הפקולטה לרפואה
ע"ש סאקלר
אוניברסיטת תל אביב

Tel-Aviv Sourasky Medical Center

תחקור קוצבי לב ודפיברילטורים
PPM and ICD troubleshooting

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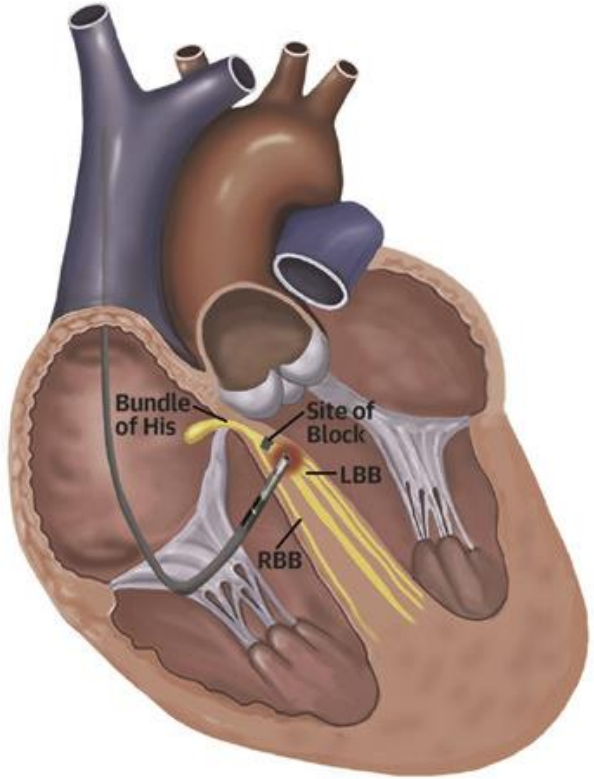
Electrophysiology unit
TLVMC
03.04.2024

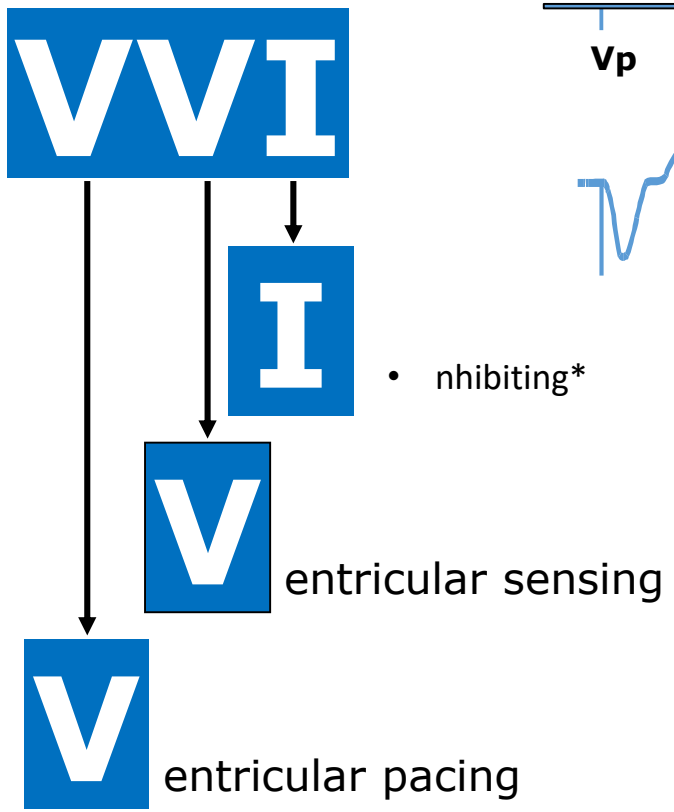


CIED - interrogation

Pacing Code Nomenclature

Position I	Position II	Position III	Position IV
Chamber Paced	Chamber Sensed	Response to Sensing	Rate Modulation
O: None	O: None	O: None	O: None
A: Atrium	A: Atrium	I: Inhibited	R: Rate adaptive
V: Ventricle	V: Ventricle	T: Triggered	
D: Dual (A + V)	D: Dual (A + V)	D: Dual (T + I)	

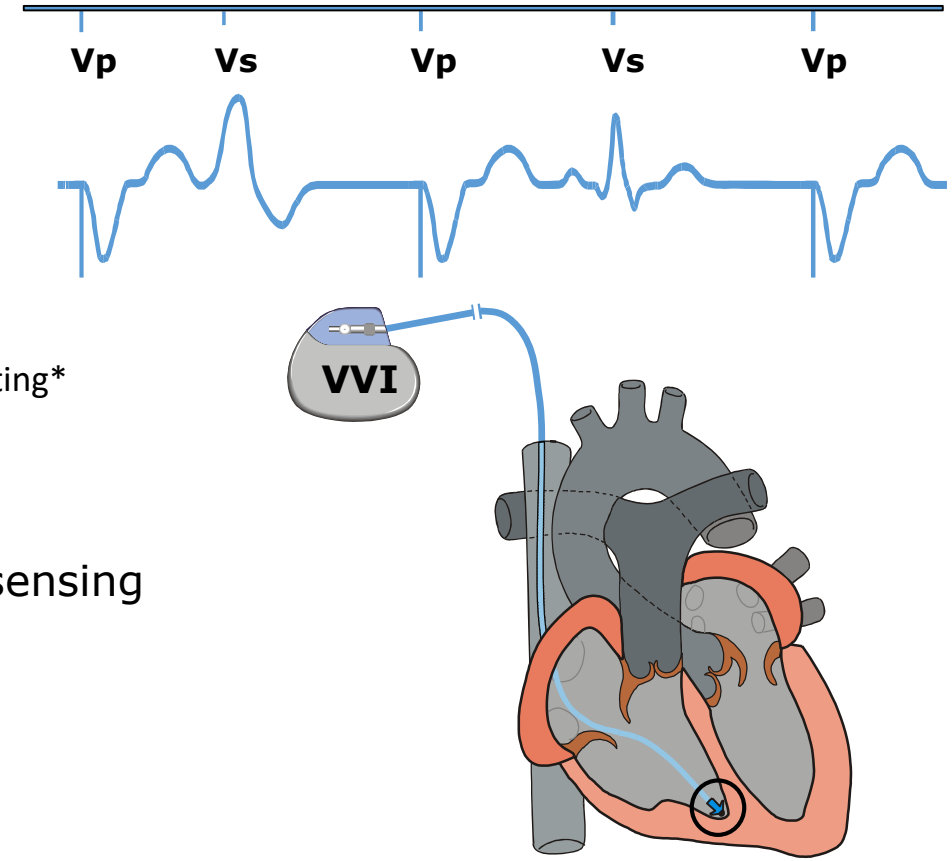
VVI-Mode



- nhibiting*

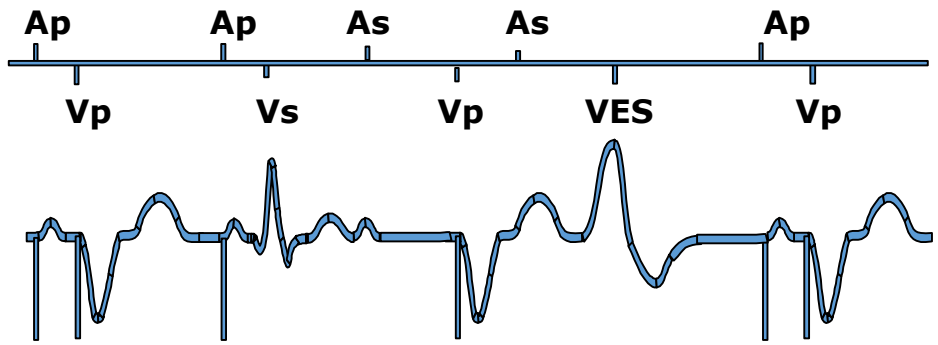
entricular sensing

entricular pacing



* I = only response to sensed events

DDI-Mode



DDI

I

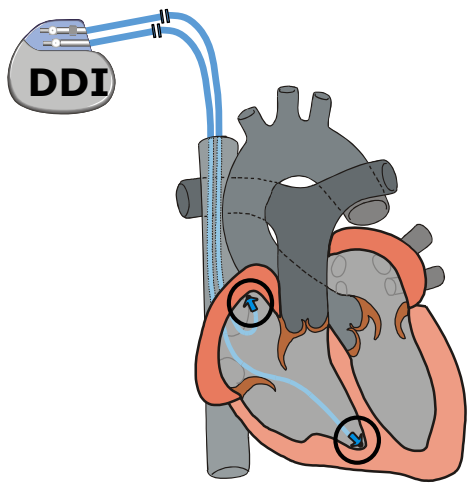
- nhibiting*

D

ual: atrial AND ventricular sensing

D

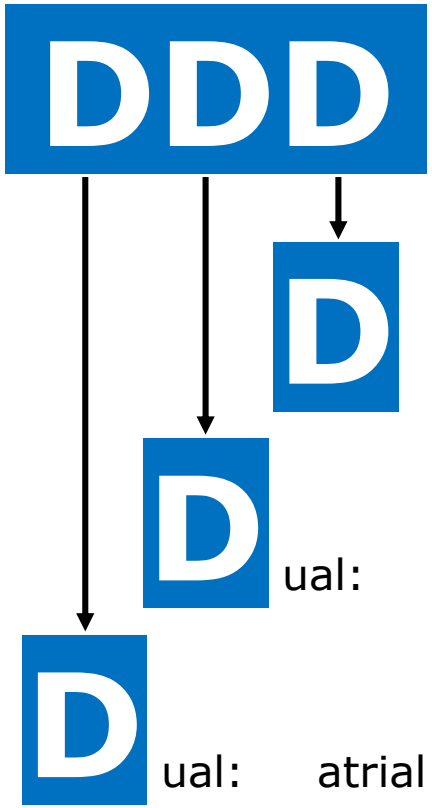
ual: atrial AND ventricular pacing

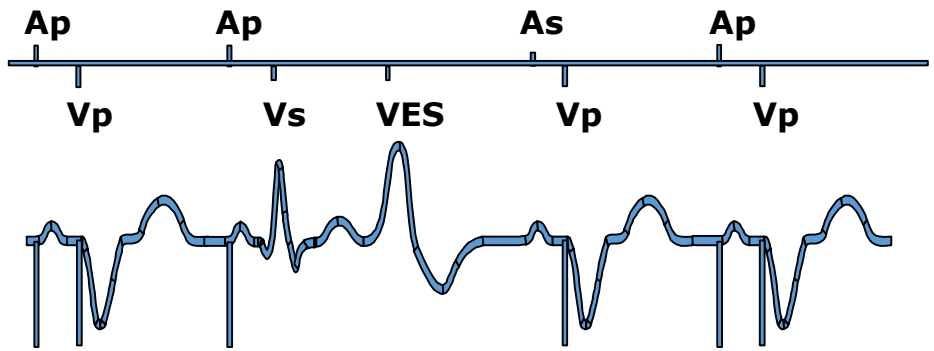


* I = only response to sensed events

DDD-Mode

The definition of tracking is:
An event in the (right) atrium is seen by the pacemaker and followed by an event in the (right) ventricle, e.g.:
A pace -> V pace,
A sense -> V pace

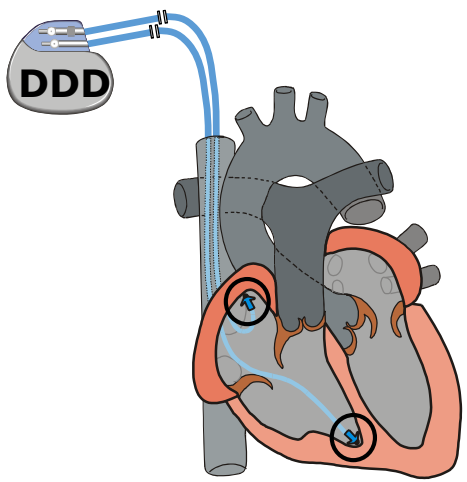




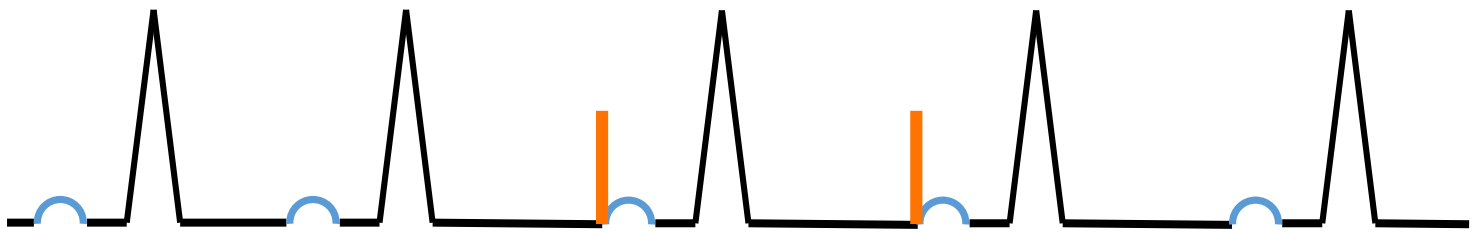
- ual: triggering (T) and inhibiting (I)

ual: atrial AND ventricular sensing

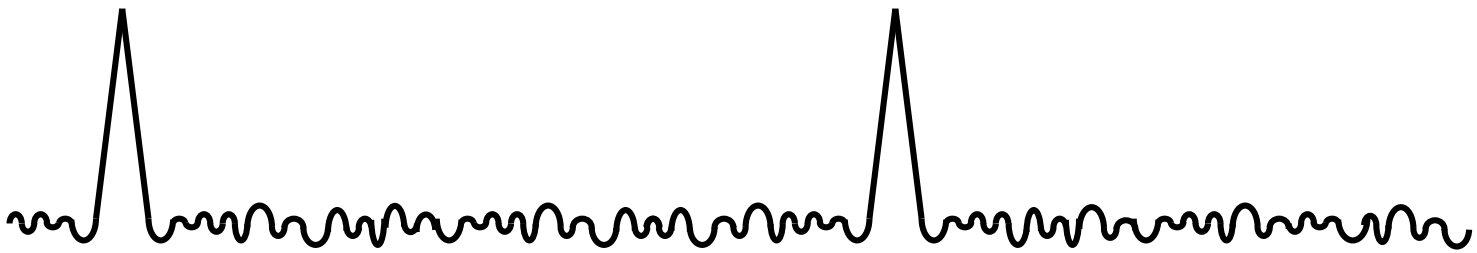
ual: atrial AND ventricular pacing



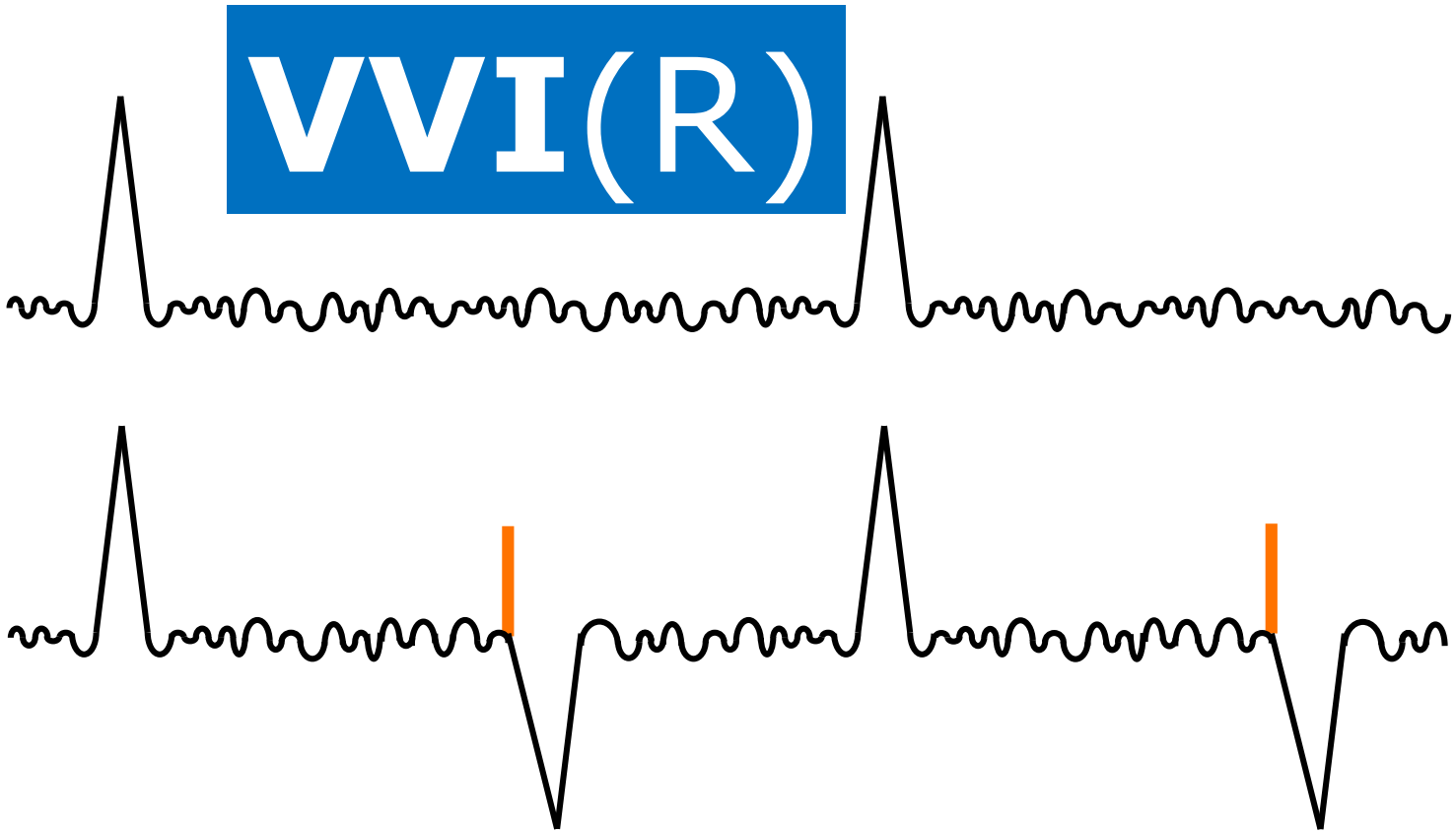
Pacemaker Mode Selection



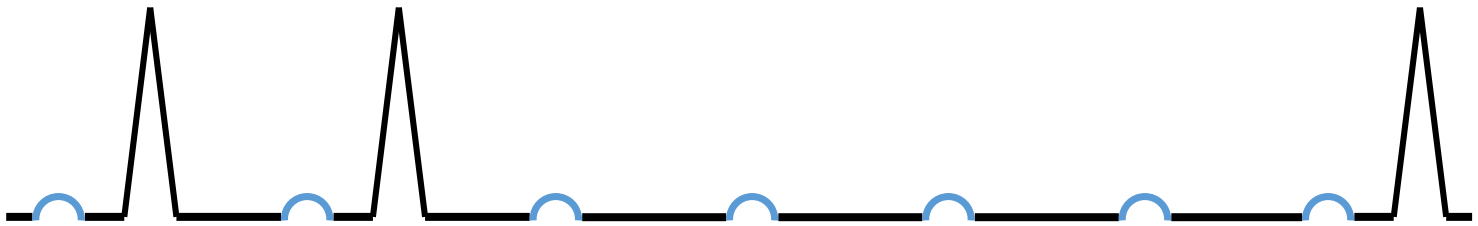
Pacemaker Mode Selection



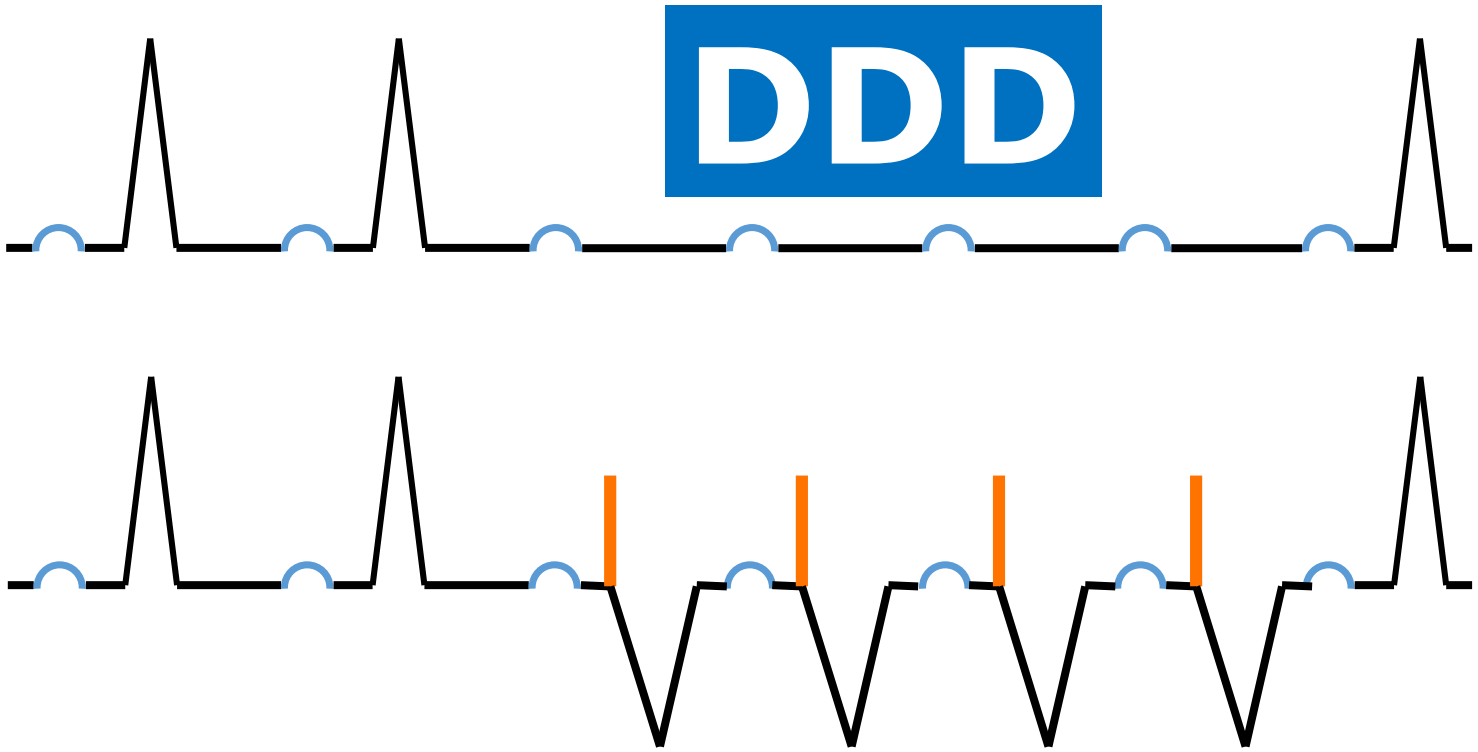
Pacemaker Mode Selection



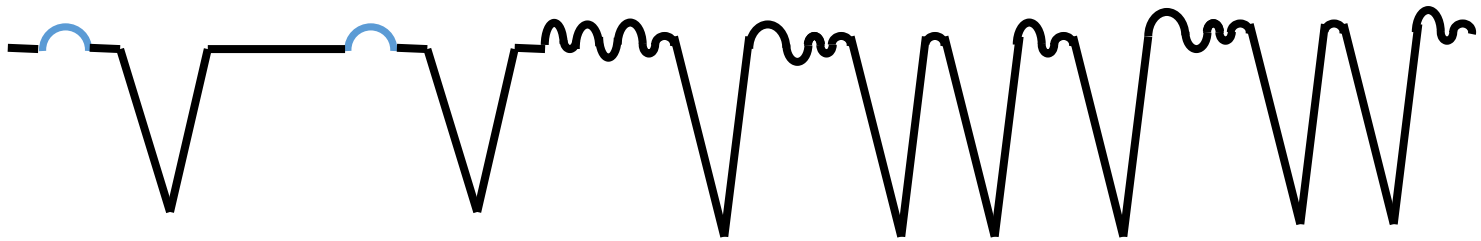
Pacemaker Mode Selection



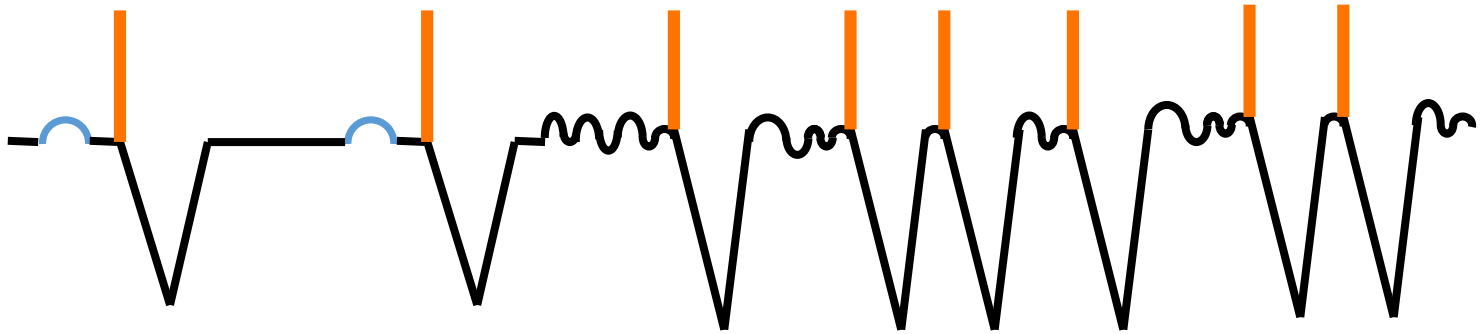
Pacemaker Mode Selection



Pacemaker Mode Selection



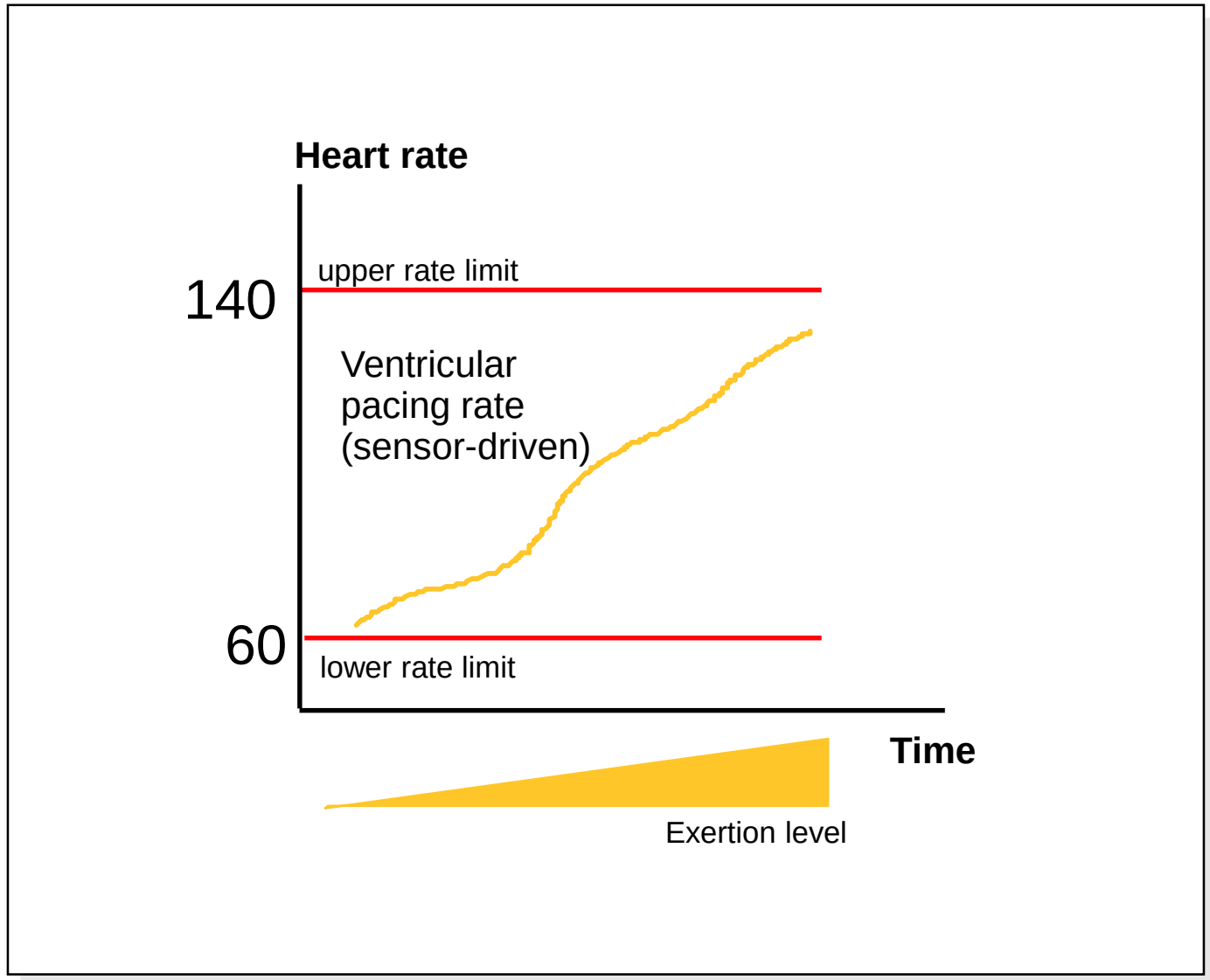
Pacemaker Mode Selection



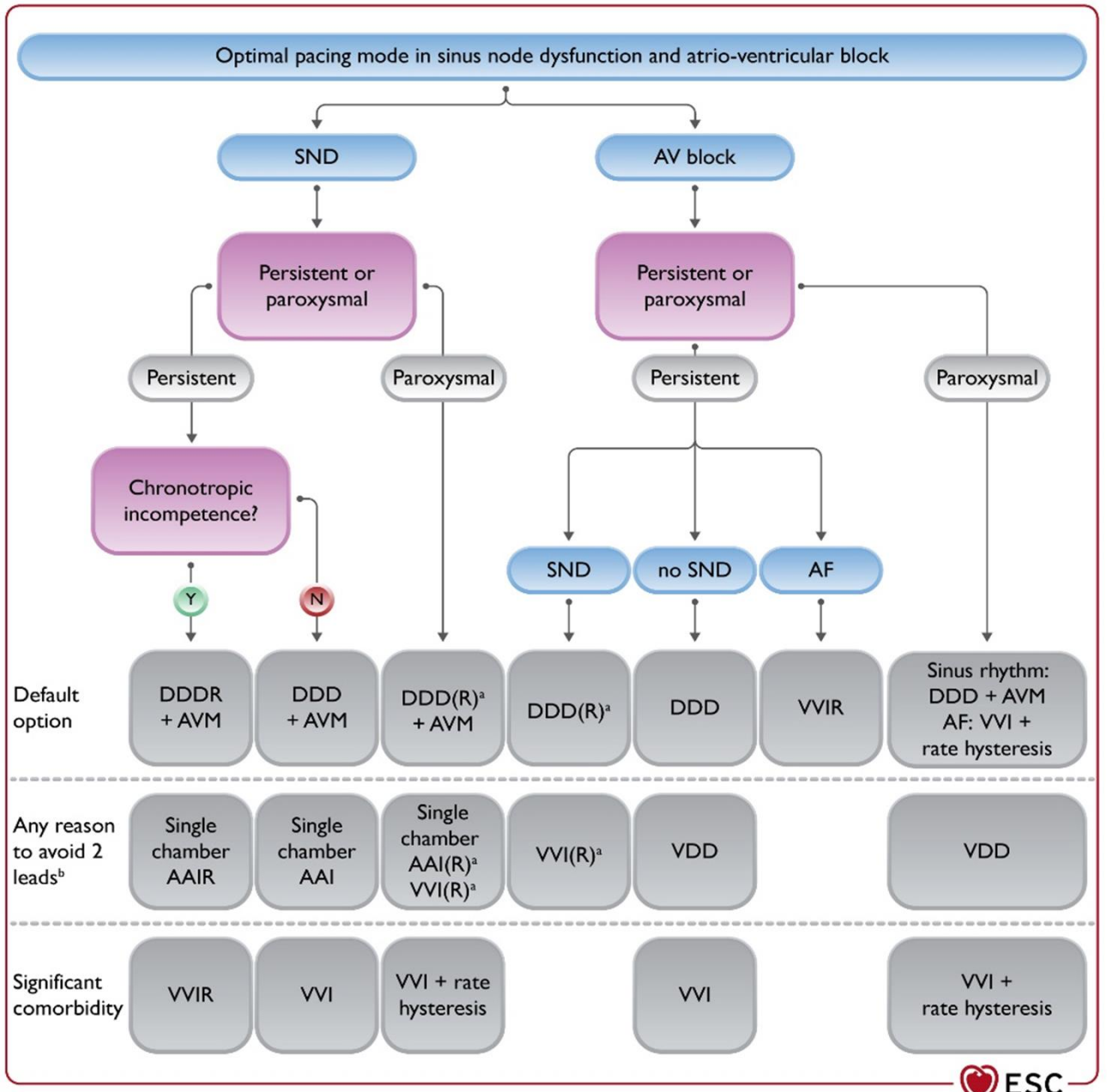
Mode-Switch (DDD/R)

- Pacemaker detects atrial fibrillation and switches into a preferable mode!

Rate response - VVIR pacing



Pacing mode and algorithm selection



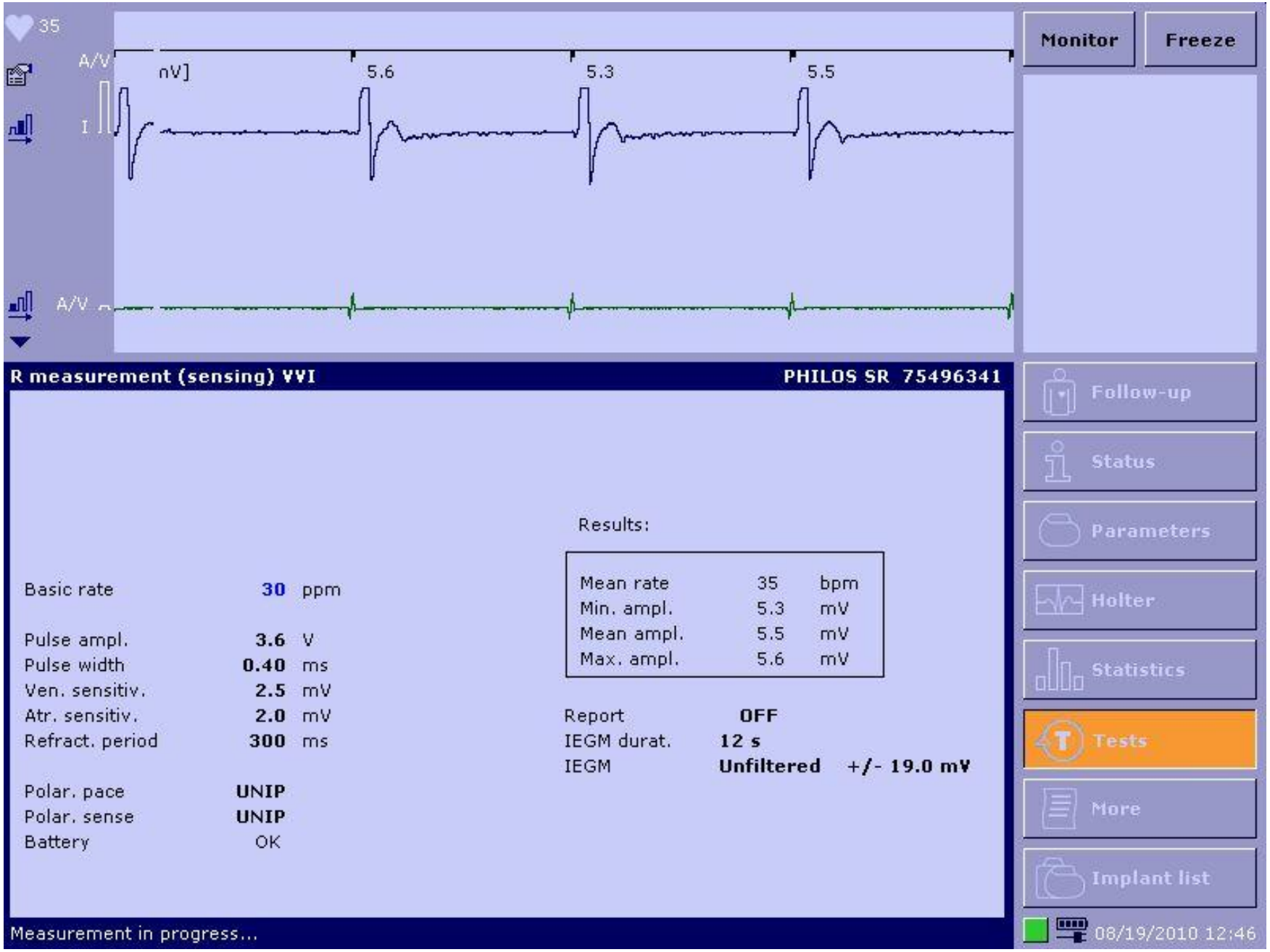
Sensing

Sensing Test

- To determine the amplitude of the intracardiac electrogram as picked up by the PM leads
  - pacing rate lower than intrinsic rate
  - measurement of cardiac signals (p-wave, R-wave)
  - adjustment of sensing threshold (sensitivity) accordingly

  →Programming sensing threshold: half the measured value

Sensing

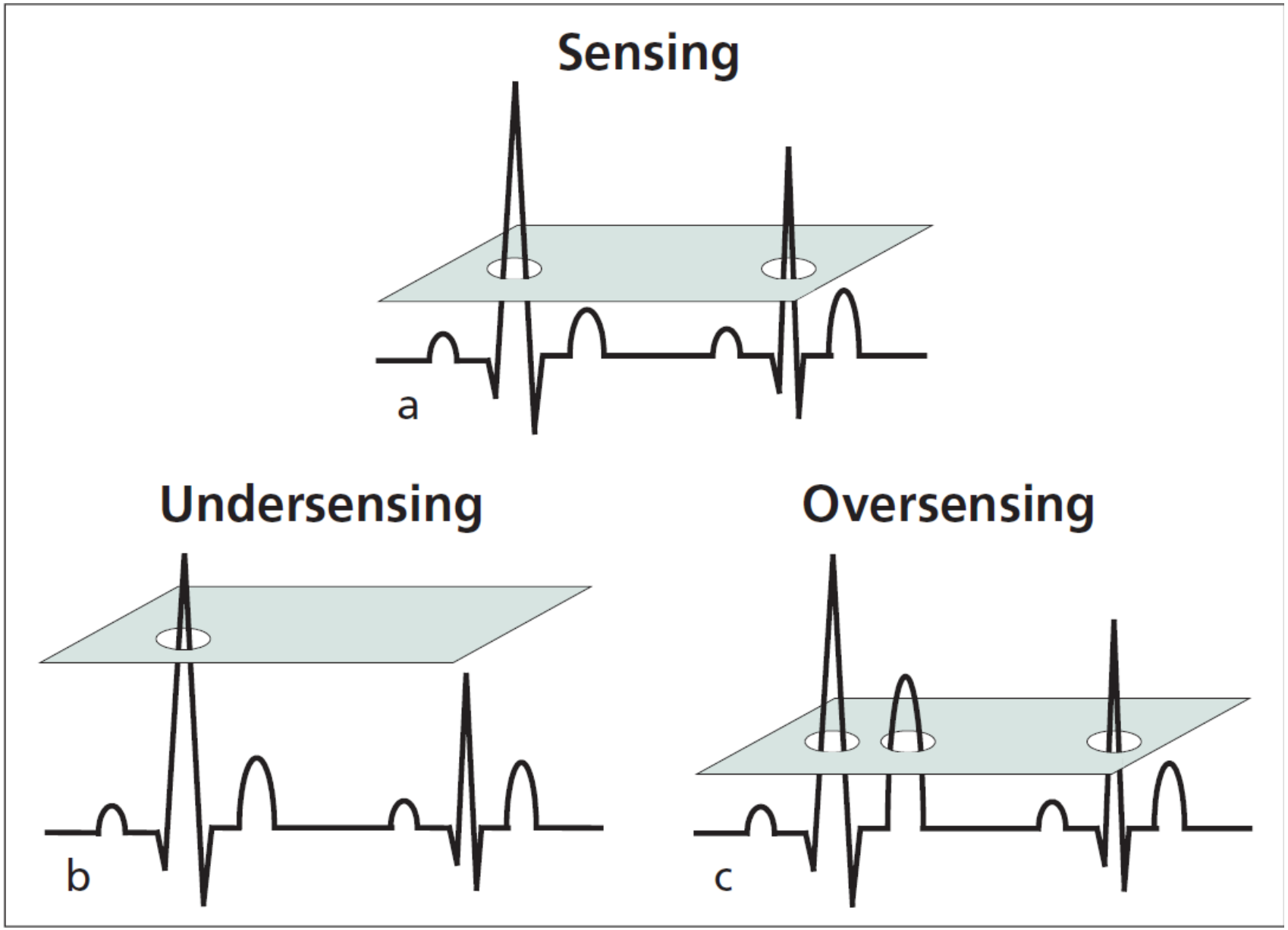

35
A/V
nV]
5.6
5.3
5.5
I
A/V
Monitor
Freeze
R measurement (sensing) VVI
PHILOS SR 75496341
Basic rate 30 ppm
Pulse ampl. 3.6 V
Pulse width 0.40 ms
Ven. sensitiv. 2.5 mV
Atr. sensitiv. 2.0 mV
Refract. period 300 ms
Polar. pace UNIP
Polar. sense UNIP
Battery OK
Results:
Mean rate 35 bpm
Min. ampl. 5.3 mV
Mean ampl. 5.5 mV
Max. ampl. 5.6 mV
Report OFF
IEGM durat. 12 s
IEGM Unfiltered +/- 19.0 mV
Follow-up
Status
Parameters
Holter
Statistics
Tests
More
Implant list
Measurement in progress...
08/19/2010 12:46

Sensing


Freeze
2362ms [1]
[2] 25ppm
Test results
[mV] 1 2
A -0.14 -0.14
V -0.54 -0.54
1
2
1+2
Adjust
25 mm/s
Grid
Marker texts
Print/Save
Window content
Print
Store
Close
Test successful.
03/10/2010 14:30

Ventricular Sensing

Sensing



Pacing Threshold

Pacing Threshold

To ensure capture of the pacing stimulus

- pacing rate above intrinsic rhythm
- stepwise reduction of pulse amplitude (V) until loss of capture
- last amplitude with capture determines pacing threshold
- adjust pacing amplitude accordingly

→Optimal programming for patient safety and device longevity
→Safety: 2x threshold pulse amplitude

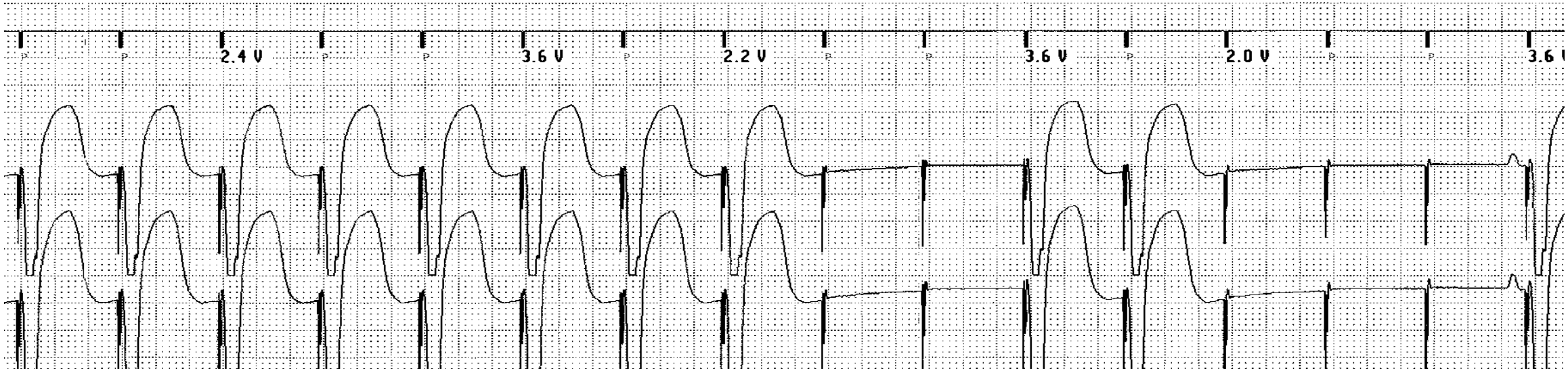
Pacing Threshold

Pacing Threshold Test

Gradual reduction of

- pulse amplitude (V) at constant pulse width

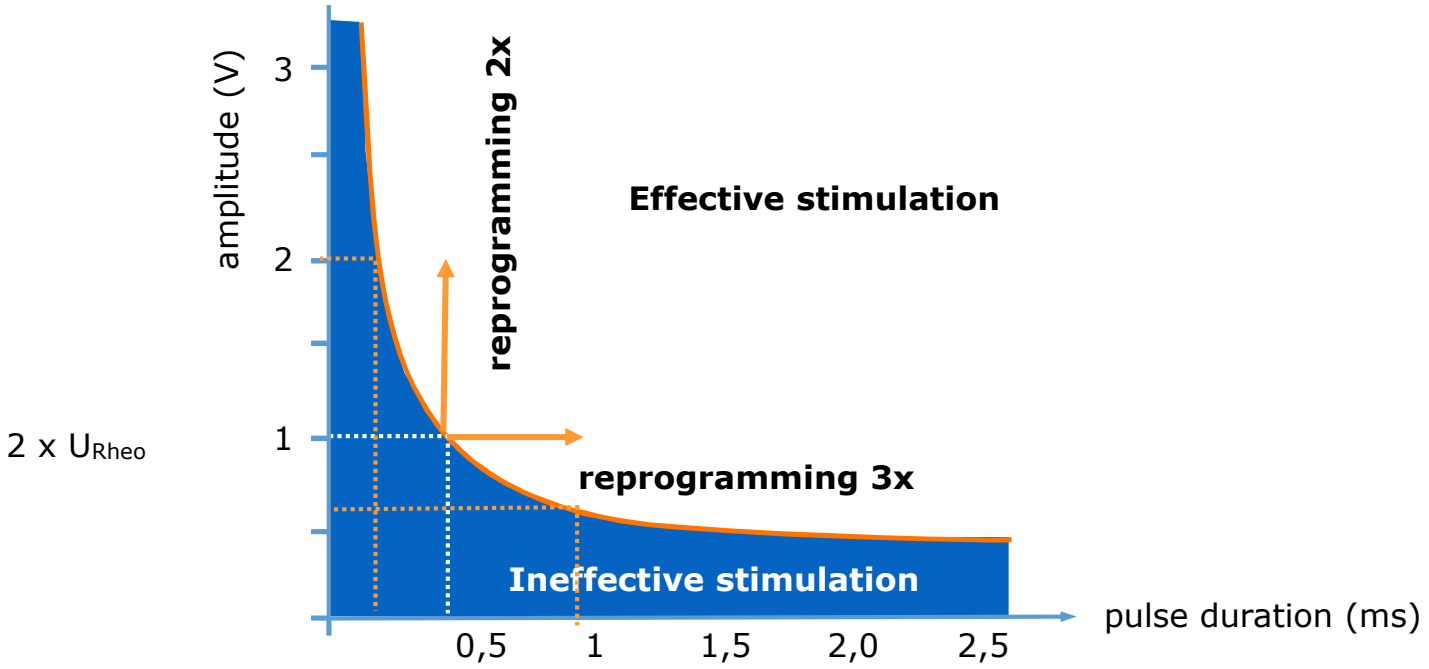
  until loss of capture occurs



Pacing Threshold

The minimal amount of energy to ascertain effective stimulation is related to ...

- pulse amplitude (V)
  safety margin (2 times threshold)



Lead Impedance

Lead impedance

Changes over times trend

- increase in lead impedance → lead fracture?
- decrease in lead impedance → insulation failure?

Further diagnostics:

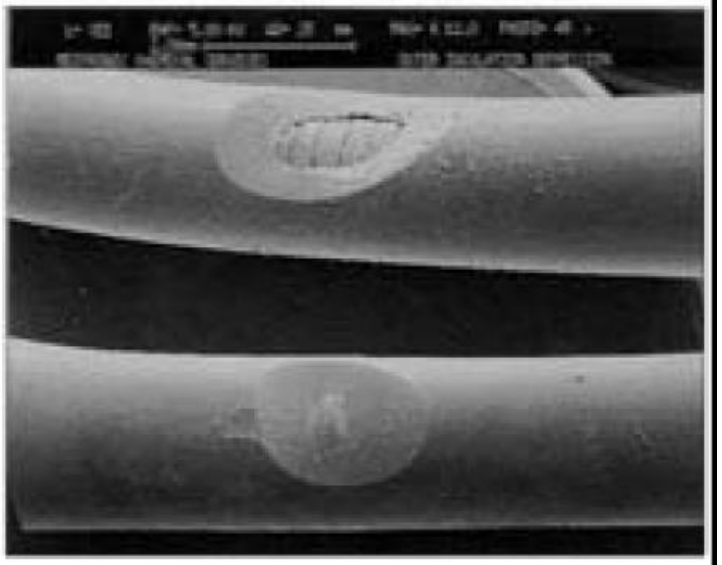
- chest x-ray
- paced ECG
- threshold

Lead failure

Insulation defect

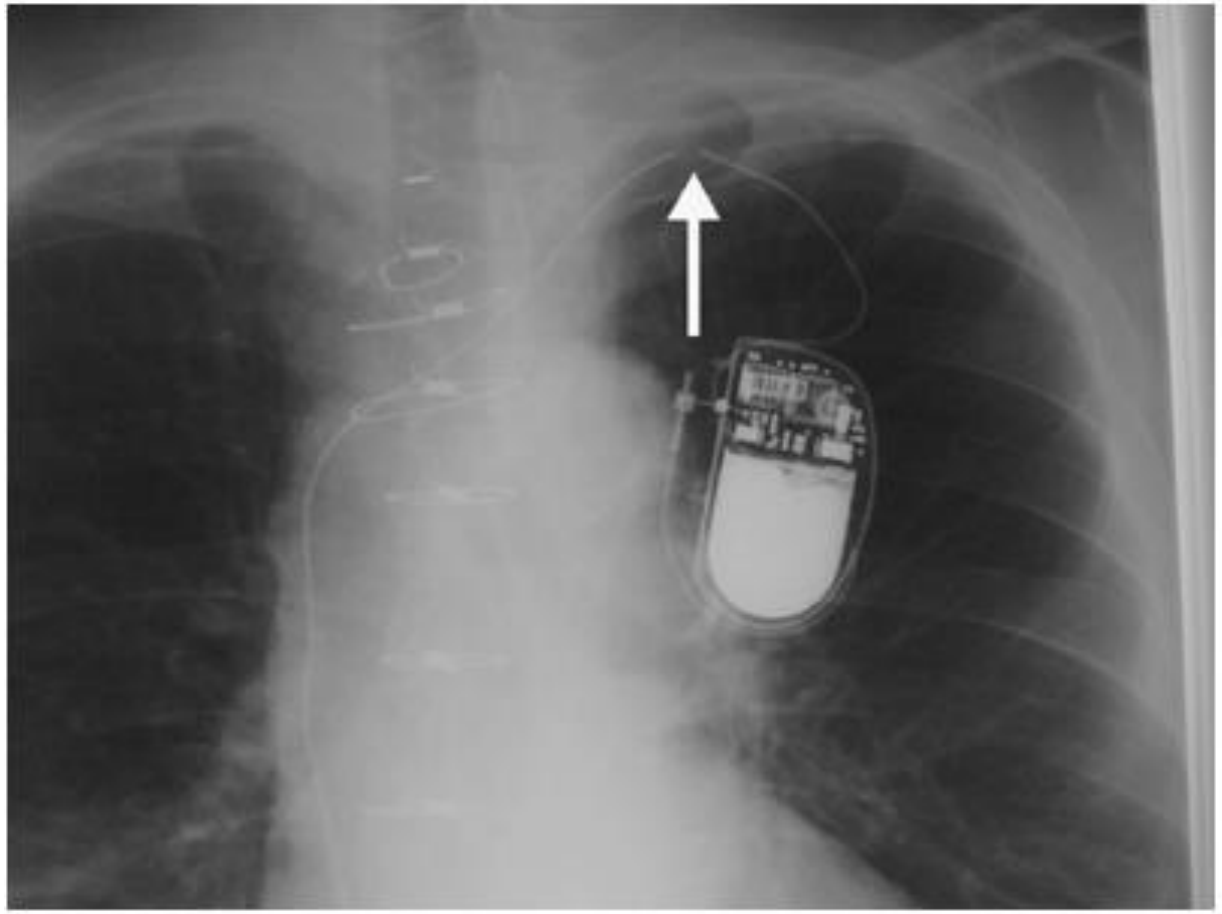
Lead fracture

Lead fracture



Abrasion defect

X-ray of Lead Fracture



Lead fracture

Case-Based Learning # 1

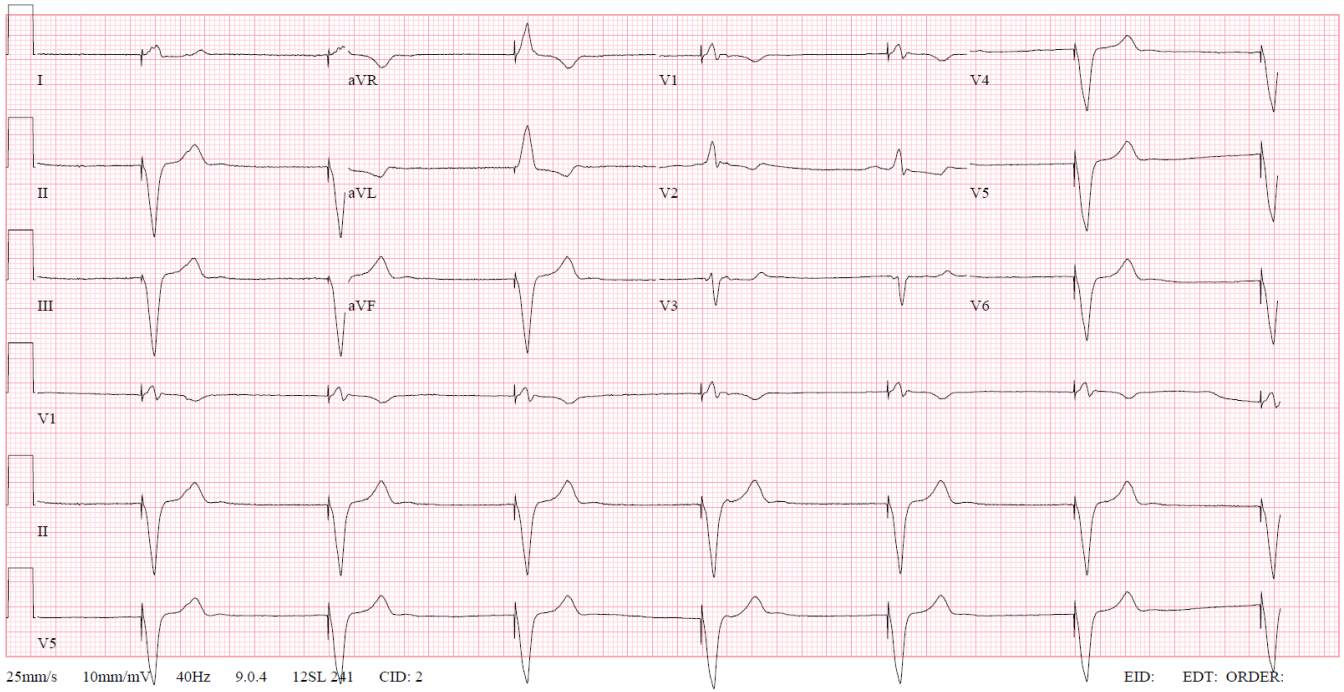
בן 76, ברקע יל"ד, DM, מחלת לב איסכמית.

עבר השתלת קוצב לב 4 ימים טרם פנייתו.

Dual Chamber, DDD

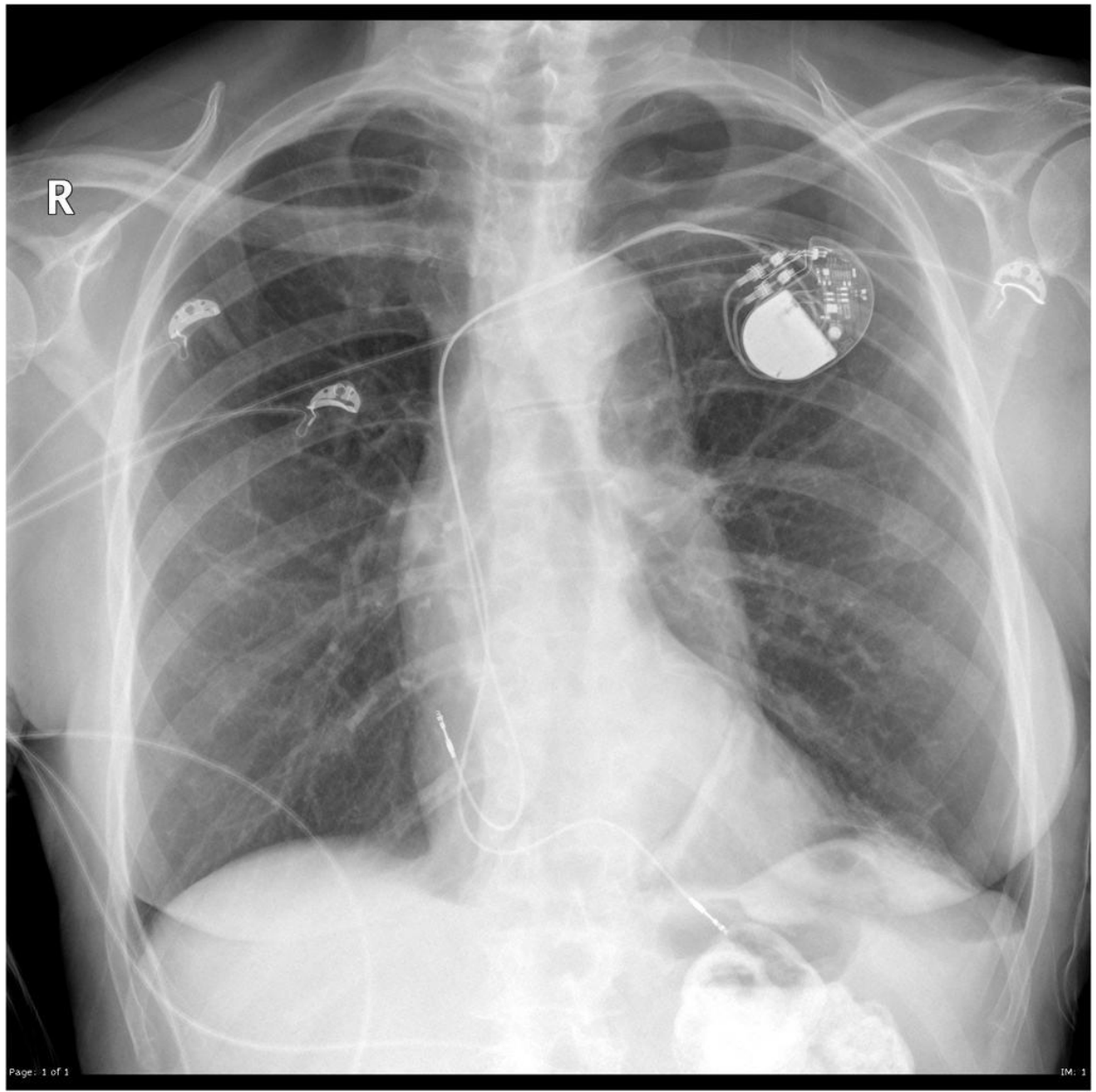
פונה למיון עקב קוצר נשימה

בבדיקת אק"ג:

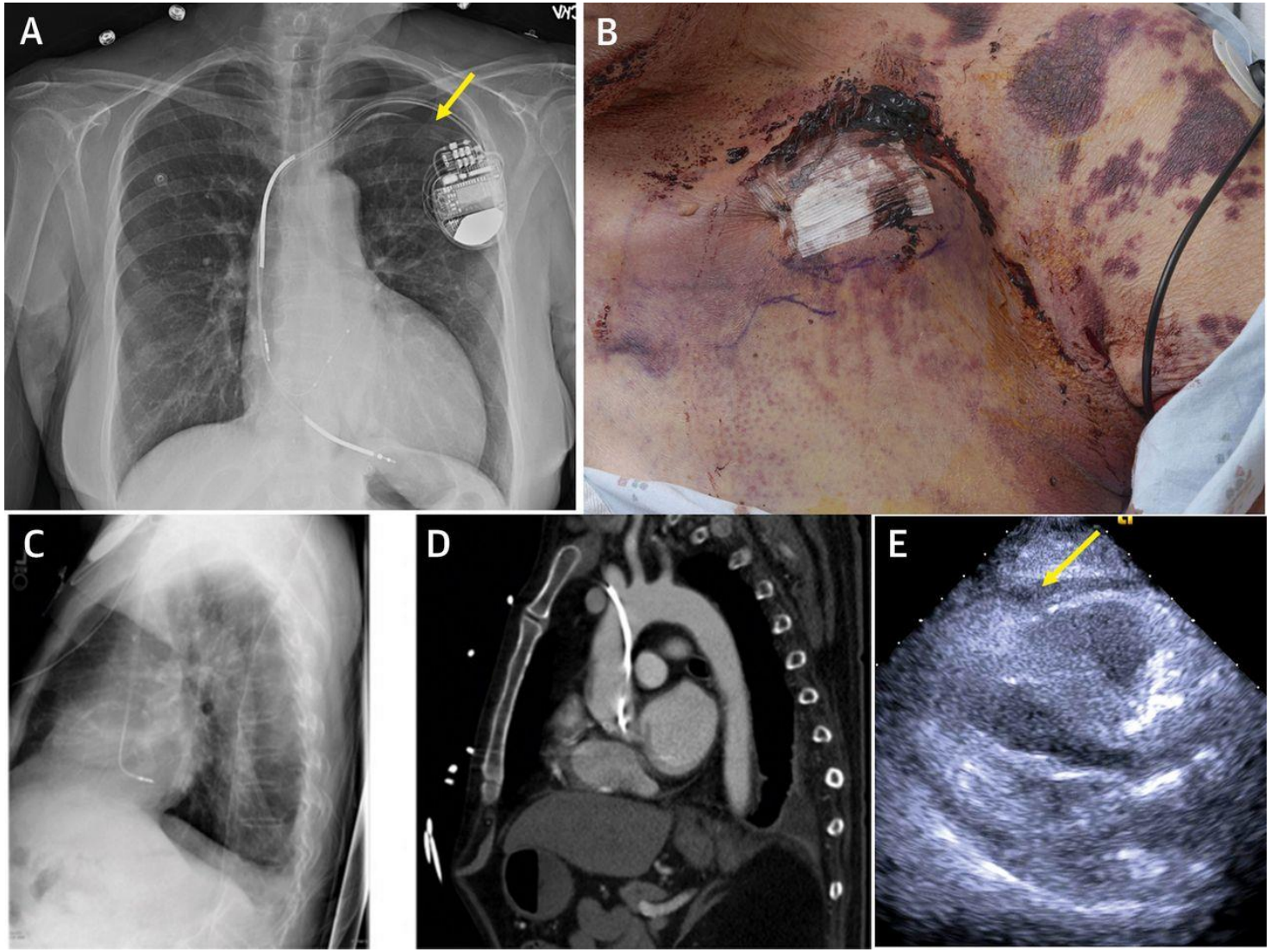


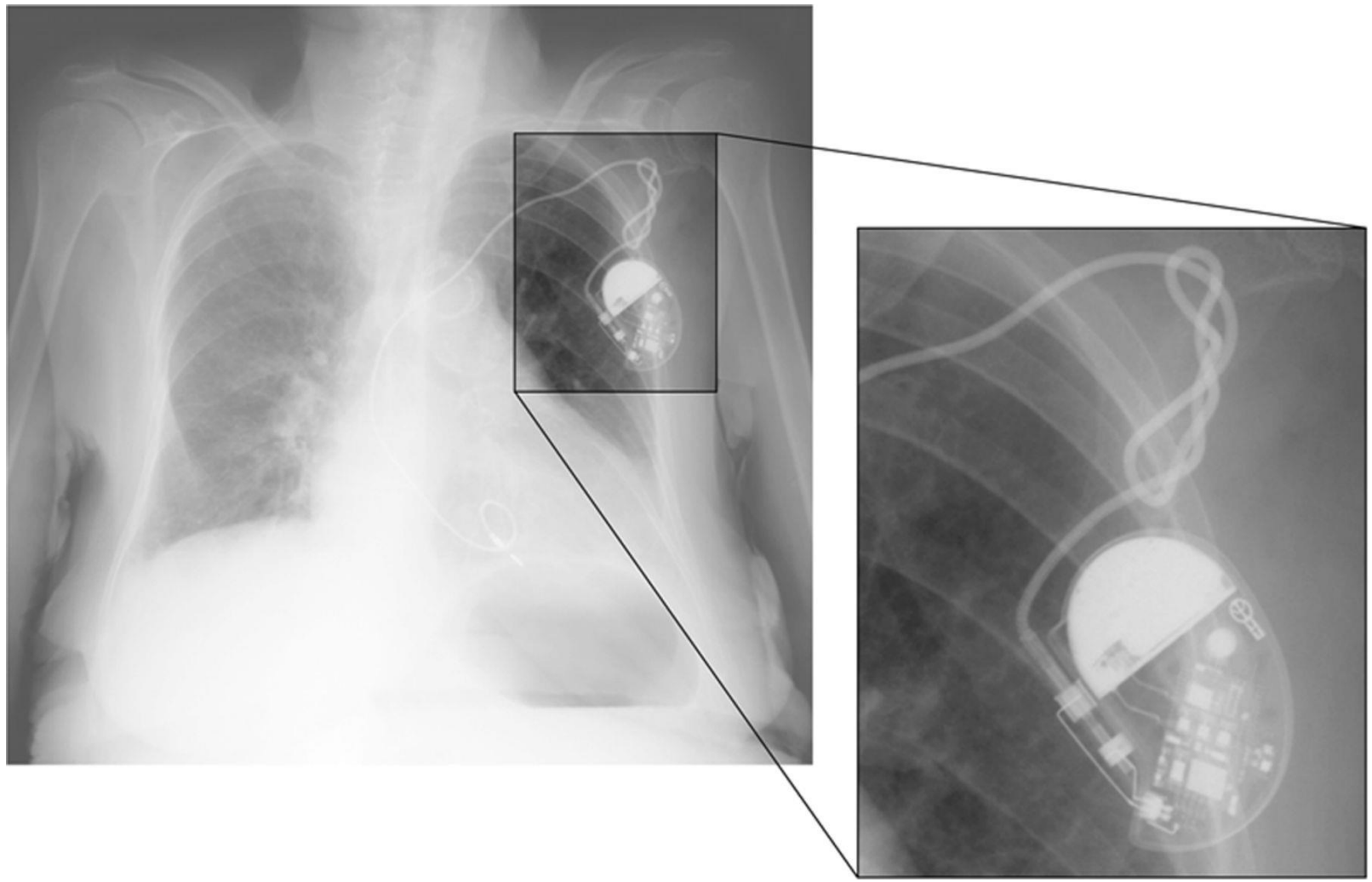
מה השלב הבא?

Chest X ray

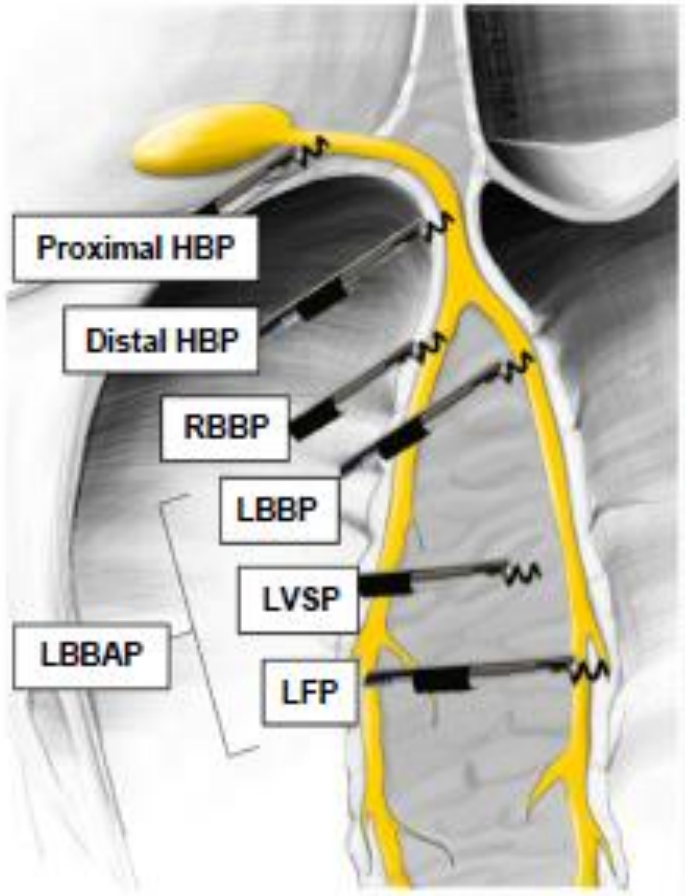


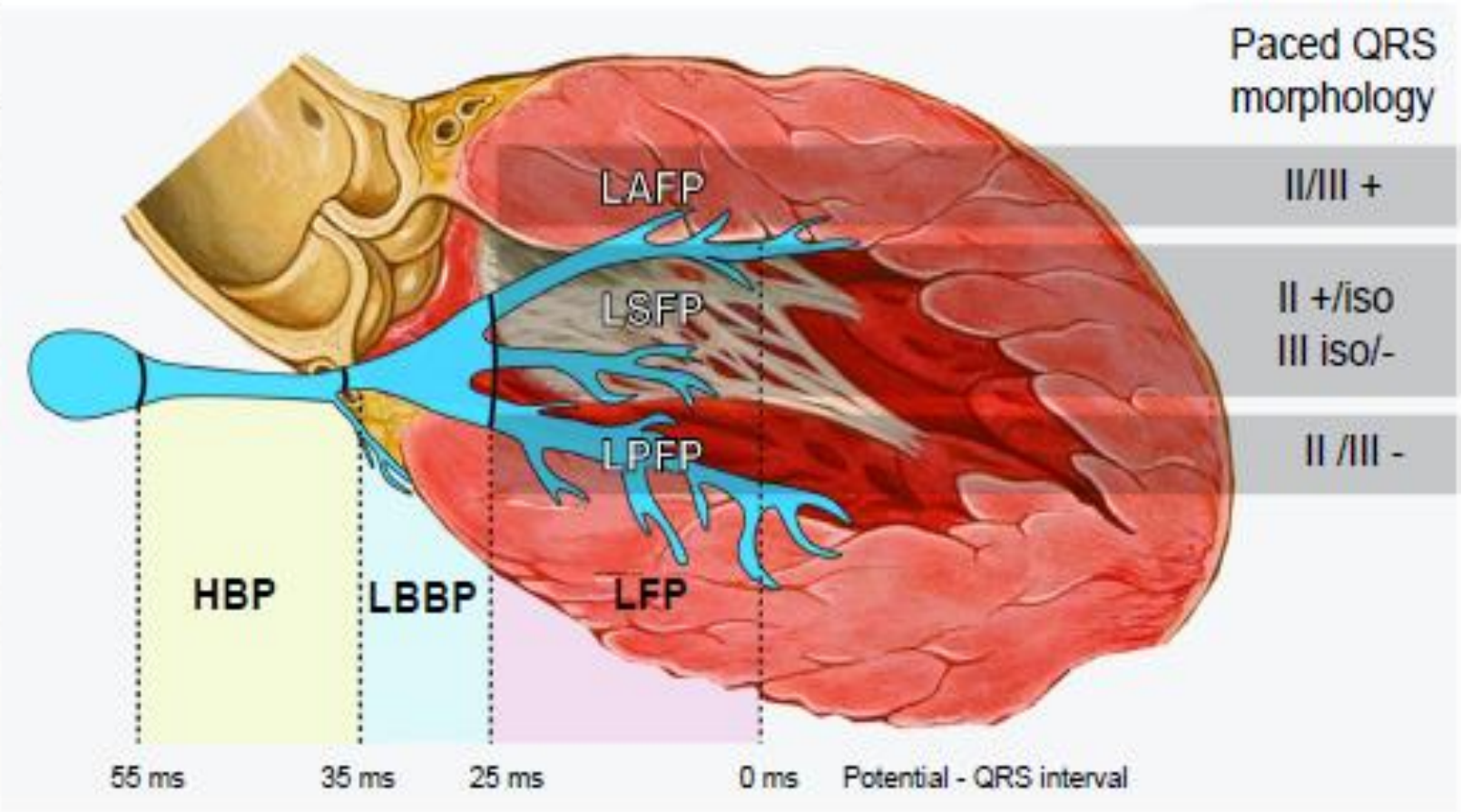
Complications Associated With Pacemaker Implantation



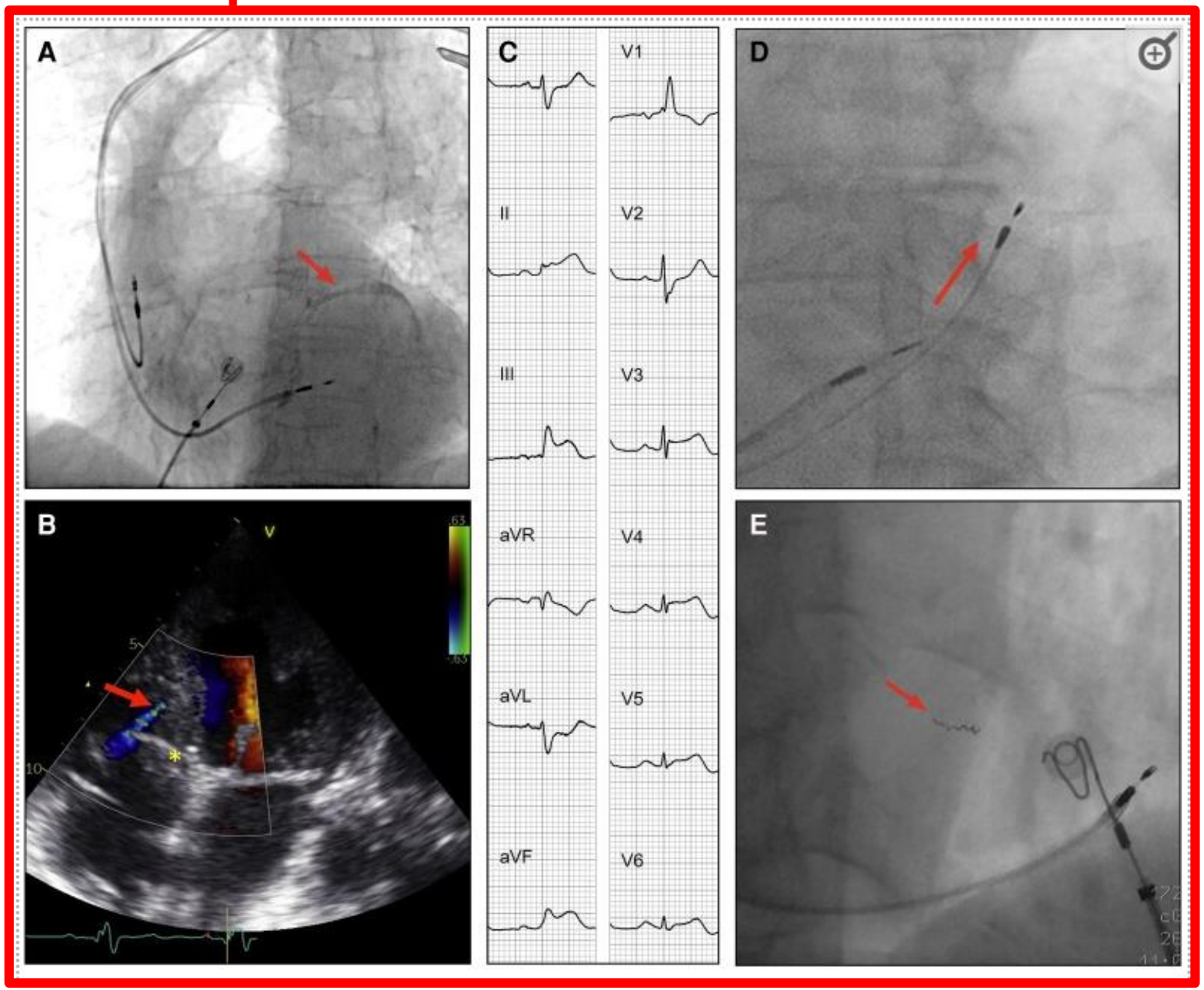


Conduction system pacing (CSP)





Complications Associated With CSP

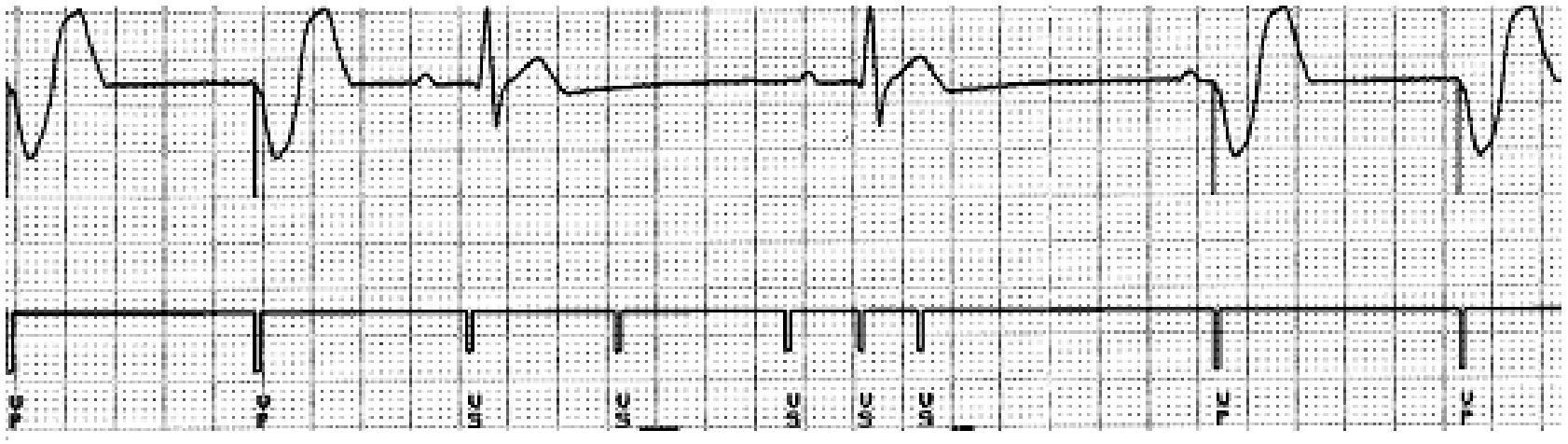


Case-Based Learning # 2

בן 76, ברקע יל"ד, DM, מחלת לב איסכמית.
מושתל קוצב לב על רקע **CAVB**.
Dual Chamber, DDD, **60-130**
פונה למיון עקב חולשה לסירוגין ואירוע של סינקופה
בבדיקת אק"ג:

מה השלב הבא?

Knowledge Checkpoint

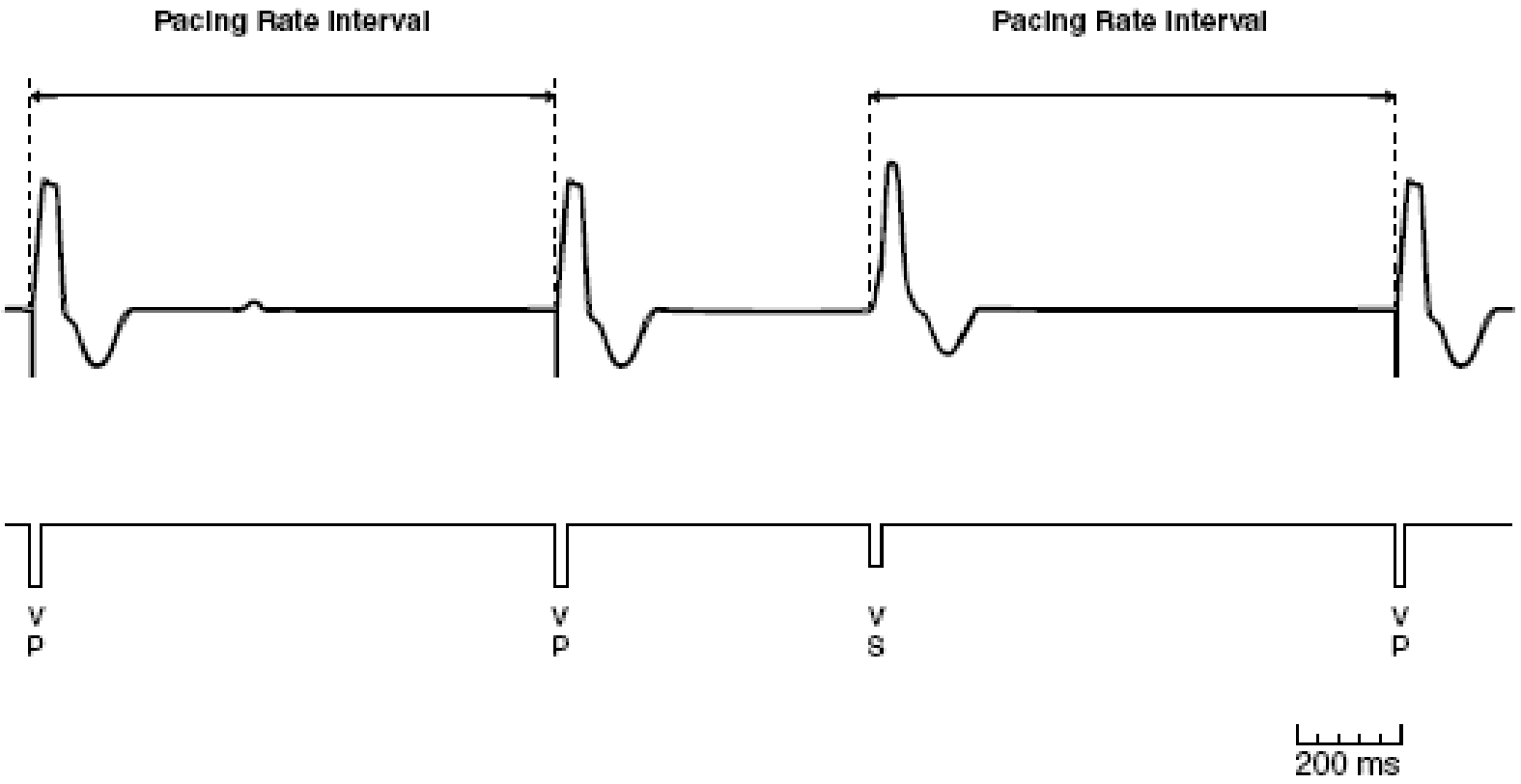


A. Undersensing
B. Oversensing
C. Loss of Capture
D. Loss of Output
E. Normal

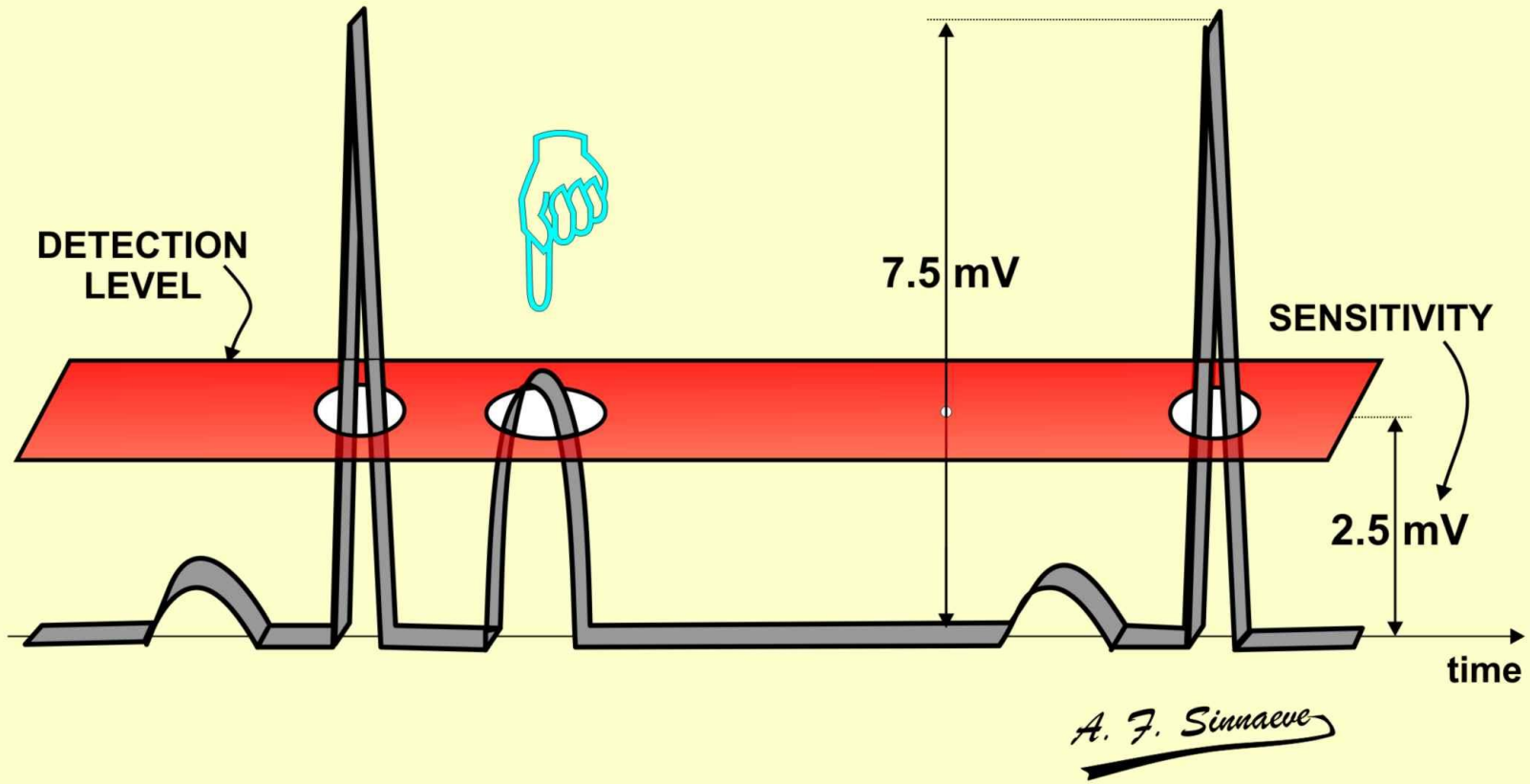
Timing intervals

Lower Rate

The lowest rate the pacemaker will pace the heart in the absence of intrinsic events.

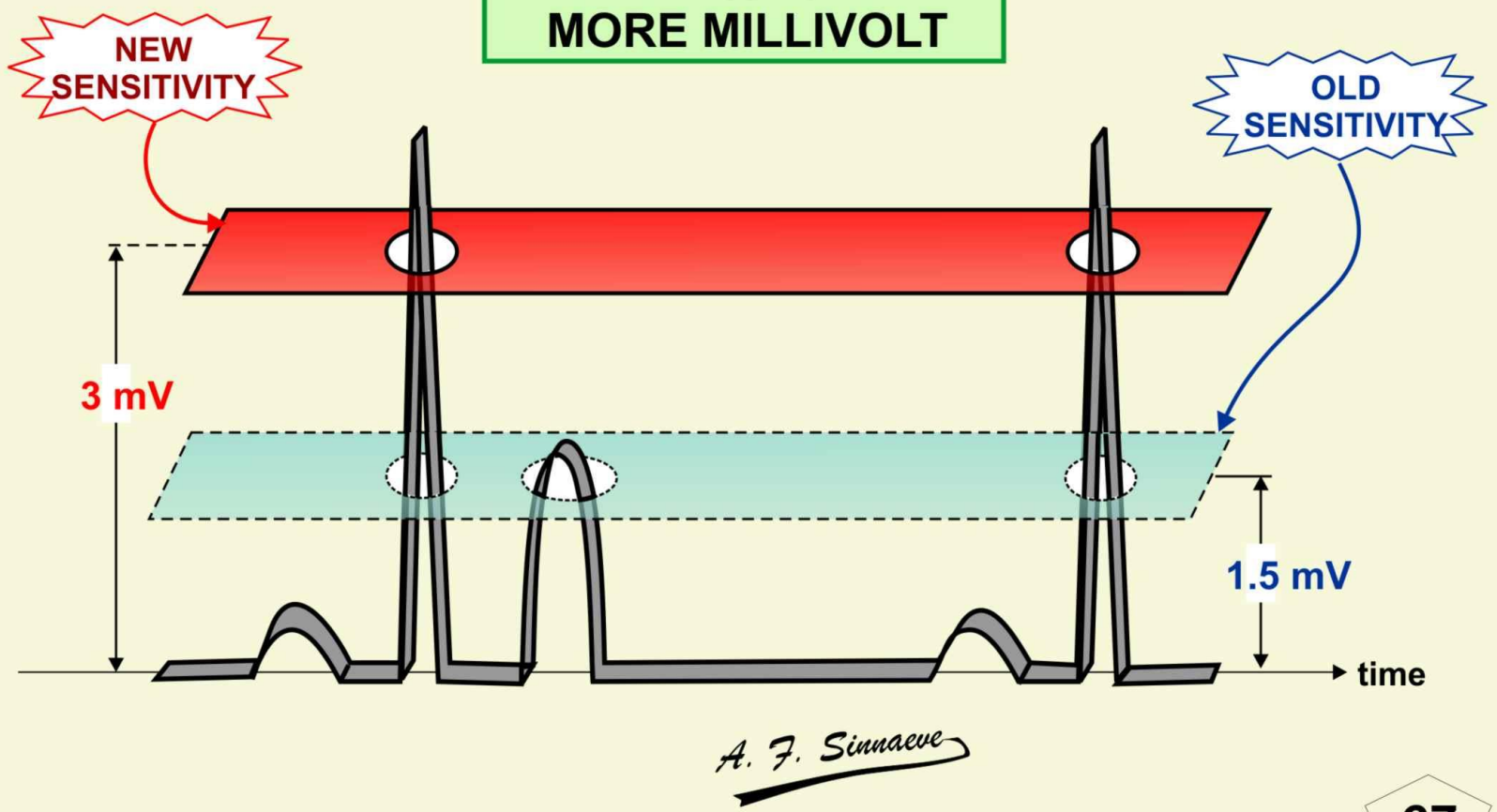


OVERSENSING



PROGRAMMING LOWER SENSITIVITY

LOWER SENSITIVITY
means
MORE MILLIVOLT



Case-Based Learning # 3

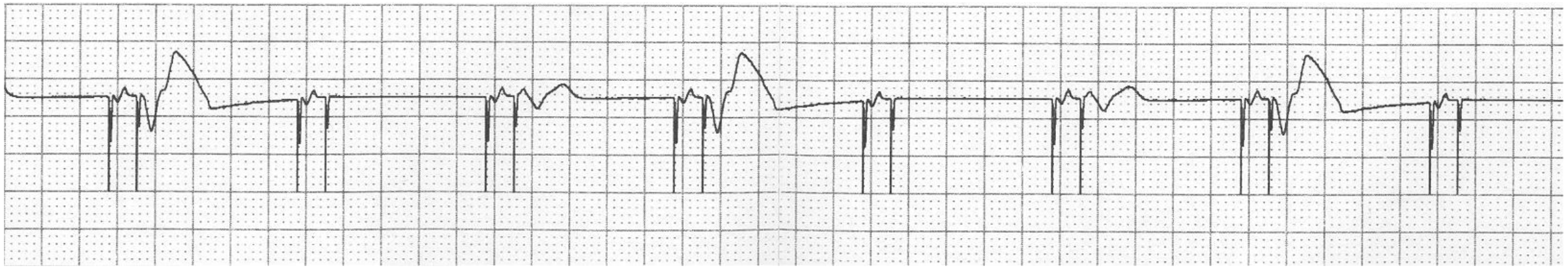
בן 76, ברקע יל"ד, DM, מחלת לב איסכמית.

מושתל קוצב לב על רקע **CAVB**.

Dual Chamber, DDD, **60-130**

פונה למיון עקב חולשה לסירוגין ואירוע של סינקופה

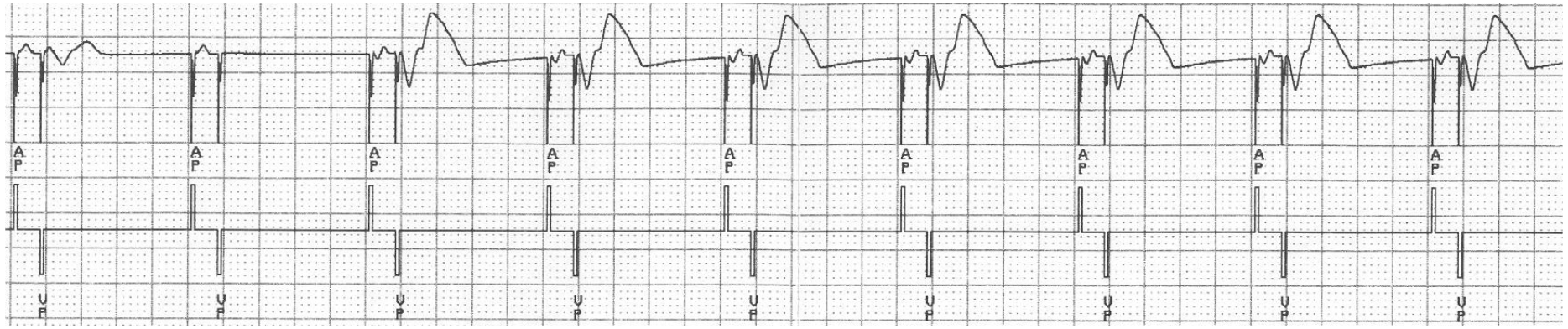
בבדיקת אק"ג:



A. Undersensing
B. Oversensing
C. Loss of Capture
D. Loss of Output
E. Normal

Case 3

Loss of Capture



Perform a threshold test

Loss of Capture

Causes

- If there were changes in medications, or an MI, or the patient had renal failure, etc. ?
- If chronic lead impedance is high?
- If lead impedance is ok?
- If acute lead impedance is high?

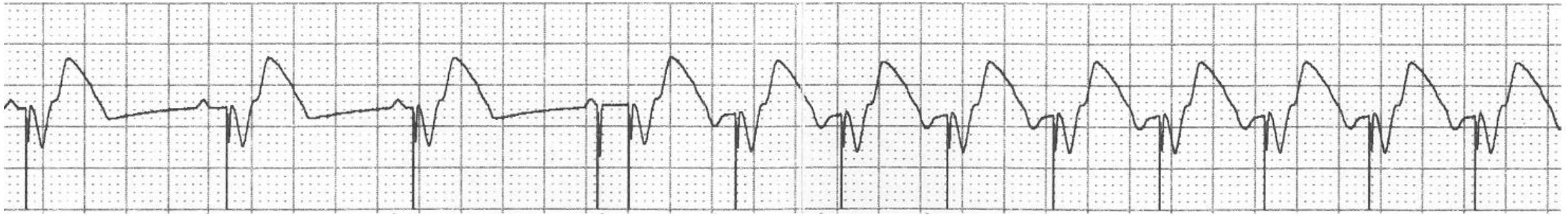
Considerations

- Program a higher output for an increased safety margin, as conditions are changing
- Suspect fracture. Could try unipolar temporarily, but this will likely require a lead replacement.
- Suspect dislodgement. Can try a higher output, but permanent fix will likely be repositioning.
- Likely a loose set screw. Need to re-open the pocket and retighten it.

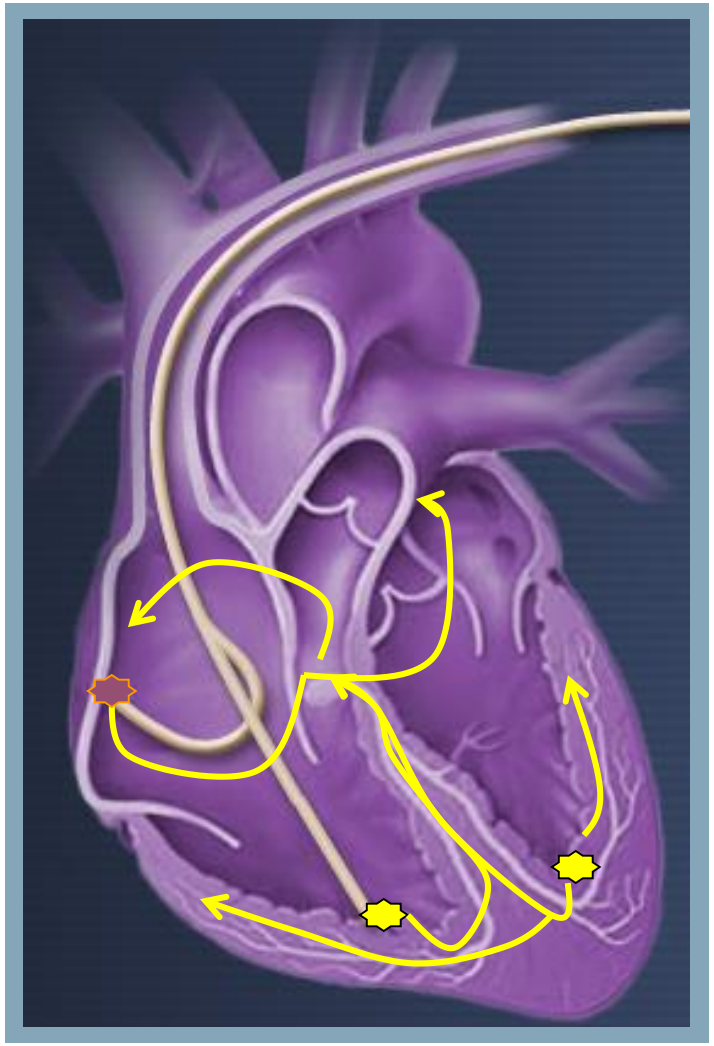
Case-Based Learning # 4

בן 76, ברקע יל"ד, DM, מחלת לב איסכמית.
מושתל קוצב לב על רקע **CAVB**.
פונה למיון עקב **דפיקות לב ותחושת פרה סינקופה**

- Programming information:
  - DDD 60–120 bpm
  - PVARP: 310 ms

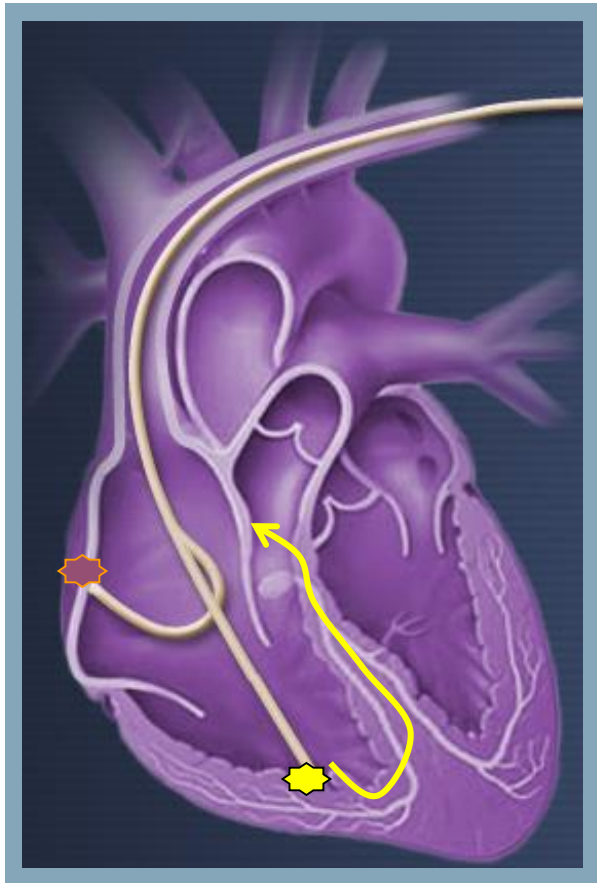


PMT Mechanism



- A ventricular event occurs
  - Paced or sensed – we show a PVC here
- Conducts retrograde through the AV node (typically)
- And results in an atrial sense
  - Which starts an SAV, and results in a ventricular pace
- This is again conducted retrograde, and the sequence starts again

PMT Requirements

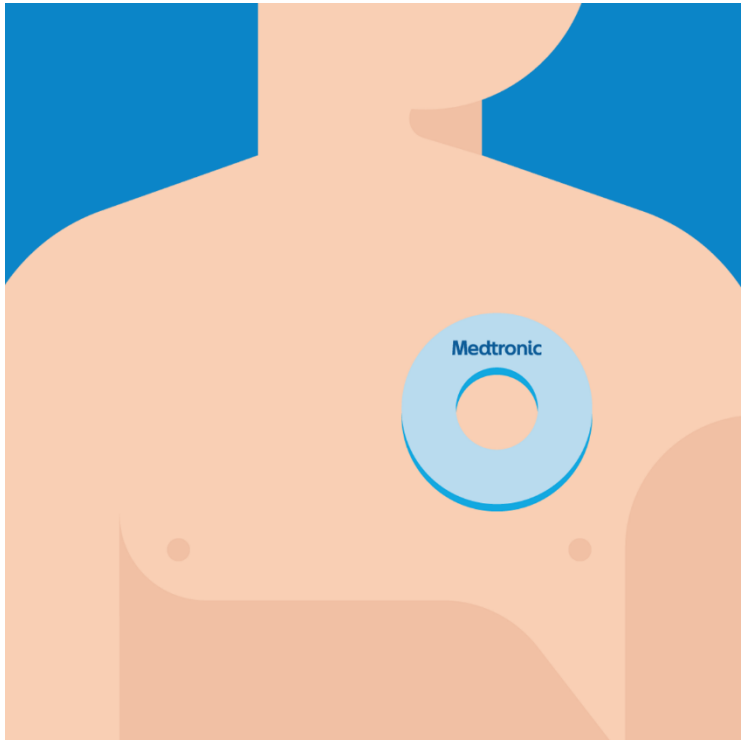


- For the sequence to be maintained:
  - The AV node and atrium must be able to conduct retrograde, i.e., not be depolarized
  - The pacemaker must be able to sense this retrograde depolarization, i.e., not be in a refractory period
  - This timing ‘ballet’ must persist

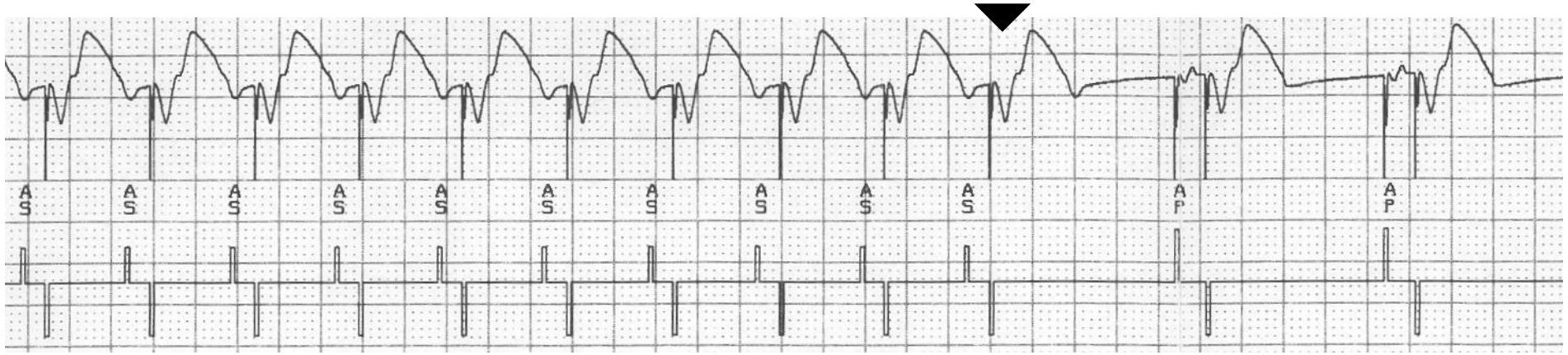
Knowledge Checkpoint

What mode does a dual chamber pacemaker change to when a magnet is applied?

A. VVI
B. DDI
C. ODO
D. DOO



- Place a magnet on the device



- DOO suspends sensing and the tachycardia terminates
- No evidence of atrial tachycardia during the asynchronous operation

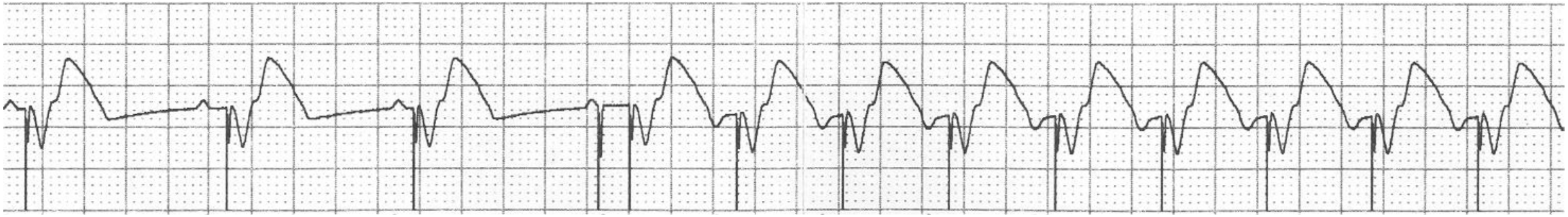
PMT

Pacemaker Mediated Tachycardia

- Occurrence minimized with introduction of Auto-PVARP

Which provide longer pacemaker atrial refractory periods at lower rates

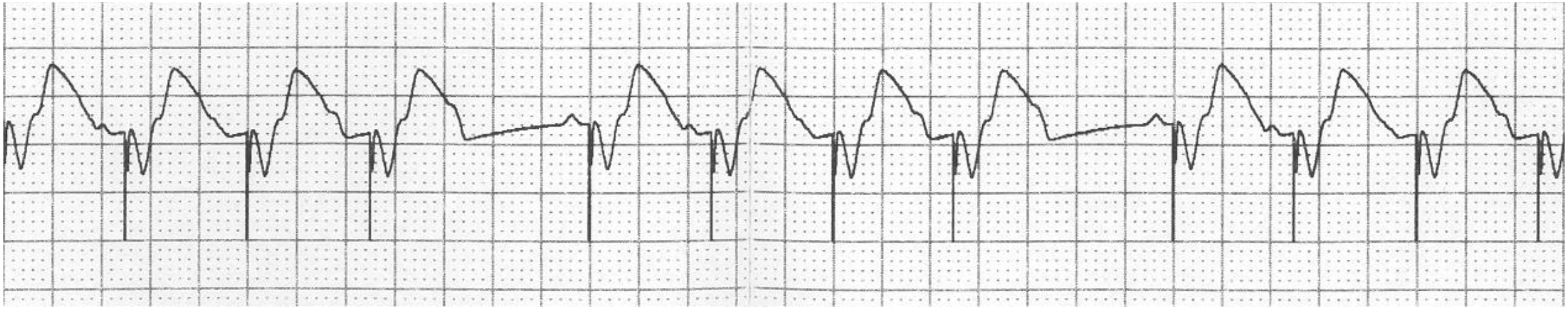
- PMT is similar to a re-entrant tachycardia
  - Except the pacemaker forms part of the re-entrant circuit



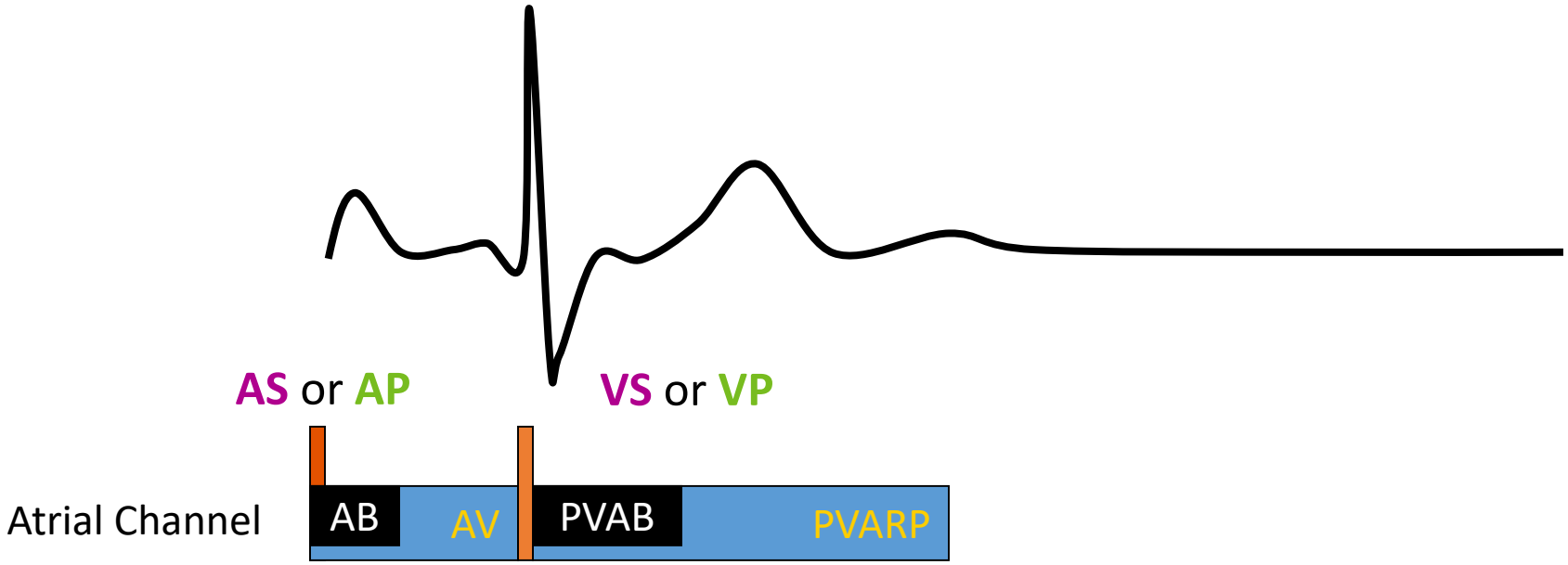
Case-Based Learning # 5

בן 76, ברקע יל"ד, DM, מחלת לב איסכמית.
מושתל קוצב לב על רקע **CAVB**.
פונה למיון עקב **דפיקות לב ותחושת פרה סינקופה**

- Programming information
  - DDD 60–120 bpm
  - PAV: 150 ms
  - SAV: 120 ms
  - PVARP: 380 ms



Dual Chamber Timing Intervals

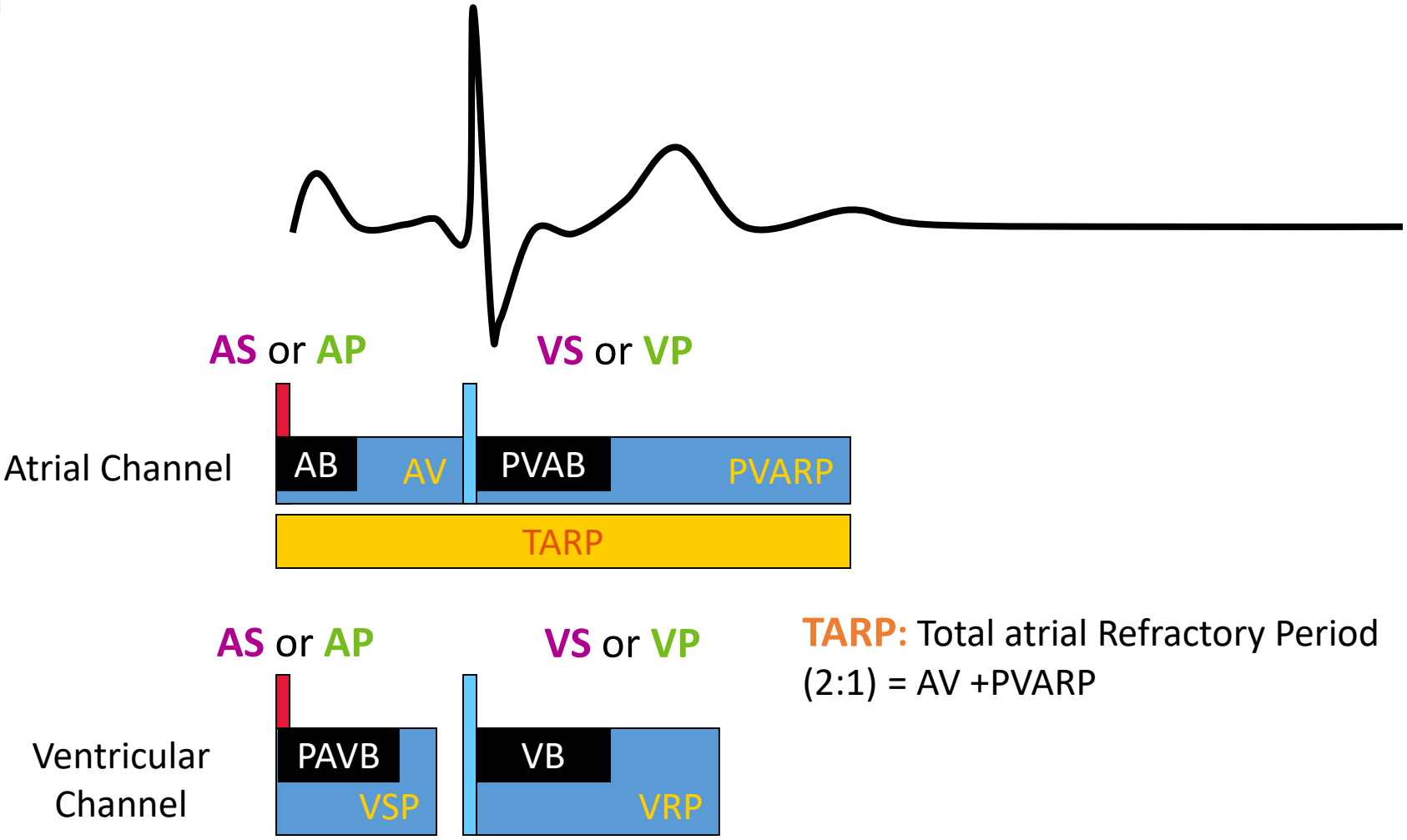


VB: Ventricular Blanking

VRP: Ventricular Refractory Period

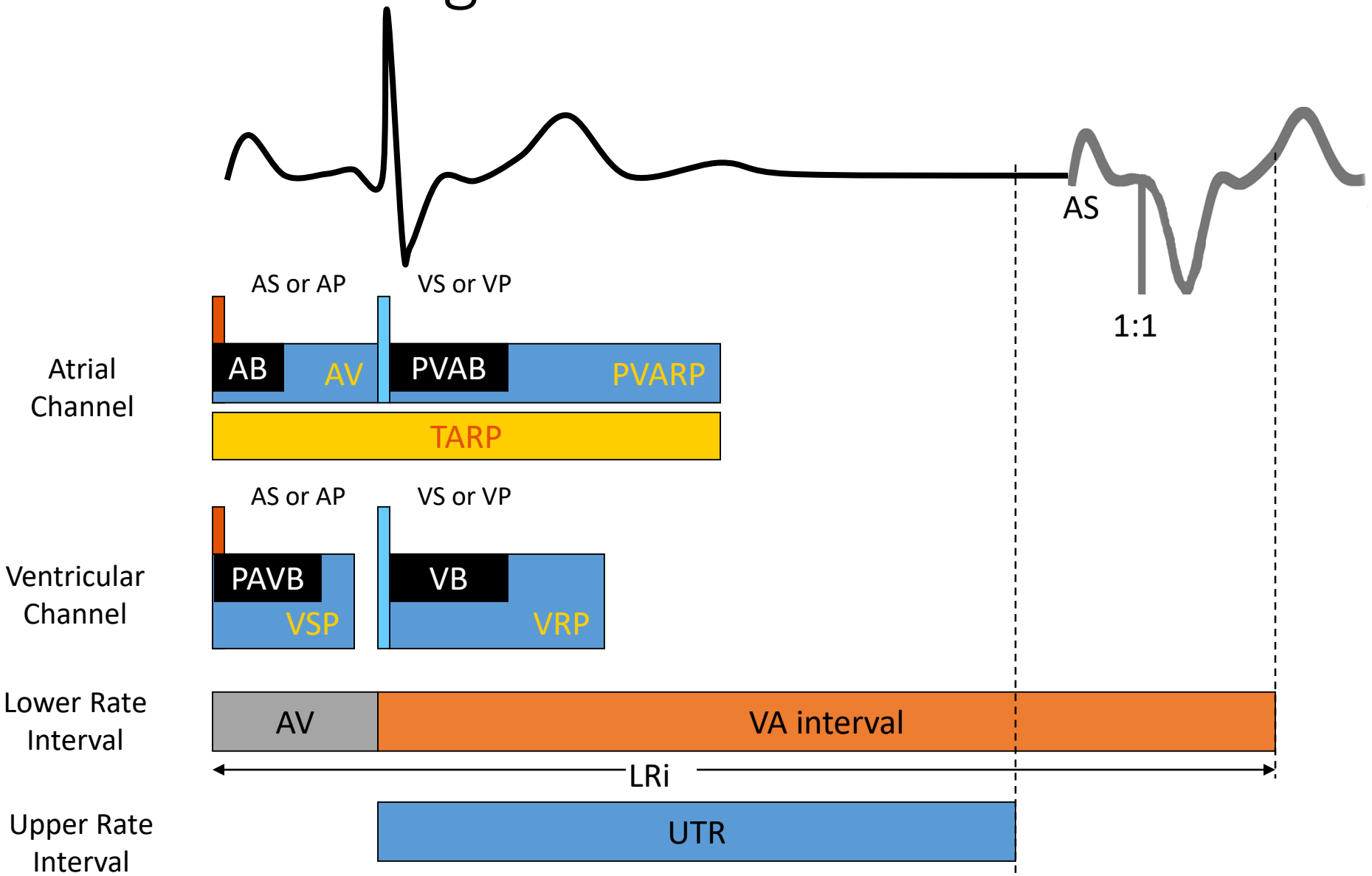
*Note: VSP window only occurs after AP

TARP

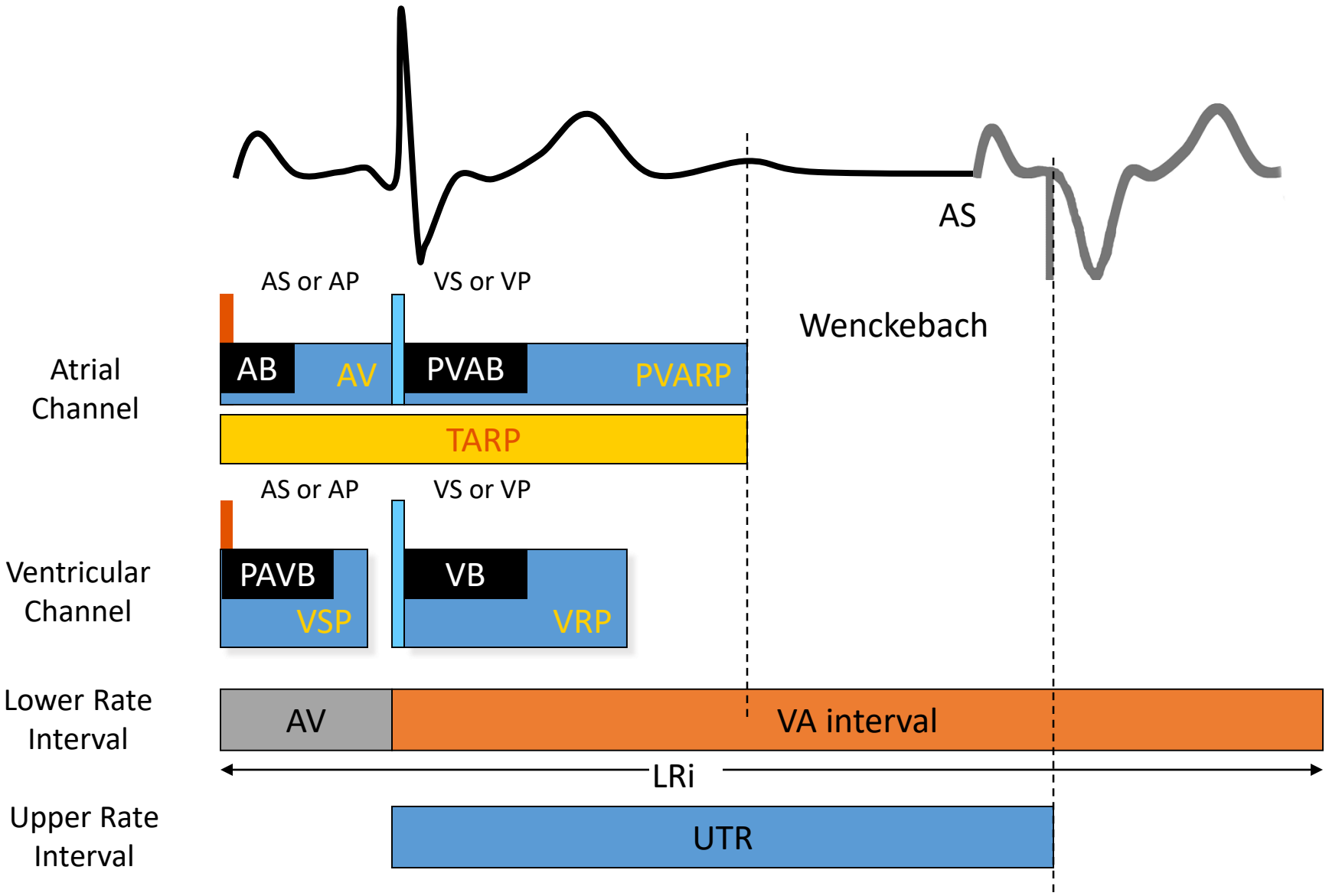


TARP: Total atrial Refractory Period (2:1) = AV +PVARP

1:1 Upper Rate Timing Intervals

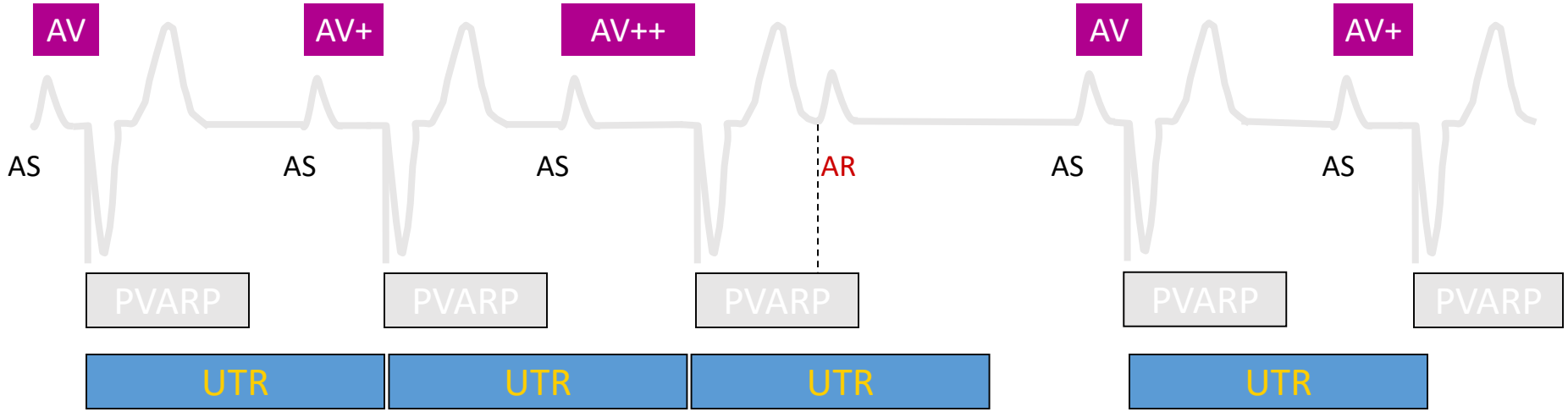


Wenckebach Upper Rate Timing



4:3 Wenckebach Upper Rate Timing

EXAMPLE

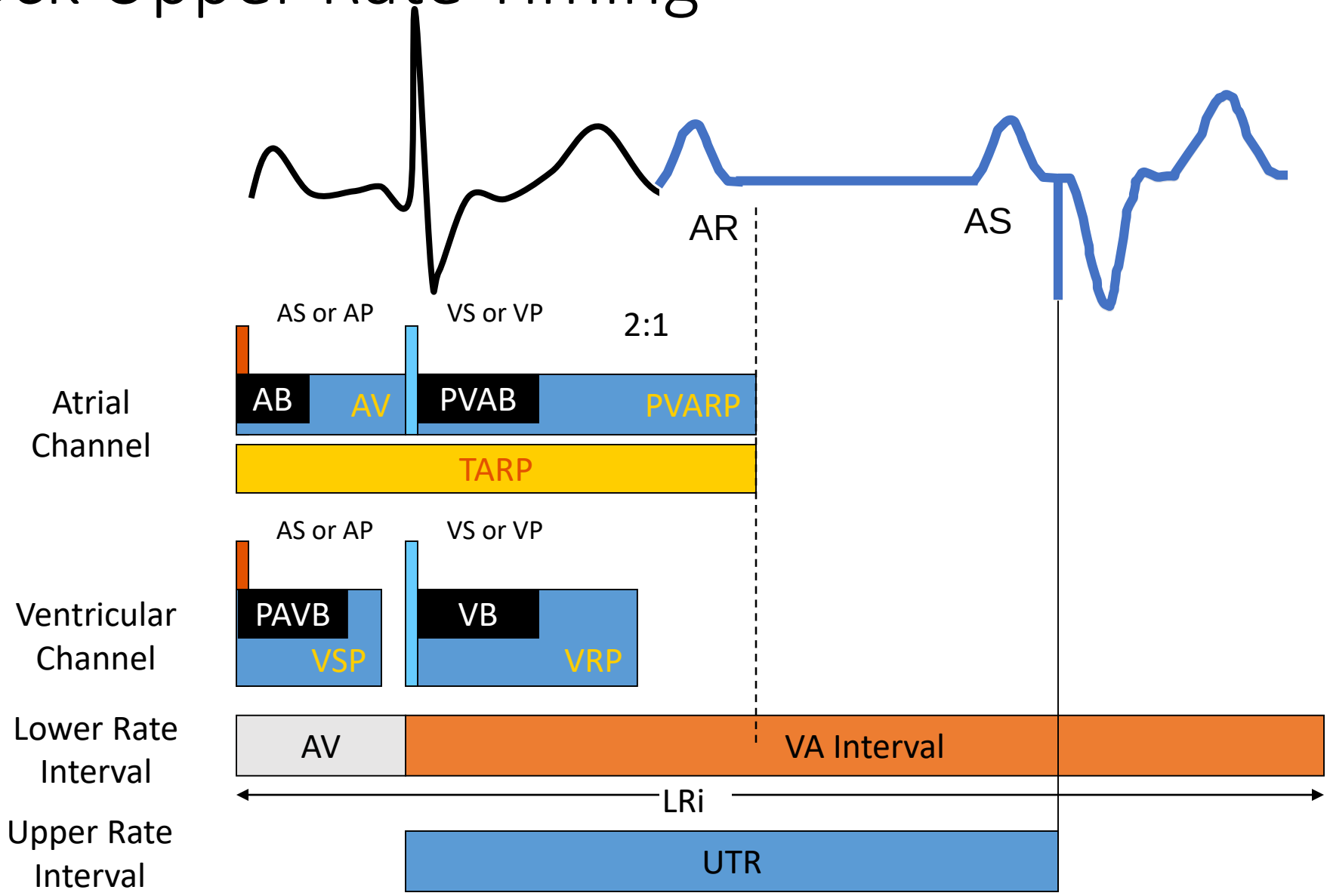


1. The patient's atrial rate falls above the upper tracking rate and below the TARP rate.

2. The ventricular pace is limited to the upper tracking rate limit which causes a lengthening of the AV delay .

3. The fourth atrial beat falls into PVARP (AR) and is not tracked. This produces a 4:3 Wenckebach and the cycle repeats until the atrial rate falls below the UTR.

2:1 Block Upper Rate Timing

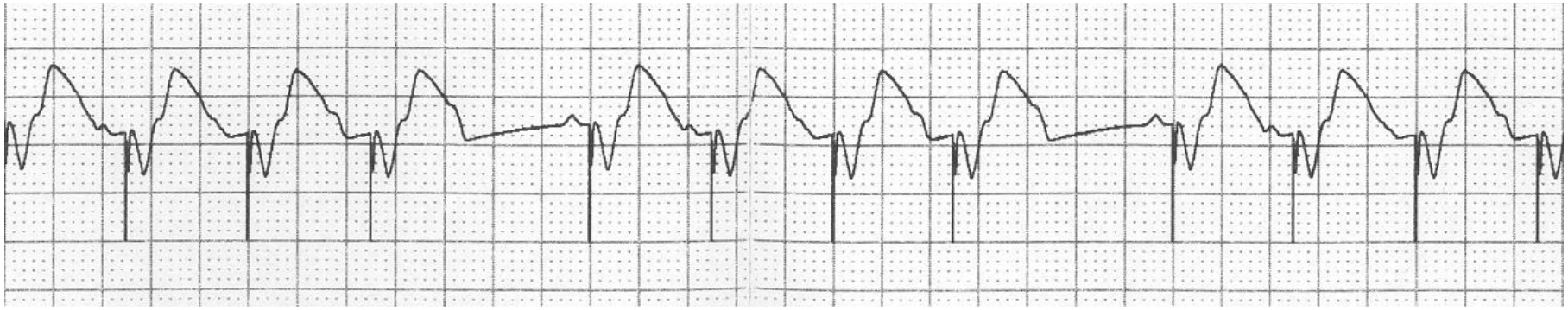


Case 5

Hypothesis: Pacemaker Wenckebach

- Upper rate behavior
  - Is this evidence of “grouped beats?”
  - Do we see regular atrial activity with increasing A-V intervals?

- Intermittent atrial undersensing
  - Do the pauses occur because a P-wave is not sensed, and thus, not tracked?



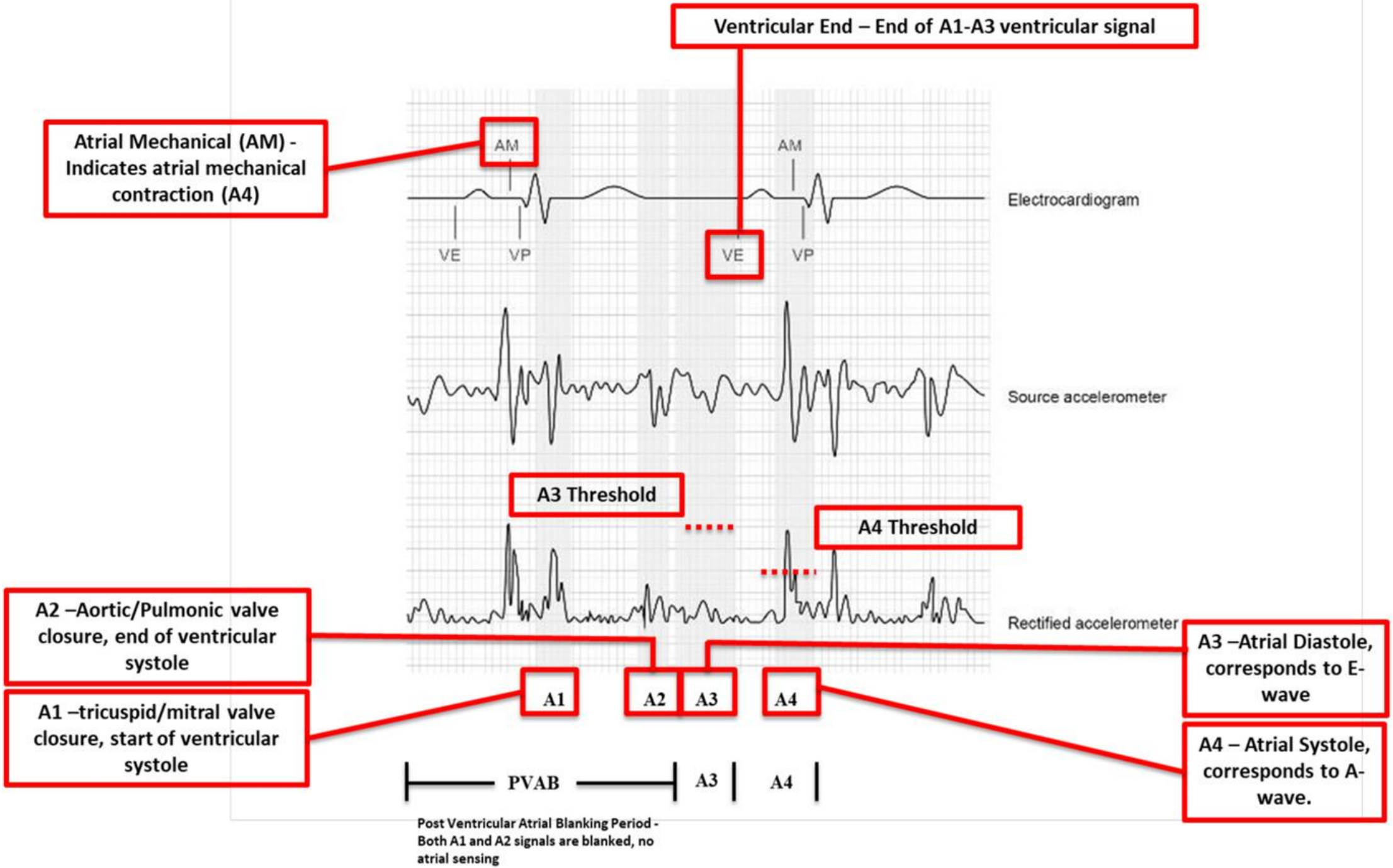
Case 5
Pacemaker Wenckebach

- Considerations
  - Is this really a problem?
    - The pacemaker is behaving normally
  - What to consider if the patient's ADL's are compromised?
    - Pacer Wenckebach occurs when the atrial rate increases and approaches the 2:1 block point
    - SAV + PVARP = TARP, so you may:
      - increase the UTR
      - decrease TARP by:
        - Less PVARP
        - Less AV – use Rate Adaptive AV
        - Use Auto-PVARP options

Case-Based Learning # 6

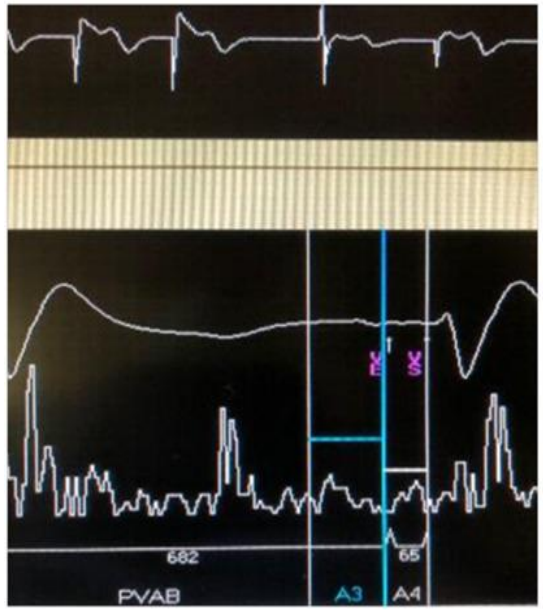
בן 85, מושתל Leadless PPM על רקע high-grade AV block

פונה לחדר מיון לאחר אירוע של סינקופה

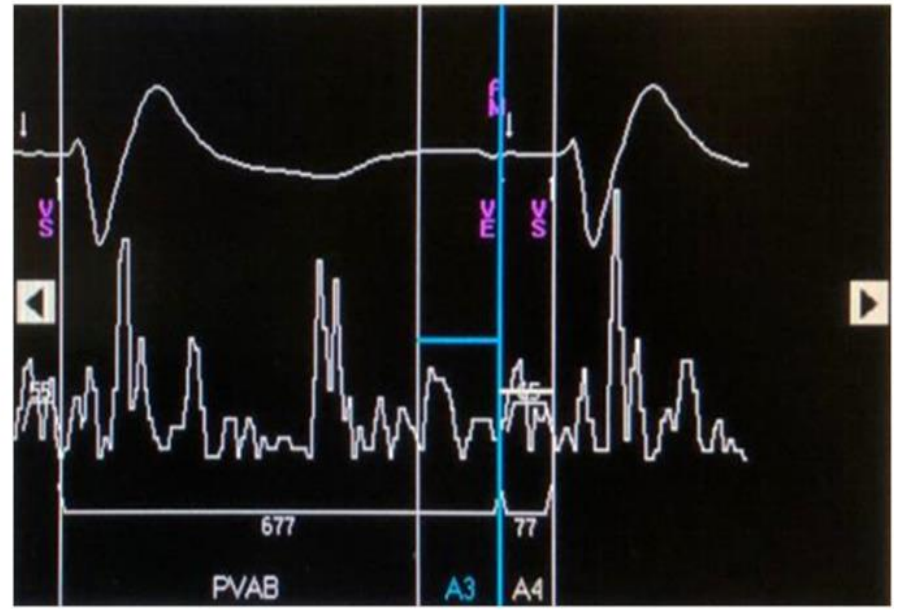

Ventricular End – End of A1-A3 ventricular signal
Atrial Mechanical (AM) - Indicates atrial mechanical contraction (A4)
AM
AM
VE
VP
VE
VP
Electrocardiogram
Source accelerometer
A3 Threshold
A4 Threshold
Rectified accelerometer
A2 –Aortic/Pulmonic valve closure, end of ventricular systole
A1 –tricuspid/mitral valve closure, start of ventricular systole
A1
A2
A3
A4
A3 –Atrial Diastole, corresponds to E-wave
A4 – Atrial Systole, corresponds to A-wave.
PVAB
A3
A4
Post Ventricular Atrial Blanking Period - Both A1 and A2 signals are blanked, no atrial sensing

Stepwise approach to troubleshooting Micra AV tracking
Ensure surface ECG lead has a clear P wave
Correlate A1-A4 with surface ECG
Adjust/change to a different sensing vector if A4 is of small amplitude
MAM test in VDI mode, then VDD mode
Optimize A4/AM sensing and tracking:
•(1). Changing A4 threshold •(2). Adjusting A3 window end •(3). Changing A3 threshold •(4). Adjusting PVAB

(A)

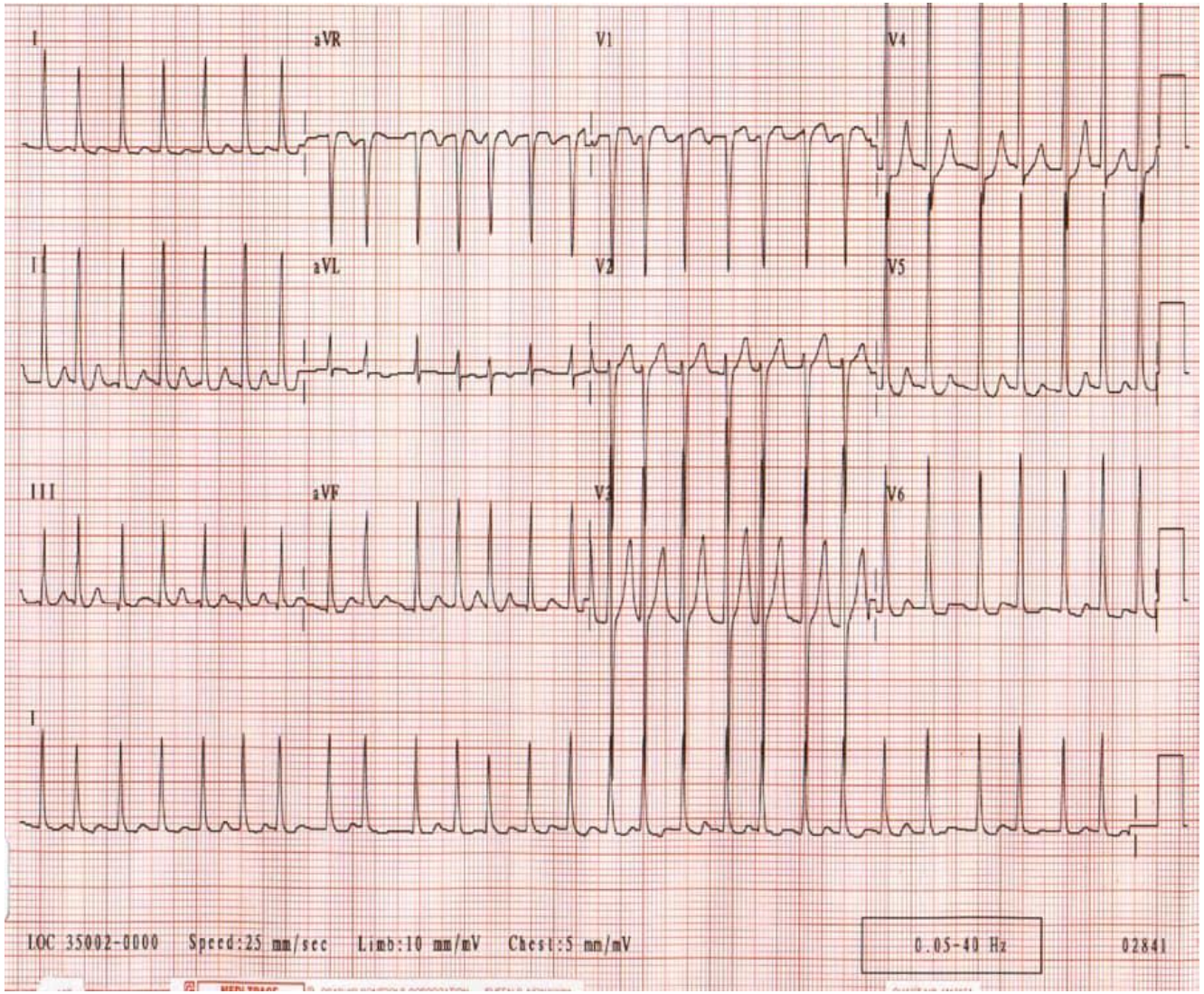


(B)



(C)

Case-Based Learning # 7



בן 55, ברקע יל"ד, DM, מחלת לב איסכמית. LVEF – 30%, מושתל ICD למניעה ראשונית פונה למיון לאחר שחש מכת חשמל.

Evaluate ICD shock

Reported ICD shock

↓

Key history

- Syncope, presyncope
- Palpitations
- Chest pain/dyspnea
- Activity
  - Exertion
  - Arm motion
- Medications
  - New
  - Non-compliance
- EMI exposure
- Recent reprogramming

Physical exam

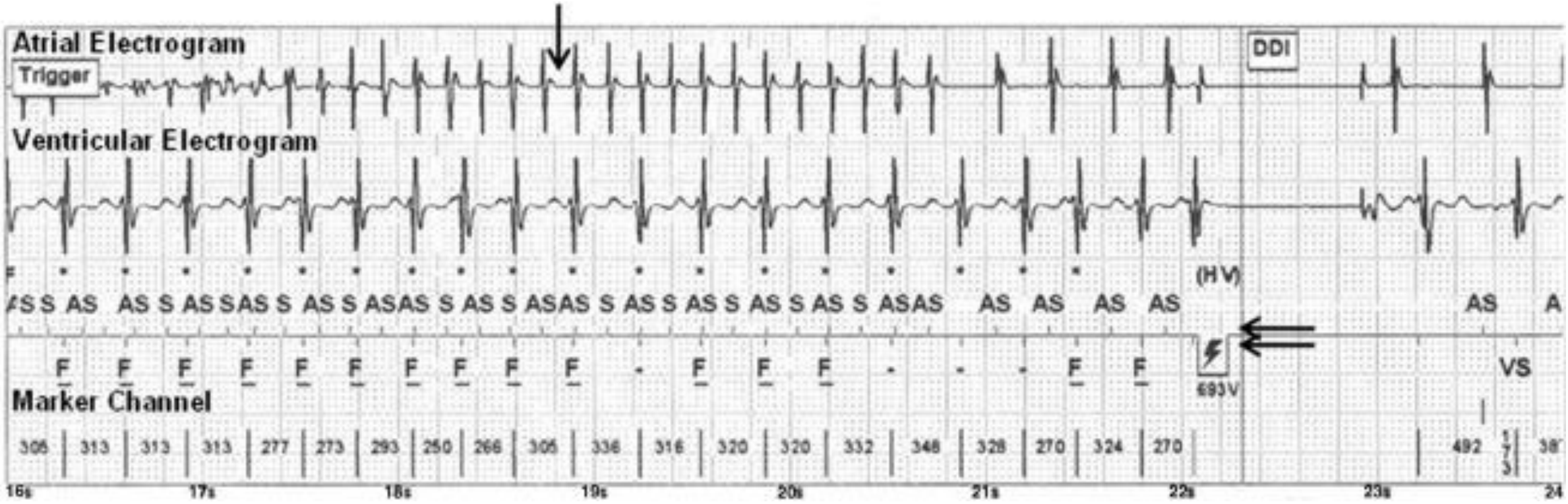
- Twiddler syndrome
- Atrial fibrillation or SVT
- Heart failure

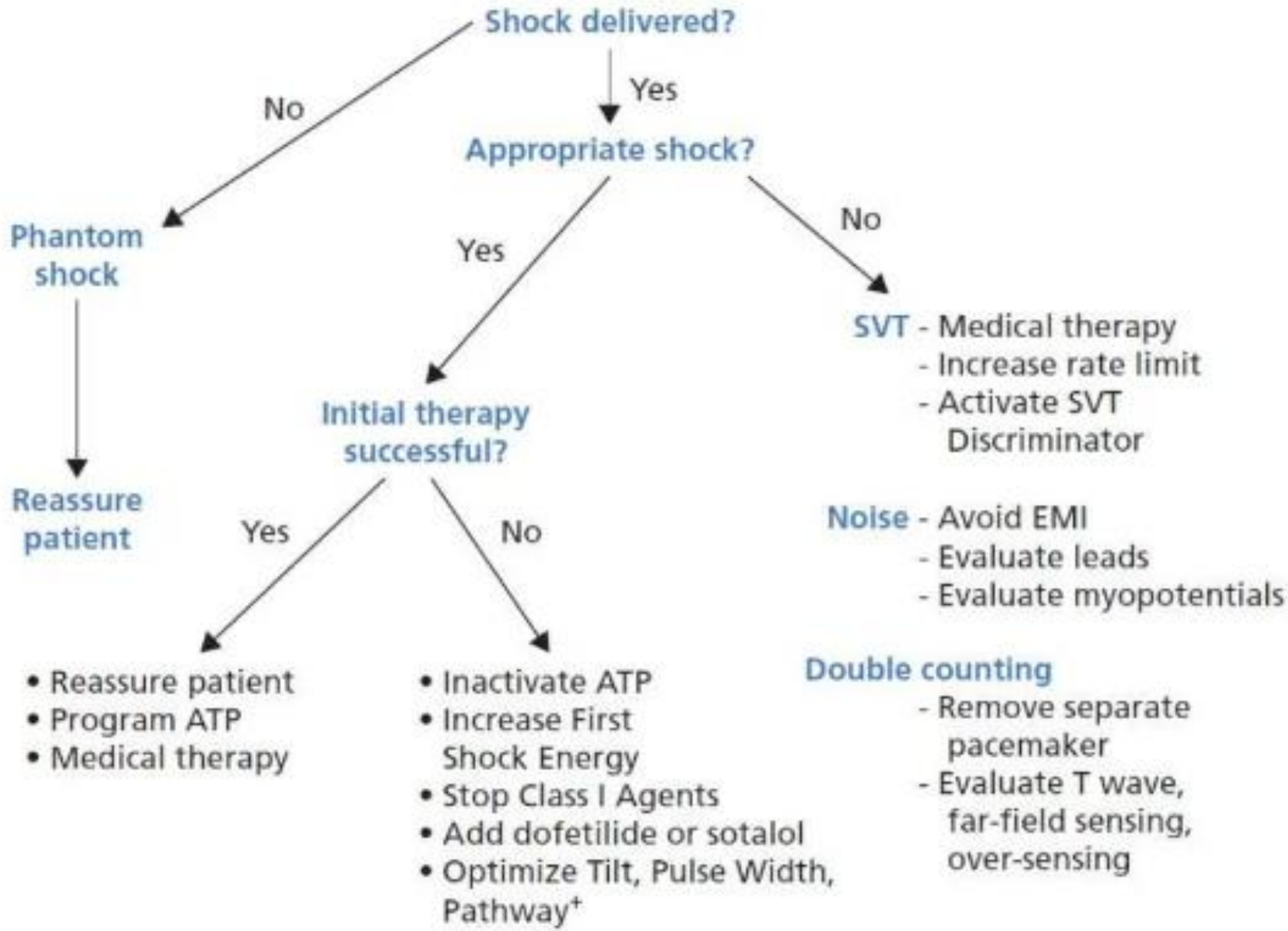
↓

ICD interrogation

- Programmed parameters
- RR intervals
- Stored EGMs
- Therapy sequence
- Telemetry with manipulation

Device interrogation



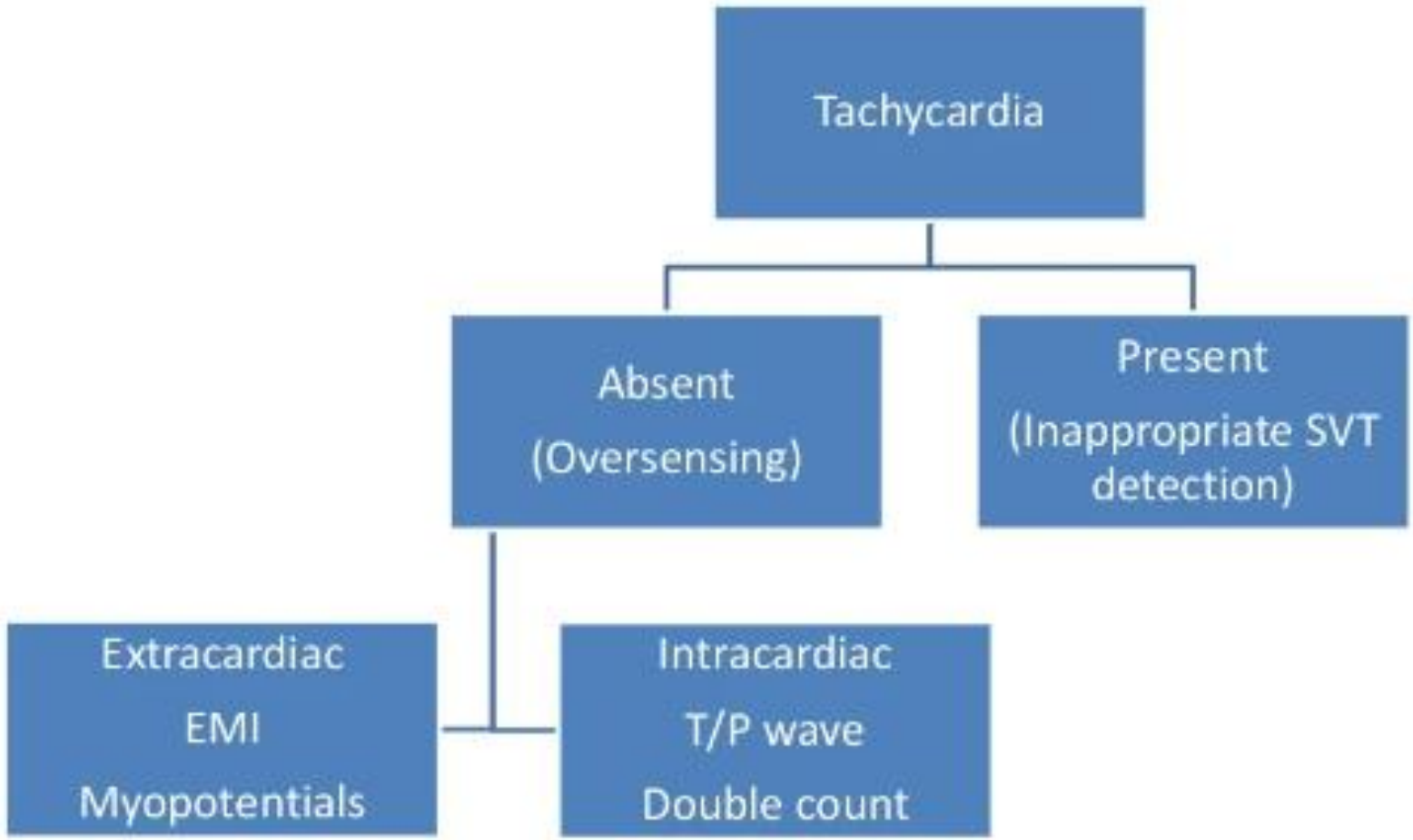

Shock delivered?
No
Yes
Appropriate shock?
Phantom shock
Yes
No
Reassure patient
Initial therapy successful?
Yes
No
• Reassure patient
• Program ATP
• Medical therapy
• Inactivate ATP
• Increase First Shock Energy
• Stop Class I Agents
• Add dofetilide or sotalol
• Optimize Tilt, Pulse Width, Pathway+
SVT - Medical therapy
- Increase rate limit
- Activate SVT Discriminator
Noise - Avoid EMI
- Evaluate leads
- Evaluate myopotentials
Double counting
- Remove separate pacemaker
- Evaluate T wave, far-field sensing, over-sensing

Case-Based Learning # 8

בן 55, ברקע יל"ד, DM, מחלת לב איסכמית.
LVEF – 30%, מושתל ICD למניעה ראשונית
פונה למיון לאחר שחש מכת חשמל.

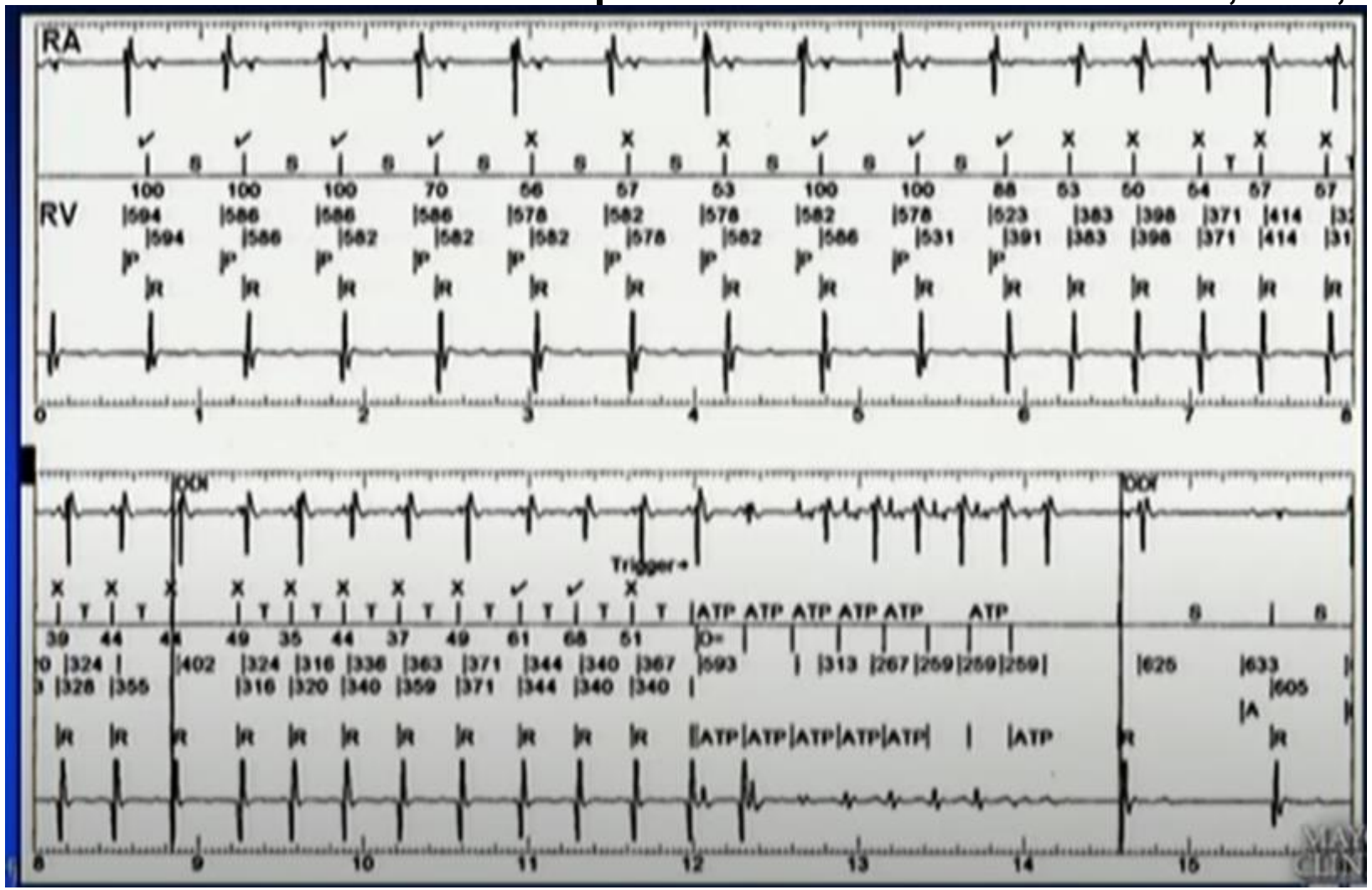
1. Myopotential oversensing
2. Electromagnetic interference
3. T wave oversensing
4. Lead fracture

Inappropriate Shock

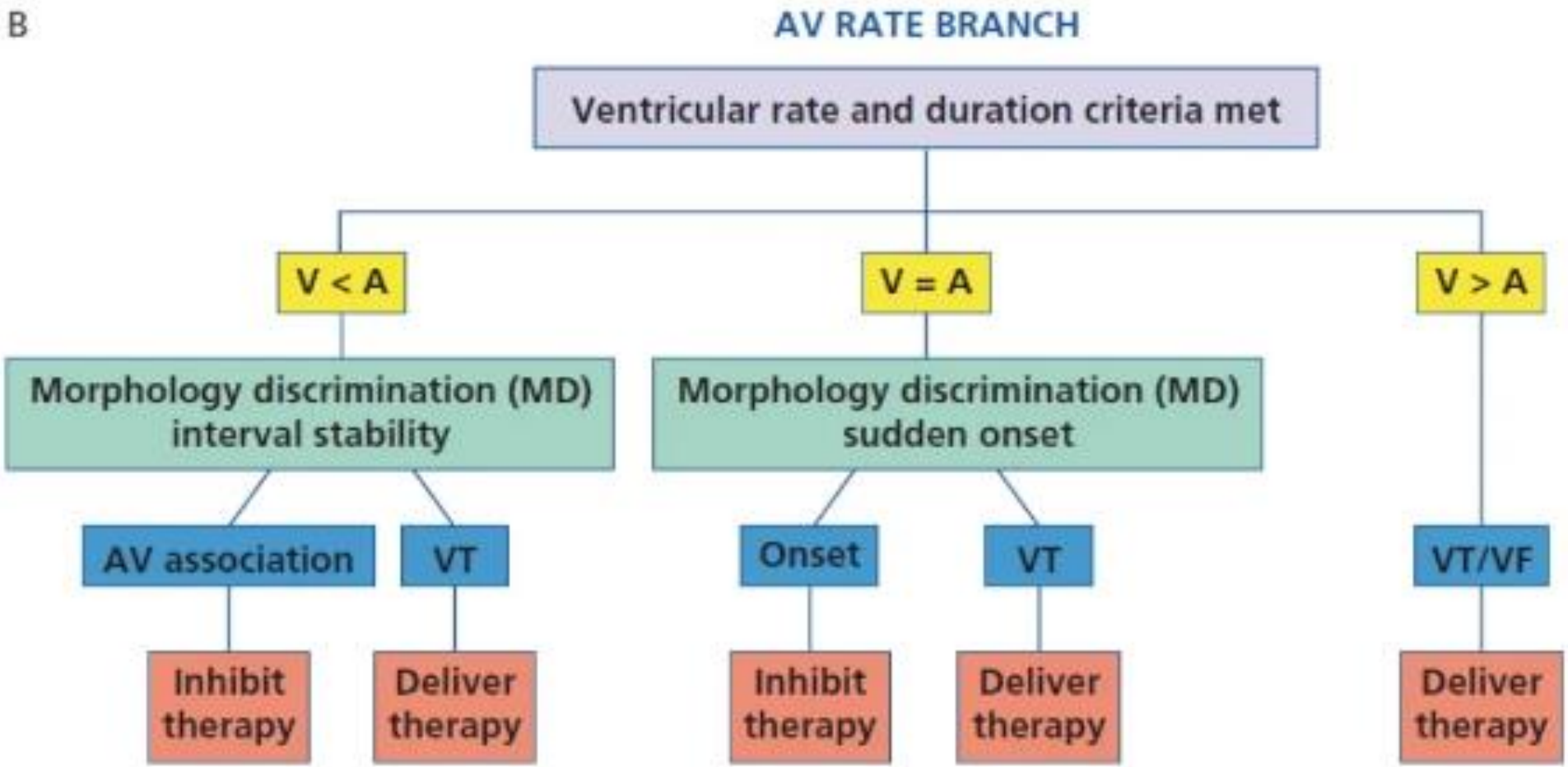


Case-Based Learning # 9

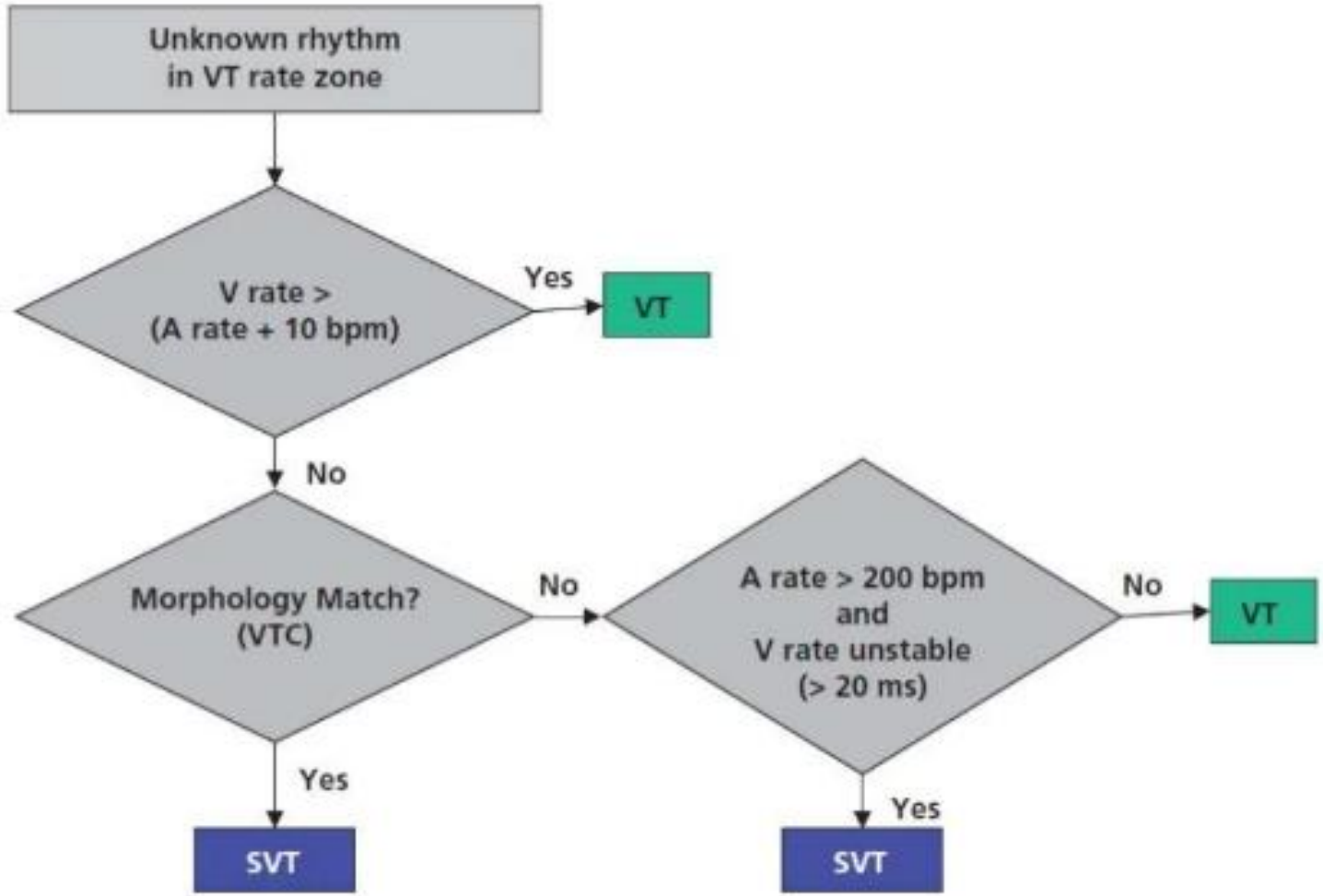
בן 55, ברקע יל"ד, DM, מחלת לב איסכמית. פונה למיון לאחר שחש מכת חשמל.



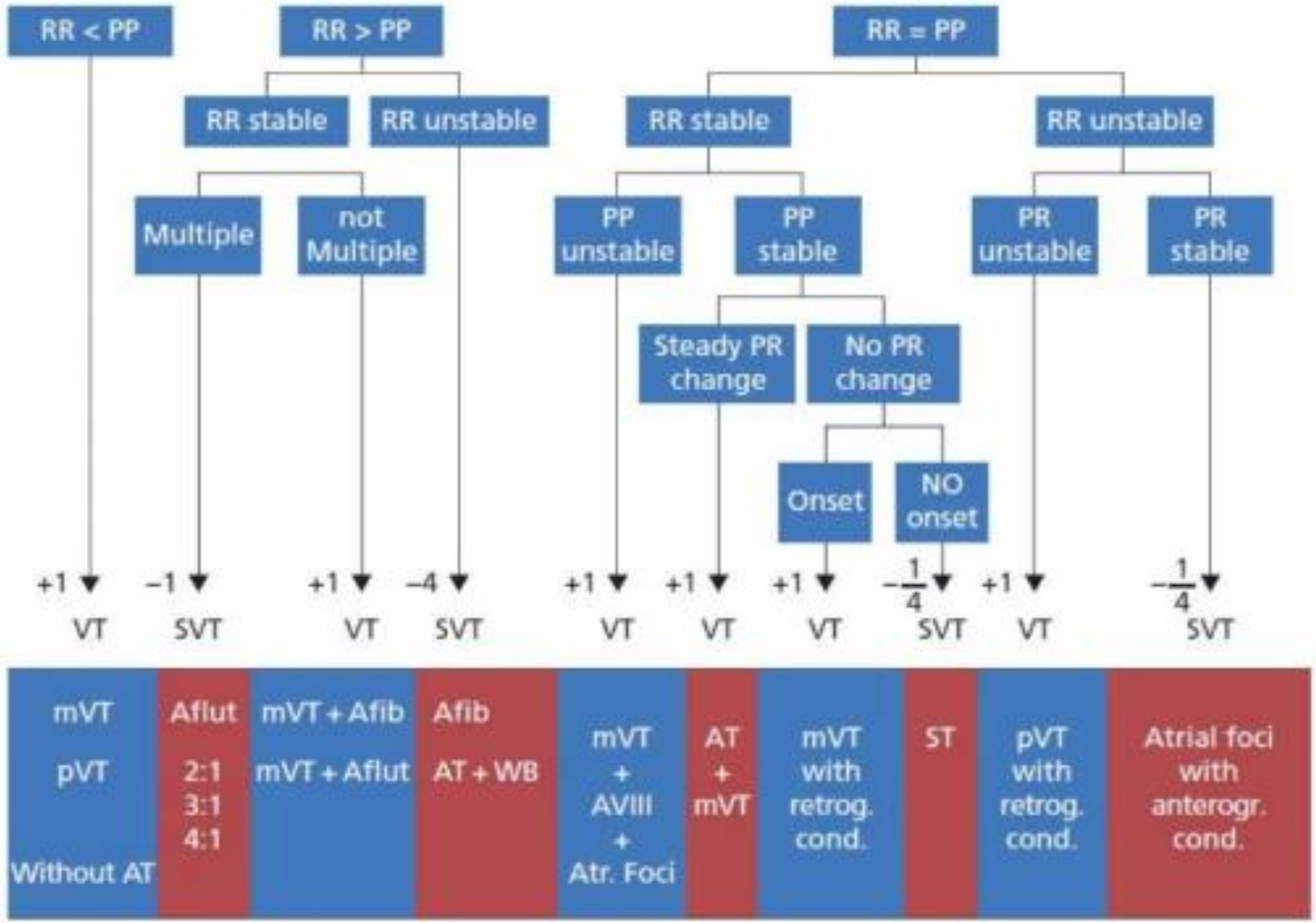
St Jude: Rate Branch



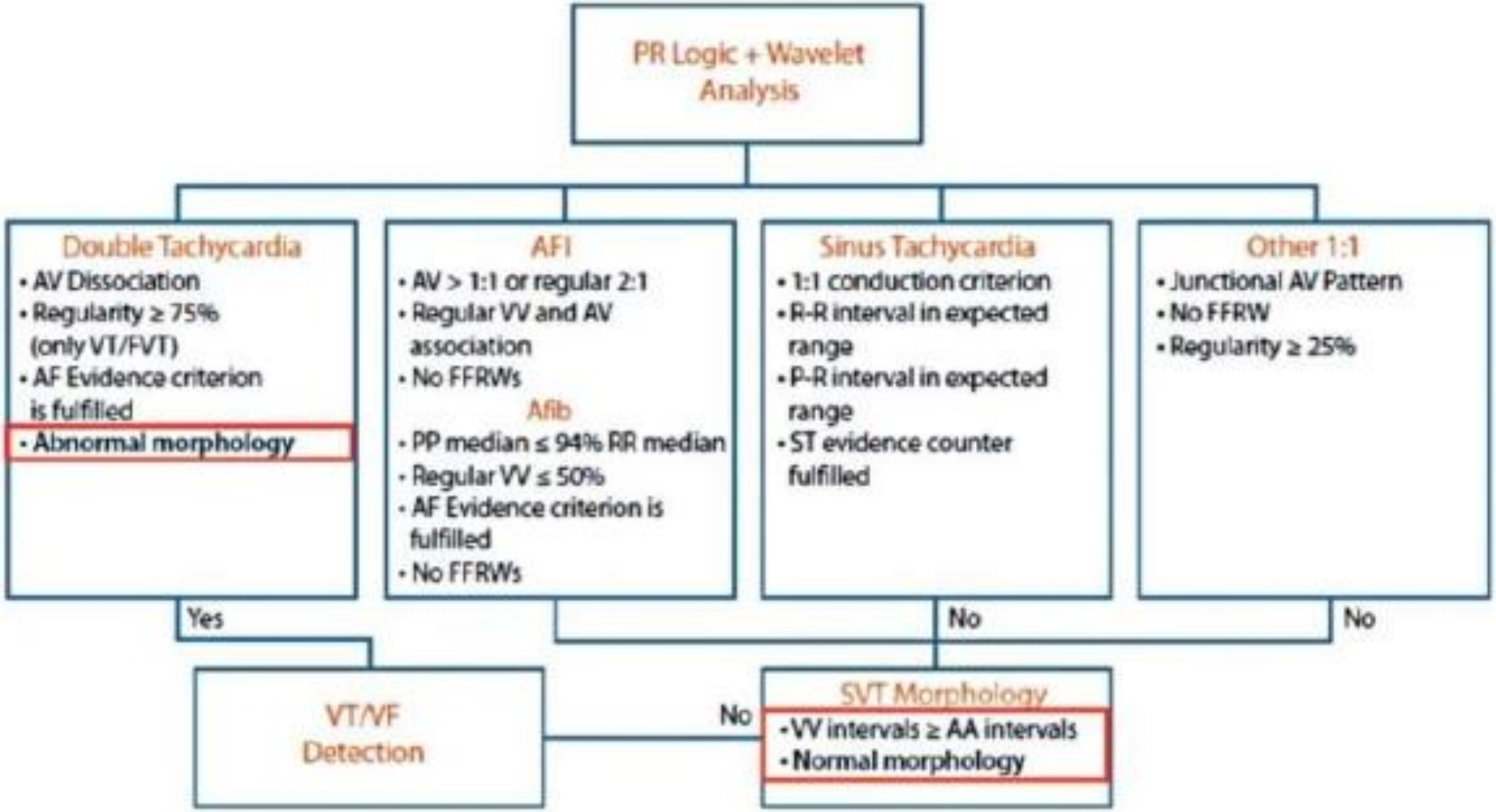
Boston scientific: RHYTHM ID



Biotronik: SMART

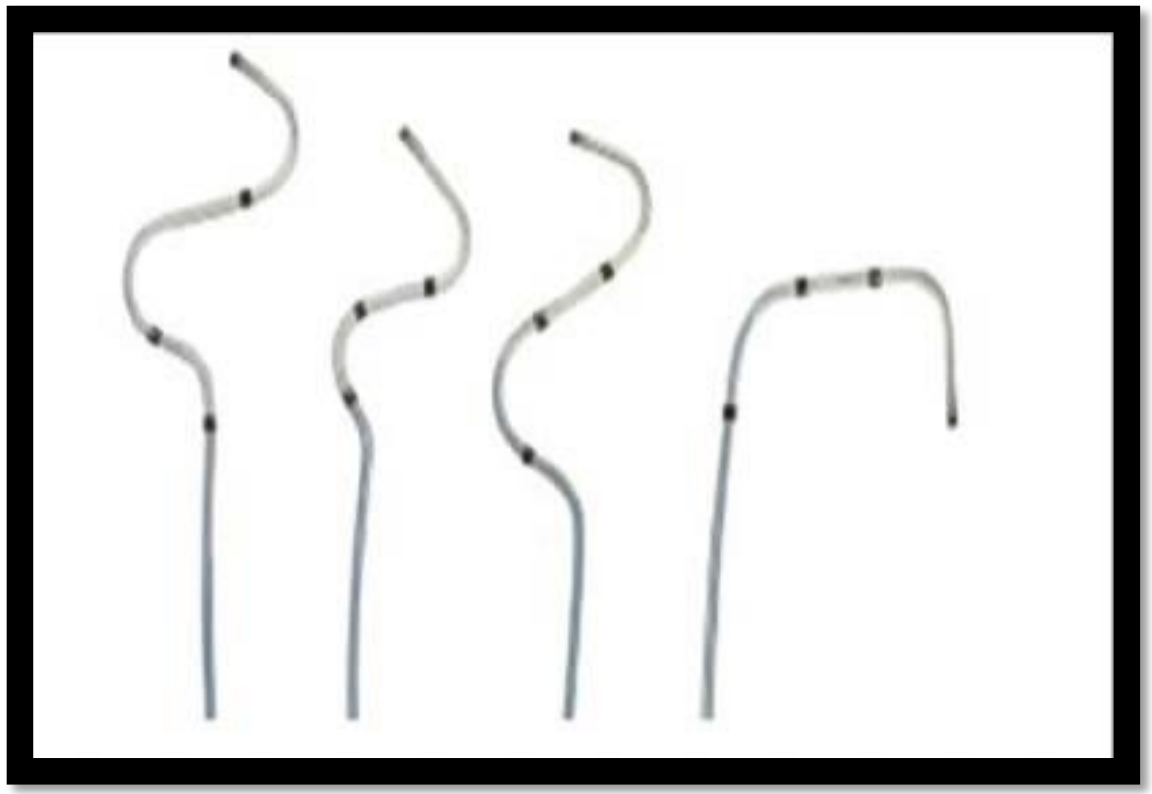


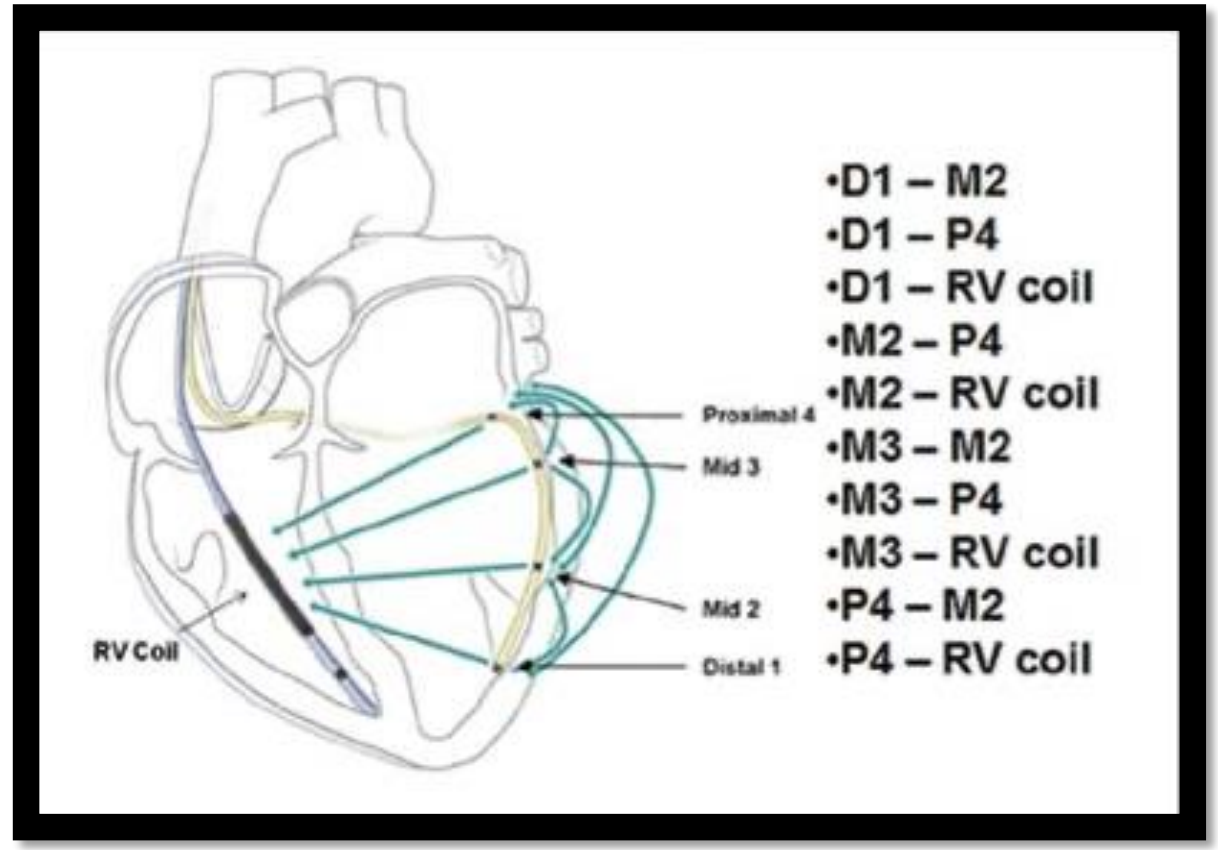
Medtronik: PR Logic



Case-Based Learning # 10

בן 62, מושתל CRTD, פונה למיון לאור אי נוחות בטנית




Proximal 4
Mid 3
Mid 2
Distal 1
RV Coil
•D1 – M2
•D1 – P4
•D1 – RV coil
•M2 – P4
•M2 – RV coil
•M3 – M2
•M3 – P4
•M3 – RV coil
•P4 – M2
•P4 – RV coil

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