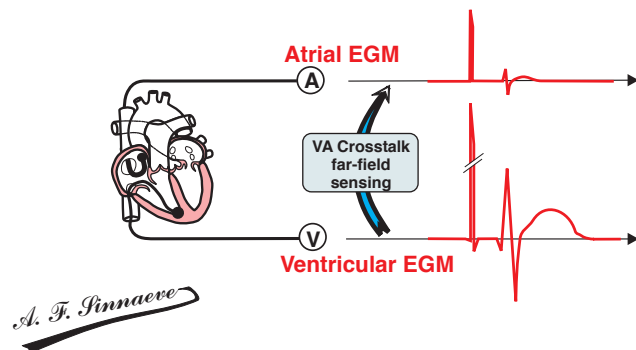
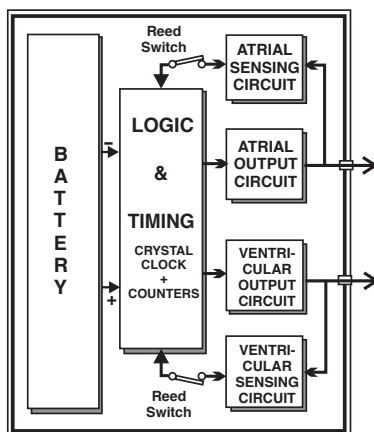
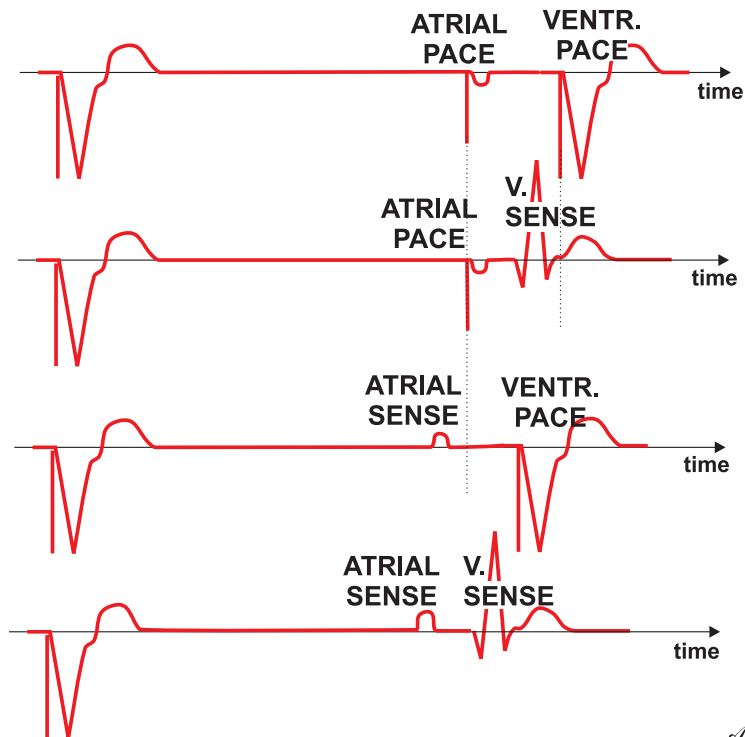
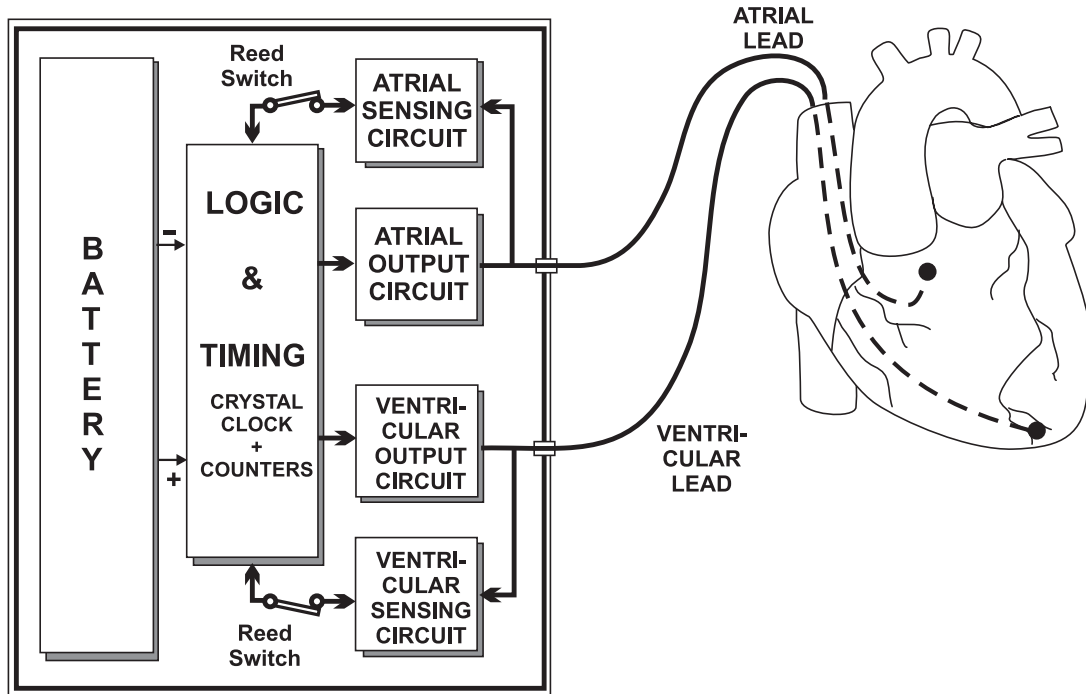


DDD PACEMAKERS - BASIC FUNCTIONS

- * Block diagram of dual chamber pacemakers
- * 4 fundamental timing cycles - part 1
- * 4 fundamental timing cycles - part 2
- * Functions of the postventricular atrial blanking period
- * Pacemaker with 4 timing cycles at work
- * Three-letter-code for dual chamber pacemakers
- * Manifestations of crosstalk
- * Fifth timing cycle : postatrial ventricular blanking
- * Postatrial ventricular blanking
- * Addition of a 6th cycle. Diagram
- * Ventricular safety pacing (VSP)
- * VSP and crosstalk
- * ECG with VSP
- * VSP with VPCs
- * Testing for crosstalk
- * Prevention of crosstalk
- * Sensing the terminal part of QRS



DUAL CHAMBER PACING



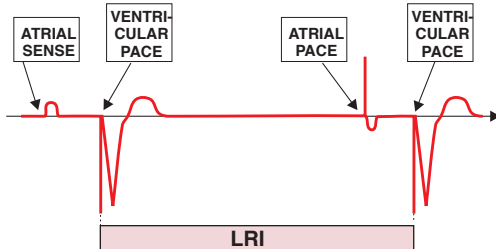
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THE 4 FUNDAMENTAL TIMING CYCLES OF A DDD PACEMAKER

PART 1 : THE VENTRICULAR CHANNEL



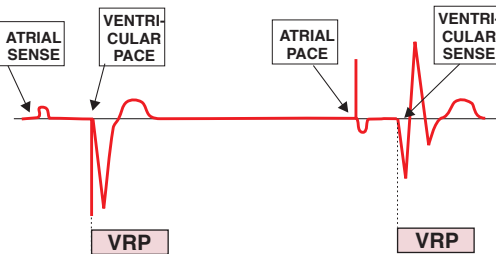
FUNDAMENTAL TIMING CYCLE 1 LRI = LOWER RATE INTERVAL



Longest interval between a paced or sensed ventricular event and the succeeding ventricular paced event without intervening sensed events



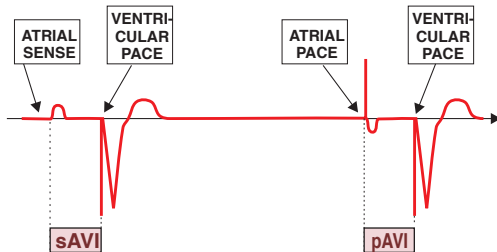
FUNDAMENTAL TIMING CYCLE 2 VRP = VENTRICULAR REFRACTORY PERIOD



Interval initiated by a ventricular event during which a new lower rate interval (LRI) cannot be initiated



FUNDAMENTAL TIMING CYCLE 3 AVI = ATRIOVENTRICULAR INTERVAL



Interval between an atrial event and the scheduled delivery of a ventricular stimulus

sAVI = after a sensed atrial event
pAVI = after a paced atrial event

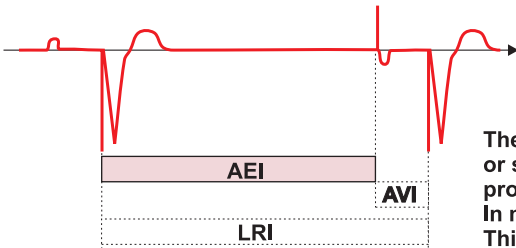
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- * the electronic analog of the P-R interval
- * the atrial channel is refractory during the AV interval (a new AV delay cannot be initiated when one is already in progress)

THE 4 FUNDAMENTAL TIMING CYCLES OF A DDD PACEMAKER

PART 2 : THE ATRIAL CHANNEL

DERIVED : AEI = ATRIAL ESCAPE INTERVAL



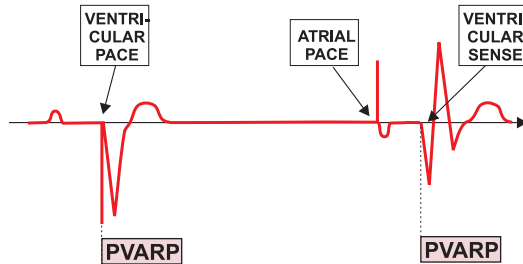
$$AEI = LRI - AVI$$

With AVI = AV interval
and LRI = lower rate interval

The atrial escape interval is the interval between a paced or sensed ventricular event to the succeeding atrial stimulus provided there are no intervening sensed events. In most pacemakers lower rate timing is ventricular-based. This means that the LRI starts with a ventricular event. In such a system the atrial escape interval is always constant.



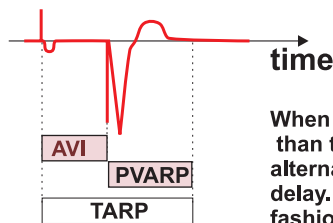
FUNDAMENTAL TIMING CYCLE 4 PVARP = POSTVENTRICULAR REFRACTORY PERIOD



Interval after a ventricular paced or sensed event during which an atrial event cannot initiate a new AVI

- * avoids inappropriate atrial sensing of ventricular events
- * eliminates sensing of retrograde P waves from ventriculoatrial conduction

DERIVED : TARP = TOTAL ATRIAL REFRACTORY PERIOD



$$TARP = AVI + PVARP$$

When the interval between 2 consecutive P waves becomes shorter than the TARP, tracking of every P wave becomes impossible. Every alternate P wave will fall in the PVARP where it cannot initiate an AV delay. The pacemaker will thus respond to the P waves in a 2 : 1 fashion. This form of upper rate response is called 2 : 1 block and the TARP effectively becomes the upper rate interval.

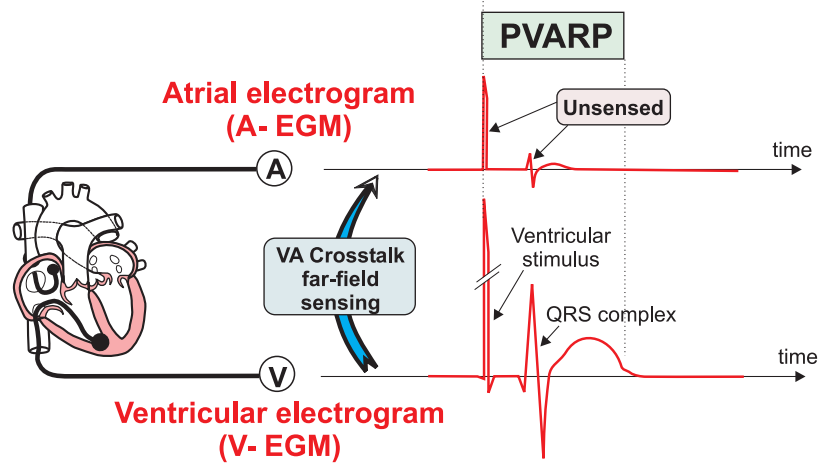
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All examples of pacemaker timing in this book involve ventricular-based lower rate timing, unless otherwise specified.

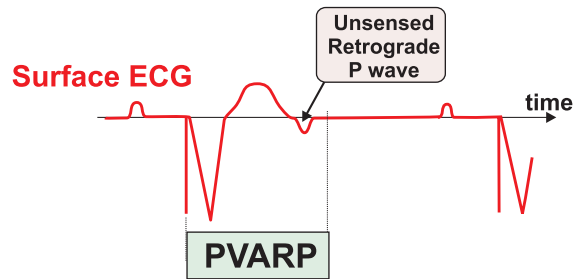
FUNCTIONS OF THE POSTVENTRICULAR ATRIAL REFRACTORY PERIOD (PVARP)

PVARP Interval after a ventricular paced or sensed event during which the atrial channel is refractory !!!

1. Avoids the inappropriate atrial sensing of ventricular events (ventricular stimuli, QRS complexes, aberrant T waves)

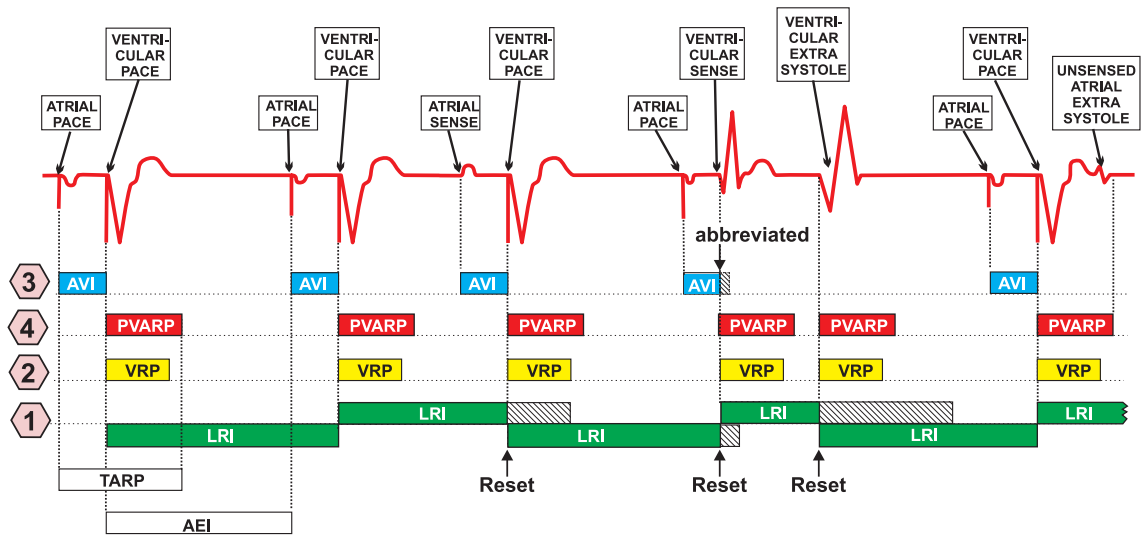


2. Avoids sensing of retrogradely conducted P waves



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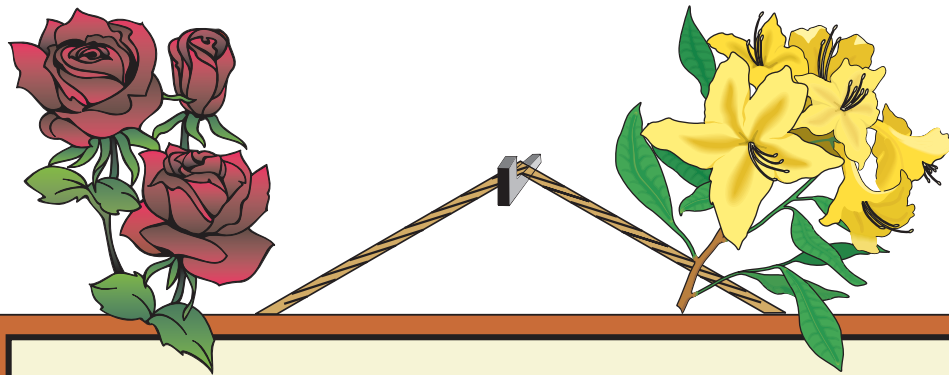
DDD PACEMAKER WITH 4 TIMING CYCLES AT WORK



- ### FUNDAMENTAL INTERVALS
- 1 LRI = Lower Rate Interval
 - 2 VRP = Ventricular Refractory Period
 - 3 AVI = Atrioventricular Interval
 - 4 PVARP = Postventricular Atrial Refractory Period

- ### DERIVED INTERVALS
- TARP = Total Atrial Refractory Period
= AVI + PVARP
= Upper Rate Interval
= URI
 - AEI = Atrial Escape Interval
= LRI - AVI

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THREE-LETTER PACEMAKER CODE (ICHD)

POSITION	1st	2nd	3rd
CATEGORY	CHAMBER(S) PACED	CHAMBER(S) SENSED	MODE OF RESPONSE
LETTERS	V = VENTRICLE A = ATRIUM S = SINGLE D = DOUBLE (V & A)	V = VENTRICLE A = ATRIUM S = SINGLE O = NONE D = DOUBLE (V & A)	T = TRIGGERED I = INHIBITED O = NONE D = DOUBLE inhibited & triggered

EXAMPLE :

DDD = a pacemaker pacing and sensing in both the atrium and the ventricle; pacing is inhibited in the atrial channel by sensed ventricular or atrial activity and is inhibited in the ventricular channel by ventricular activity but triggered by sensing atrial activity.

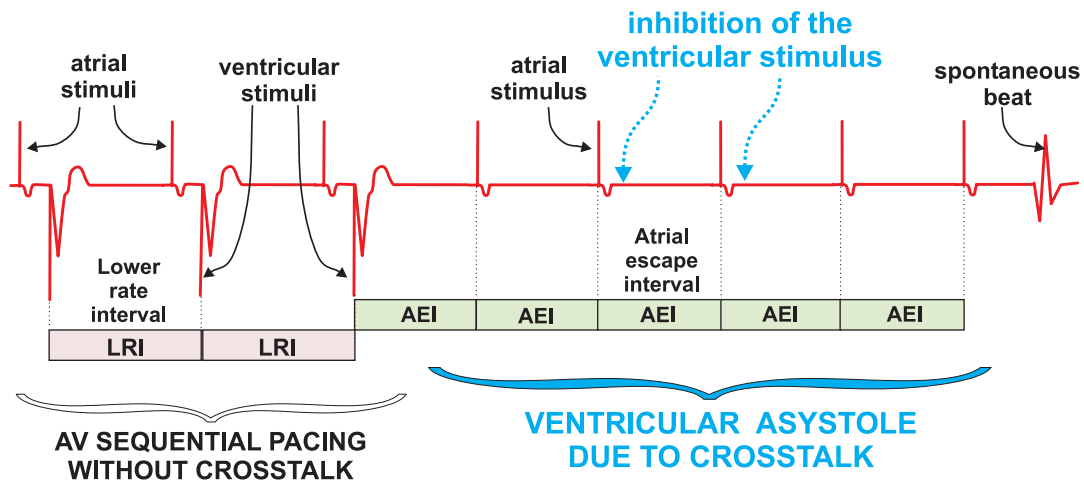
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MANIFESTATIONS of AV CROSSTALK

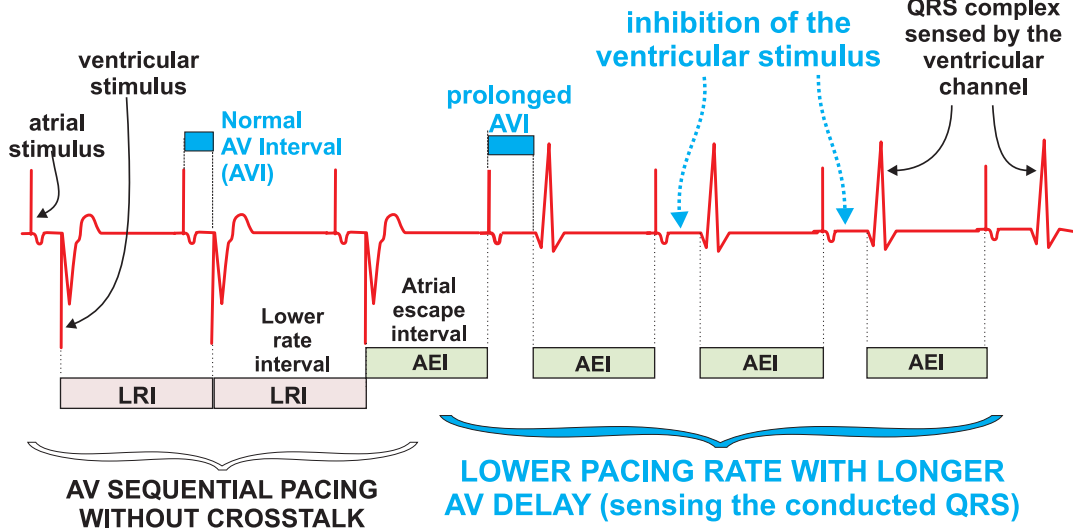
SENSING OF THE ATRIAL STIMULUS BY THE VENTRICULAR CHANNEL

During crosstalk, the atrial pacing rate increases if the ventricular channel does not sense any QRS complexes either because they are absent or they fall in the ventricular refractory period

In a patient without underlying spontaneous rhythm



In a patient with first-degree AV block

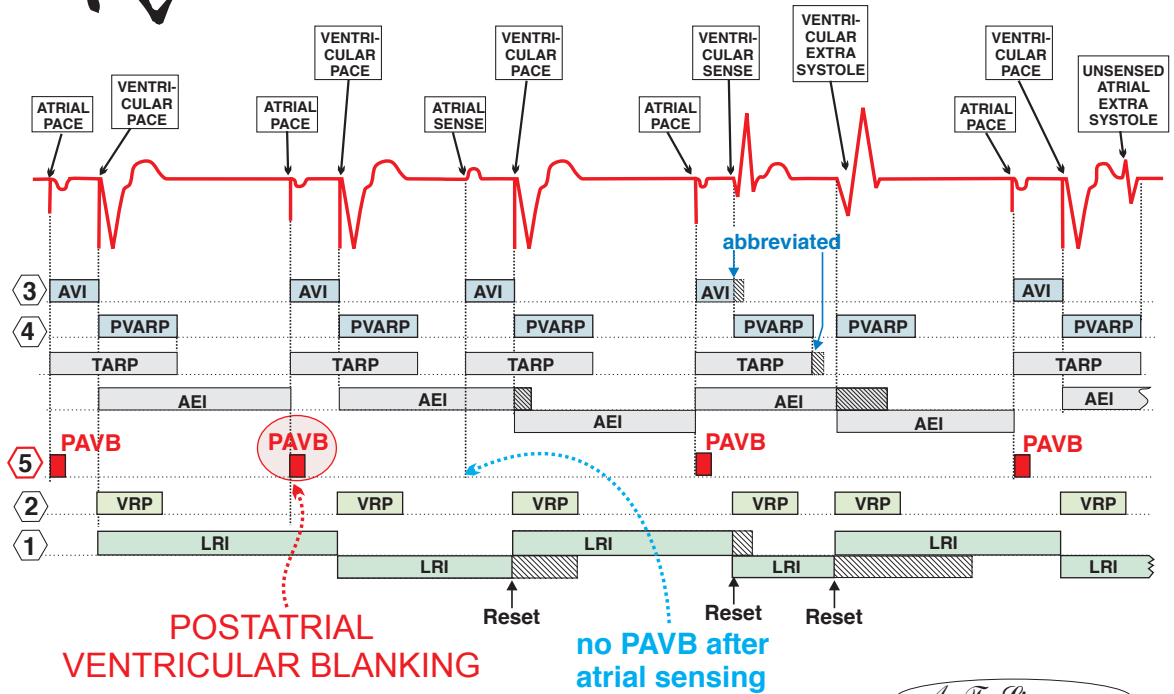


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ADDITION OF A FIFTH TIMING CYCLE TO A SIMPLE DDD PACEMAKER TO PREVENT AV CROSSTALK



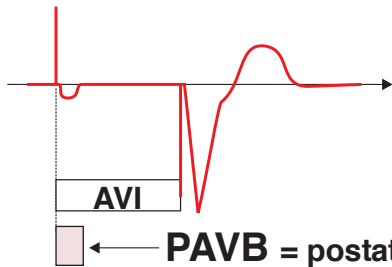
Stop the influence of the atrial stimulus upon the ventricular channel !!



PAVB = a brief interval (10 to 60 ms) initiated by an atrial output pulse when the ventricular channel is switched off and cannot sense. PAVB is often programmable

Abbreviations : AEI = atrial escape interval ; AVI = atrioventricular interval ; LRI = lower rate interval ; PAVB = post-atrial ventricular blanking ; PVARP = postventricular atrial refractory period ; TARP = total atrial refractory period ; VRP = ventricular refractory period

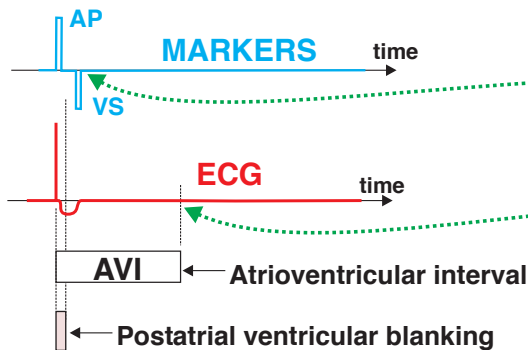
THE POSTATRIAL VENTRICULAR BLANKING PERIOD



A brief ventricular interval initiated by an atrial output pulse when the ventricular sensing amplifier is switched off. It prevents AV crosstalk or sensing of the atrial stimulus by the ventricular channel

← **PAVB** = postatrial ventricular blanking

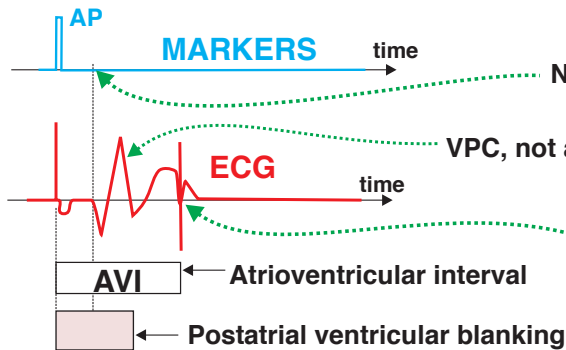
WHEN PAVB IS TOO SHORT : OVERSENSING



Crosstalk : ventricular oversensing of the voltage generated by the atrial pulse

Inhibition of the ventricular pulse "self-inhibition"

WHEN PAVB IS TOO LONG : UNDERSENSING



No ventricular sensing during PAVB

VPC, not a conducted beat from the paced P wave

DANGEROUS : stimulus on T wave

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Abbreviations : AVI = atrioventricular interval ; AP = atrial pace ; VS = ventricular sense