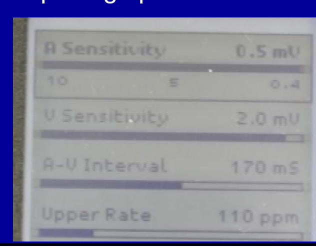
- The **A-V Interval** after an atrial sensed event (that is, sensed atrioventricular interval (SAV)) is not programmable. The SAV is automatically set to a value 30 ms less than the **A-V Interval** in DDD pacing mode. In DDI pacing mode, SAV = PAV.
- Unless manually adjusted, **A-V Interval** is set to a value determined by the **RATE** setting. It can never be shorter than 50 ms or longer than 250 ms.

Warning: If **A-V Interval** is set shorter than 50 ms, ventricular events may not be sensed during that interval, due to ventricular blanking after an atrial event.

Question?

How long after an intrinsic P-wave will the pacer wait for a spontaneous R-wave (QRS) before firing a V-pacing spike?

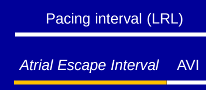
Answer=140 msec



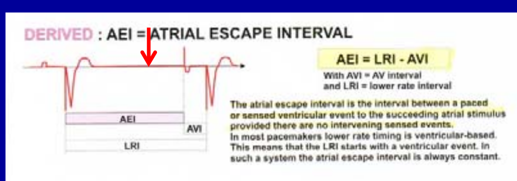
4. Atrial Escape Interval

- Atrial Escape Interval (AEI)—the period in a dual chamber pacemaker's timing cycle initiated by a ventricular sensed or paced event and ending with the next atrial paced event.
- This is a derived interval
  - Depends on the programmed LRL and the AVI

4. Atrial Escape Interval



4. Atrial Escape Interval



What would happen if a P wave occurred at the arrow?

What would happen if a PVC occurred at the arrow?

Barold, Cardiac Pacemakers and Resynch. p.92

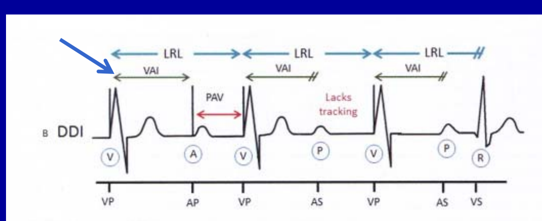
AEI=VAI

Atrial Escape Interval (AEI)

often called the

Ventricular-Atrial Interval (VAI)

Ventricular-Atrial Interval



With the LRL, LRI, AVI, and AEI you can program any VOO, AOO or DOO pacemaker

If you want to use the sensing function of the pacer, many more timing cycles are needed

Sensing Revisited

Pacer sensors depend on signal amplitude and slew rate to detect appropriate signals such as the P-wave or R-wave.

The Sensors also need methods to avoid detection of inappropriate signals that can negatively affect the pacer function

What kinds of Signals can be sensed inappropriately?

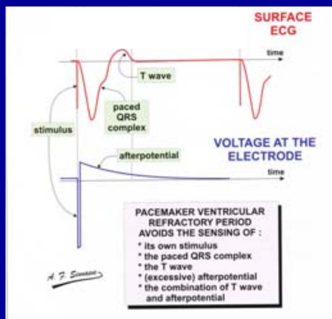
Detectable Signals after a Paced Beat

- Same chamber signals
- Far-field signals

1. Same Chamber Signals

- Stimulus artifact
- After-depolarization
- Evoked Potential (QRS/P-wave)
- Repolarization (T-wave)

Detectable Signals on Ventricular Channel



Barold, Cardiac Pacemakers and Resynch. p.64

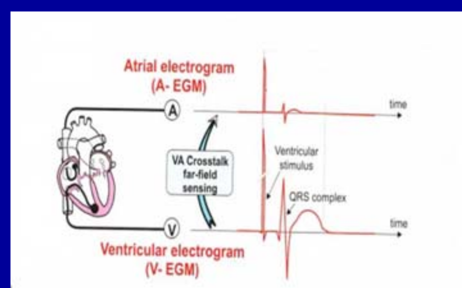
Detectable Signals on the Atrial Channel

- Atrial paced stimulus
- Atrial paced stimulus after-potential
- Evoked response (P-wave)
- Spontaneous P-wave

2. Far-Field Signals

- Atrial pacing artifacts sensed on V-channel
  - AV Crosstalk
- Vent pacing artifacts or QRS sensed on A-channel
  - VA Crosstalk

Far-Field Signals: VA Crosstalk



Ventricular pacing stimulus and evoked QRS are sensed on the AEGM

Barold, Cardiac Pacemakers and Resynch.

How does the Pacemaker minimize the likelihood of Sensing Inappropriate Signals?

Sensing-Related Timing Cycles

- Blanking Periods
- Refractory Periods
- Cross Talk Periods

Blanking Period

- Blanking Period—an interval of time during which the pacemaker is unable to sense any pacer-derived or myocardial signals
  - Sensing function is essentially OFF

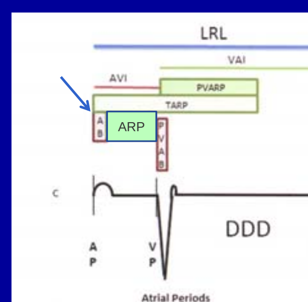
Refractory Period

- Refractory Period—a brief period after either a sensed beat or a paced beat in which the sensing circuit response is blunted
  - Typically follows a blanking period
  - Sensed events do not reset AVI or LRL
  - Sensed events can be counted to detect dysrhythmias or noise

5. Atrial Blanking Period

- Atrial sensor will not detect any atrial-sensed event immediately after an atrial event
- Lasts 30-60 msec
- Occurs at the beginning of the AV interval and the atrial refractory period
- Prevents sensing of the atrial pacing stimulus after-depolarization in particular
- Usually only employed after an atrial pacing impulse (not when AS occurs)

5. Atrial Blanking Period



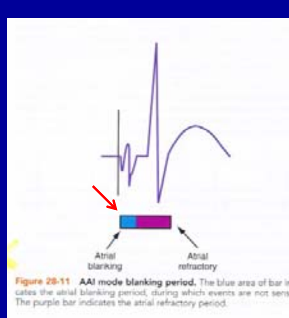
1. Atrial Blanking period begins after an atrial paced output
2. Atrial sensor does not reset timing cycle or count any electrical events that would otherwise be detected in this period
3. The ABP is essentially the early part of the ARP and the AVI
4. It primarily prevents atrial sensing of the atrial pacing stimulus and its afterdepolarization

Ellenbogen, Cardiac Pacing and ICDs, p. 210

5. Atrial Blanking Period

The AB prevents atrial channel sensing of the AP spike, its after-depolarization, and the evoked P-wave

It starts at the onset of the AP and merges into the ARP—the two combined last for the entire AVI

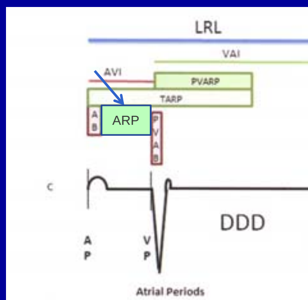


Ellenbogen p.816

6. Atrial Refractory Period

- The period during which the atrial sensor will not reset the LRL or AVI in response to a sensed event
- Sensed events are counted for other algorithms such as the atrial tachycardia detection program
- Starts immediately after the AB period if there is a paced atrial beat, or immediately after a sensed P-wave
- Lasts as long as the AVI

6. Atrial Refractory Period



1. Atrial Refractory Period begins after the AB or a sensed P wave
2. Atrial sensor does not reset timing cycle, but will count any electrical events that are detected during this period
3. The ARP lasts as long as the AVI
4. It primarily prevents atrial sensing of the atrial evoked response (paced P wave), the latter part of the sensed P-wave, or the repolarization of the atrium

Ellenbogen, Cardiac Pacing and ICDs, p. 210

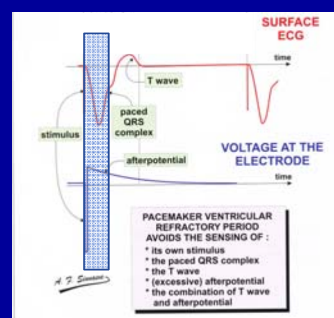
6. Atrial Refractory Period

- Another way to think about the ARP is to consider it equal in duration to the AVI with two components, a blanked component (AB) and an un-blanked component (ARP)
- If there is a sensed P-wave the ARP is entirely un-blanked

7. Ventricular Blanking Period

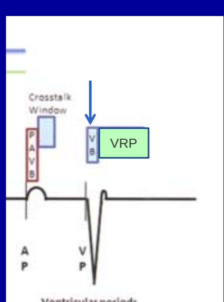
- Ventricular sensor will not detect any ventricular-sensed event immediately after a ventricular event (paced or sensed)
- Lasts 50-100 msec
- Occurs at the onset of a VP or VS event
- Prevents sensing of the pacer stimulus after-depolarization, the evoked response (pQRS) or the latter part of the spontaneous QRS

Ventricular Blanking Period



Barold, Cardiac Pacemakers and Resynch. p.64

7. Ventricular Blanking Period



1. Ventricular Blanking period begins after a Ventricular event (VP or VS)
2. Vent. sensor does not reset timing cycle or count any electrical events that would otherwise be detected in this period
3. The VBP is essentially the early part of the VRP
4. It primarily prevents vent. sensing of the ventricular pacing stimulus evoked response and after-depolarization, or the early part of a spont. QRS

Ellenbogen, Cardiac Pacing and ICDs, p. 210

7. Ventricular Blanking Period

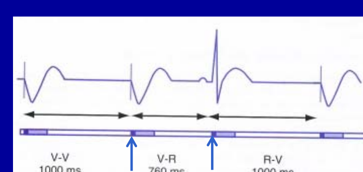


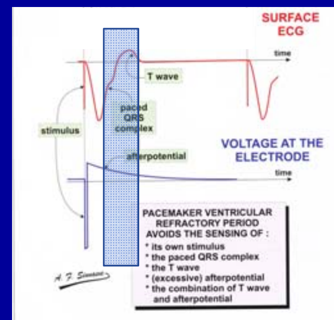
Figure 28-3 VVI ventricular refractory periods. The solid blue squares in the open bar indicate the ventricular blanking periods, during which events are not sensed. The shaded blue rectangles in the bar indicate the ventricular refractory periods, during which ventricular sensed events are not used to reset timing cycles.

Ellenbogen, large version p. 814

8. Ventricular Refractory Period

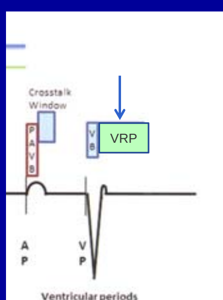
- The period during which the ventricular sensor will not reset the LRL or AEI in response to a sensed event
- Sensed events are counted for other algorithms such as the noise reversion mode
- Starts immediately after the VB period
- Intended to prevent oversensing of the evoked QRS or T-wave

Detectable Signals on Ventricular Channel



Barold, Cardiac Pacemakers and Resynch. p.64

8. Ventricular Refractory Period

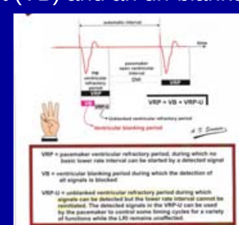


1. Ventricular Refractory period begins after the VB
2. Vent. sensor does not reset timing cycle but will count sensed events for algorithms such as the noise reversion mode
3. It primarily prevents vent. sensing of the ventricular pacing stimulus evoked response after-depolarization, the latter part of a spont. QRS, or the T-wave

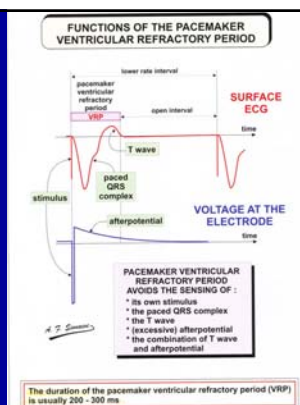
Ellenbogen, Cardiac Pacing and ICDs, p. 210

8. Ventricular Refractory Period

- Another way to think about the VRP is to consider it to have two components, a blanked component (VB) and an un-blanked component (VRP)



Barold, Cardiac Pacemakers and Resynch.

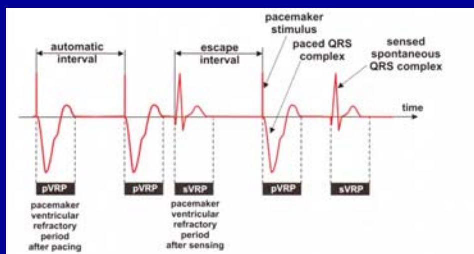


Barold, Cardiac Pacemakers and Resynch.

Ventricular Refractory Period Duration

- Because the width of a paced QRS is significantly longer than a sensed QRS, there are often two separate VRPs—one paced VRP and one sensed VRP

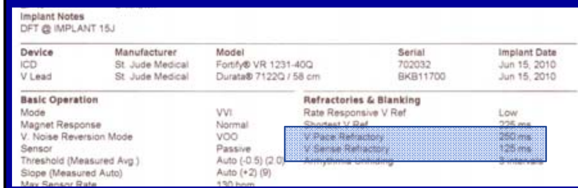
Two Different VRPs



The evoked QRS is wider than the spontaneous QRS

Barold, Cardiac Pacemakers and Resynch.

What are the Ventricular Refractory Period Durations?



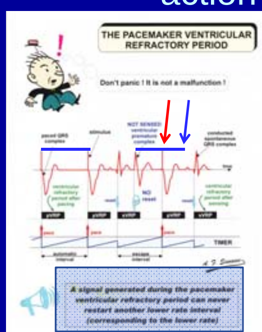
Implant Notes
DFT @ IMPLANT 15J

Device	Manufacturer	Model	Serial	Implant Date
ICD	St. Jude Medical	Fortify® VR 1231-40Q	702032	Jun 15, 2010
V Lead	St. Jude Medical	Durata® 7122Q / 58 cm	BKB11700	Jun 15, 2010

Basic Operation		Refractories & Blanking	
Mode	VVI	Rate Responsive V Ref	Low
Magnet Response	Normal		
V. Noise Reversion Mode	VOO	V Pace Refractory	250 ms
Sensor	Passive	V Sense Refractory	125 ms
Threshold (Measured Avg.)	Auto (-0.5) (2.0)		
Slope (Measured Auto)	Auto (+2) (9)		

The difference is large in this case because the device is an ICD

Ventricular Refractory Period in action



1. If you did not see the marker channel you might wonder why the pacer spike after the PVC (red arrow) comes so "early"
2. But it is not early since the LRL (EI) is not reset because the PVC occurs during the sVRP
3. Had the LRL reset the VP would occur later at the blue arrow
4. The message in the box is important to understand

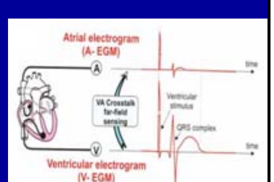
Barold, Cardiac Pacemakers and Resynch. p.65

Far-Field Noise

- How do the pacemaker sensors manage noise from the opposite chamber?
  - Atrial sensor (V-A crosstalk)
  - Ventricular sensor (A-V crosstalk)

Atrial Sensor Far-Field Noise

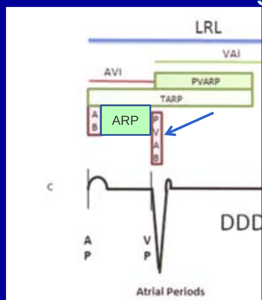
- V-A crosstalk far-field sensing
  - V. Pacing stimulus
  - V. Pacing stimulus after depolarization
  - Evoked potential QRS
  - Spontaneous QRS
  - T-wave



9. Post-Ventricular Atrial Blanking Period

- Period where atrial sensing is essentially off after a ventricular-paced or –sensed event
  - Sensor does not reset timing cycles and does not count any events during this period
- Lasts 50-100 msec
- Avoids over-sensing of V-pacing impulse, early evoked potential or early spont QRS

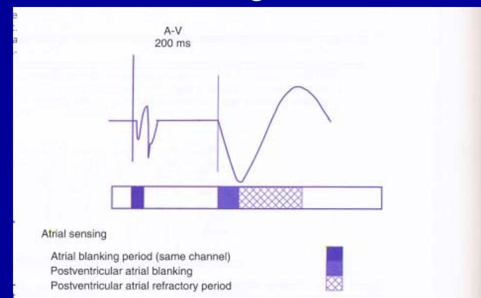
9. Post-Ventricular Atrial Blanking Period



1. Starts after a VP or VS
2. Blanks sensor during the first 50-100 msec to prevent sensing of the VP spike and its after-potential, the early evoked potential (QRS), or the early spont. QRS

Ellenbogen, Cardiac Pacing and ICDs, p. 210

9. Post-Ventricular Atrial Blanking Period



What would happen if there were no PVAB?

- If a ventricular impulse were detected by the atrial channel of a DDD pacemaker, the AVI would start and this would be followed by another VP event creating a pacemaker mediated tachycardia with loss of the atrial kick

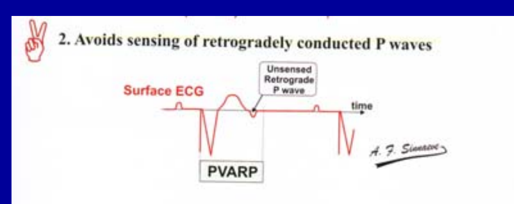
Can you find the PVAB?

Basic Operation		**Refractories & Blanking**	
Mode	DDD	PVARP	275 ms
V. Triggering	Off	Post-Vent. Atrial Blanking	100 ms
Magnet Response	Battery Test	Rate Responsive PVARP/V Ref	High
V. Noise Reversion Mode	VOO	Shortest PVARP/V Ref	175 ms
Sensor	Off	A/V Pace Refractory	190/250 ms
		A/V Sense Refractory	93/250 ms
Rates		Ventricular Blanking	Auto
Base Rate	60 bpm	Ventricular Safety Standby	On
Rest Rate	Off	PVC Response	Off
Max Track Rate	130 bpm	PMT Response	Atrial Pace
Hysteresis Rate	Off	PMT Detection Rate	110 bpm
2:1 Block Rate	216 bpm		
		AT/AF Detection & Response	
Delays		Auto Mode Switch	DDI
Paced AV Delay	200 ms	A. Tachycardia Detection Rate	180 bpm
Sensed AV Delay	150 ms	AMS Base Rate	80 bpm
Rate Responsive AV Delay	Medium	AF Suppression™	Off
Shortest AV Delay	100 ms		
Ventricular Intrinsic Preference (VIP®)	On		
VIP® Extension	200 ms		
Search Interval	1 min		
Search Cycles	1		
Neg. AV Hysteresis/Search	Off		

10. Post-Ventricular Atrial Refractory Period (PVARP)

- Follows the PVAB after a VP or VS event
- Any sensed event does not activate the AVI, but the event can be counted for the algorithms such as the mode switch function
- Prevents inappropriate atrial channel sensing of ventricular events
  – Latter part of the QRS, especially a paced QRS, and the T-wave
- Eliminates atrial sensing of retrograde P waves from ventriculoatrial conduction

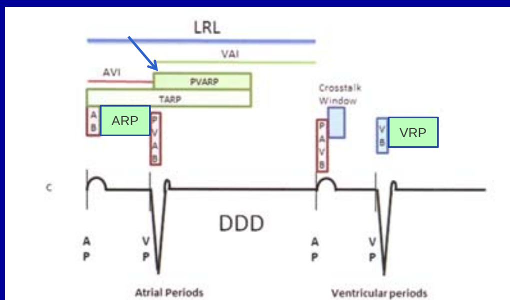
10. PVARP



Sensed retrograde P-waves from paced beats or PVCs can precipitate PMT
If not for the PVARP, the retro. P-wave would activate the AVI and lead to relatively rapid V-pacing without a functional atrial kick

Barold, Cardiac Pacemakers and Resync. p. 93

10. PVARP



Ellenbogen, Cardiac Pacing and ICDs, p. 210

Find the PVARP

Basic Operation	
Mode	DDD
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	VOO
Sensor	Off
Rates	
Base Rate	60 bpm
Rest Rate	Off
Max Track Rate	130 bpm
Hysteresis Rate	Off
2:1 Block Rate	216 bpm
Delays	
Paced AV Delay	200 ms
Sensed AV Delay	150 ms
Rate Responsive AV Delay	Medium
Shortest AV Delay	100 ms
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VIP® Extension	200 ms
Search Interval	1 min
Search Cycles	1
Neg. AV Hysteresis/Search	Off
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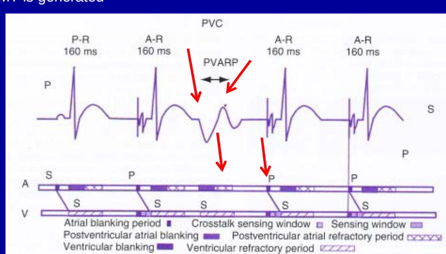
A/V Pace Refractory	190/250 ms
A/V Sense Refractory	93/250 ms
Ventricular Blanking	Auto
Ventricular Safety Standby	On
PVC Response	Off
PMT Response	Atrial Pace
PMT Detection Rate	110 bpm
AT/AF Detection & Response	
Auto Mode Switch	DDI
A. Tachycardia Detection Rate	180 bpm
AMS Base Rate	80 bpm
AF Suppression™	Off

If the HR increases the PVARP can be shortened to maximize the URL

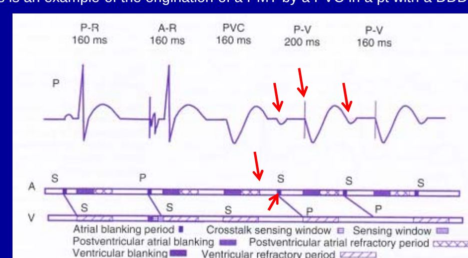
PVARP Effective

1. A PVC leads to a retrograde P-wave
2. Because the atrial sensor is still in the PVARP, the P-wave does not initiate the AVI
3. The ventricular sensor detected the PVC and restarted the AEI
4. An AP follows the ending of the AEI
5. No PMT is generated



PVARP related PMT

1. The PVC leads to a late retrograde P-wave which occurs after the PVARP ends
2. This sensed P-wave starts the AVI interval (diagonal line)
3. After the AVI ends, a VP occurs and this VP causes another retro. P-wave
4. This is an example of the origination of a PMT by a PVC in a pt with a DDD pacer



How is the PMT prevented?

Answer: Extend the PVARP

PVARP Extension after PVC

Refractory

	Initial Value	Present Value
Dynamic PVARP	On	On
Maximum PVARP	300	300 ms
Minimum PVARP	240	240 ms
PVARP after PVC/PAC	400	400 ms
V-Blanking after A-Pace	40	40 ms
A-Blanking after V-Pace	120	120 ms

A-Tachy Response

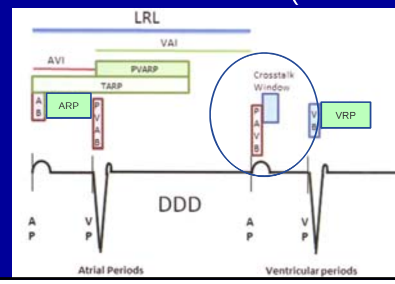
	Initial Value	Present Value
A-Tachy Response	On	On
Trigger Rate	170	170 bpm
Duration	8	8 cycles
Entry Count	8	8 cycles
Exit Count	8	8 cycles
Fallback Mode	DDIR	DDIR
Fallback Time	30	30 sec
Lower Rate Limit	70	70 ppm
Atrial Flutter Response	170	170 bpm
PMT Termination	On	On
Ventricular Rate Regulation	Off	Off
Max Pacing Rate	--	-- ppm

How does the Ventricular Channel manage Far-Field Signals?

- Post-Atrial Ventricular Blanking Period
- Crosstalk Detection Window/Ventricular Safety Pacing

11. Post-Atrial Ventricular Blanking Period

- Must address the ventricular sensor response after an atrial event (A-V crosstalk)

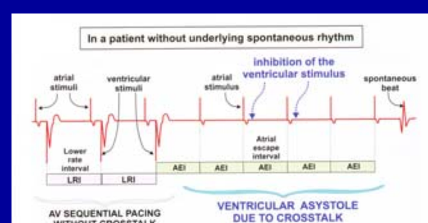


A-V Crosstalk

- Atrial pacing stimuli detected by the ventricular sensor of a DDD pacer would lead to inhibition of the ventricular pacing output—and cause asystole in pacer dependent patients

A-V Crosstalk Causing Asystole

1. A-V pacing without problem in the first three beats
2. The 4th AP is sensed by the ventricular sensor which inhibits VP and restarts the AEI
3. The problem persists
4. The AP rate increases because the AVI is no longer occurring

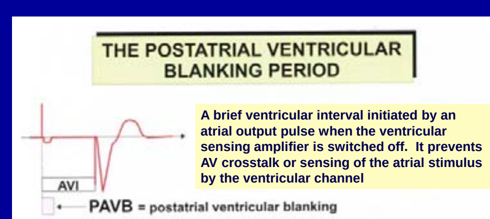


Barold, Cardiac Pacemakers and Resynch. p.96

11. Post-Atrial Ventricular Blanking Period

- PAVB—a period in which the ventricular channel is off for 10-60 msec following atrial paced (AP) events
- Prevents detection of the atrial pacing stimulus or its after-depolarization as a ventricular event and then inappropriately inhibiting ventricular output
- Usually not activated after an AS event

11. PAVB



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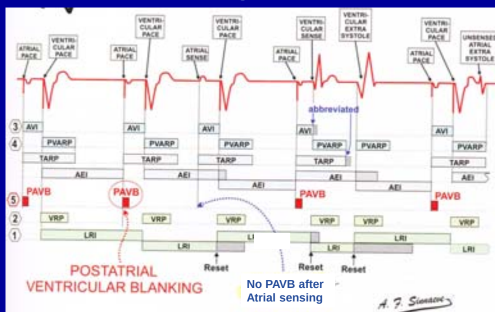
11. Post-Atrial Ventricular Blanking Period



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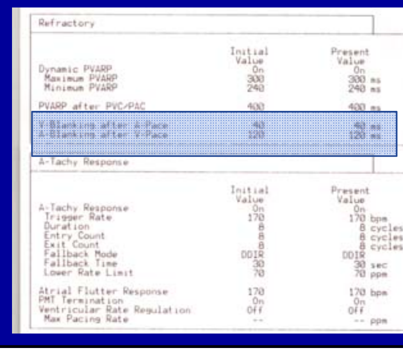
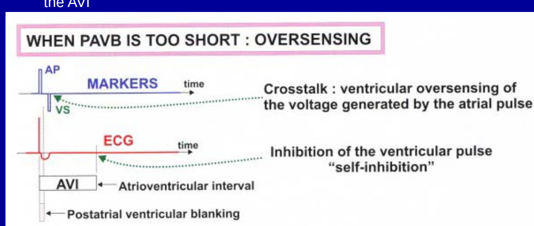
11. PVAB



11. PAVB

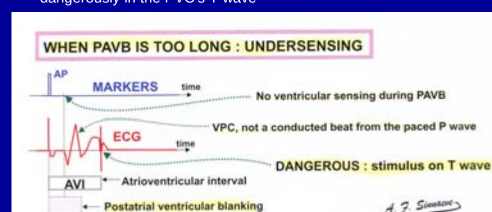
1. When the PAVB is too short or not on at all, the atrial pacing impulse is sensed on the ventricular channel
2. The ventricular channel assumes this event is ventricular in nature and therefore inhibits the VP output that would otherwise occur at the end of the AVI



Barold, Cardiac Pacemakers and Resynch.

11. PAVB

1. When the PAVB is programmed too long, a PVC that would have been sensed on the ventricular channel and would have inhibited the impending VP, is not detected
2. The AVI continues and when it elapses, the ventricular pacer fires dangerously in the PVC's T-wave



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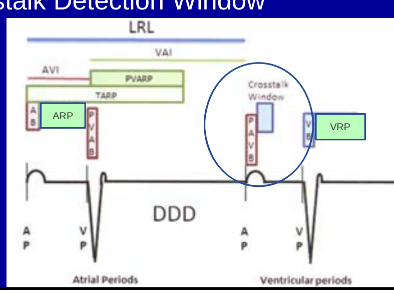
12. Crosstalk Detection Window

- Solution: A shorter PAVB period and a Crosstalk Detection Window



12. Cross Talk Detection Window

- Cross Talk Detection Window (CDW)—A short timing cycle occurring immediately after the post atrial ventricular blanking period in some DDD pacemakers that alters the usual response to a ventricular sensed event. Any sensed event during the CDW results in a triggered ventricular output at the end of an abbreviated AV interval and is often referred to as Ventricular Safety Pacing

Ventricular Safety Pacing

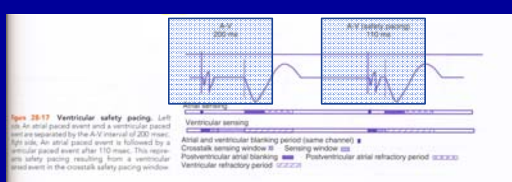
- Any sensed event during the CDW will lead to a paced event early enough so that if the sensed event were a true ventricular depolarization (PVC), the pacing stimulus will not be dangerous (in the T-wave)
- If the sensed event were not a PVC, but rather cross-talk from the atrium, the VP event will simply be a little early and certainly not harmful

Solution to A-V Crosstalk

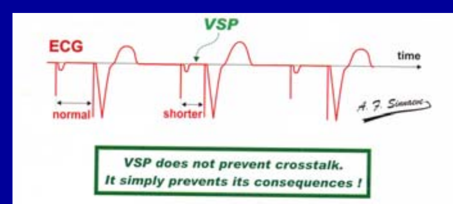
Short PAVB + VSP > Longer PAVB

How does one Recognize VSP?

- AP followed by a VP with a very short AV interval
- “VSP” on the marker channel



How does one Recognize VSP?



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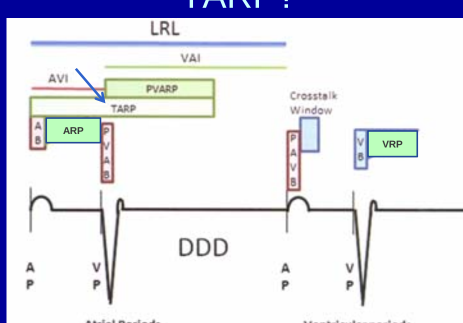
Almost Done! What is the TARP?

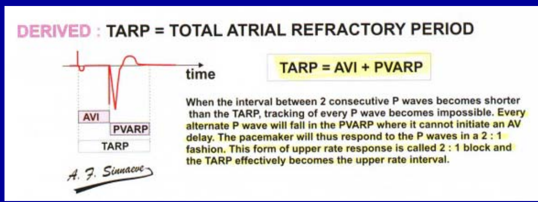


Ellenbogen, Cardiac Pacing and ICDs, p. 210

13. TARP

- Total Atrial Refractory Period —the sum of the avtrioventicular interval and the PVARP. The total atrial refractory period limits the maximum upper rate tracking limit possible in a dual-chamber pacemaker

13. TARP



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What does this mean?

- If the Atrial Channel is refractory during the TARP, the atrial channel cannot sense intrinsic atrial beats.
- If it cannot sense intrinsic atrial beats, the ventricular channel cannot track the intrinsic atrial rhythm
- The longer the AVI and PVARP the less time leftover for atrial sensing

14. Upper Rate Interval

- The interval that defines the maximal tracking rate the pacemaker can accomplish without the 2:1 block just described.
- URI = TARP
- Example: AVI 200 msec PVARP 300 msec
  URI = 500 msec
  MTR = 60,000/500 = 120 bpm

15. Maximum Tracking Rate (MTR)

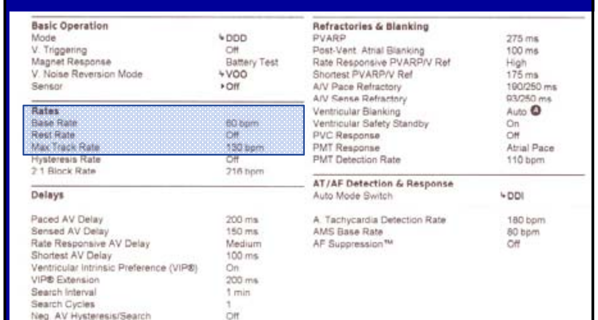
- Maximum Tracking Rate—a programmable value in dual-chamber tracking modes that determines the highest ventricular pacing that can be achieved in response to atrial sensed events with one-to-one AV synchrony at the programmed AV interval.
- It is also known as the Upper Rate Limit (URL).

15. Maximum Tracking Rate

- The MTR must be programmed in pacemakers in the DDD/DDDR modes

- The MTR is not necessary if the pacer is in the following modes since there is no tracking
  – VVI
  – AAI
  – DOO
  – DDI

St Jude Pacer DDD Mode



Basic Operation	
Mode	DDD
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	VOO
Sensor	Off
Rates	
Base Rate	60 bpm
Rest Rate	Off
Max Track Rate	130 bpm
Hysteresis Rate	Off
2:1 Block Rate	216 bpm
Delays	
Paced AV Delay	200 ms
Sensed AV Delay	150 ms
Rate Responsive AV Delay	Medium
Shortest AV Delay	100 ms
Ventricular Intrinsic Preference (VIP®)	On
VIP® Extension	200 ms
Search Interval	1 min
Search Cycles	1
Neg. AV Hysteresis/Search	Off

Refractories & Blanking	
PVARP	275 ms
Post-Vent. Atrial Blanking	100 ms
Rate Responsive PVARP/V Ref	High
Shortest PVARP/V Ref	175 ms
A/V Pace Refractory	190/250 ms
A/V Sense Refractory	93/250 ms
Ventricular Blanking	Auto
Ventricular Safety Standby	On
PVC Response	Off
PMT Response	Atrial Pace
PMT Detection Rate	110 bpm
AT/AF Detection & Response	
Auto Mode Switch	DDI
A. Tachycardia Detection Rate	180 bpm
AMS Base Rate	80 bpm
AF Suppression™	Off

St Jude DDDR Mode

Basic Operation	
Mode	DDDR
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	120 bpm
Reaction Time	Fast
Recovery Time	Medium
Rates	
Base Rate	60 bpm
Rest Rate	Off
Max Sensor Rate	120 bpm
Max Track Rate	130 bpm
Hysteresis Rate	Off
2:1 Block Rate	216 bpm

Max Tracking Rate vs Max Sensor Rate

- The Max Sensor Rate applies to a pacemaker that has a Rate Response Mode (e.g., DDDR or VVIR)
  - The Max Sensor Rate is the highest rate at which the pacemaker will raise the LRL in response to perceived increased activity
  - It is not related to tracking at all
  - It may or may not be the same as the MTR

Boston Scientific DDDR Mode

Model 1280 Serial 528860 2891 Sof

Brady Parameters

	Initial Value
Mode	DDDR -->
Lower Rate Limit	40
Max Tracking Rate	120 -->
Max Sensor Rate	120 -->
AV Delay (paced)	DYN -- -->
ATRIAL	
Pulse Width	0.40
Amplitude	2.0
Sensitivity	0.50
Refractory (PVARP)	280
VENTRICULAR	
Pulse Width	0.50
Amplitude	2.0
Sensitivity	1.5
Refractory	250

Let's See How Much You Know

Basic Operation	
Mode	DDD
V. Triggering	Off
Magnet Response	Battery Test
V. Noise Reversion Mode	VOO
Sensor	Off
Rates	
Base Rate	60 bpm
Rest Rate	Off
Max Track Rate	130 bpm
Hysteresis Rate	Off
2:1 Block Rate	216 bpm
Delays	
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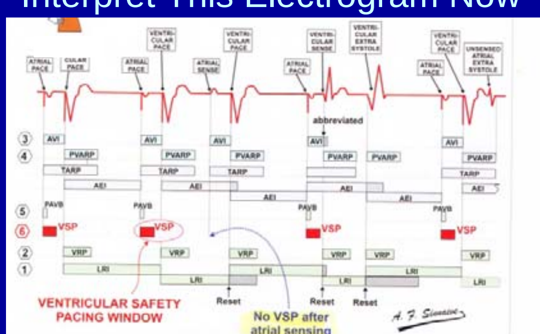
Interpret This Electrogram Now



Barold, Cardiac Pacemakers and Resynch.

Summary

- You have now learned 15 important pacer timing cycles that will make your comprehension of pacemaker modes much more in depth
- You will also be well prepared to start analyzing pacemaker electrograms for proper or improper pacemaker function

Timing Cycles