SVT: Differentiation and Management

Yousef Darrat

6/6/2021

Objectives

- Mechanism of arrhythmia
- Types of SVT and management
- Relation of P wave morphology and origin of arrhythmia

Mechanism of Arrhythmia

1- Abnormal Automaticity

2- Triggered Activity

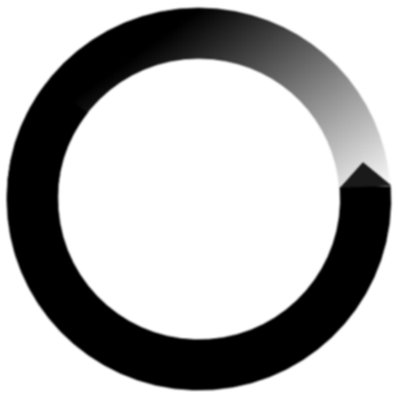
3- Re-entry

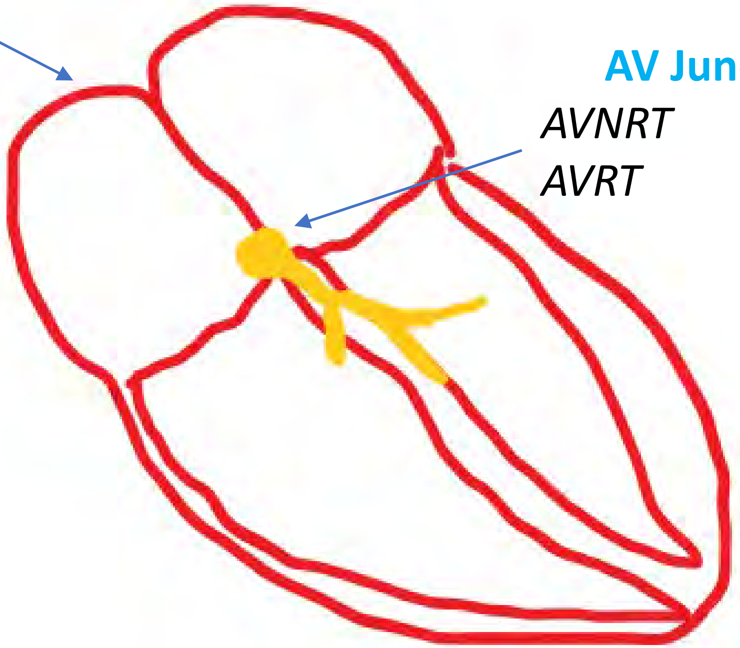
Re-entry

1- At least 2 functionally or anatomically distinct paths joined proximally and distally to form a closed circuit.

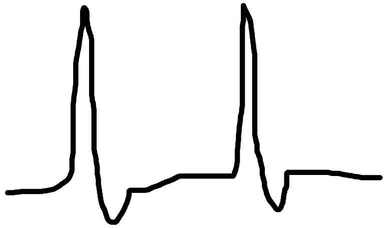
2- Unidirectional block in one path

3- Slow conduction in unblocked path

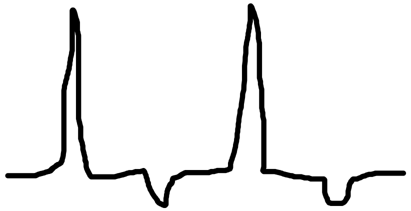


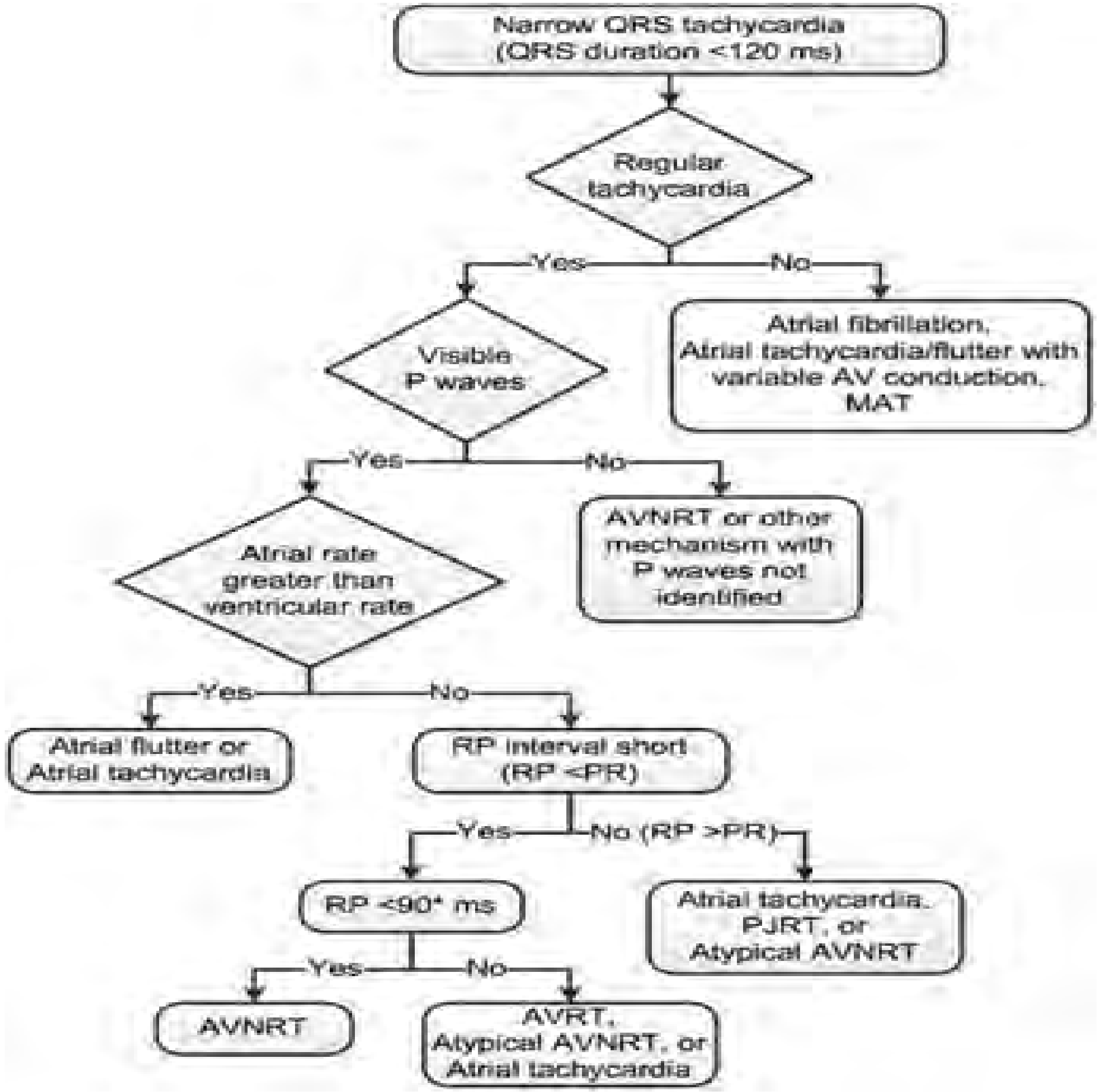


Short RP tachycardia:
Typical AVNRT
AVRT
PJRT

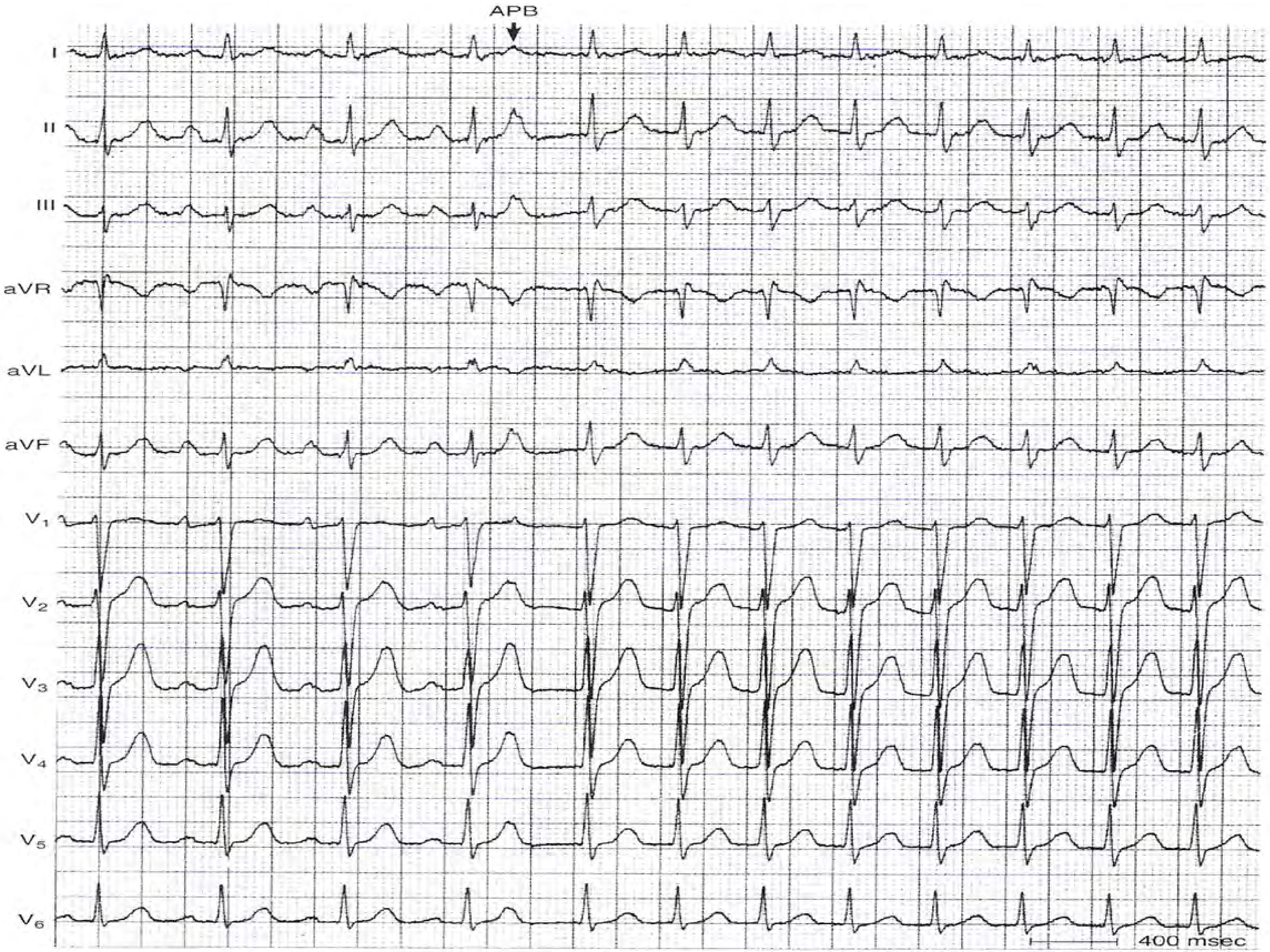


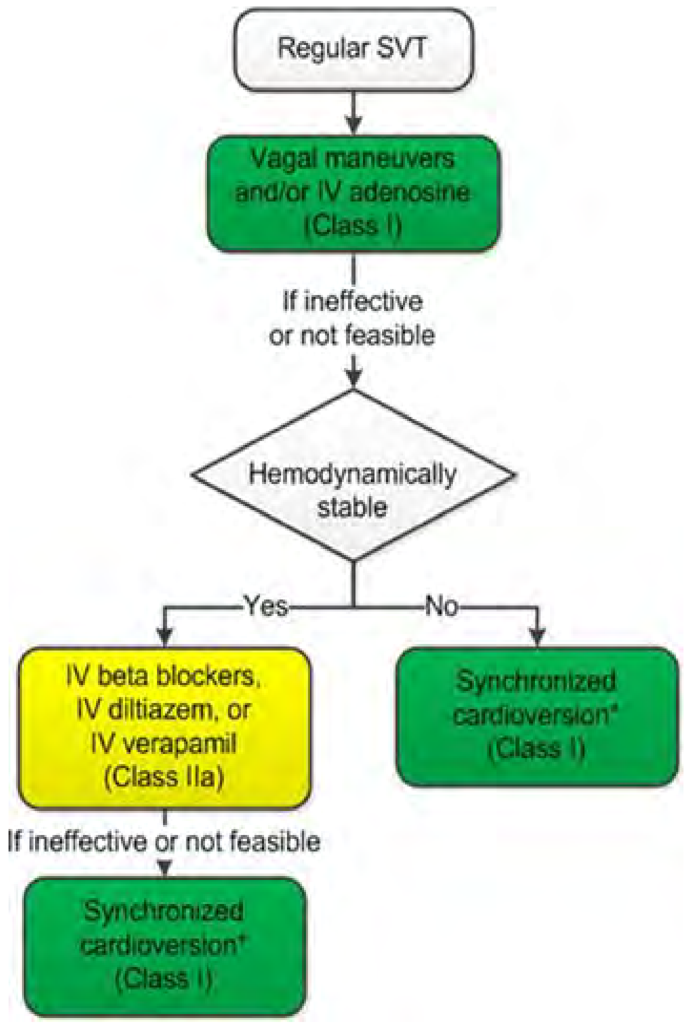
Long RP tachycardia:
Atypical AVNRT
Atrial tachycardia
AFL





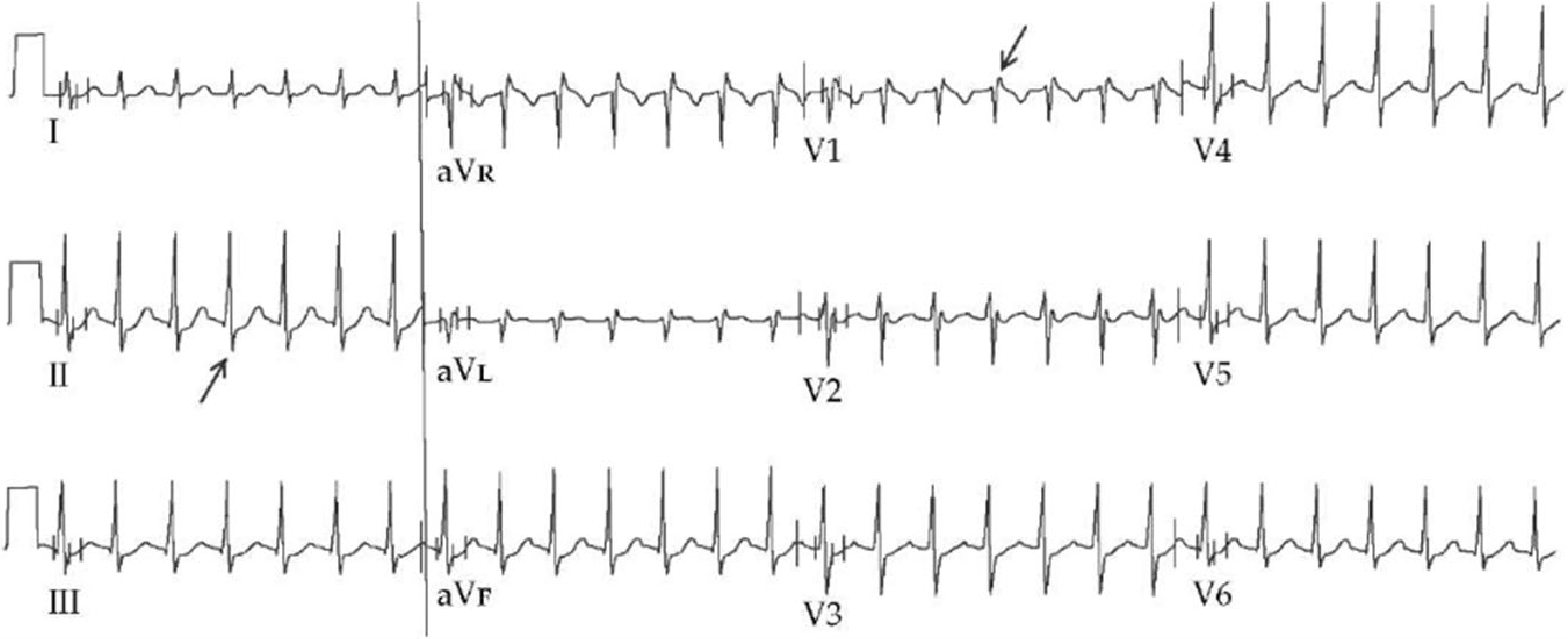
Richard L. Page. Circulation. 2015 ACC/AHA/HRS Guideline for the Management of Adult Patients With Supraventricular Tachycardia, Volume: 133, Issue: 14, Pages: e506-e574, DOI: (10.1161/CIR.0000000000000311)


APB
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
400 msec

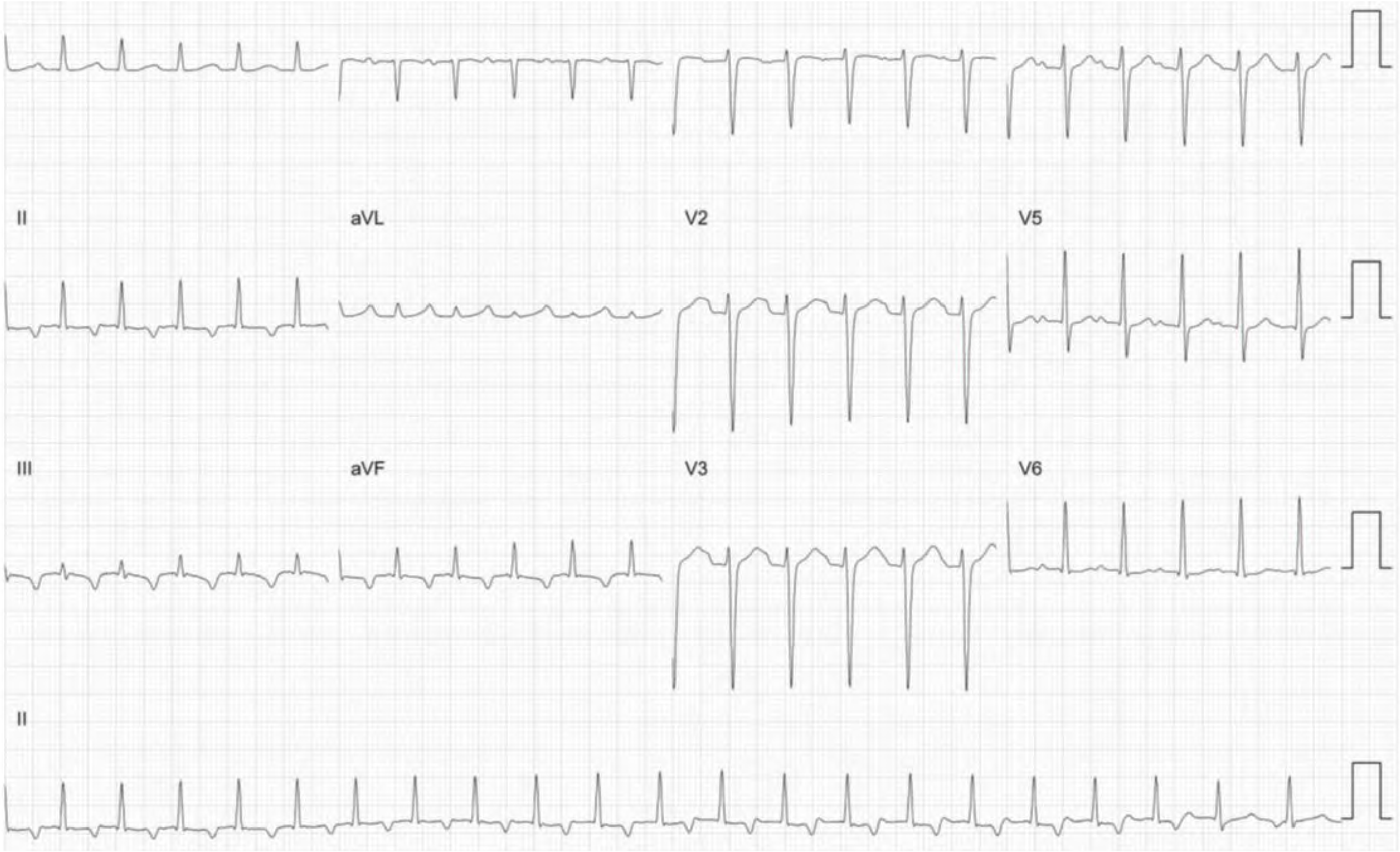


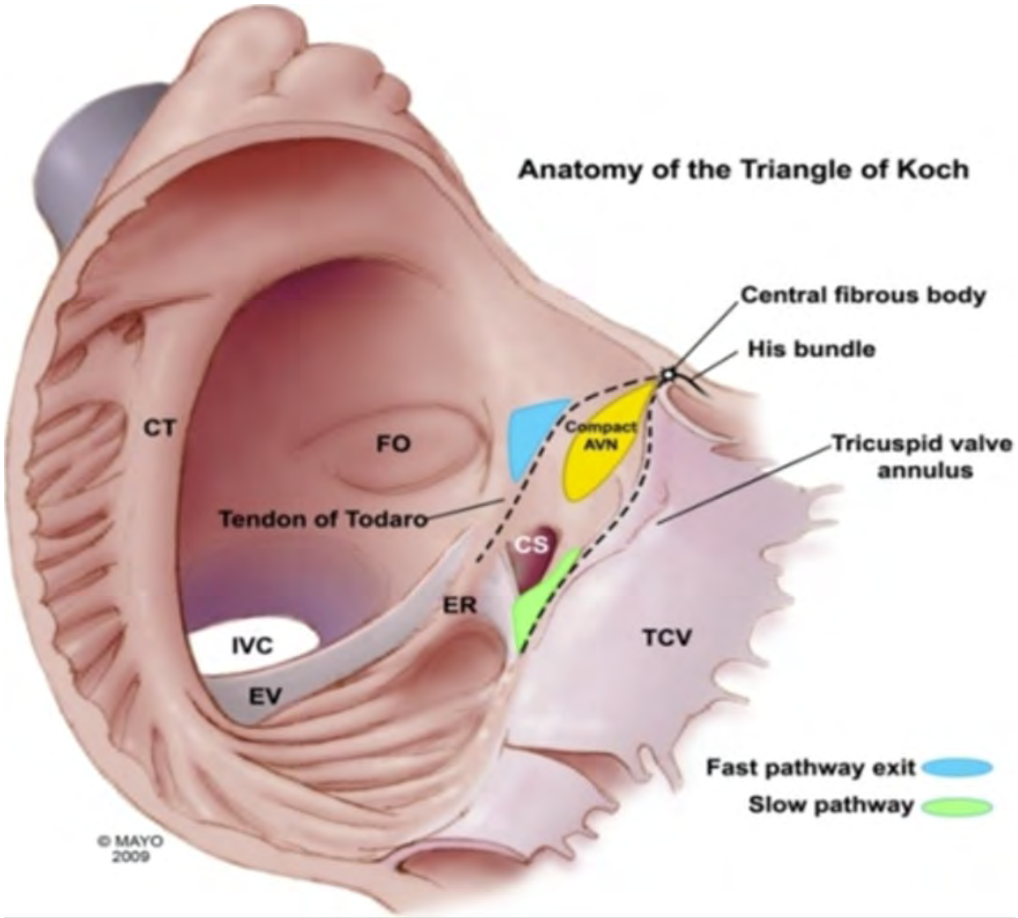
Richard L. Page. Circulation. 2015 ACC/AHA/HRS Guideline for the Management of Adult Patients With Supraventricular Tachycardia, Volume: 133, Issue: 14, Pages: e506-e574, DOI: (10.1161/CIR.0000000000000311)

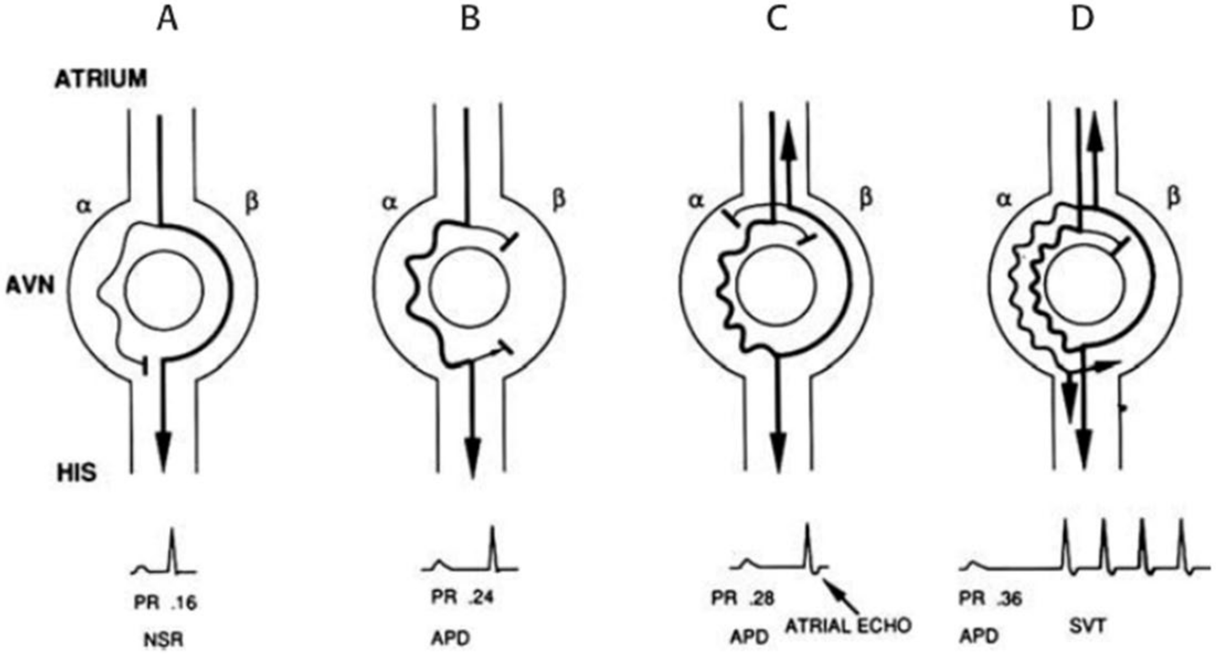
Typical AVNRT



Atypical AVNRT




Anatomy of the Triangle of Koch
Central fibrous body
His bundle
CT
FO
Compact AVN
Tricuspid valve annulus
Tendon of Todaro
CS
ER
IVC
EV
TCV
Fast pathway exit
Slow pathway
© MAYO 2009


A
B
C
D
ATRIUM
α
β
AVN
HIS
PR .16
NSR
PR .24
APD
PR .28
APD
ATRIAL ECHO
PR .36
APD
SVT

Management: AVNRT

- Acute: Vagal maneuvers, Adenosine
- Chronic:
  - Medical Management: AV blockers, Class Ic agents
- Ablation: Slow pathway modification

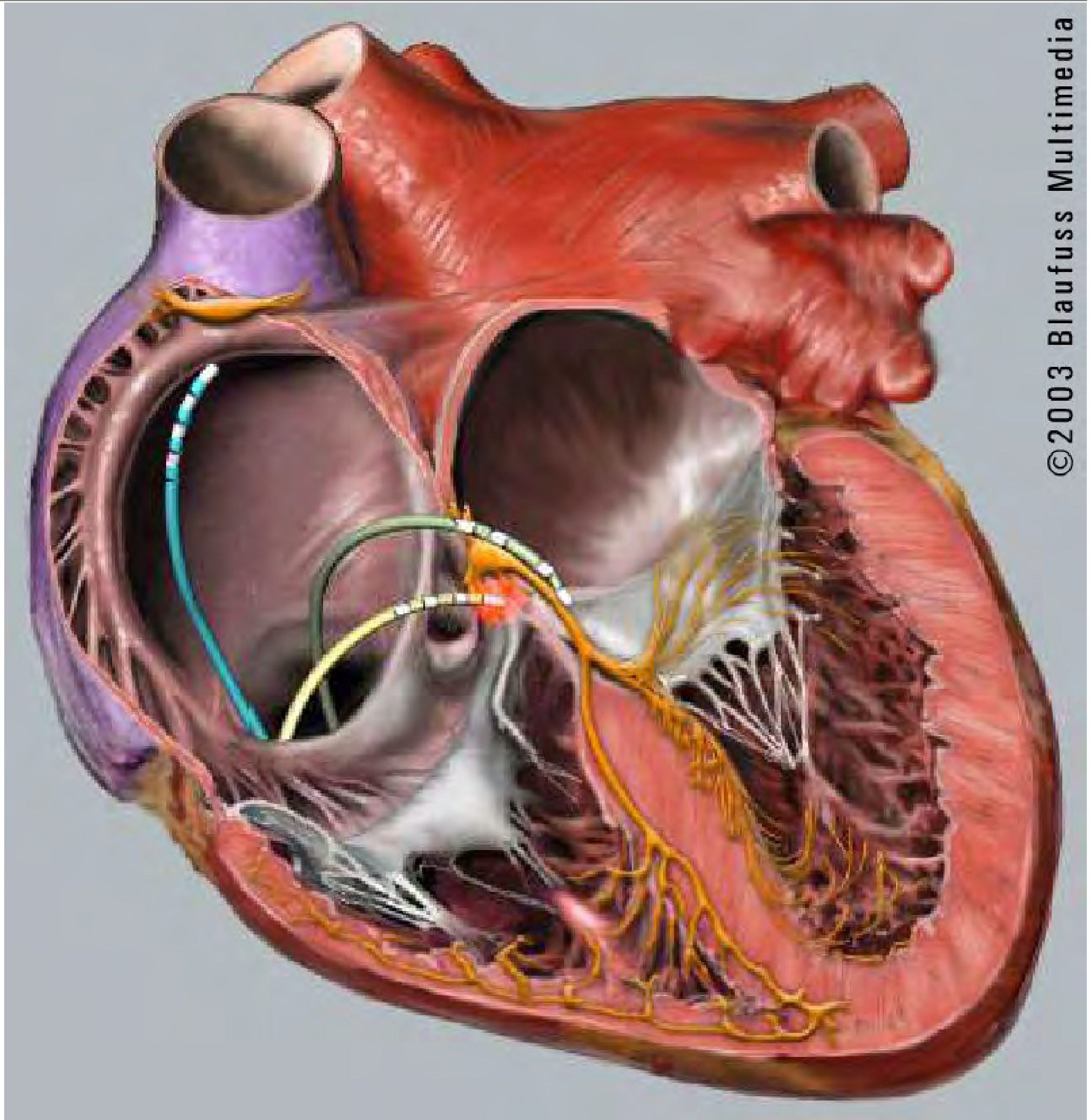
  Efficacy: 95%, Recurrence: 5%

  AV block: 2%

Kay GN. Am J Med. 1996;100:344-356.
Morady F. N Engl J Med. 1999;340:534-544.

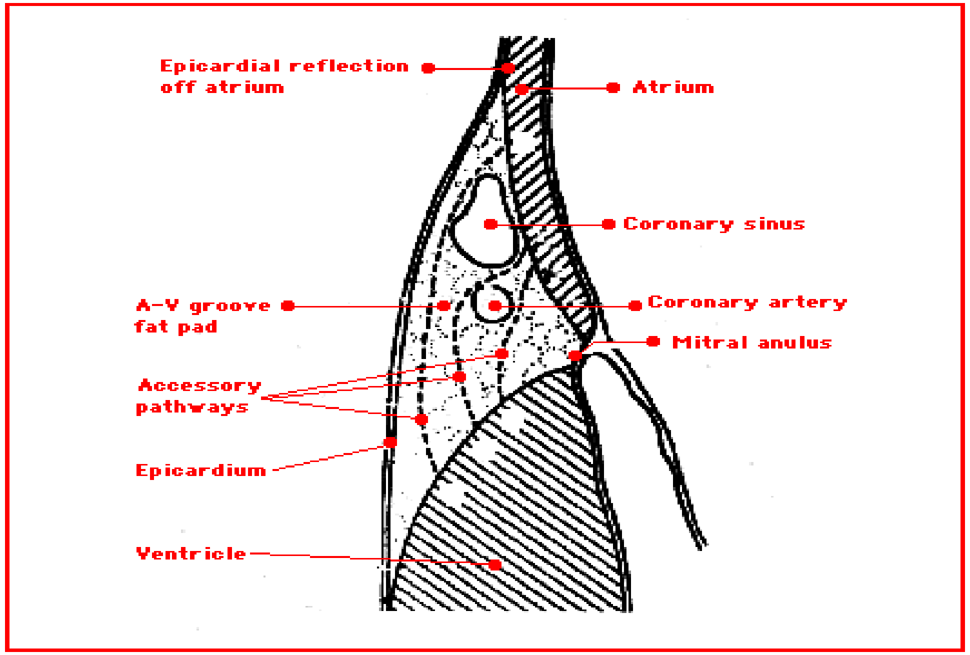
AVNRT: Catheter ablation

AVNRT can be cured permanently with catheter ablation, using radio frequency to heat and destroy the cells in the slow pathway, creating a permanent line of block.



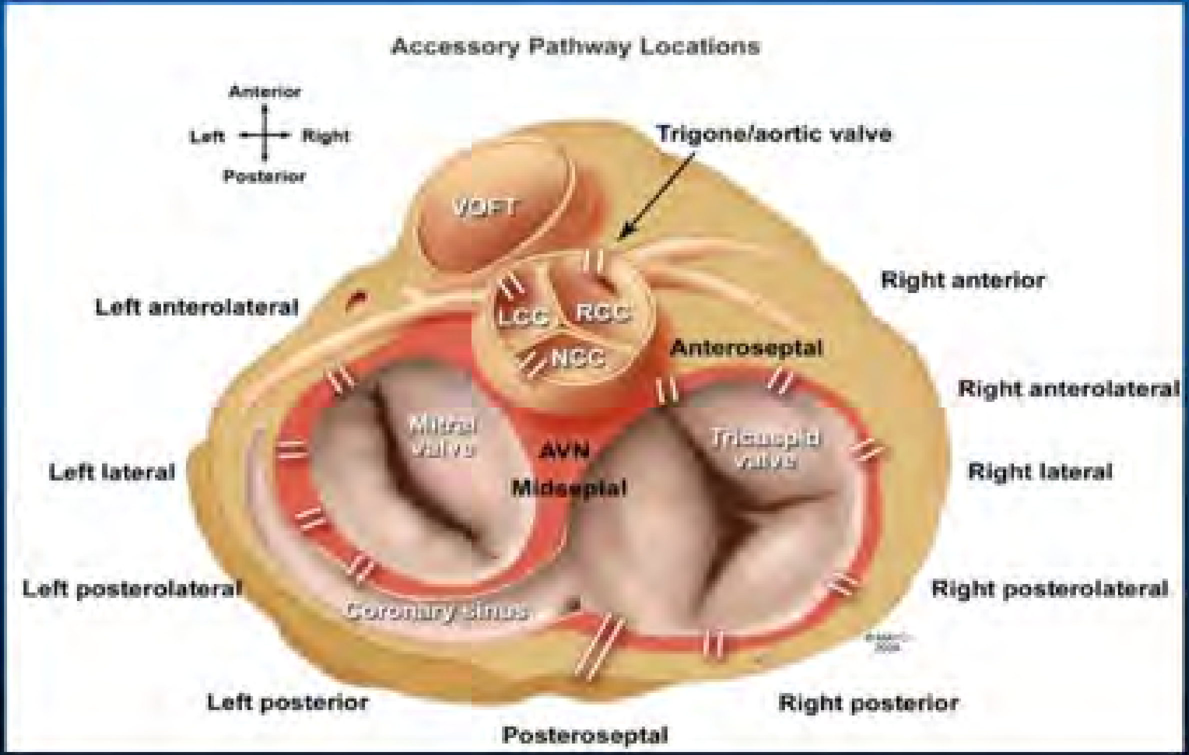
AVRT: Accessory AV Pathways

- Failure of separation of atrial and ventricular tissue
- Muscle fibers connecting atria to ventricle
- Hence the term: accessory AV pathway



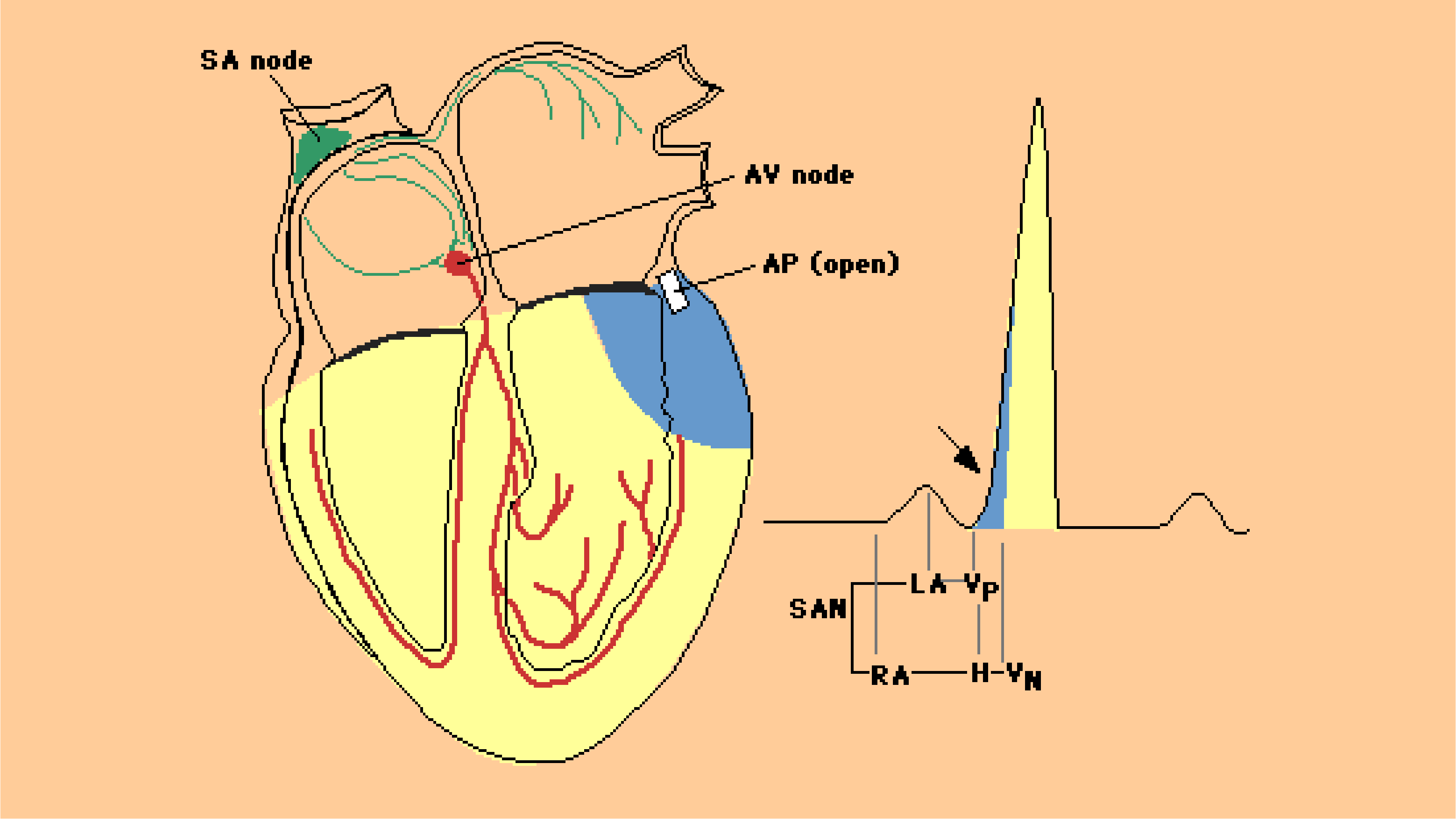
Kay GN. Am J Med. 1996;100:344-345.

Anatomic locations

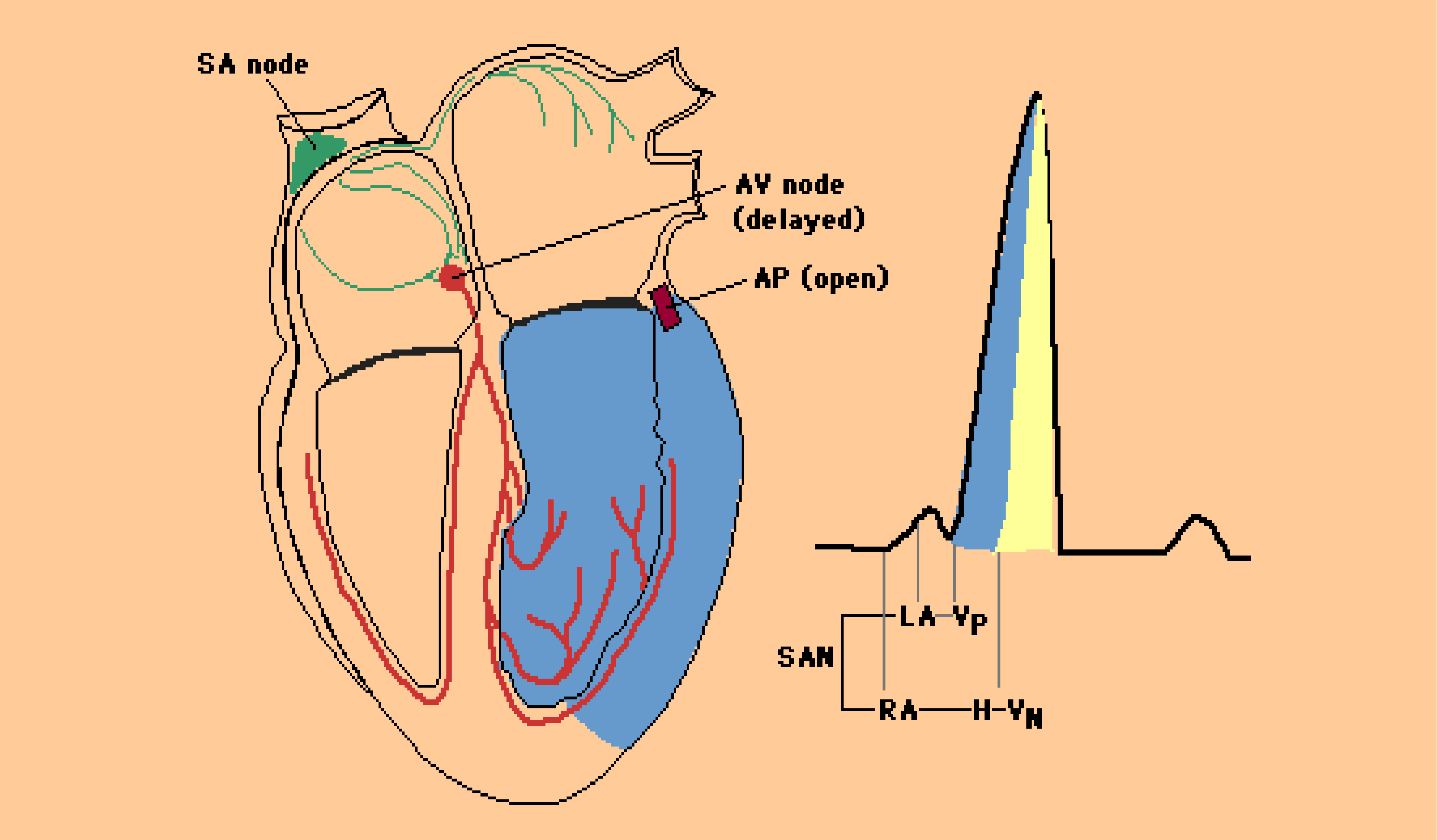


Left AP 60% Septal AP 28% Right free wall 12% (NASPE 1998)

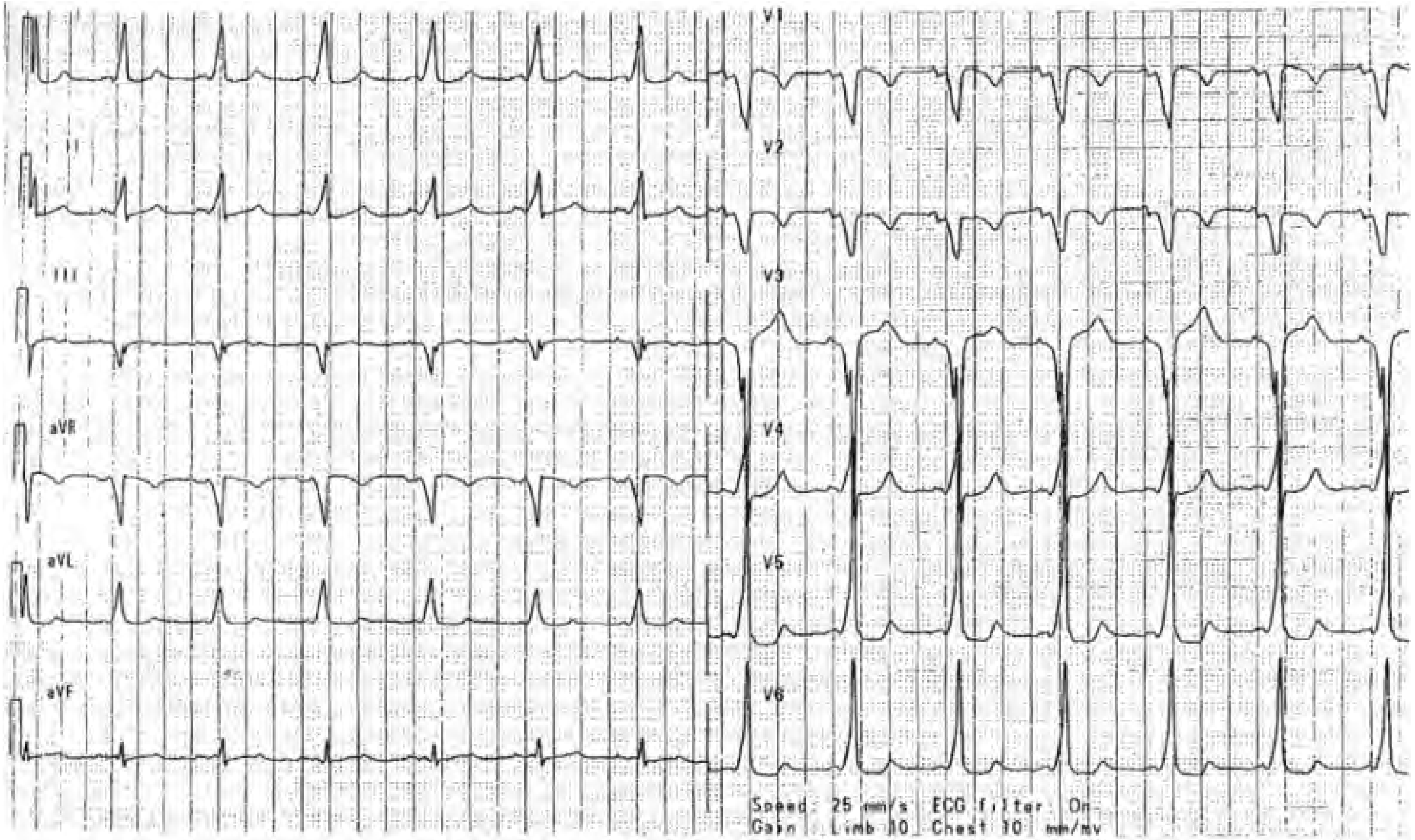
Delta wave



Delta wave



Pre-excitation



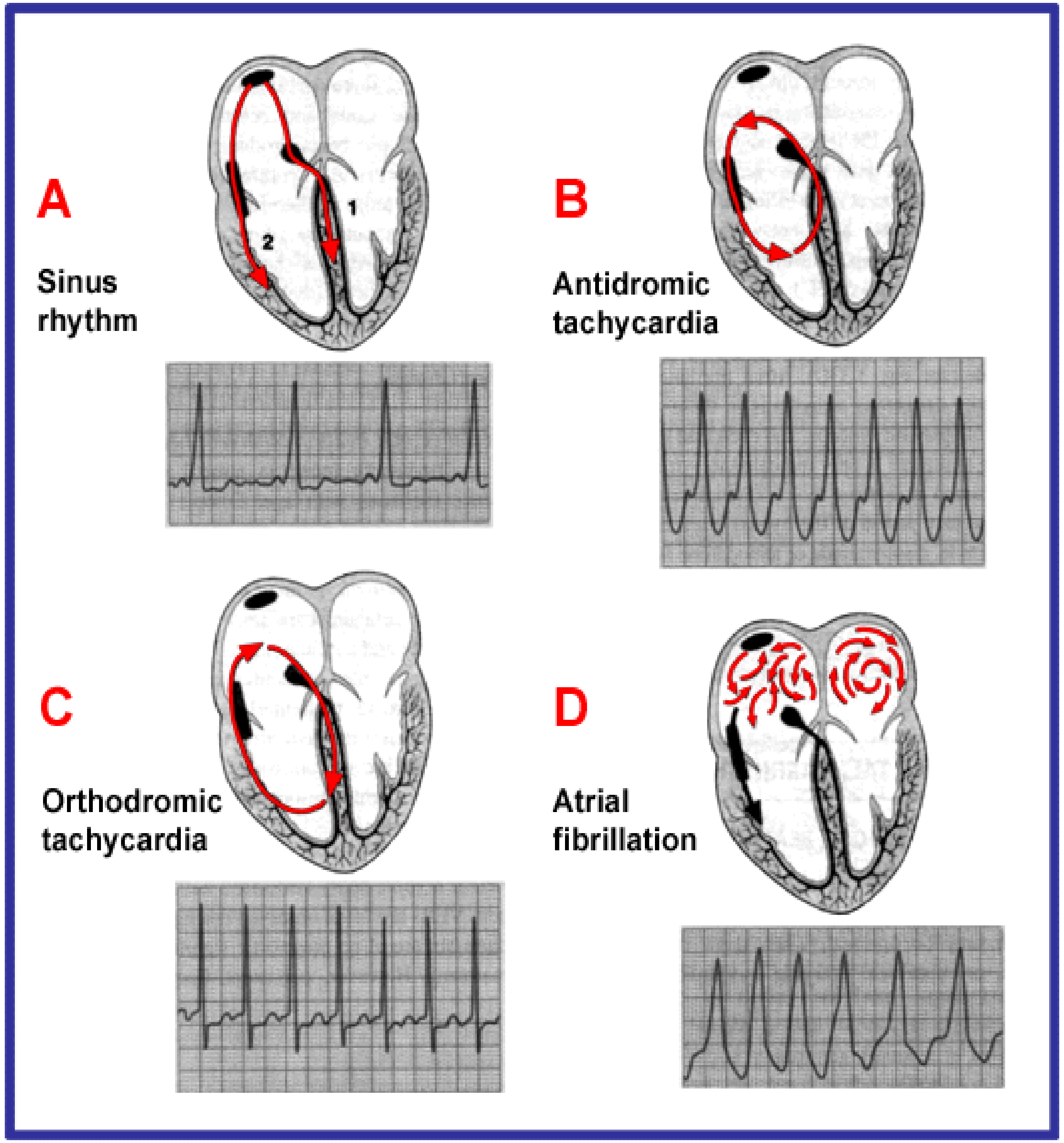
Kay NG. Am J of Med. 1996;10:344-356.

Accessory pathway and WPW

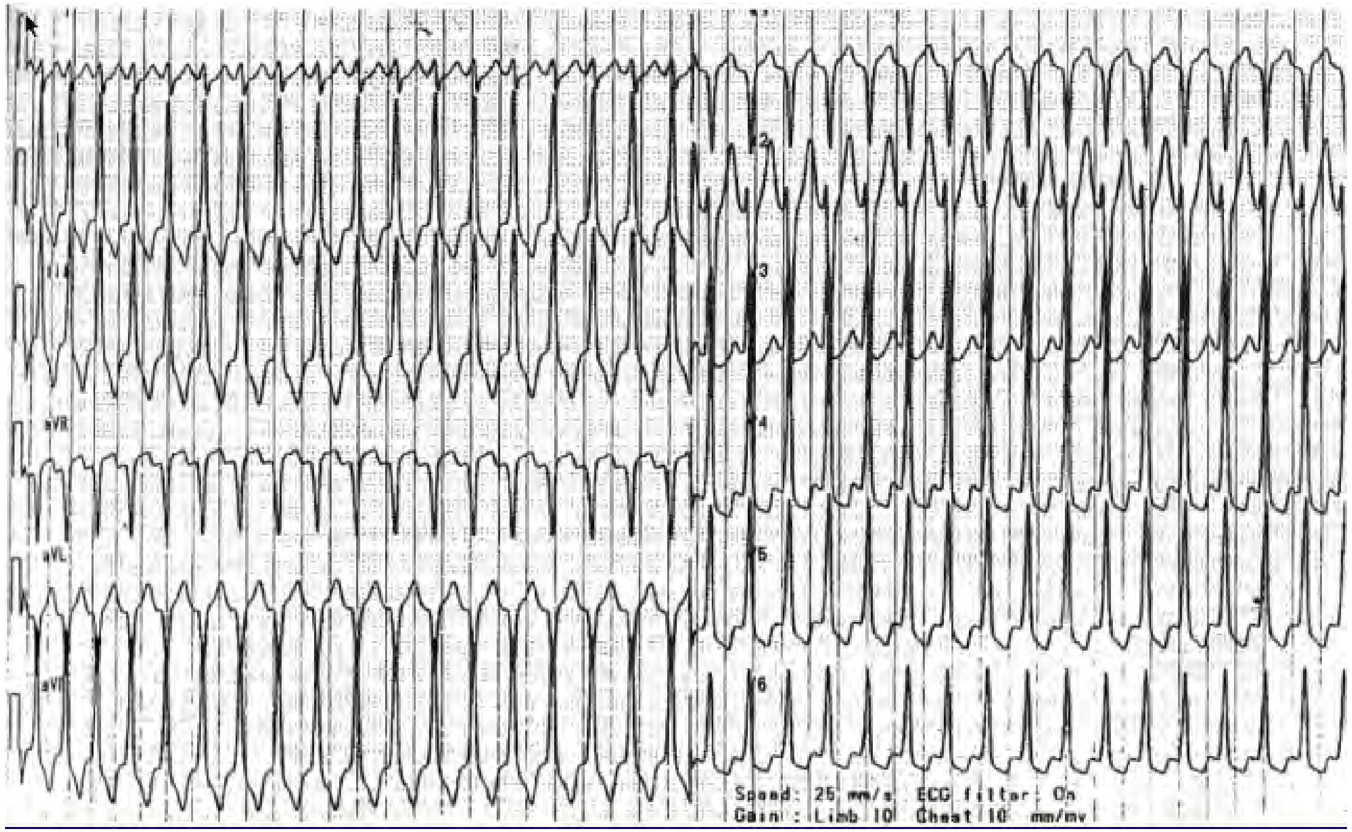
- If accessory pathway not capable of anterograde conduction, the ECG may not show delta wave (concealed pathway)

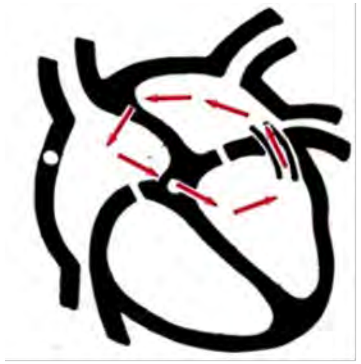
- If accessory pathway capable of rapid antegrade conduction
  - Increased risk to develop VF from rapid conduction of AF

Tachycardia with Accessory pathways



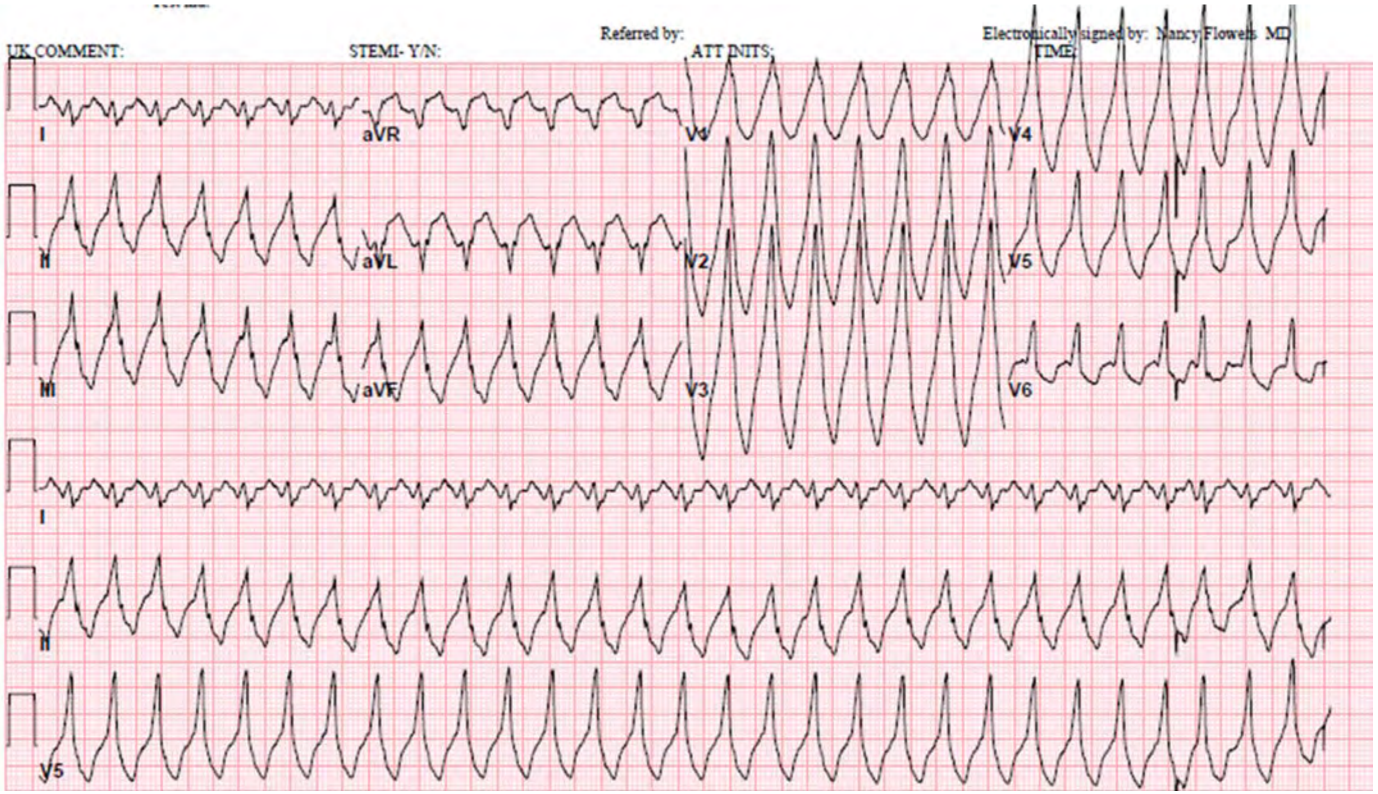
Orthodromic Tachycardia

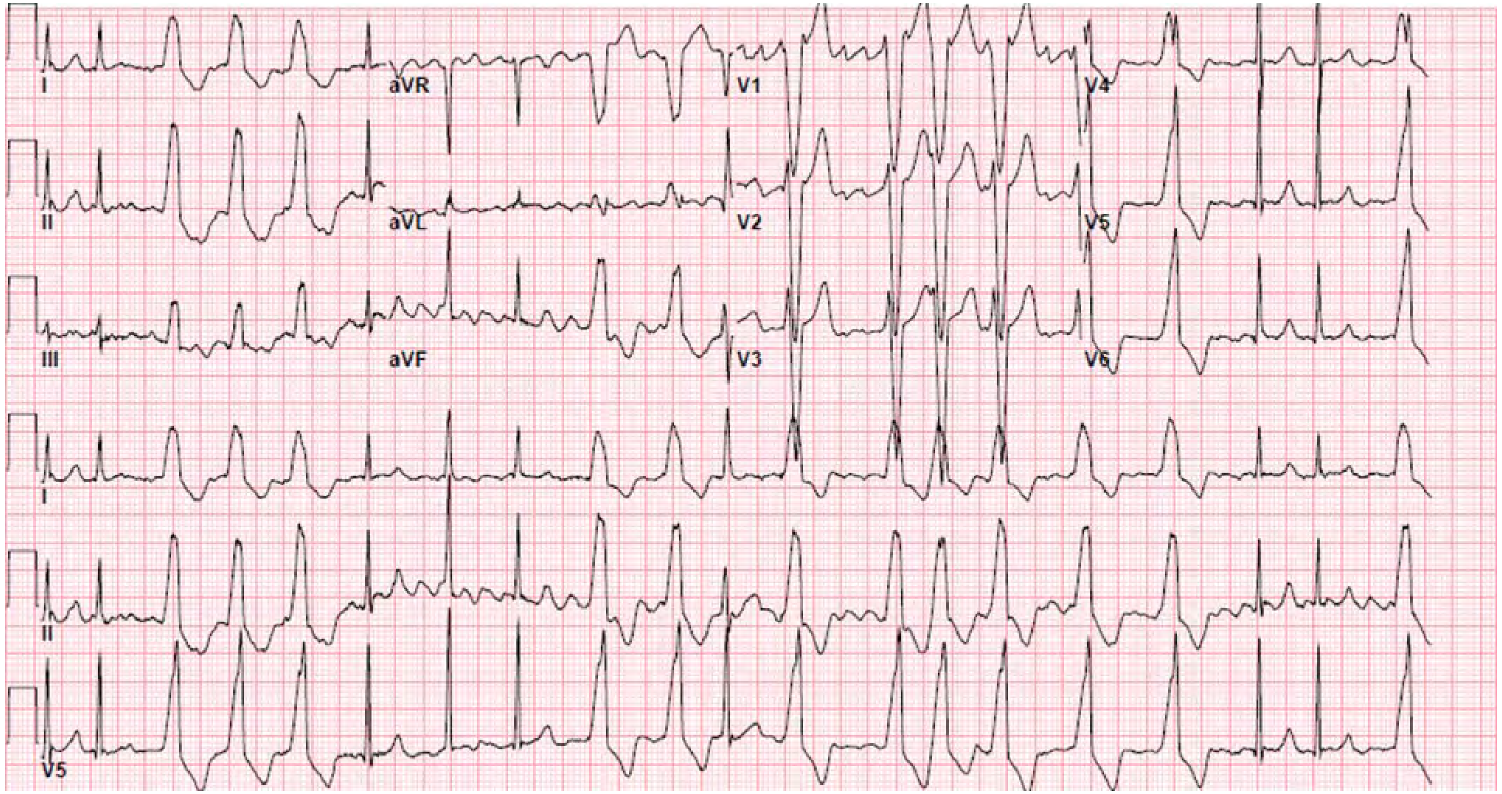


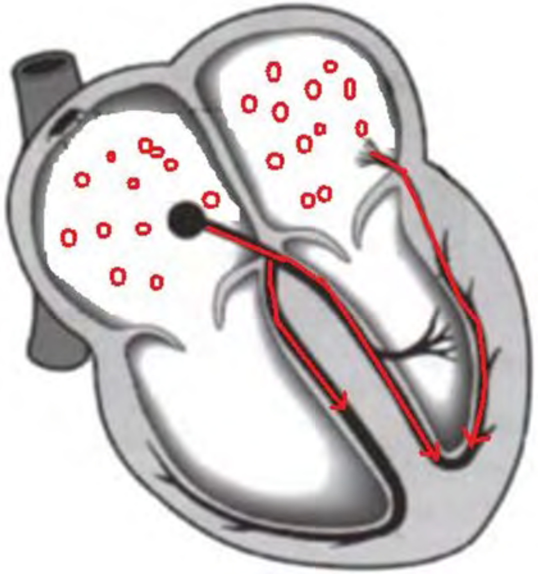


Kay NG. Am J of Med. 1996;10:344-356.

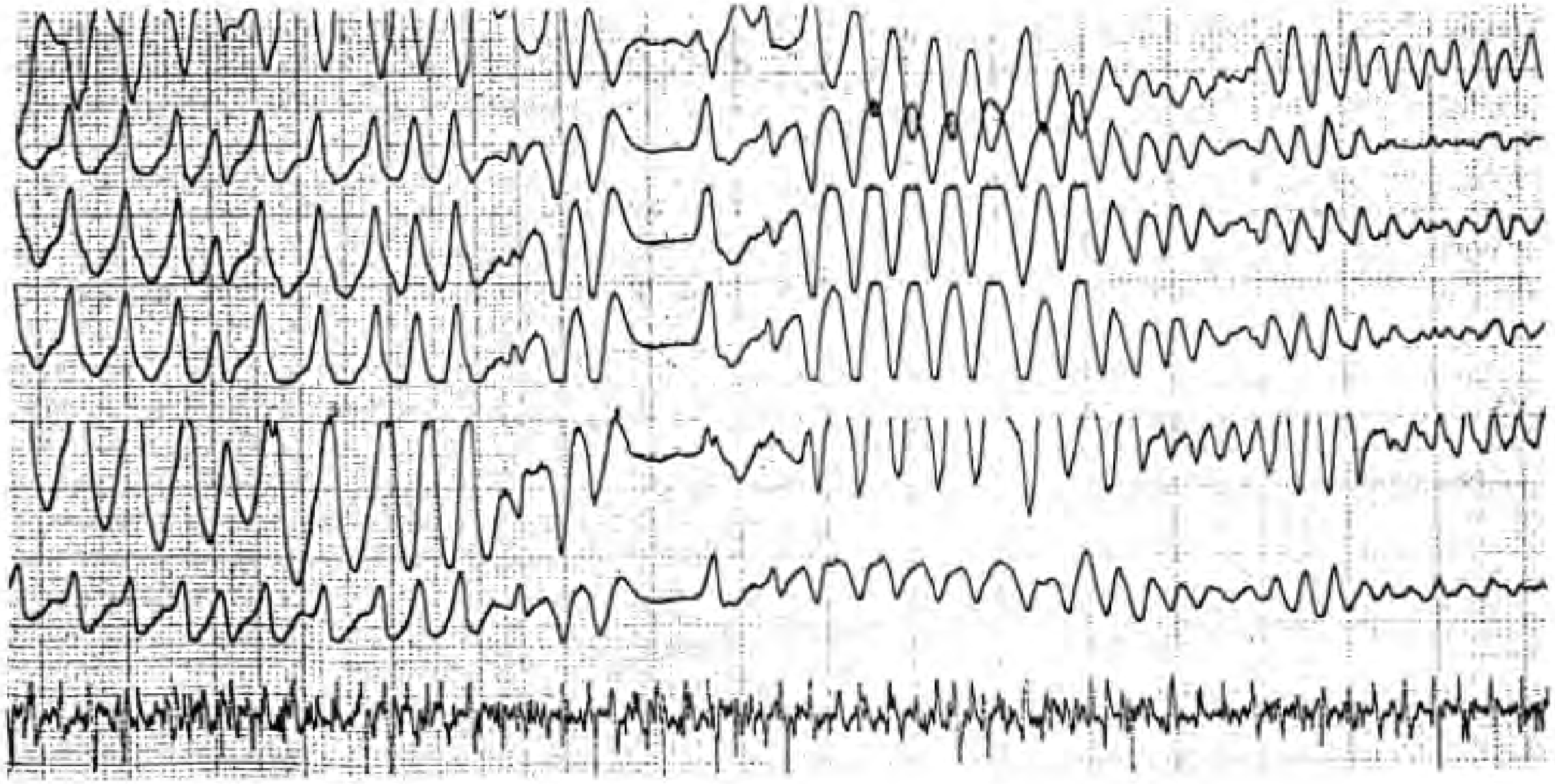
Antidromic tachycardia




I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
I
II
V5



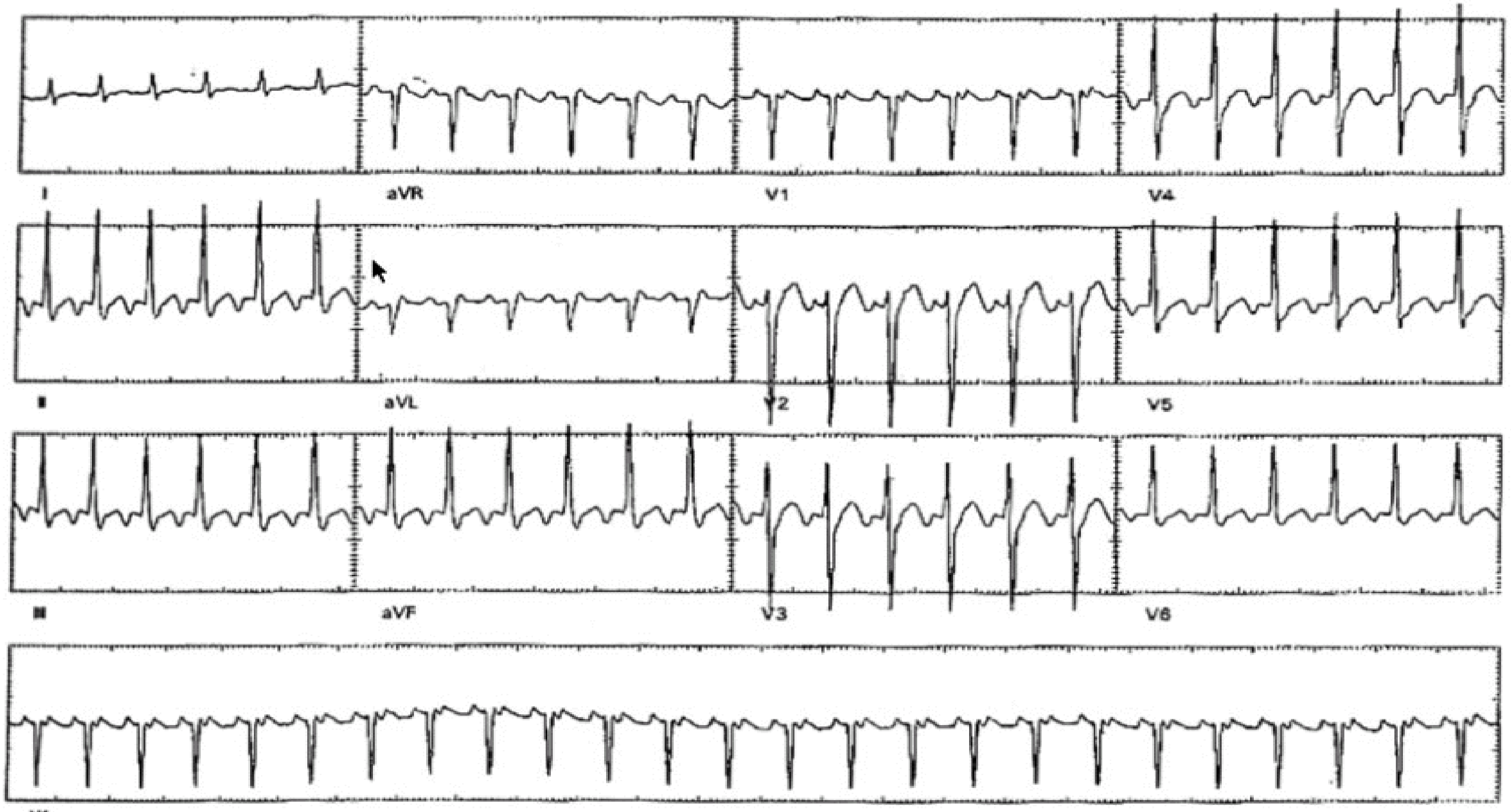
AF → VF



Courtesy of Dr. Brian Olshansky.

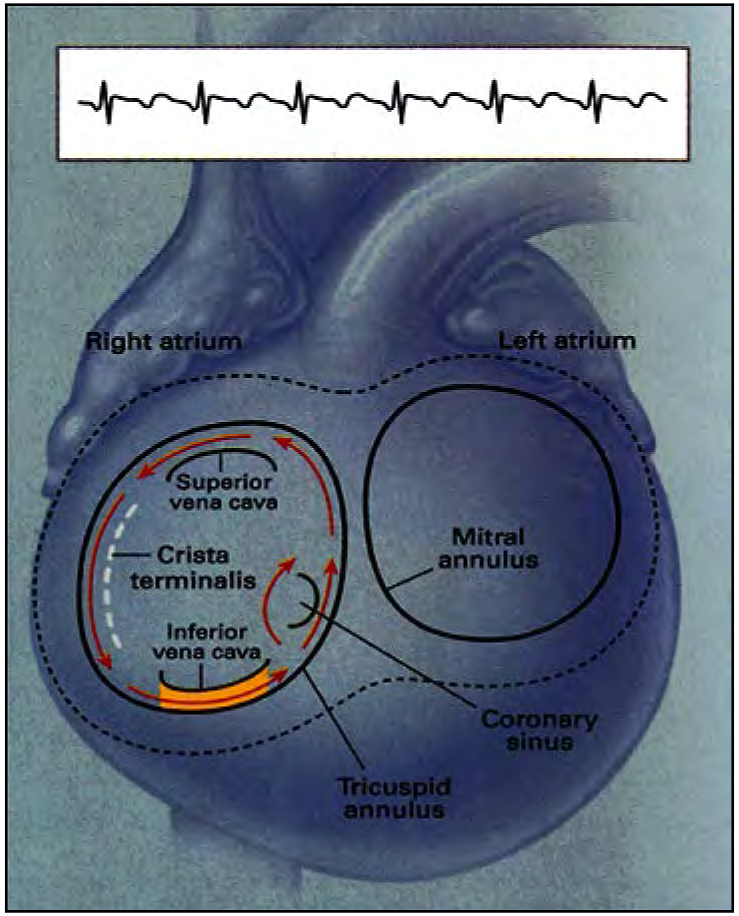
Atrial Flutter

- Macro-reentrant circuit
- May be the cause of AF in many patients



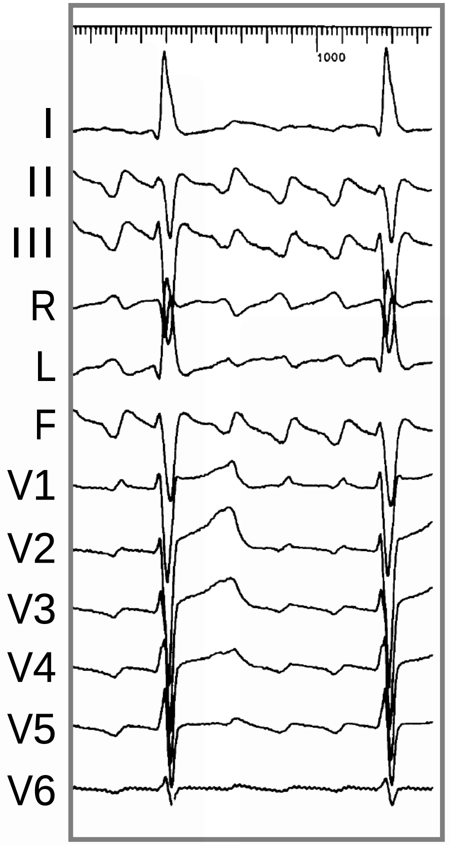
Reentry Circuit of Common Atrial Flutter

LAO View

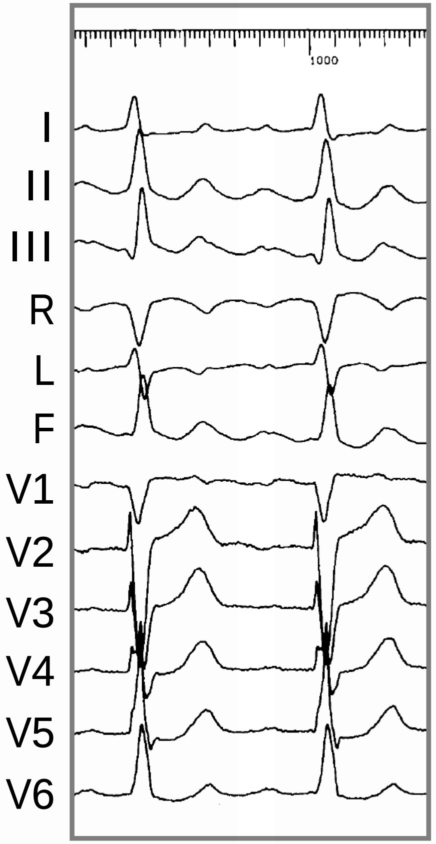


Morady F. N Engl J of Med. 1999;340:534-544.

Atrial Flutter: *Isthmus Dependent*

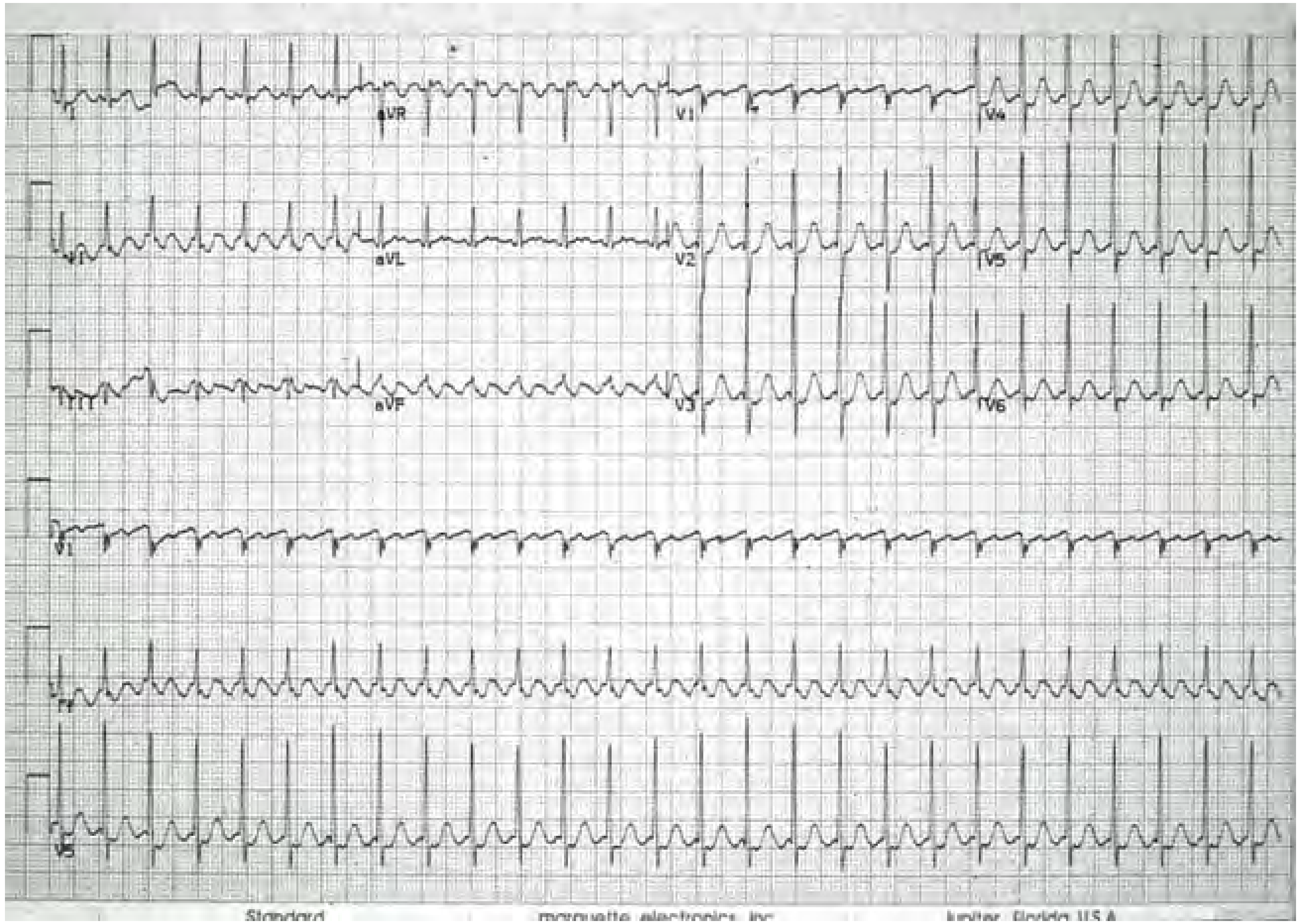


CCW



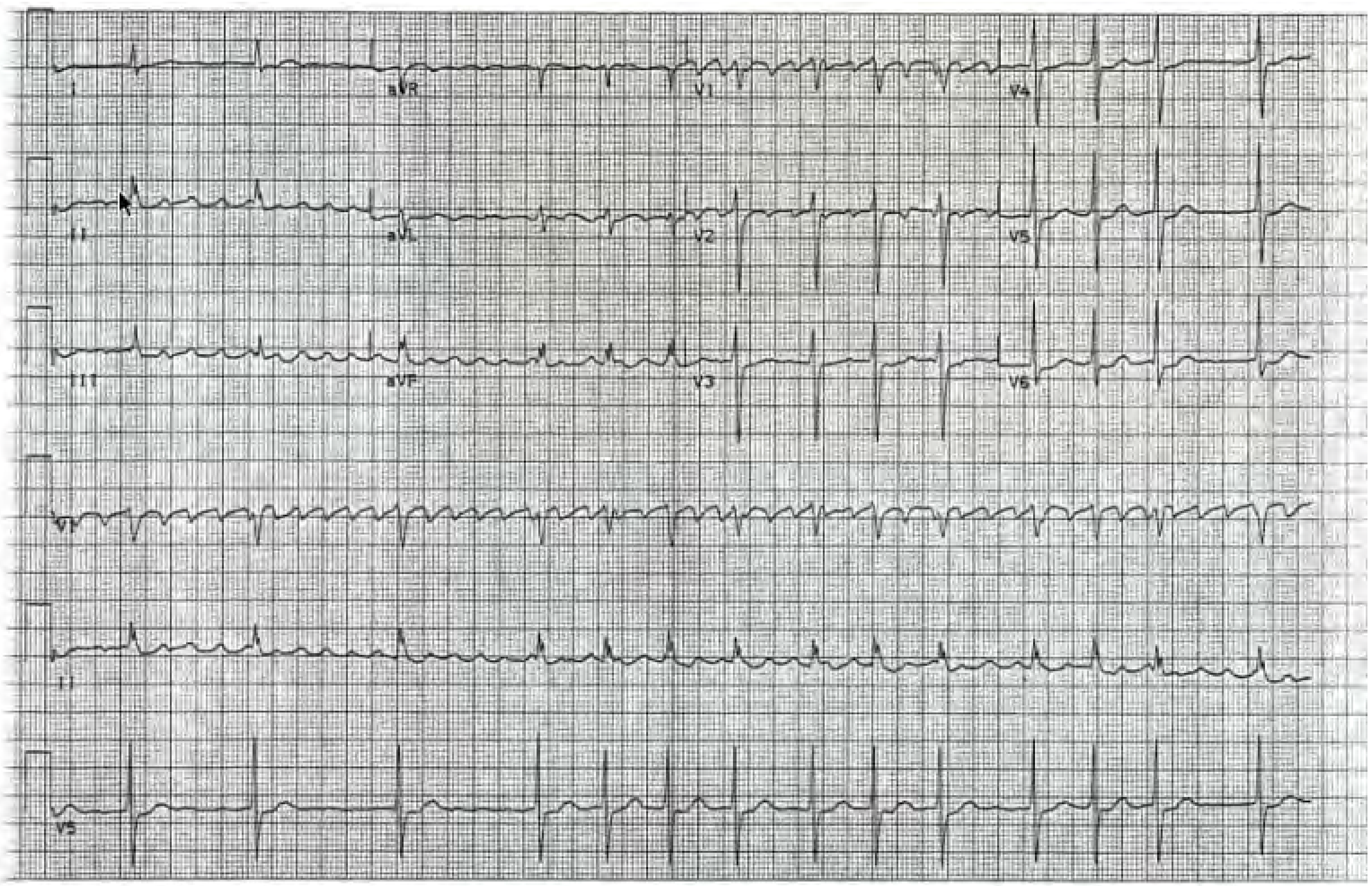
CW

Counterclockwise Atrial Flutter



Courtesy of Dr. Brian Olshansky.

Clockwise Atrial Flutter

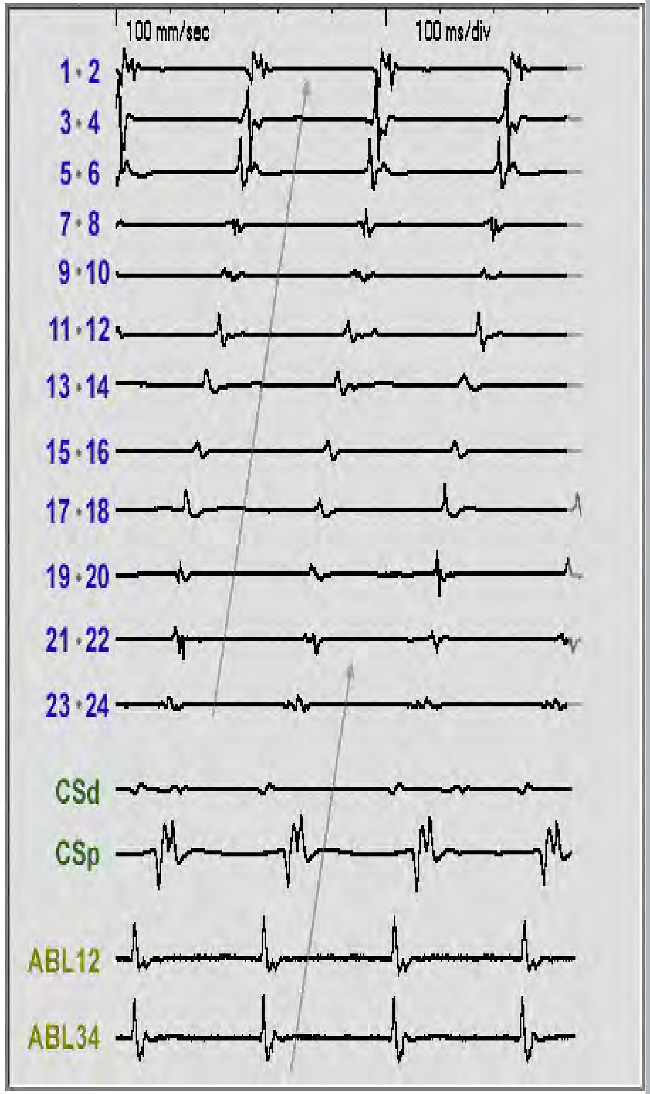


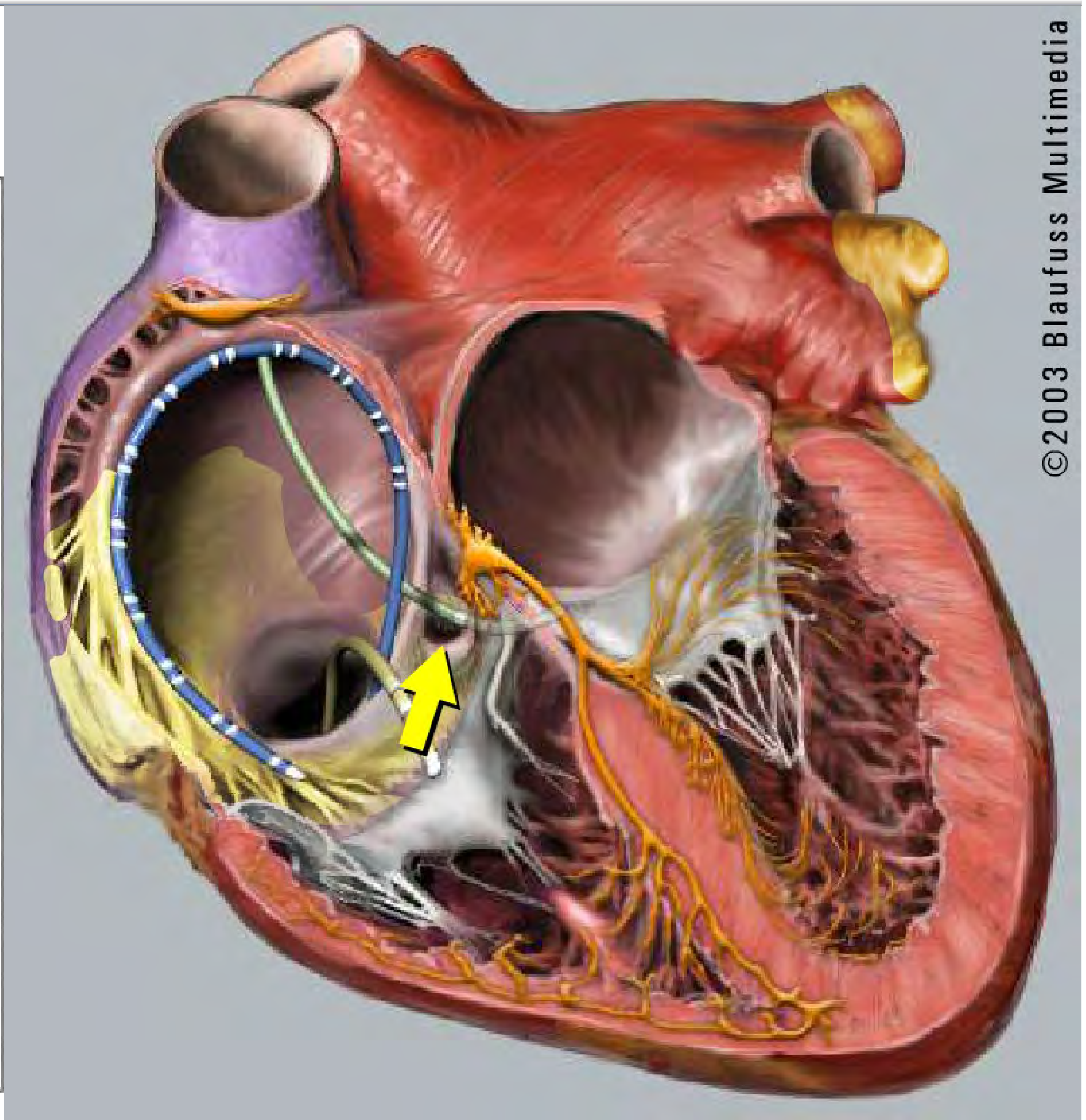
Therapeutic options

- Rate control: AV blocking agents
- Rhythm control: Cardioversion
- Anticoagulation

Atrial Flutter: Catheter mapping

Atrial activation during atrial flutter.





AF after atrial Flutter Ablation

- 25% experience AF after atrial flutter ablation
- Easier to manage AF
- Flutter initiates AF in some patients

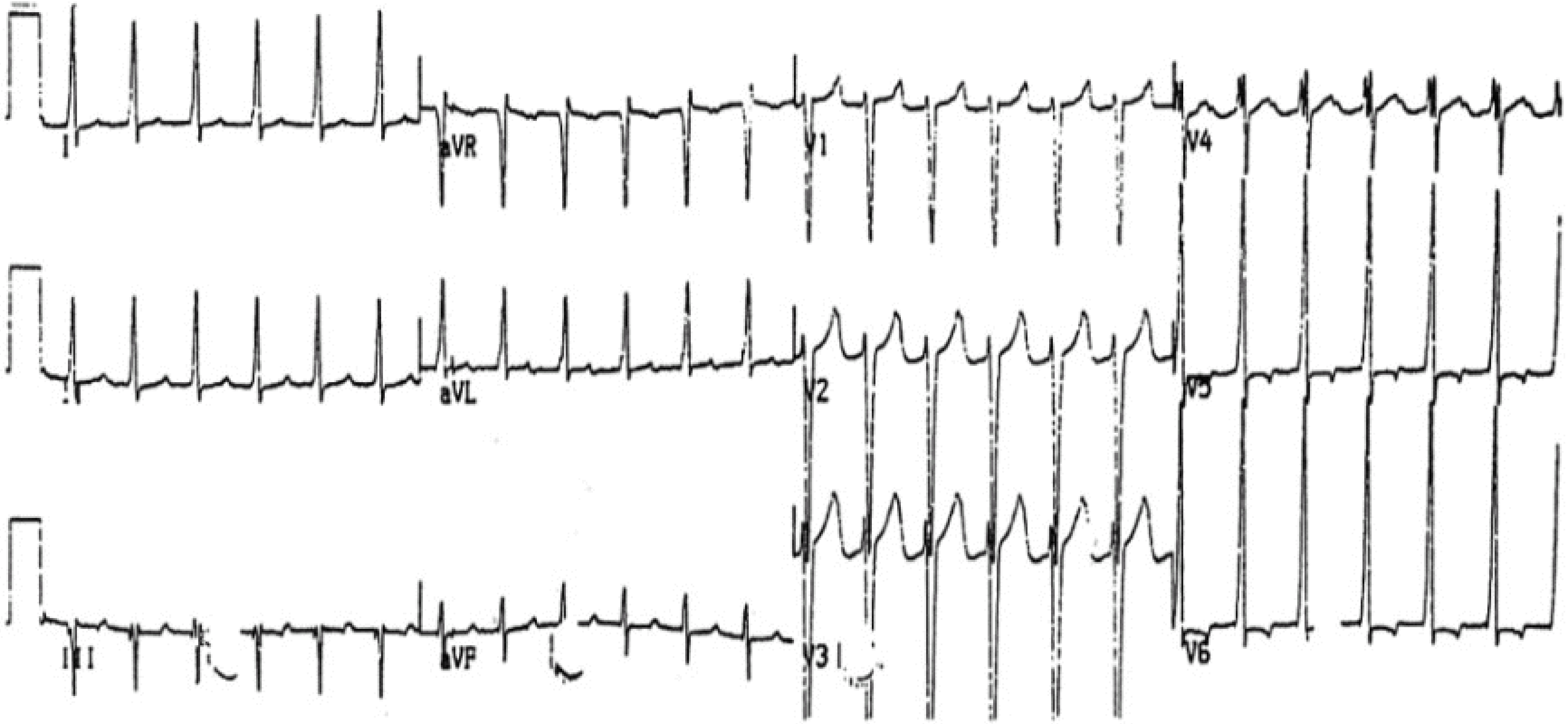
Atrial Tachycardia

- 5-15% of all SVT
  - Higher in pediatric population
  - Normal hearts
  - S/P surgery for congenital lesions
- Paroxysmal or persistent
  - Persistent atrial tachycardia can cause tachycardia induced cardiomyopathy

Tracy C. Cardiology Clinics. 1997;15:607-621.

Atrial Tachycardia

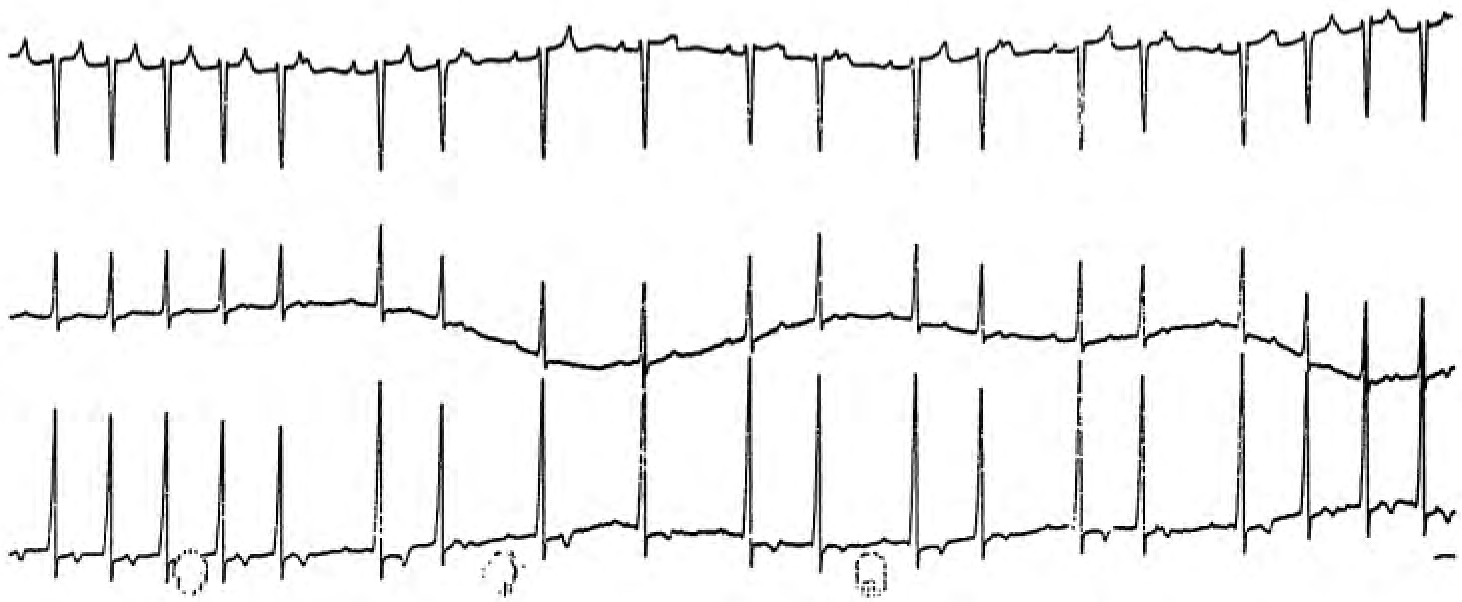
Baseline ECG



Tracy C. Cardiology Clinics. 1997;15:607-621.

Atrial Tachycardia

Transient AV Block After 12 mg IV Adenosine



Tracy C. Cardiology Clinics. 1997;15:607-621.

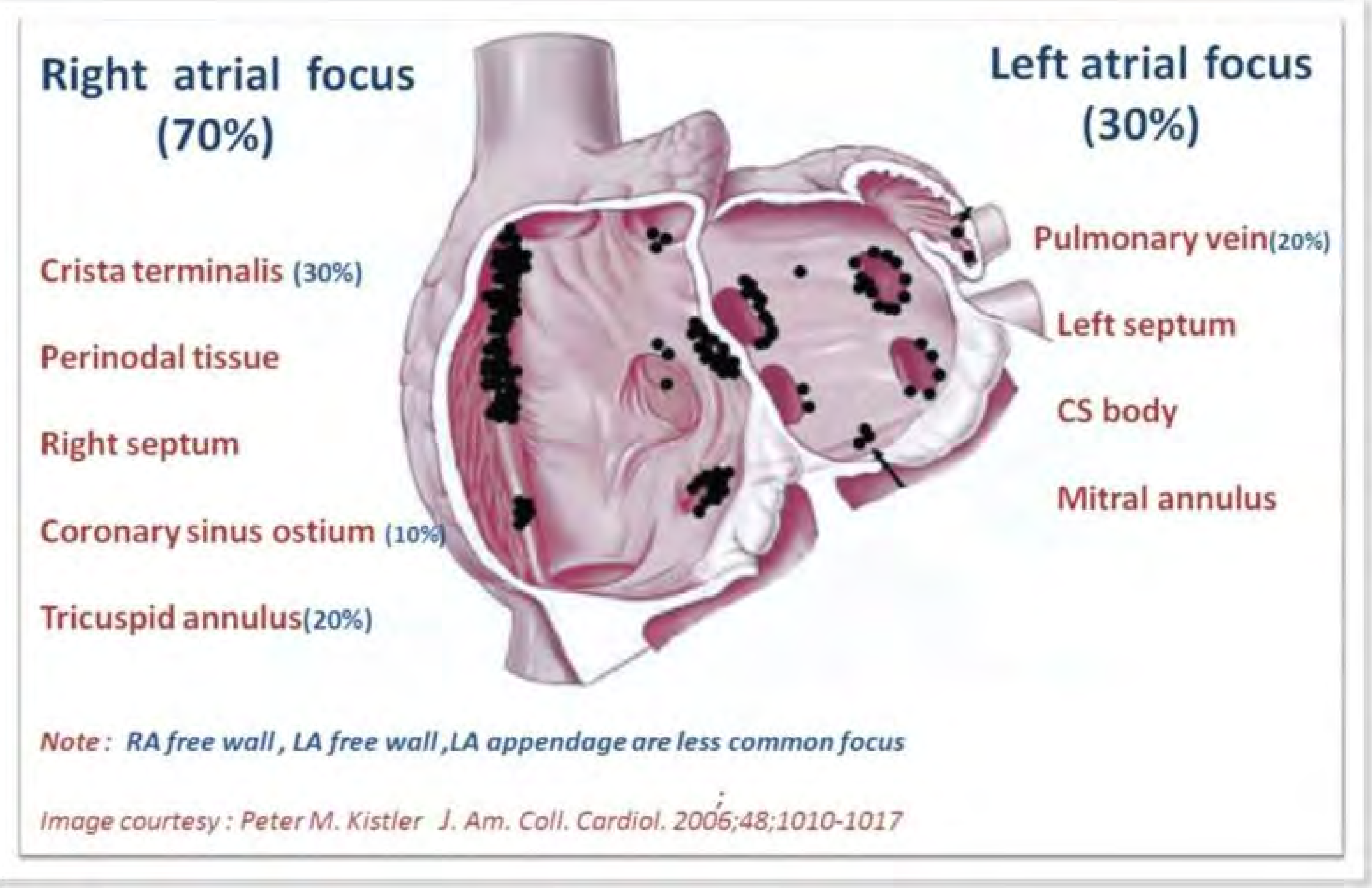
Treatment of Atrial Tachycardia

RF Ablation

- Improved success
  - Efficacy 80-98%
  - Recurrence 5-20%
  - Complications 1.6%
- Ablations for multiple foci less successful

Tracy C. Cardiology Clinics. 1997;15:607-621.

AT: Anatomical location

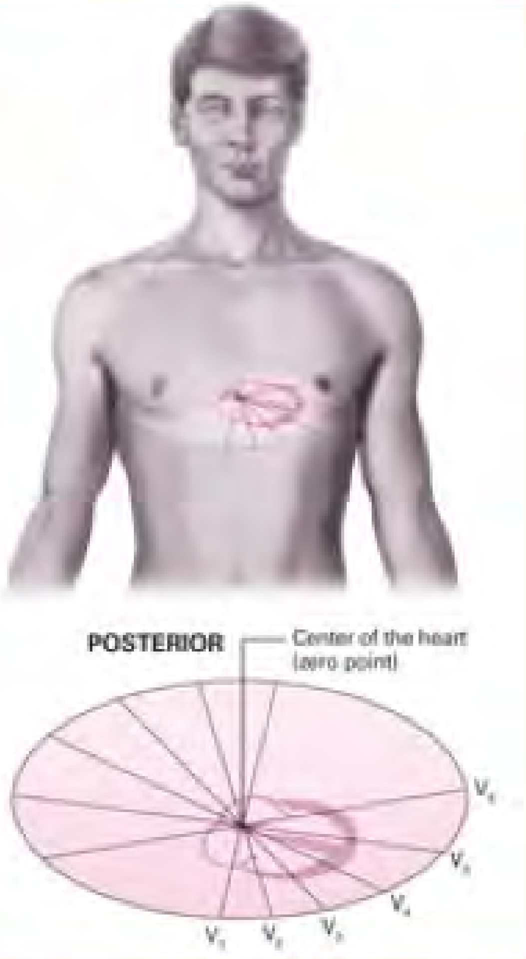


Location of AT by P wave morphology

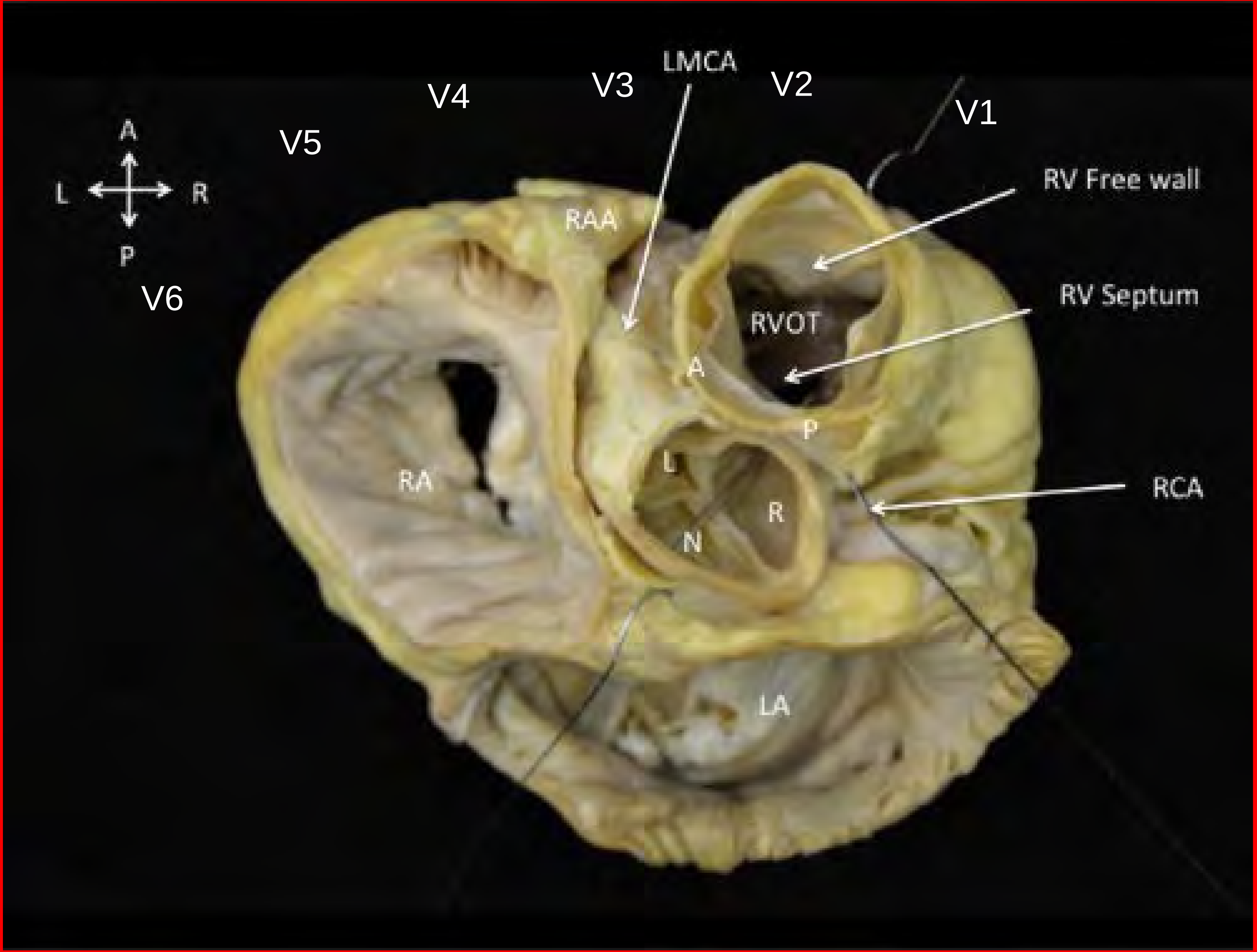
	RA	**LA**
AVL	Positive	Negative/isoelectric
V1	Negative/biphasic	Positive
I		Isoelectric or negative P wave (very specific , non sensitive, relatively uncommon)

Precordial Views

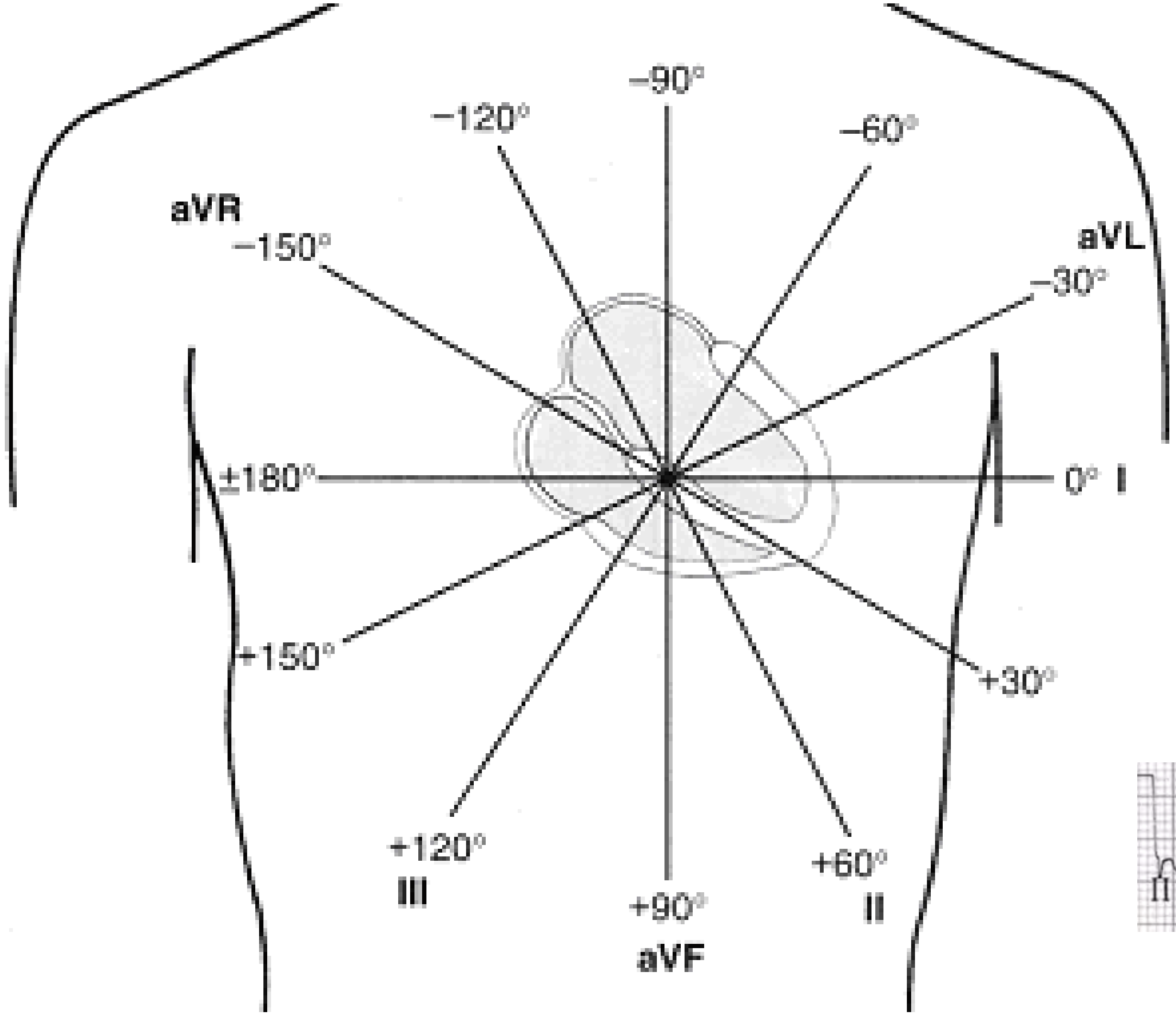
These illustrations show different views of the heart obtained from each precordial (chest) lead.



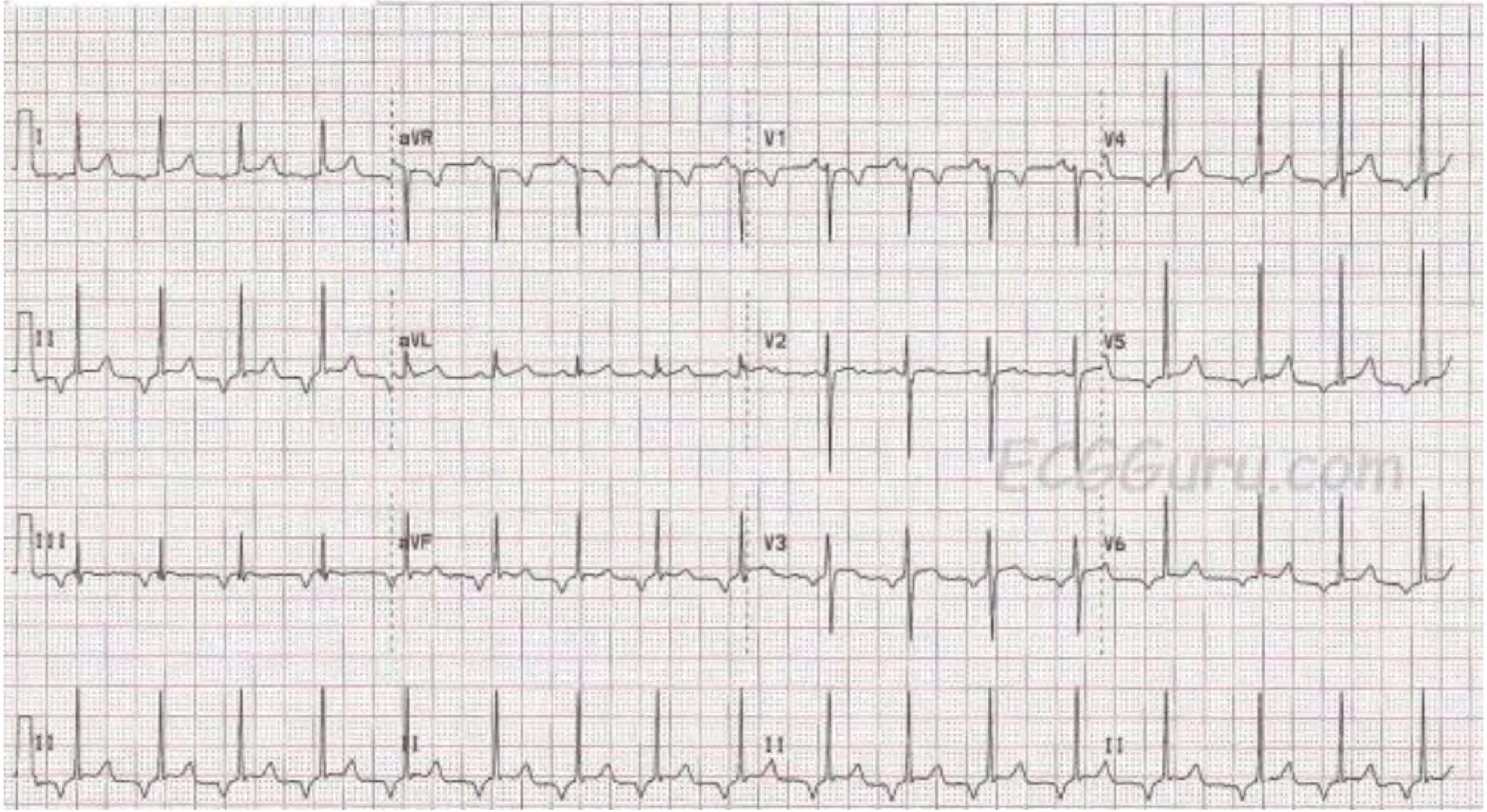
Source: *Interpreting difficult ECG: A rapid reference.* Philadelphia, Pa: Lippincott Williams & Wilkins; 2006:26.

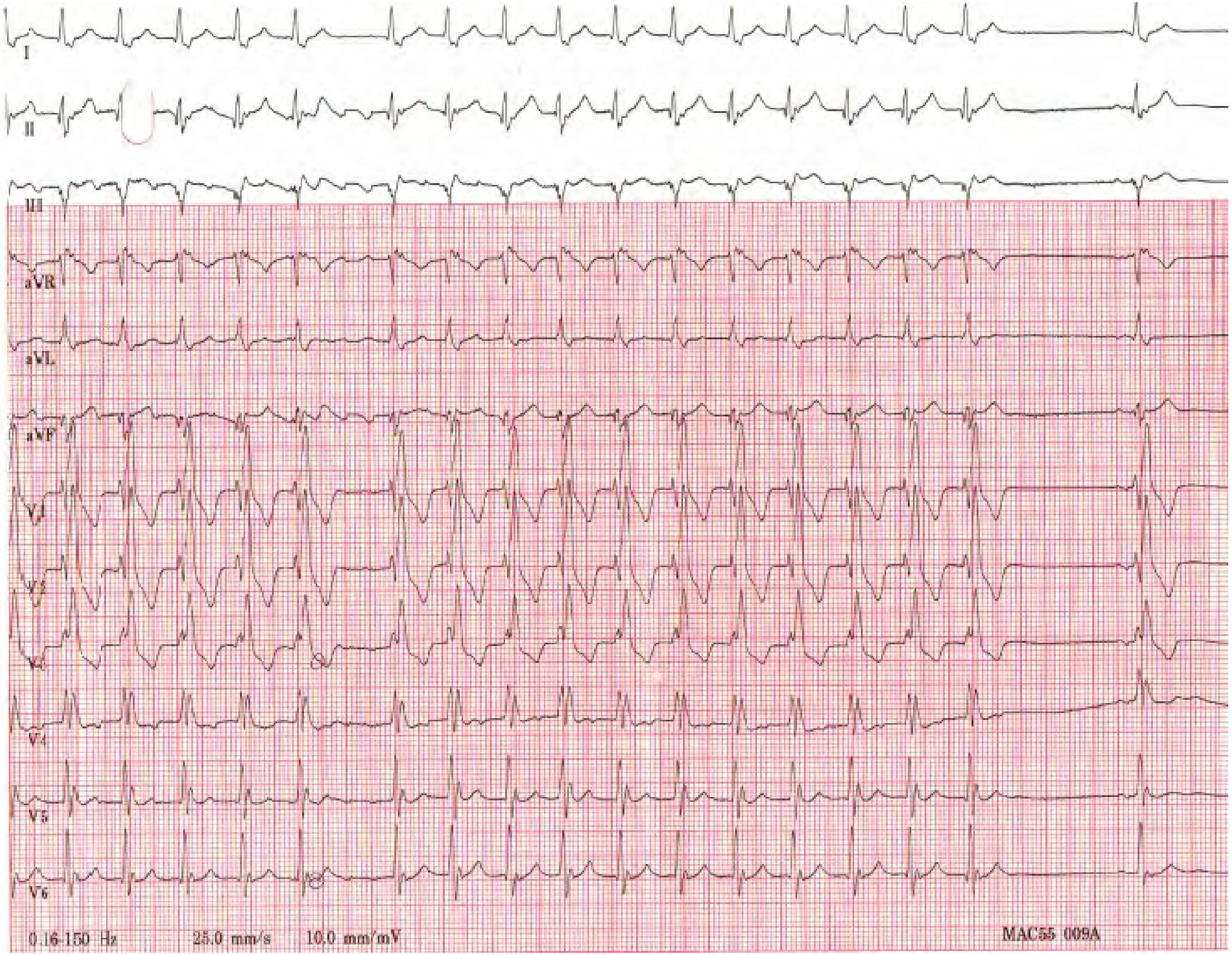

LMCA
V1
V2
V3
V4
V5
V6
A
L
R
P
RV Free wall
RAA
RVOT
RV Septum
A
P
L
RA
R
N
RCA
LA


II


−90°
−120°
−60°
aVR
−150°
aVL
−30°
±180°
0° I
+150°
+30°
+120°
III
+90°
aVF
+60°
II


II

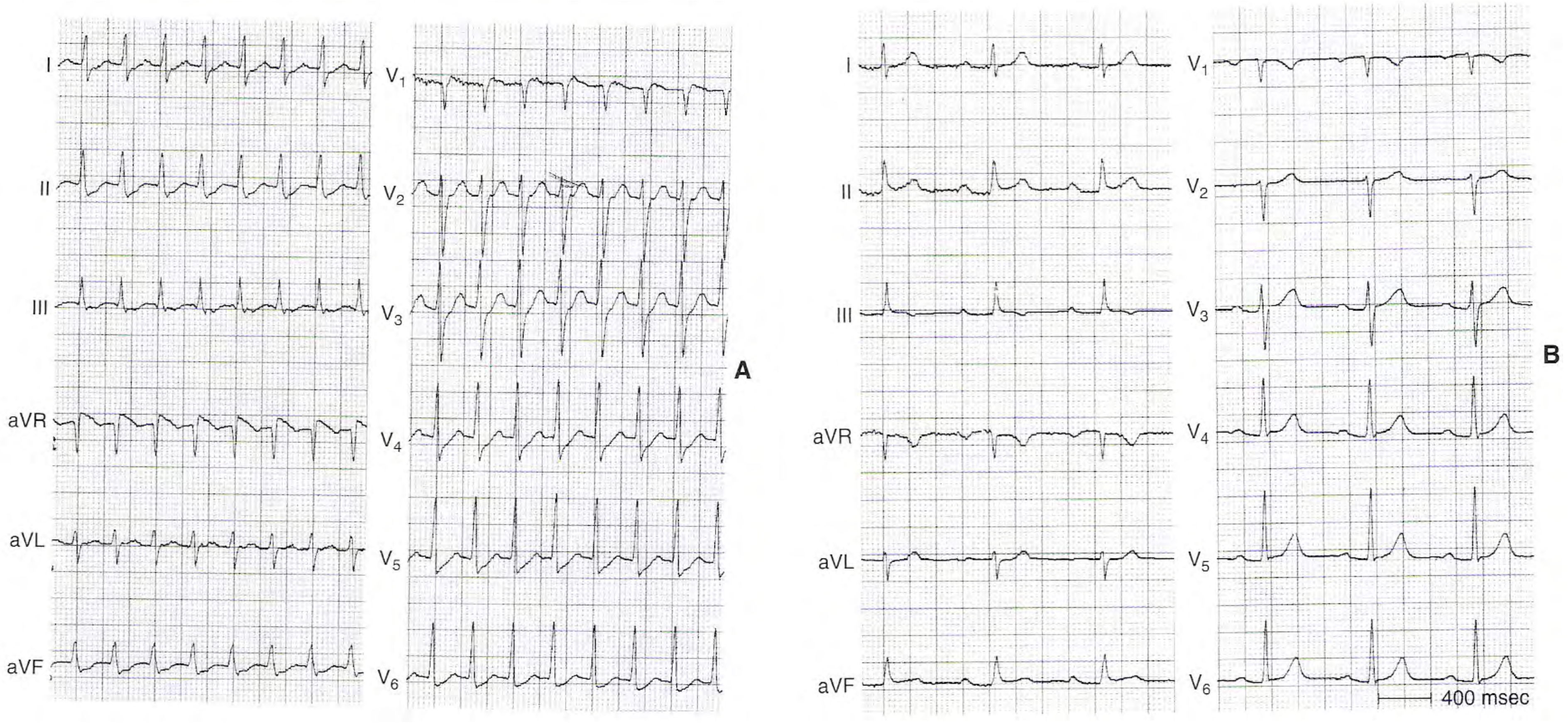

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
II
II
II
ECGGuru.com



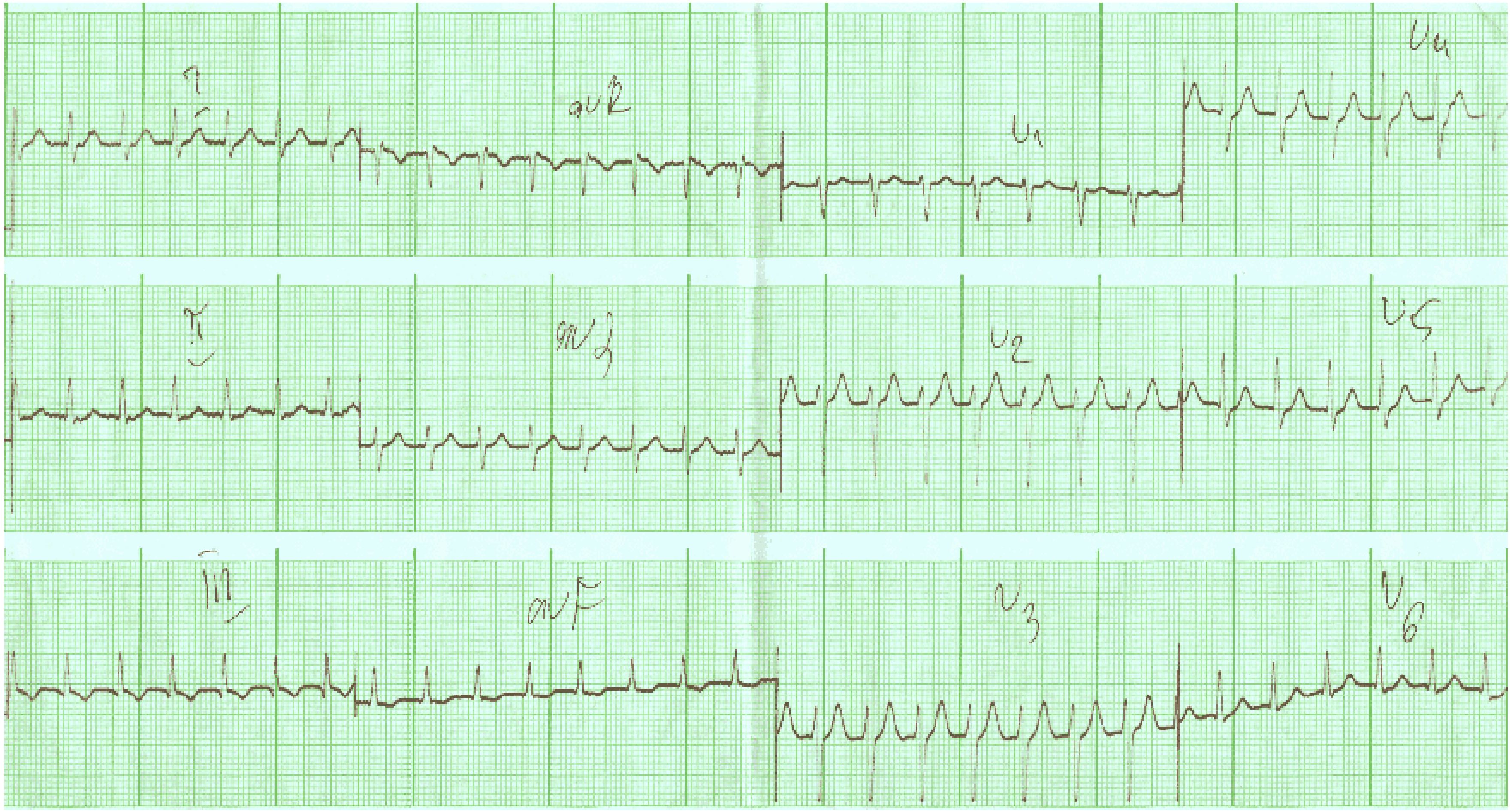
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
0.16-150 Hz
25.0 mm/s
10.0 mm/mV
MAC55 009A

SVT with aberrancy

Diagnosis?


I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
A
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
B
400 msec

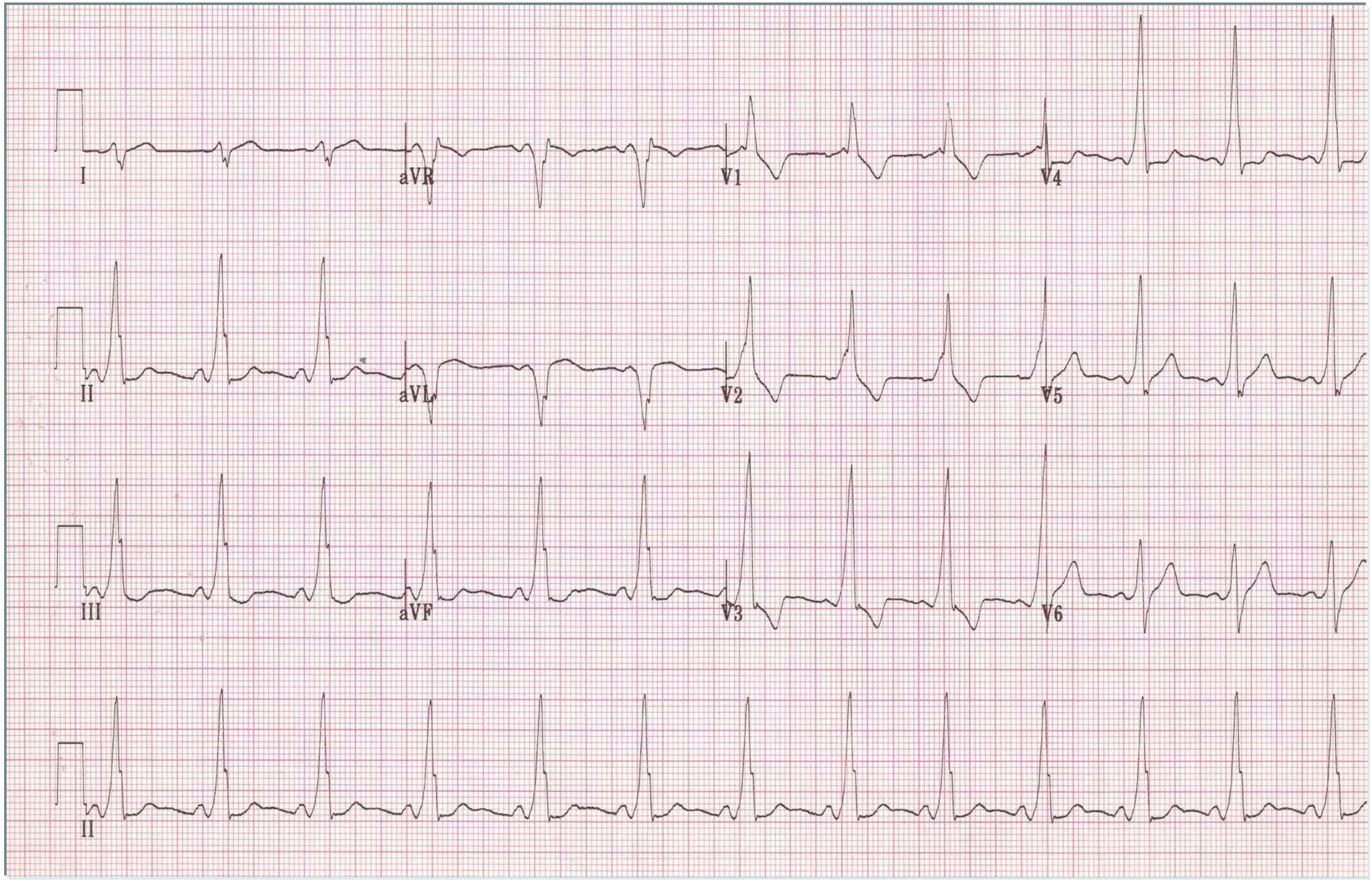
Diagnosis?



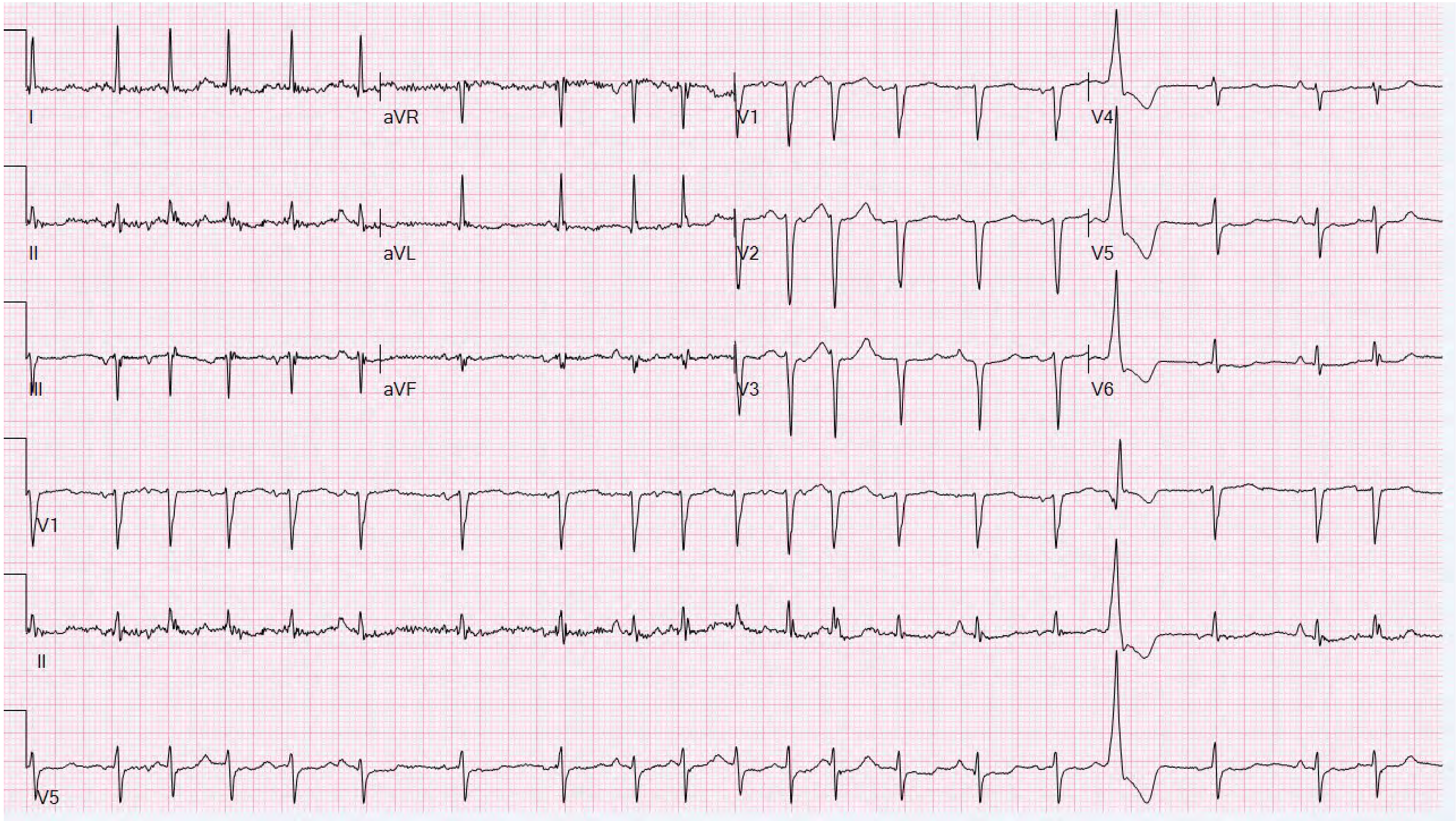
Diagnosis?

Diagnosis?

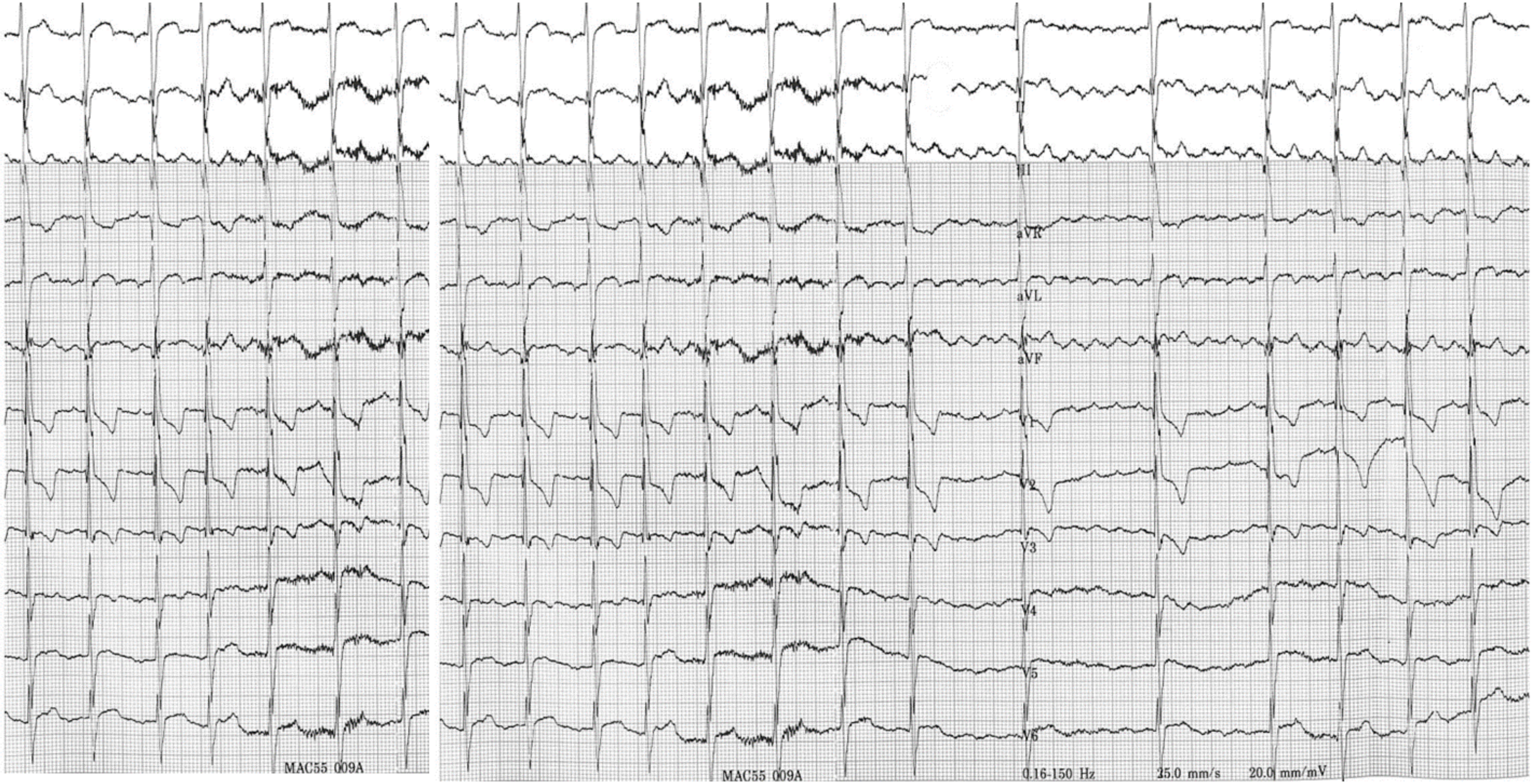
Diagnosis?



Diagnosis?



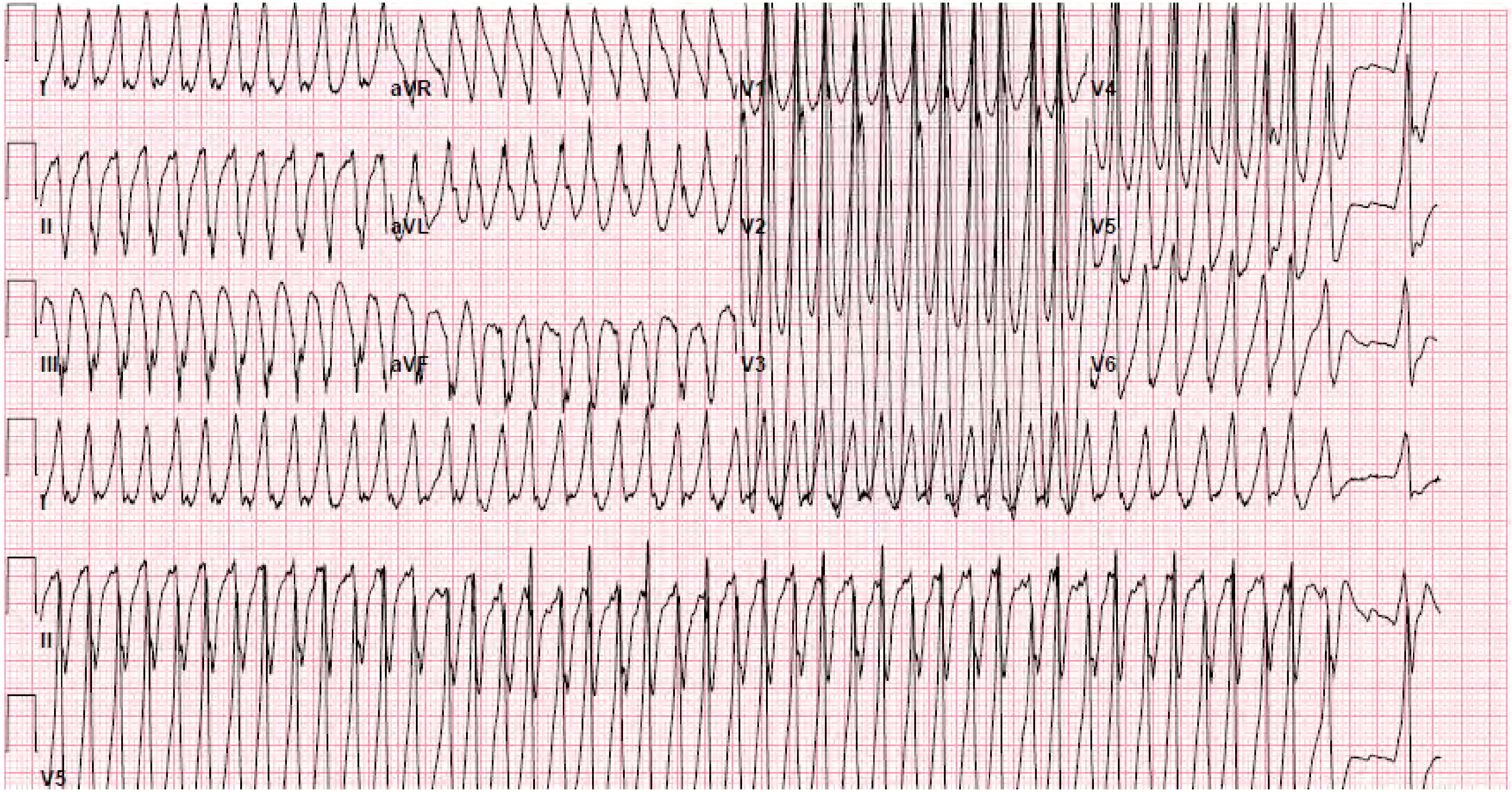
Diagnosis?



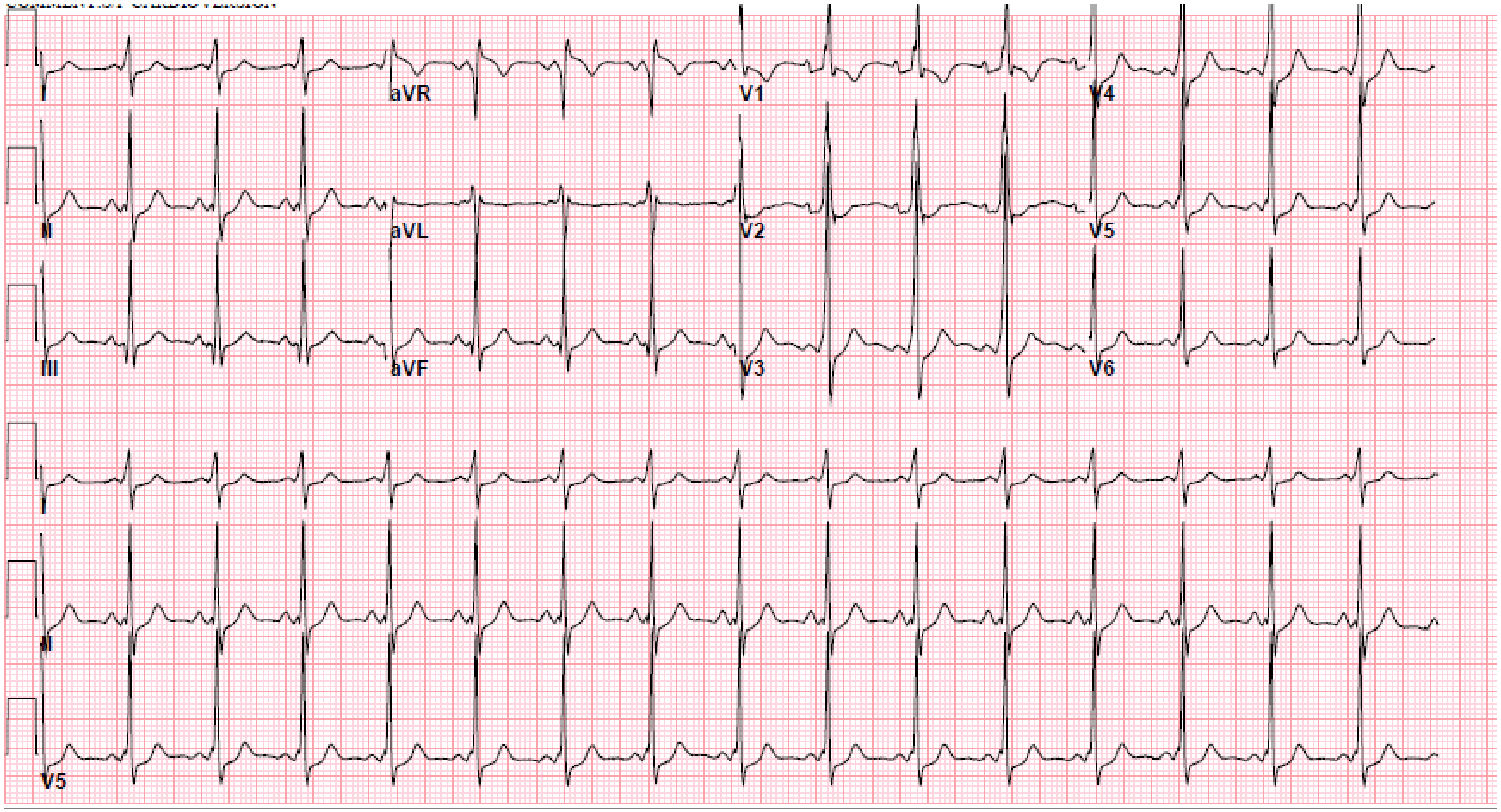
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
MAC55 009A
MAC55 009A
0.16-150 Hz
25.0 mm/s
20.0 mm/mV

EKG 1

Diagnosis?



EKG 2



All are AVN dependent except:

1. Antidromic AVRT
2. Typical AVNRT
3. Atrial tachycardia
4. Orthodromic AVNRT

Site of ablation for AVNRT is:

1. Fast pathway
2. Compact AVN
3. Slow pathway
4. Accessory AV connection

Patients with atrial flutter are at risk of developing:

1. AVRT
2. AVNRT
3. Atrial fibrillation
4. None of the above

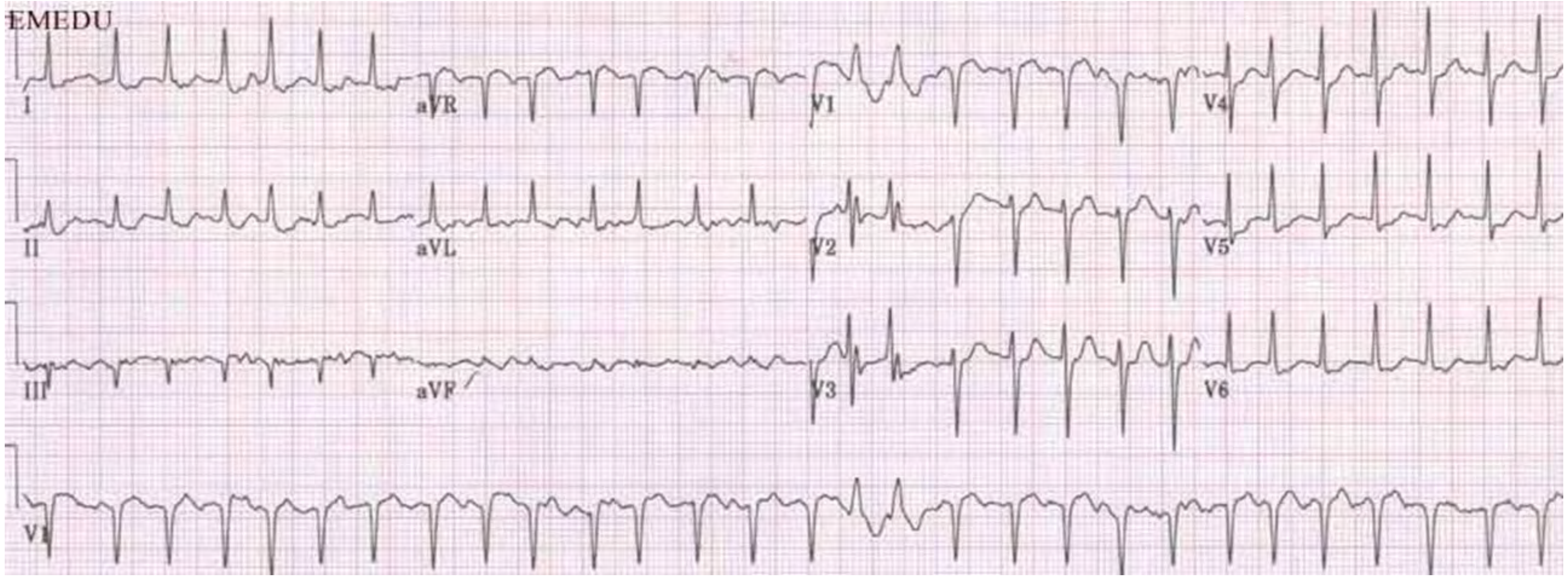
Most common anatomical location of AV connection is:

1. Left side
2. Right side
3. Atrial septum

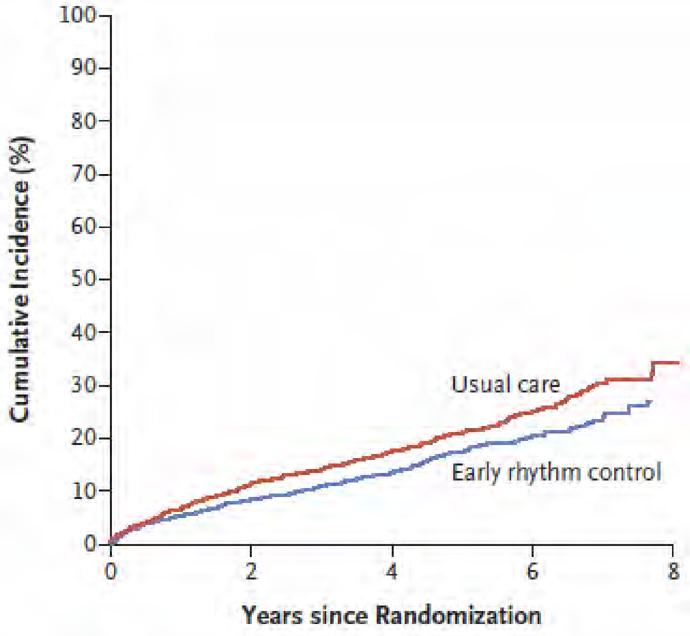
Thank you

Atrial fibrillation

- Rate versus rhythm control
- CHADSVASC score for anticoagulation
- AF ablation



EAST AFNET 4



No. at Risk

Usual care	1394	1169	888	405	34
Early rhythm control	1395	1193	913	404	26

Figure 2. Aalen–Johansen Cumulative-Incidence Curves for the First Primary Outcome.

The first primary outcome was a composite of death from cardiovascular causes, stroke, or hospitalization with worsening of heart failure or acute coronary syndrome.

Atrioventricular Conduction Abnormalities: Evaluation and Treatment

Yousef Darrat, MD

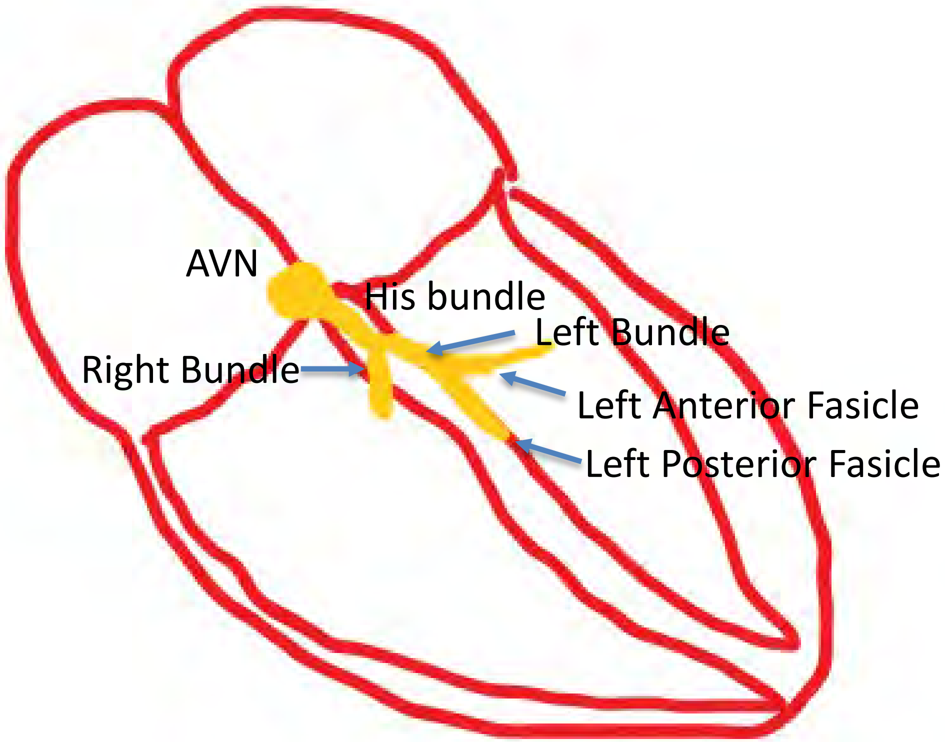
7/6/2021

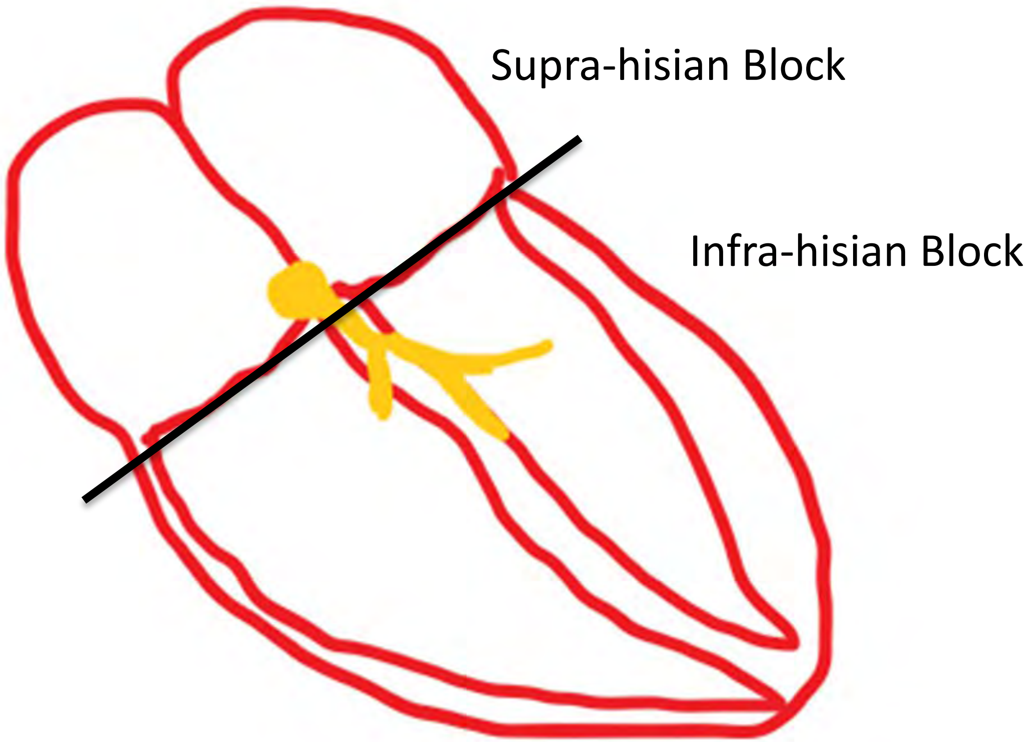
Objectives

- Identify degree and type of of AV block.
- Role of EPS in AV block.
- Understand pacemaker indications in AV block.
- When to implant a biV for AV block?

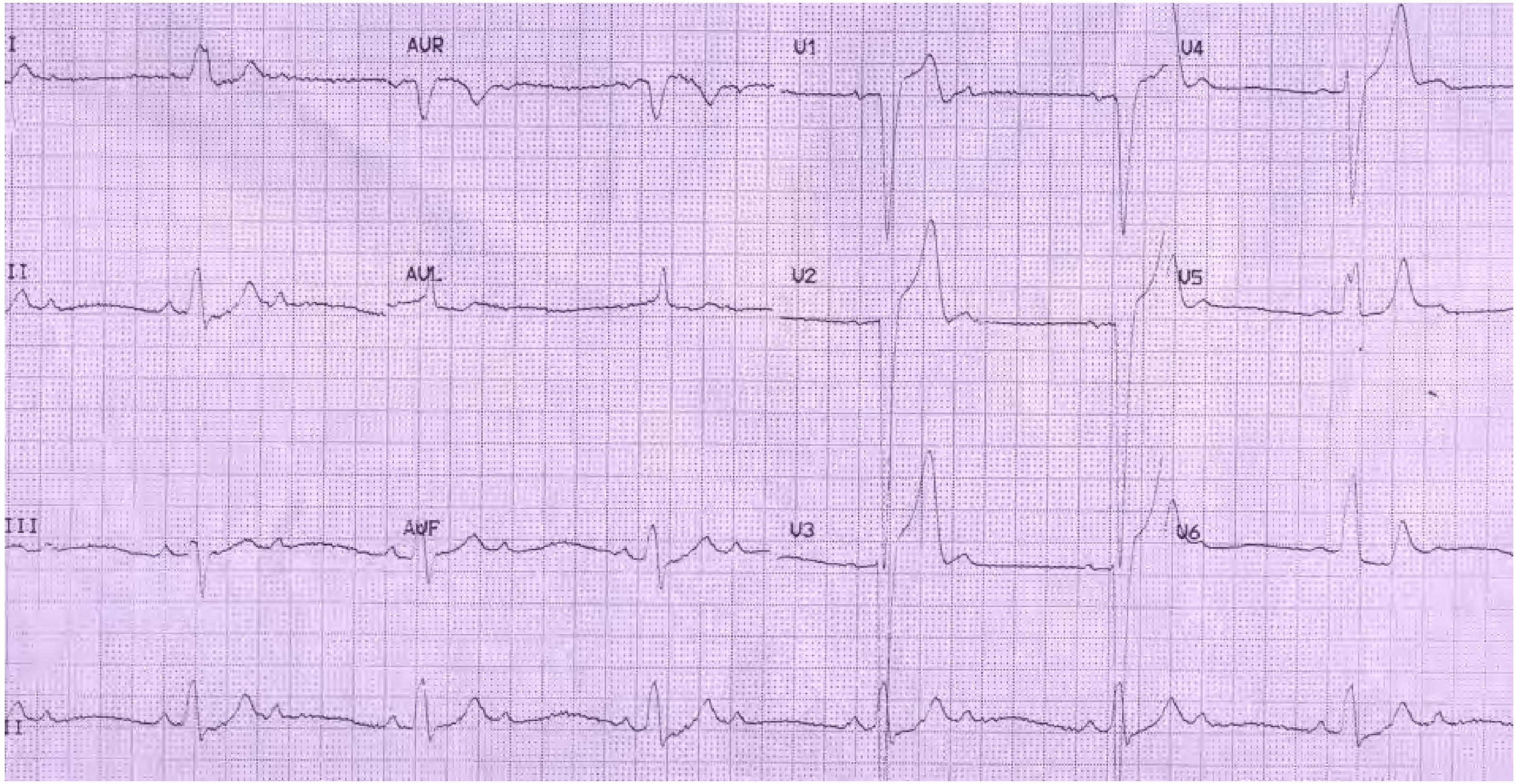
AV Block - Definitions

- **First Degree:** Prolonged conduction (>0.2 sec)
- **Second Degree:** Intermittent non-conduction
  - Type I: Progressive Prolongation
  - Type II: Sudden failure
- **Advanced second degree AV block**
- **Third Degree:** Persistent non-conduction
- **Anatomical:** supra or infra-hisian


AVN
His bundle
Left Bundle
Right Bundle
Left Anterior Fasicle
Left Posterior Fasicle


Supra-hisian Block
Infra-hisian Block

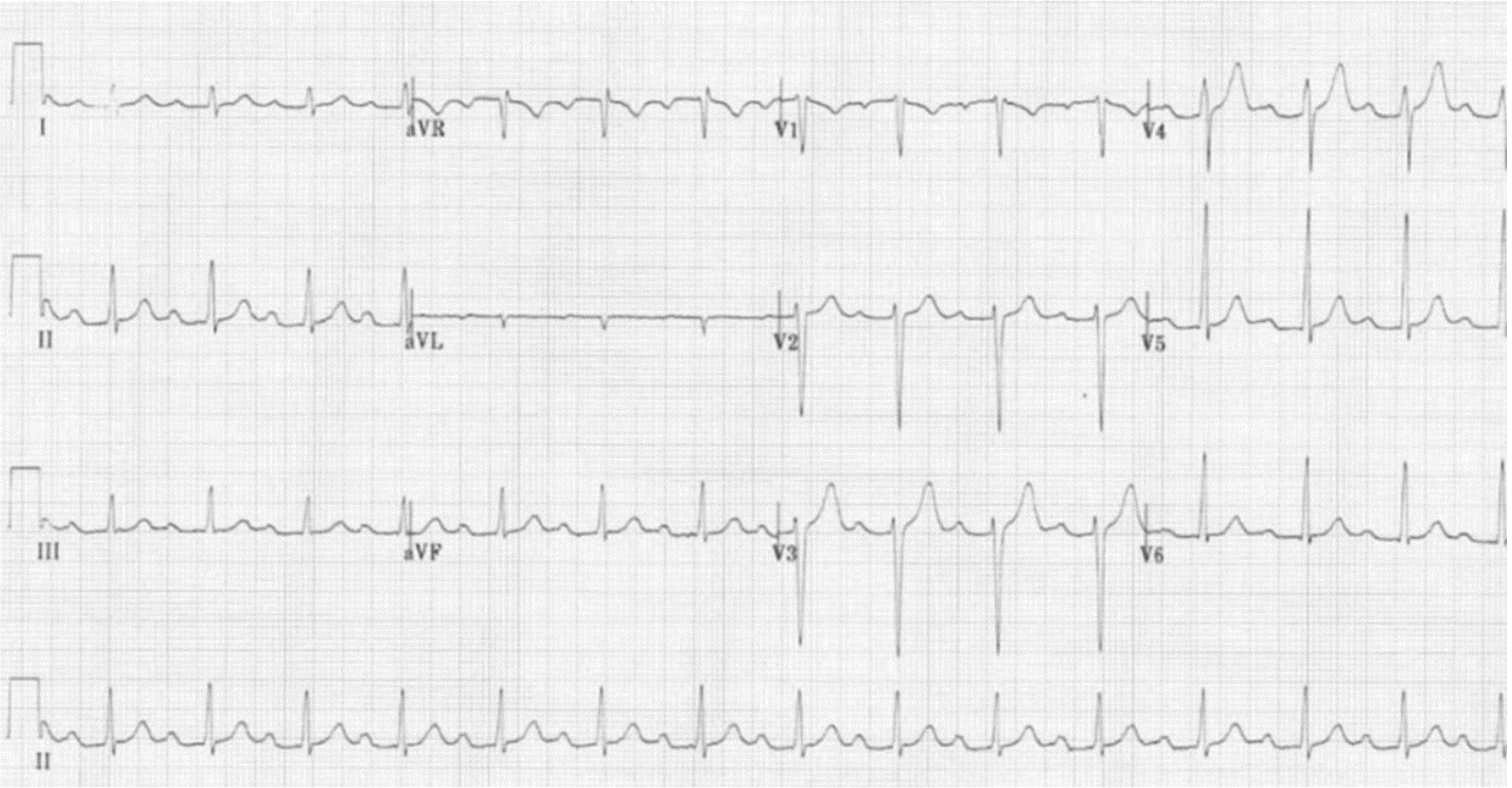
2:1 AV block



Advanced Second-Degree AV block

Case 1

- 73 year old with hypertension and diabetes presented for follow up. Has no complains. 12 lead EKG shown as follows.



- Next best step in management?

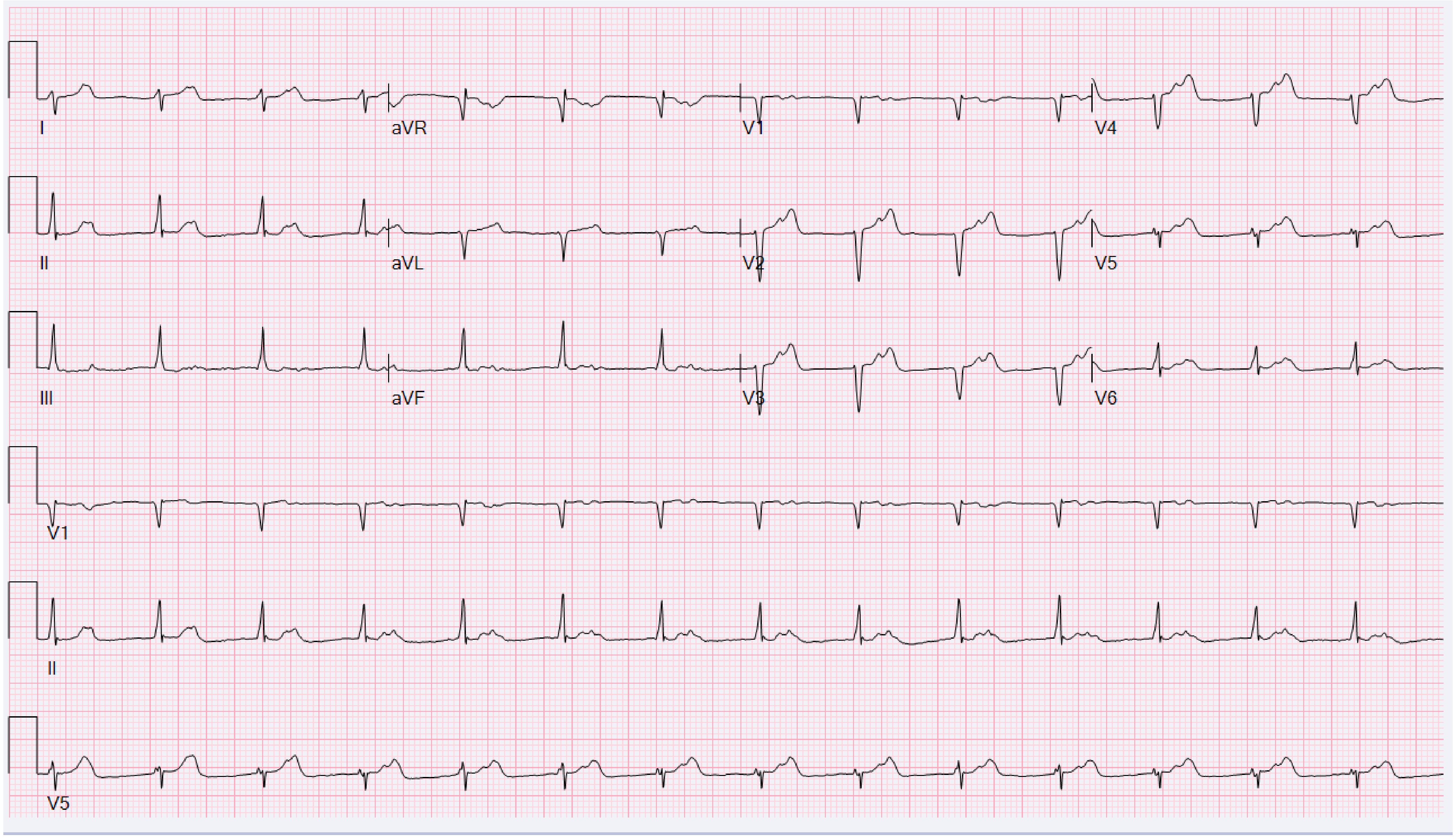
1- Refer for EPS

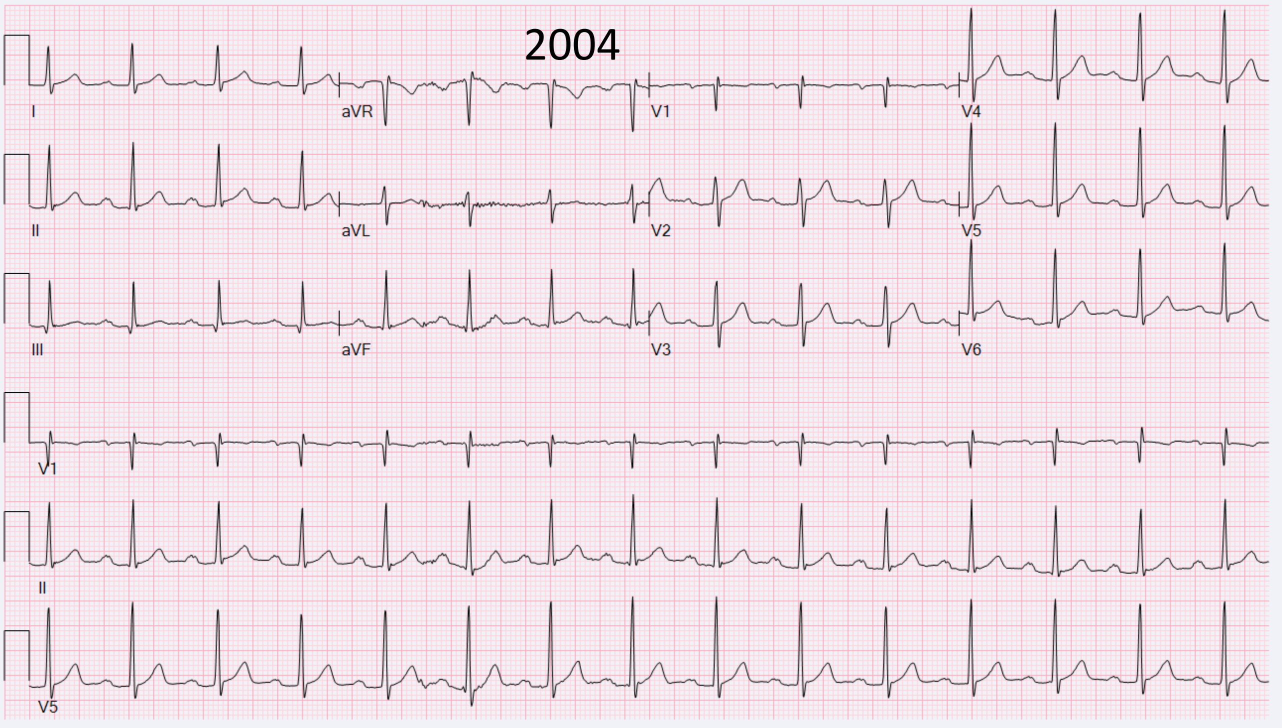
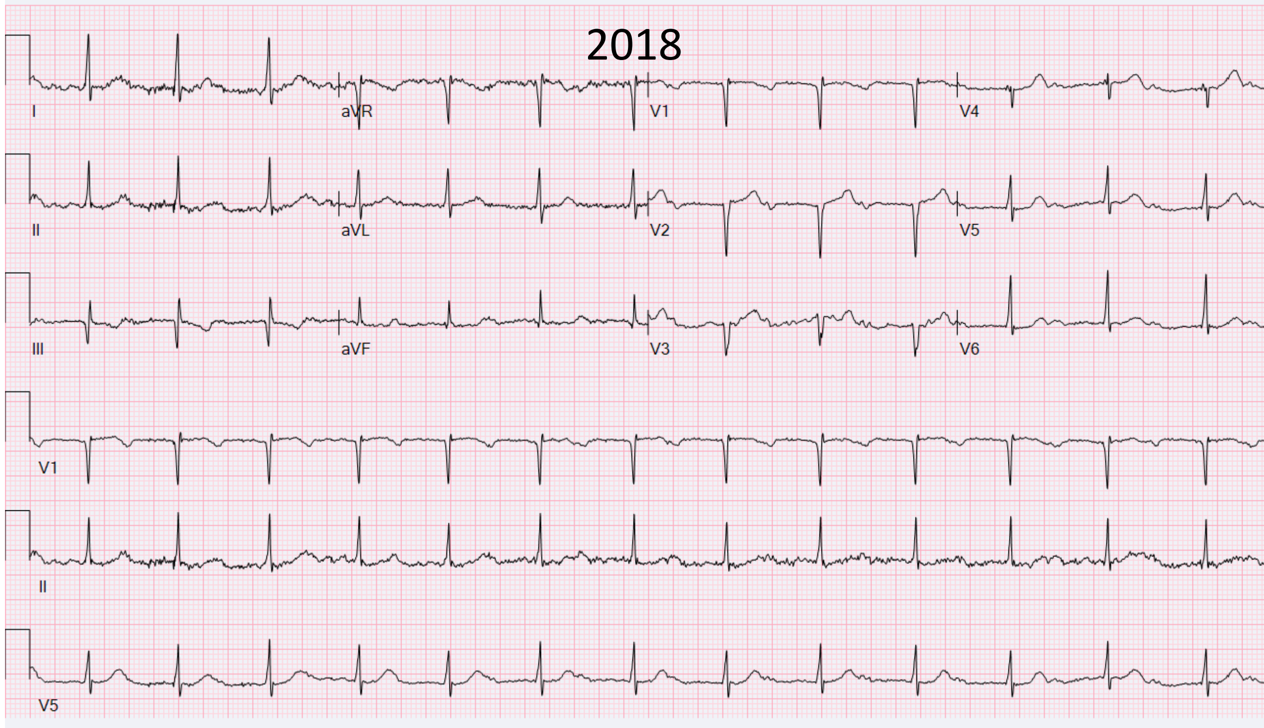
2- Refer for pacemaker

3- Do nothing

Case 2

- 87 year old male complains of dyspnea on exertion worsening over last 6 months, PND, orthopnea and lower limb edema improved with diuretics. ECHO showed preserved LVEF. EKG done at your office visit is shown:


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5


2004
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

2018
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

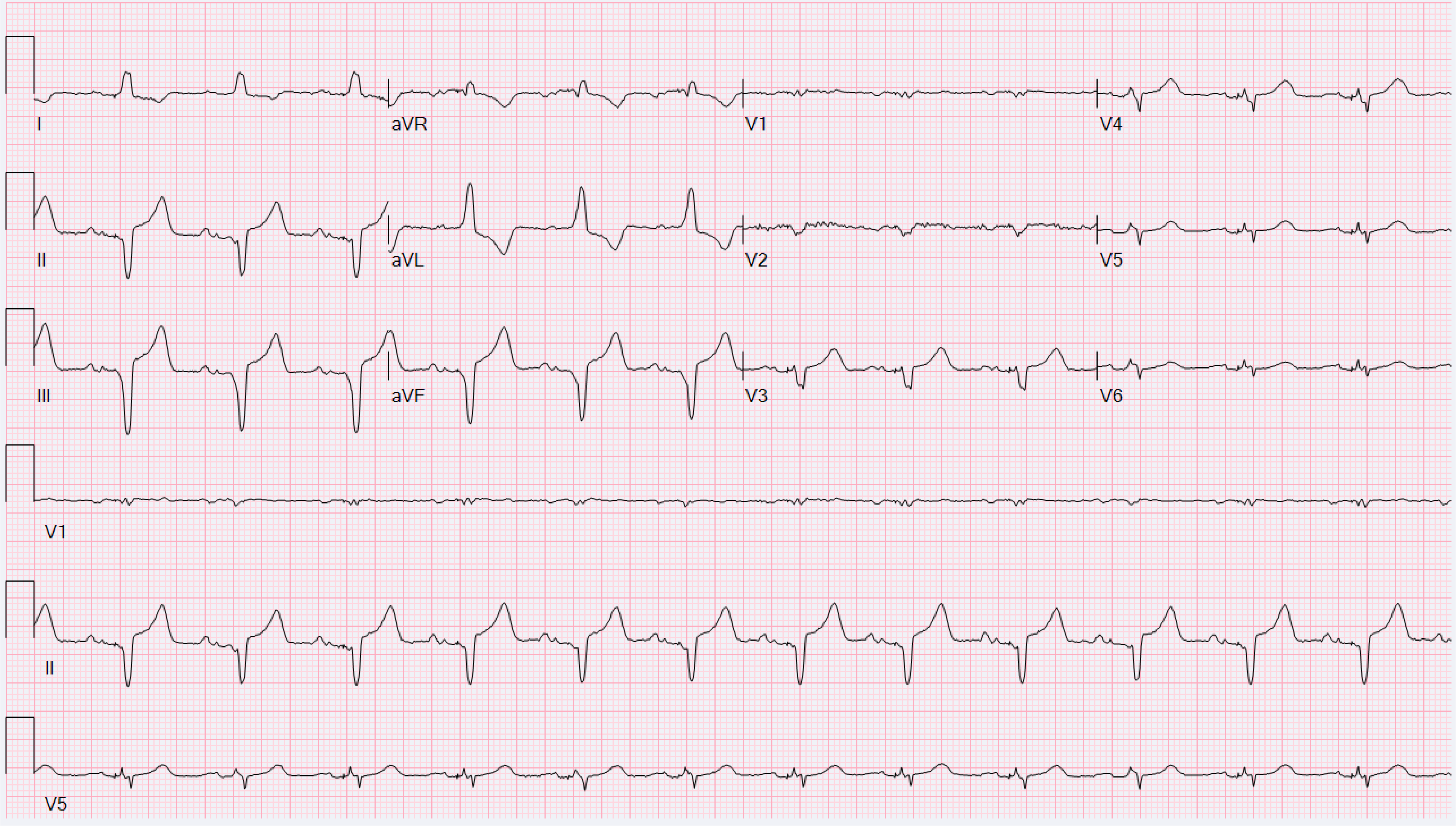
- What is next best step?

1- Continue diuretics

2- Start ACE inhibitors

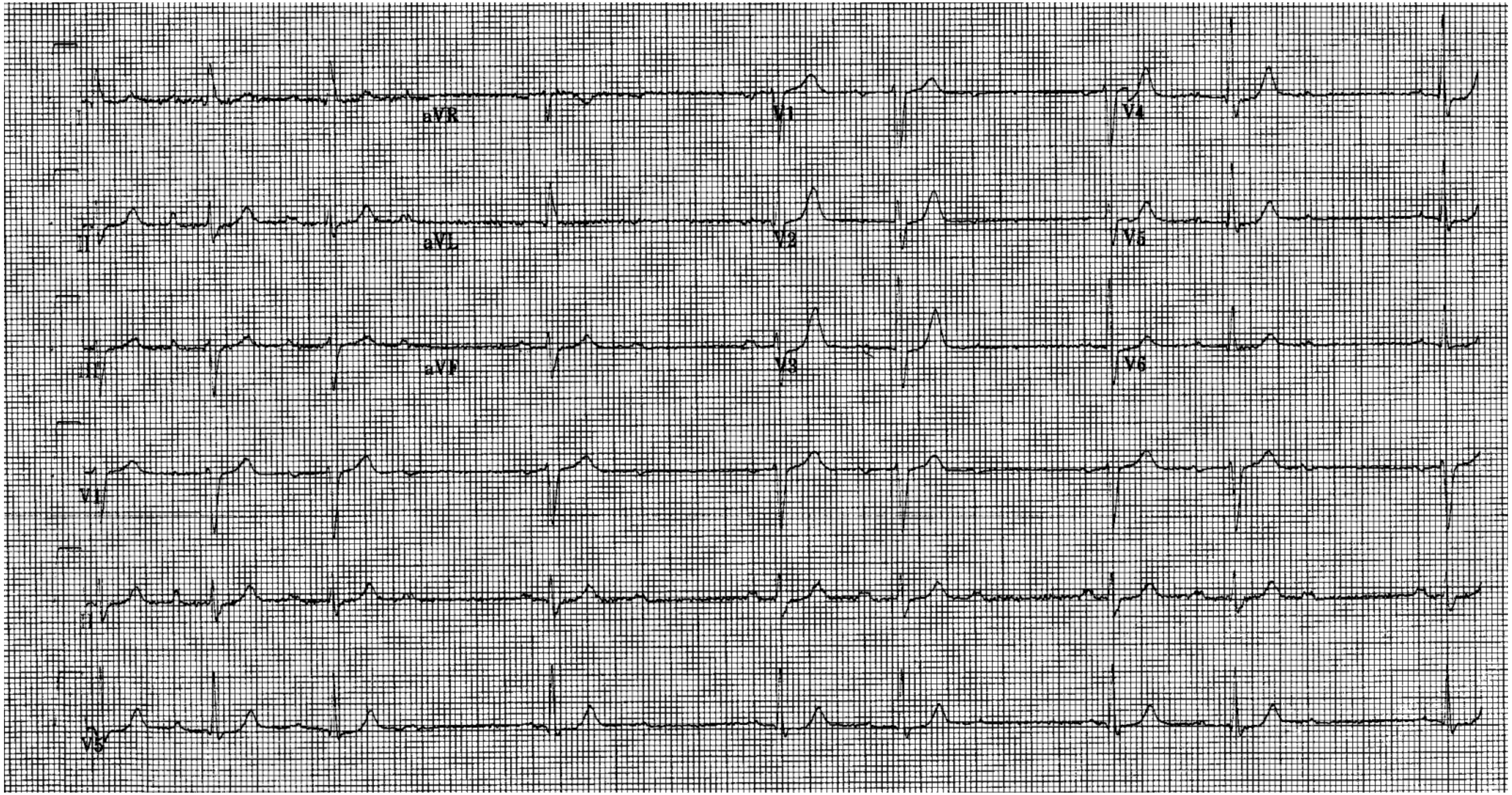
3- Implant dual chamber pacemaker

Post Pacemaker implant



Case 3

- 72-year-old male seen by his primary care doctor noted irregular pulse on physical examination. Patient denies syncope no dizziness. 12 lead EKG shown below:


aVR
V1
V4
II
aVL
V2
V5
aVF
V3
V6
V1
V5

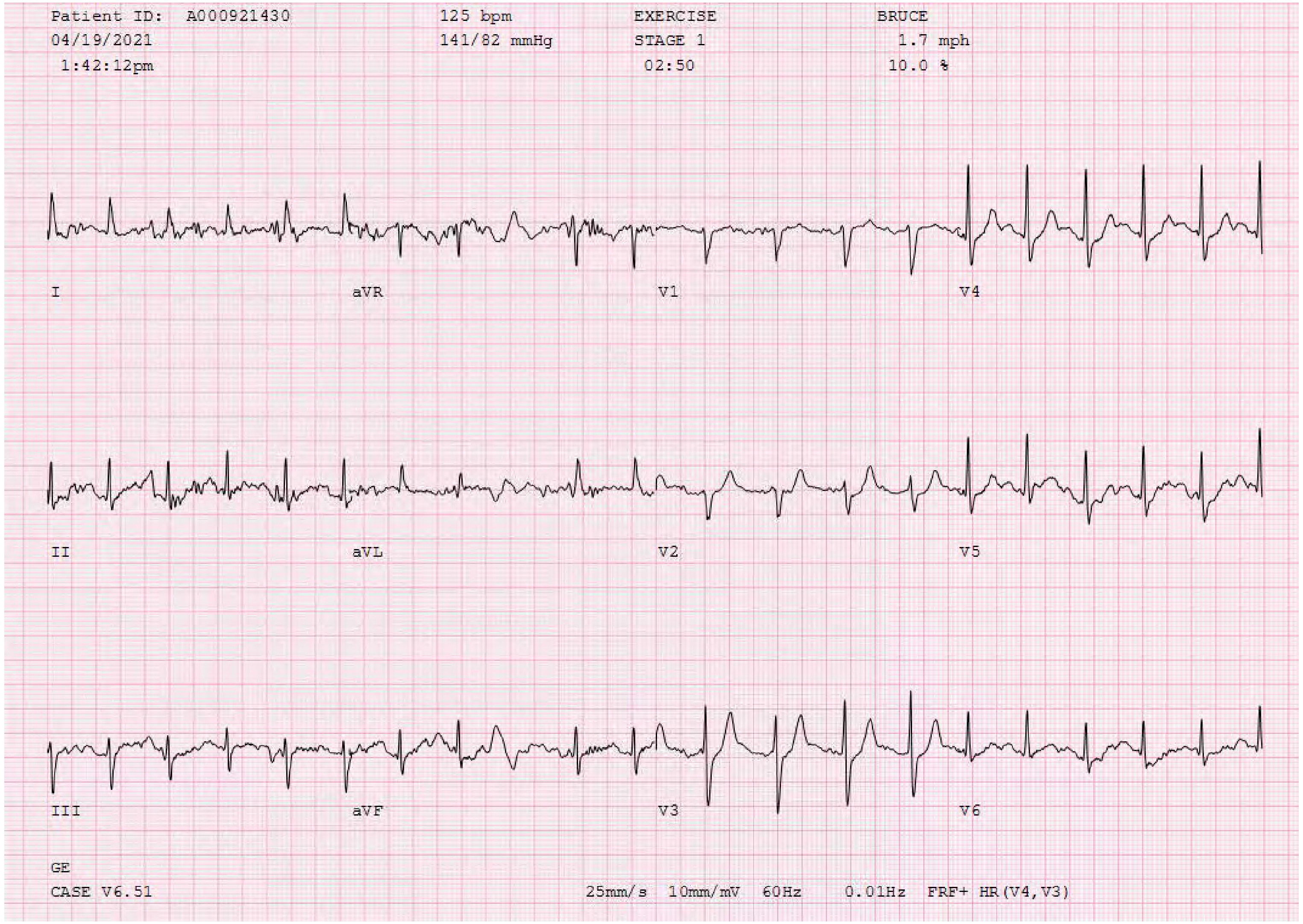
- What would you recommend?

1- Pacemaker implant

2- Loop recorder implant

3- Exercise stress test

4- Do nothing



Patient ID: A000921430
04/19/2021
1:42:12pm
125 bpm
141/82 mmHg
EXERCISE
STAGE 1
02:50
BRUCE
1.7 mph
10.0 %
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
GE
CASE V6.51
25mm/s 10mm/mV 60Hz 0.01Hz FRF+ HR(V4,V3)

Case 4

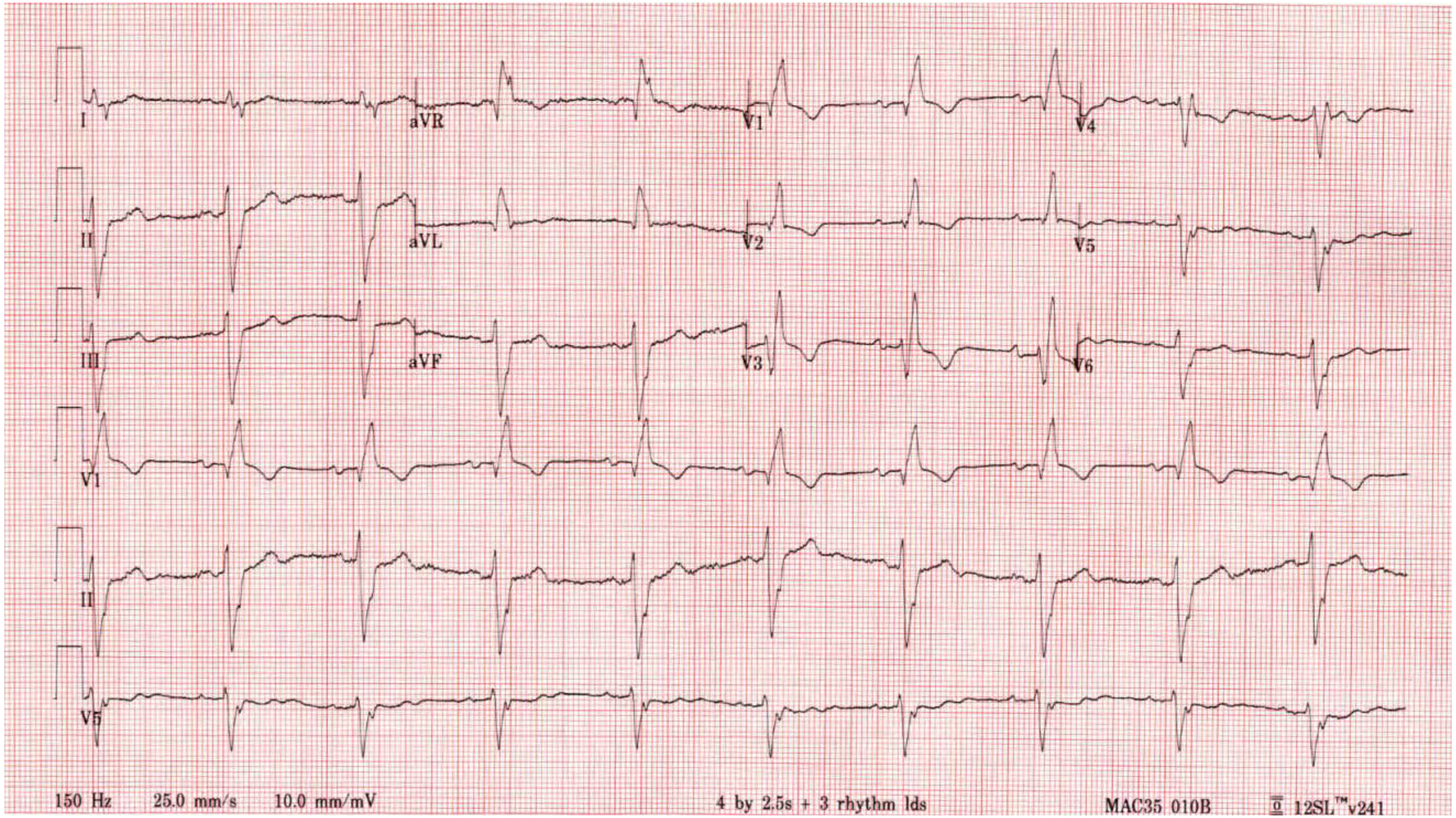
- 75 year old male with history of CAD s/p CABG, HTN. Presented with multiple syncopal spells. Occurred while sitting talking to his wife, was out for about 30 seconds.
- 12 lead EKG shows:

1- Sinus rhythm with RBBB

2- Sinus rhythm RBBB and LAD

3- Sinus rhythm, bifasicular block (RBBB+ Left anterior fascicular block)

4- Sinus rhythm, bifasicular block (RBBB+ Left posterior fascicular block)



I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5
150 Hz
25.0 mm/s
10.0 mm/mV
4 by 2.5s + 3 rhythm lds
MAC35 010B
12SL™ v241

- Next step in management:

1- Pacemaker implant

2- EP study

3- Holter monitor

4- Tilt table test

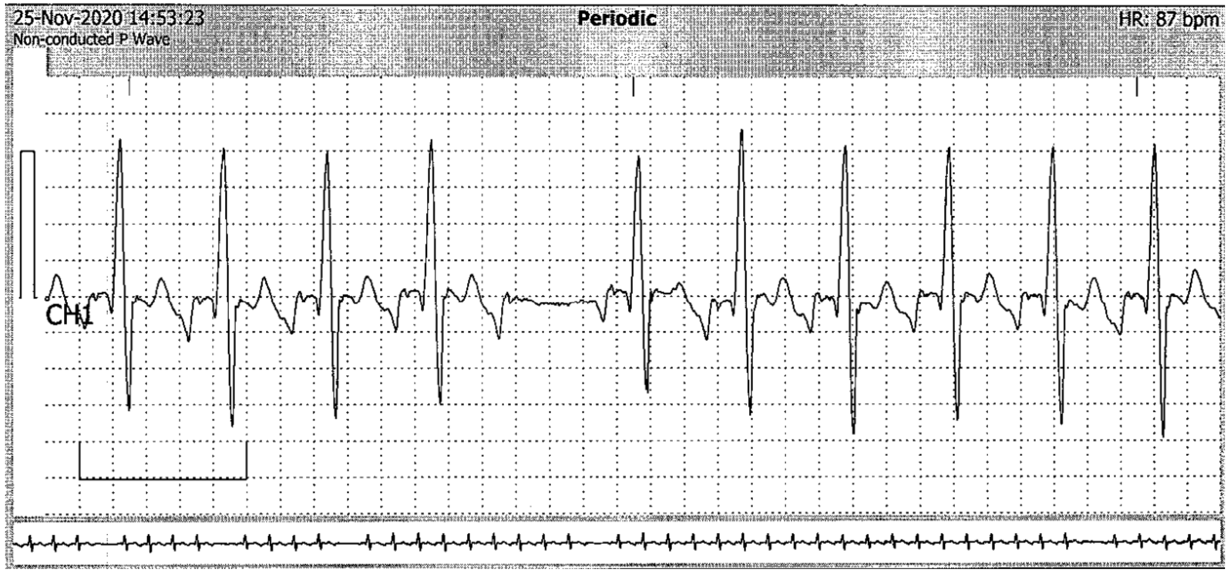
- Holter was ordered by PCP for further evaluation, what is the finding on Holter monitor?

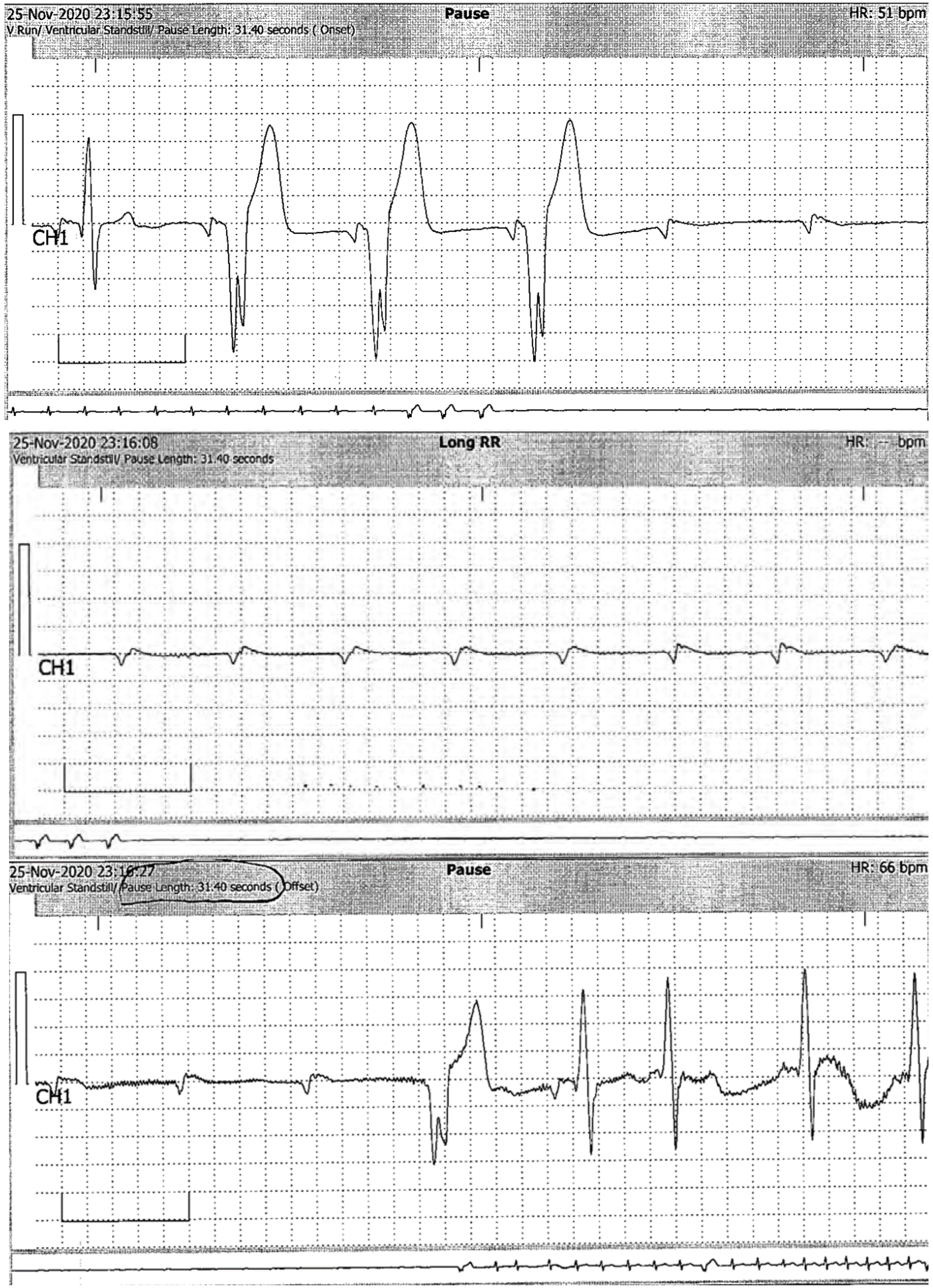
1- Second degree type I

2- Second degree type II

3- Third degree AV block

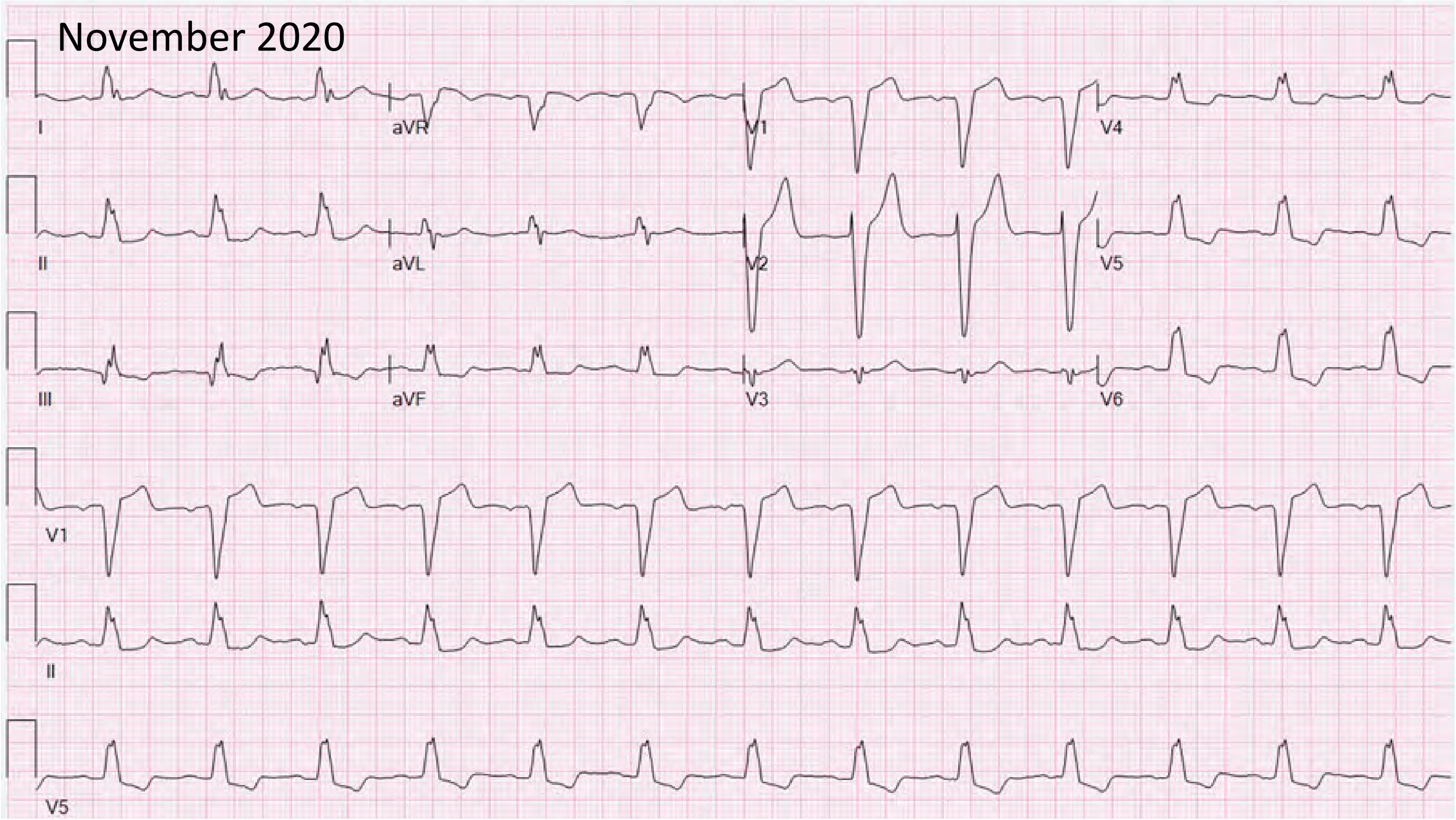
4- None of above

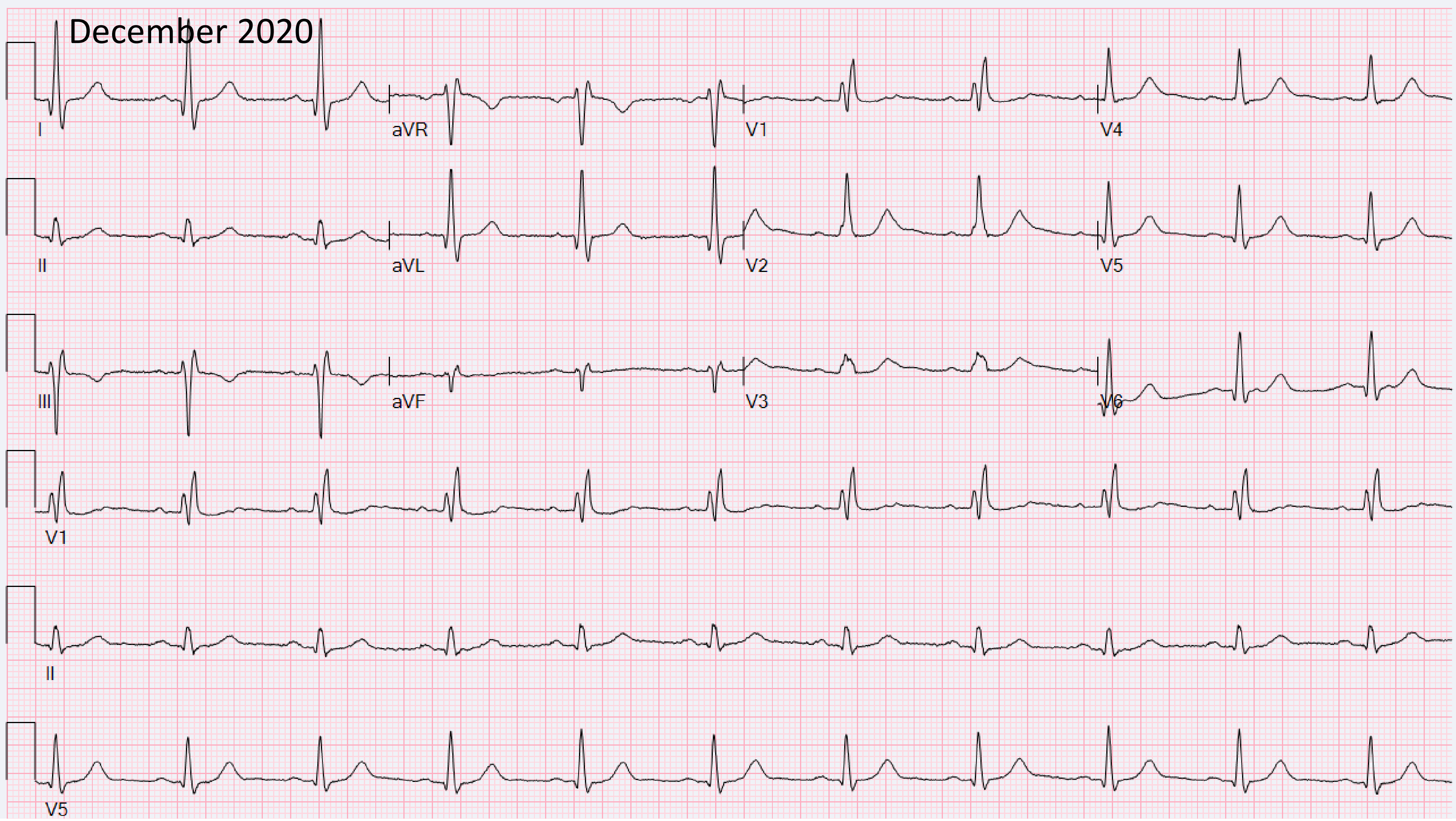

25-Nov-2020 14:53:23
Non-conducted P Wave
Periodic
HR: 87 bpm
CH1


25-Nov-2020 23:15:55
Pause
HR: 51 bpm
V Run/ Ventricular Standstill/ Pause Length: 31.40 seconds (Onset)
CH1
25-Nov-2020 23:16:08
Long RR
HR: -- bpm
Ventricular Standstill/ Pause Length: 31.40 seconds
CH1
25-Nov-2020 23:16:27
Pause
HR: 66 bpm
Ventricular Standstill/ Pause Length: 31.40 seconds (Offset)
CH1

Case 5

- 68 year old male with severe aortic stenosis, anemia and GI bleeding. Presented with fatigue, dizziness. EKG shown.




December 2020
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

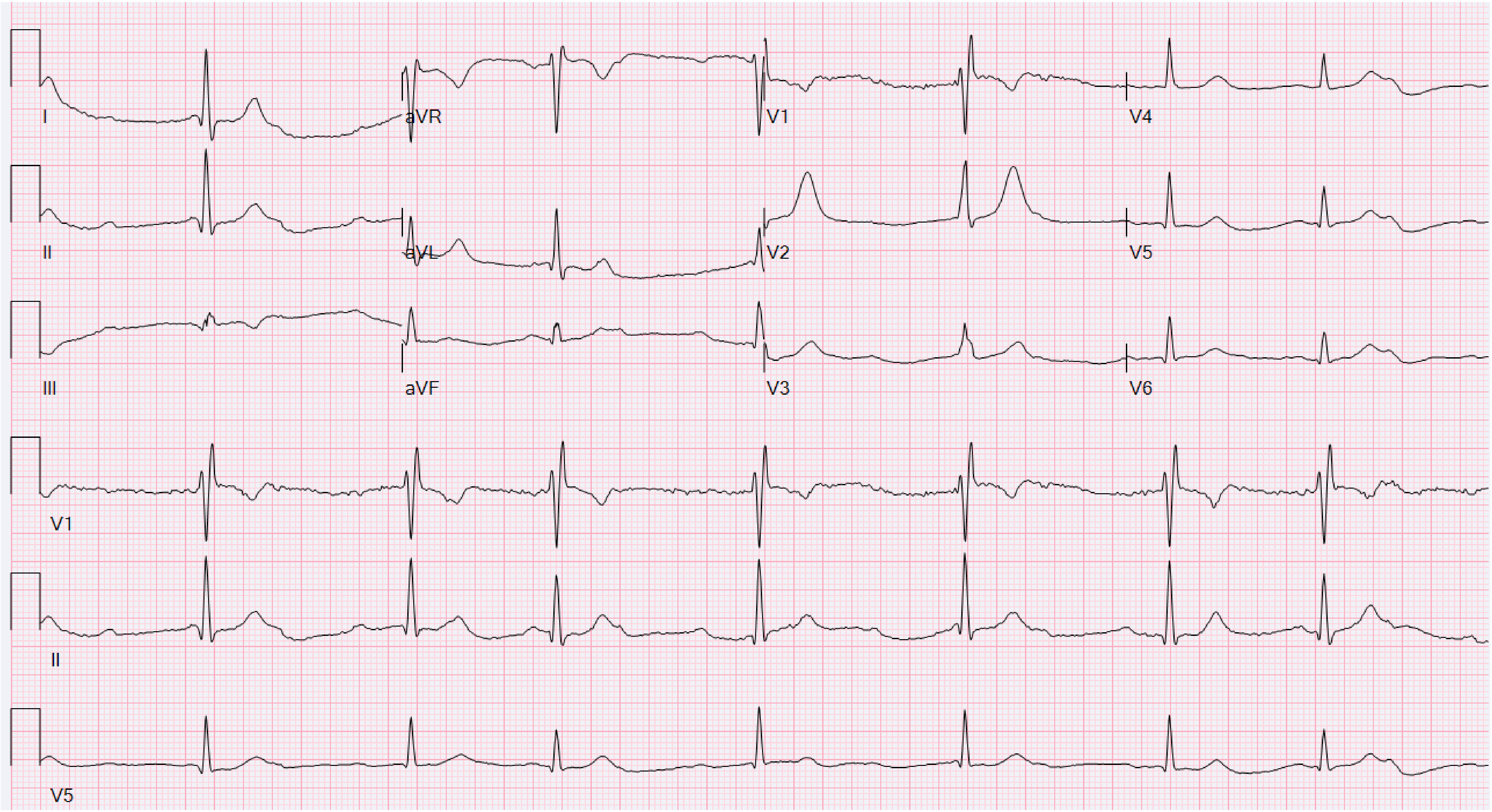
- Next best step in management?

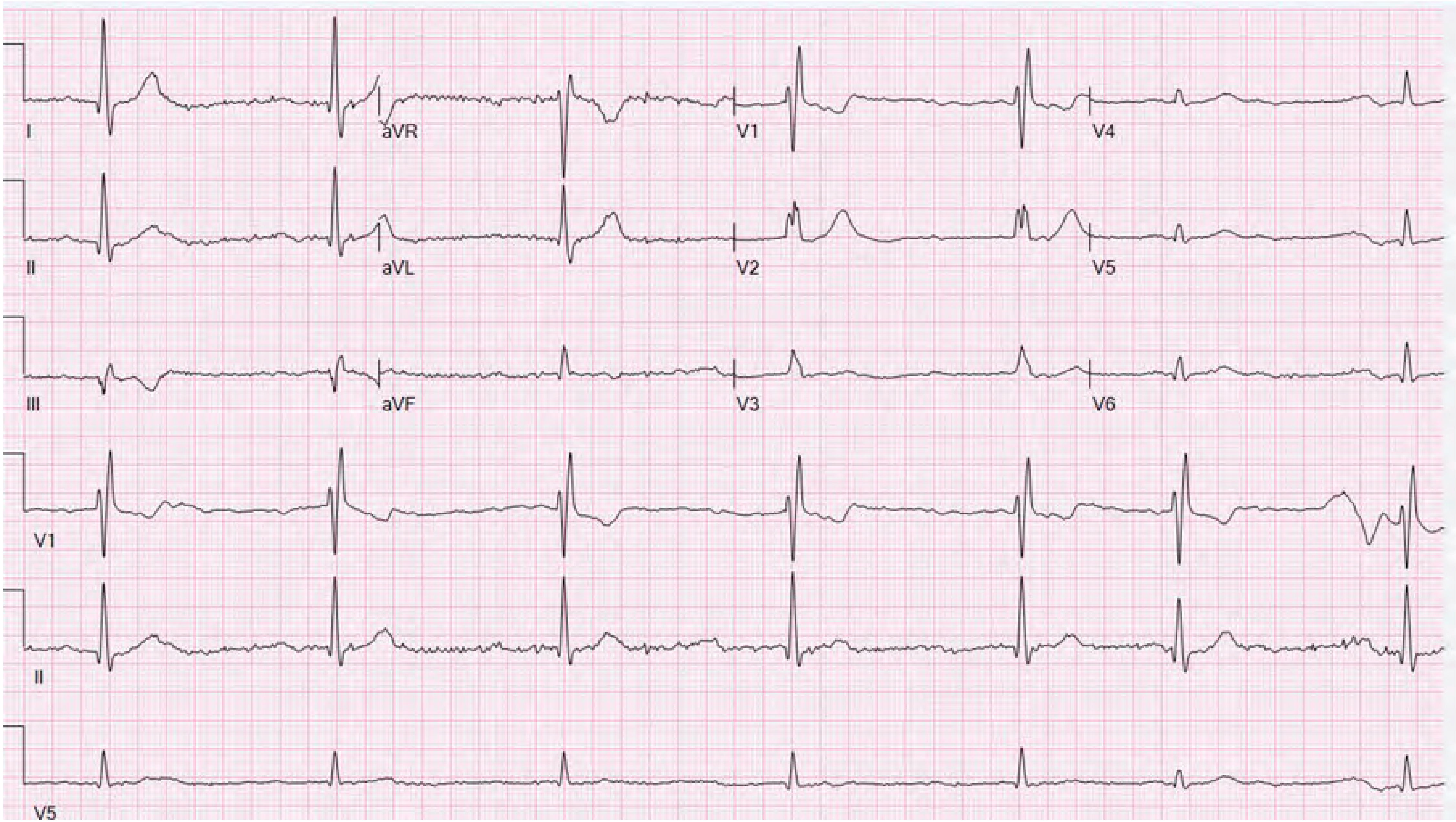
1- Holter monitor

2- Check hemoglobin for fatigue

3- Pacemaker implant

4- None of the above


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

Case 6

- 27 year old male with muscular dystrophy, LVEF 60% and syncope. His baseline 12 lead EKG shows sinus with RBBB and LAFB.

- What should be considered in this patient?

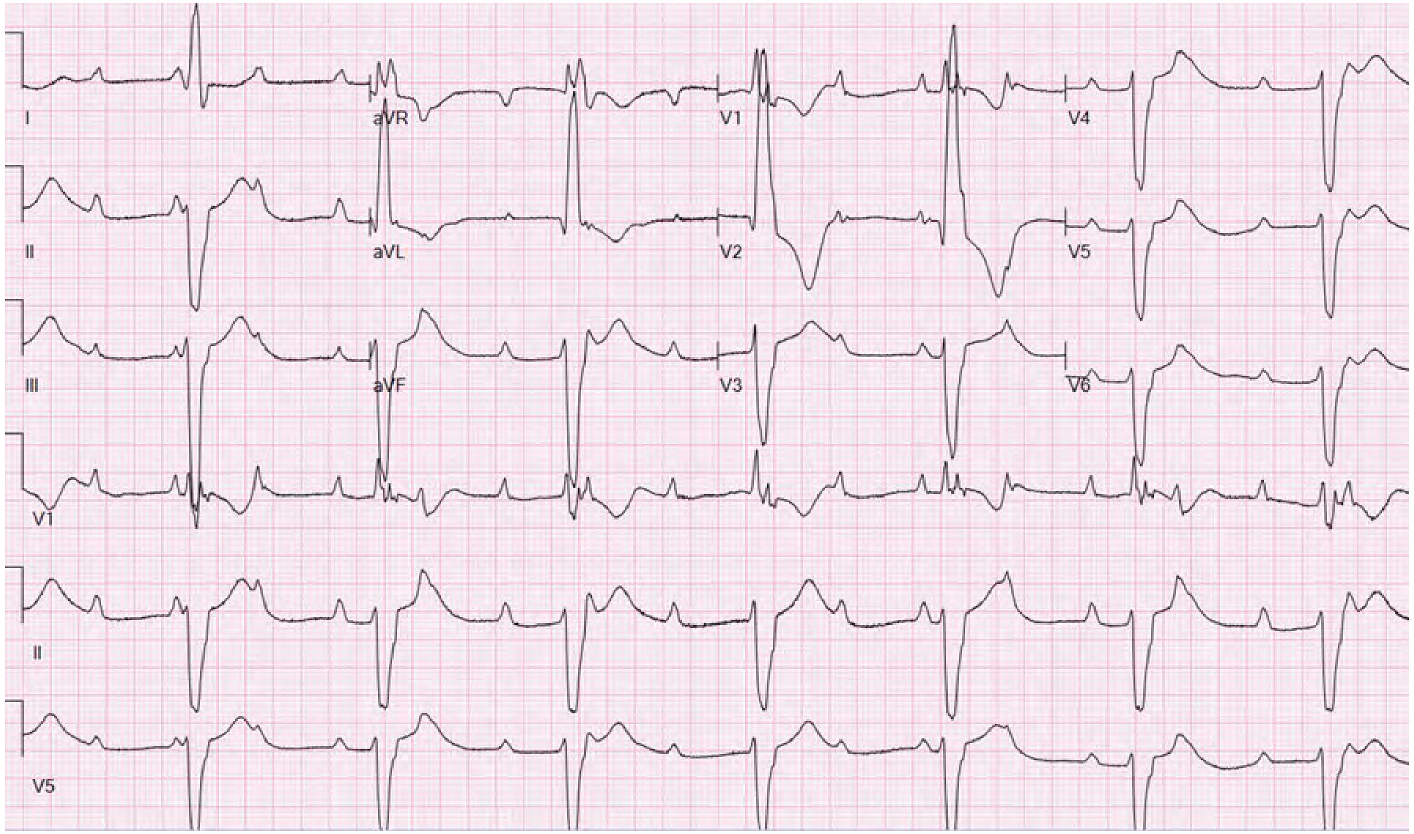
1- Permanent pacemaker implant

2- Echocardiogram

3- Coronary angiogram

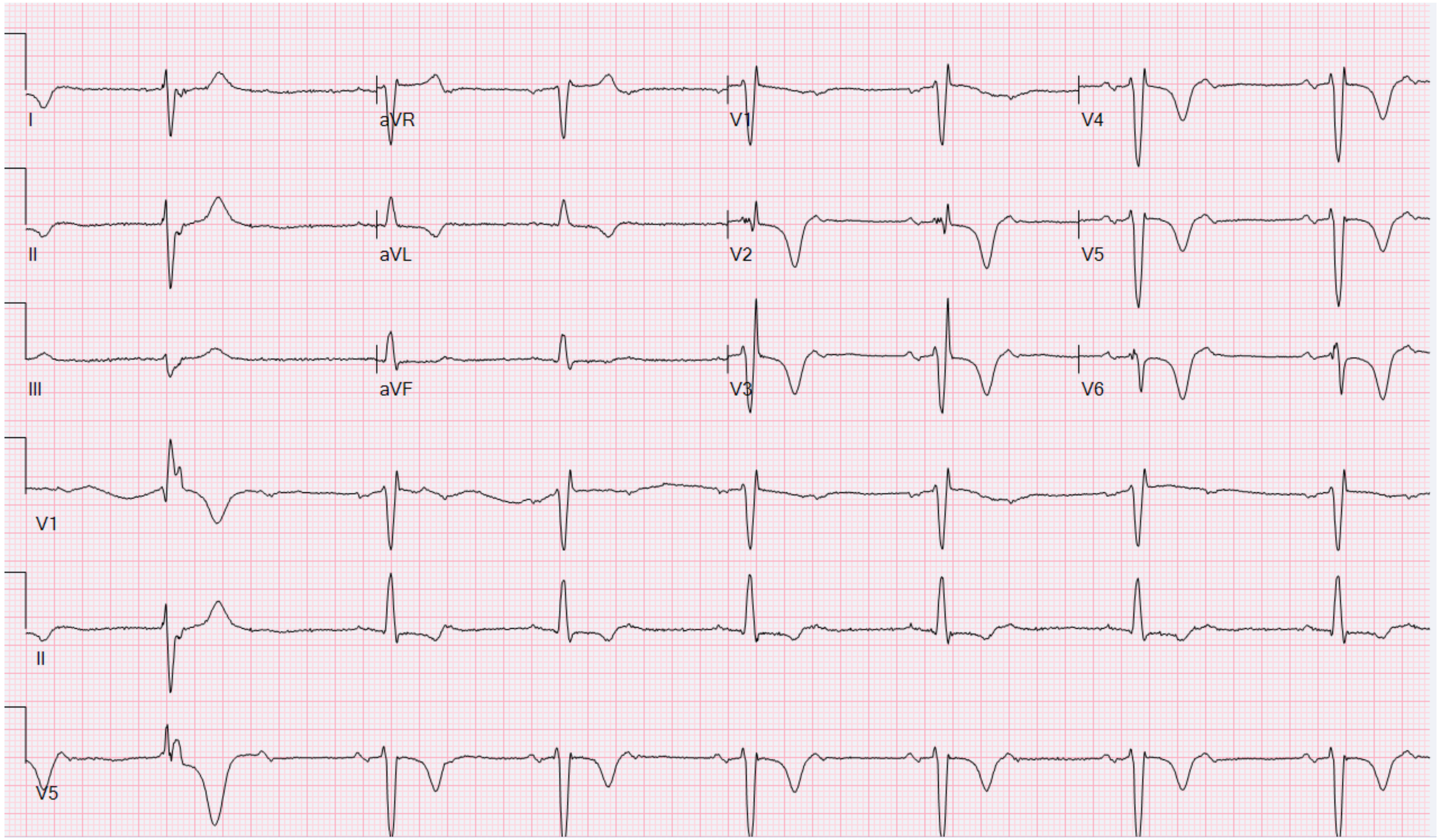
4- None of the above

- Patient declined further evaluation and presented 2 years later with recurrent syncope and following EKG.



Case 7

- 74 year presented with dizziness and weakness.



- Next best step?

1- EP study

2- Exercise stress test

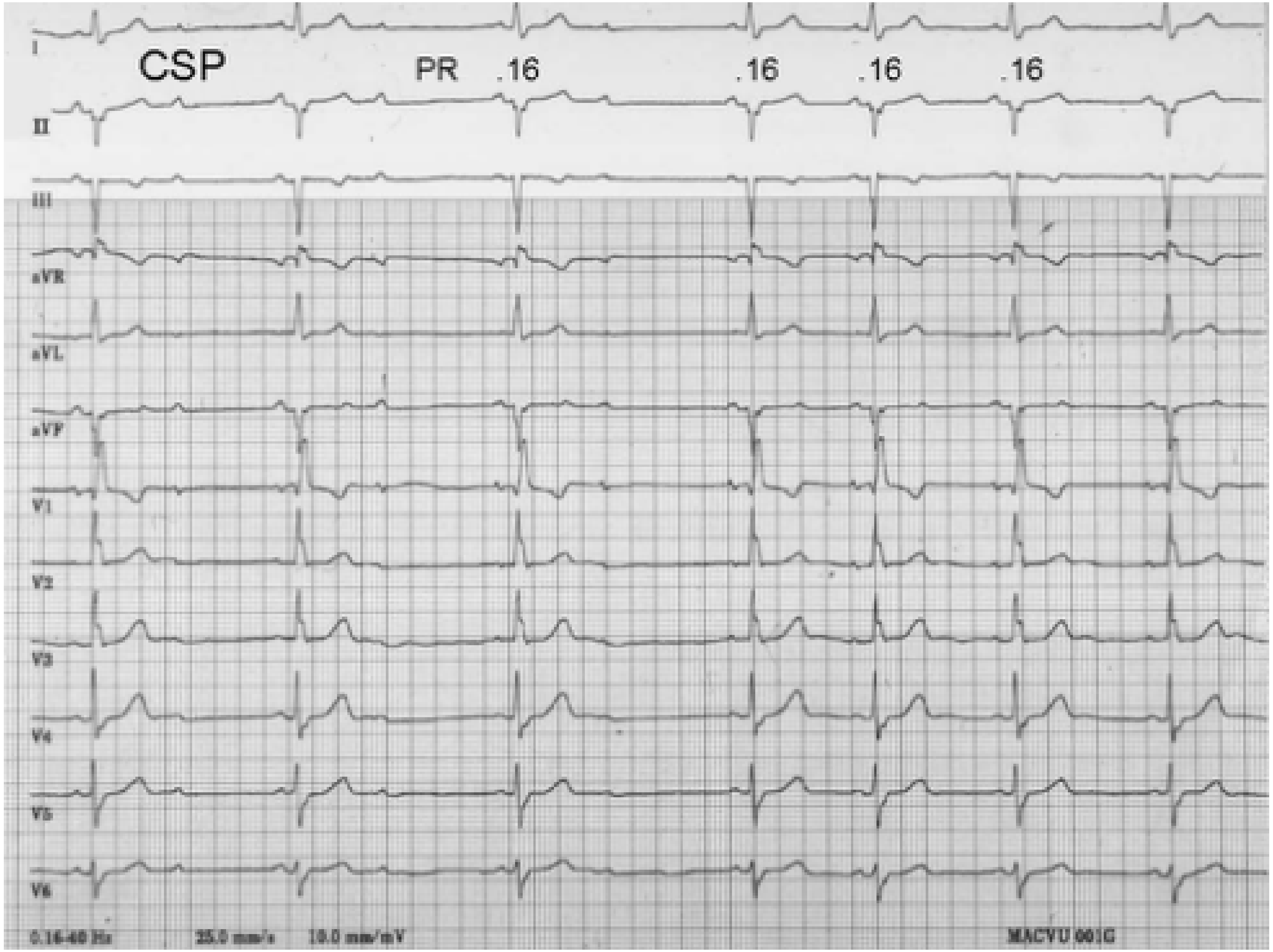
3- Echocardiogram to assess LVEF and pacemaker

4- Holter monitor

Clues to site of block in 2:1

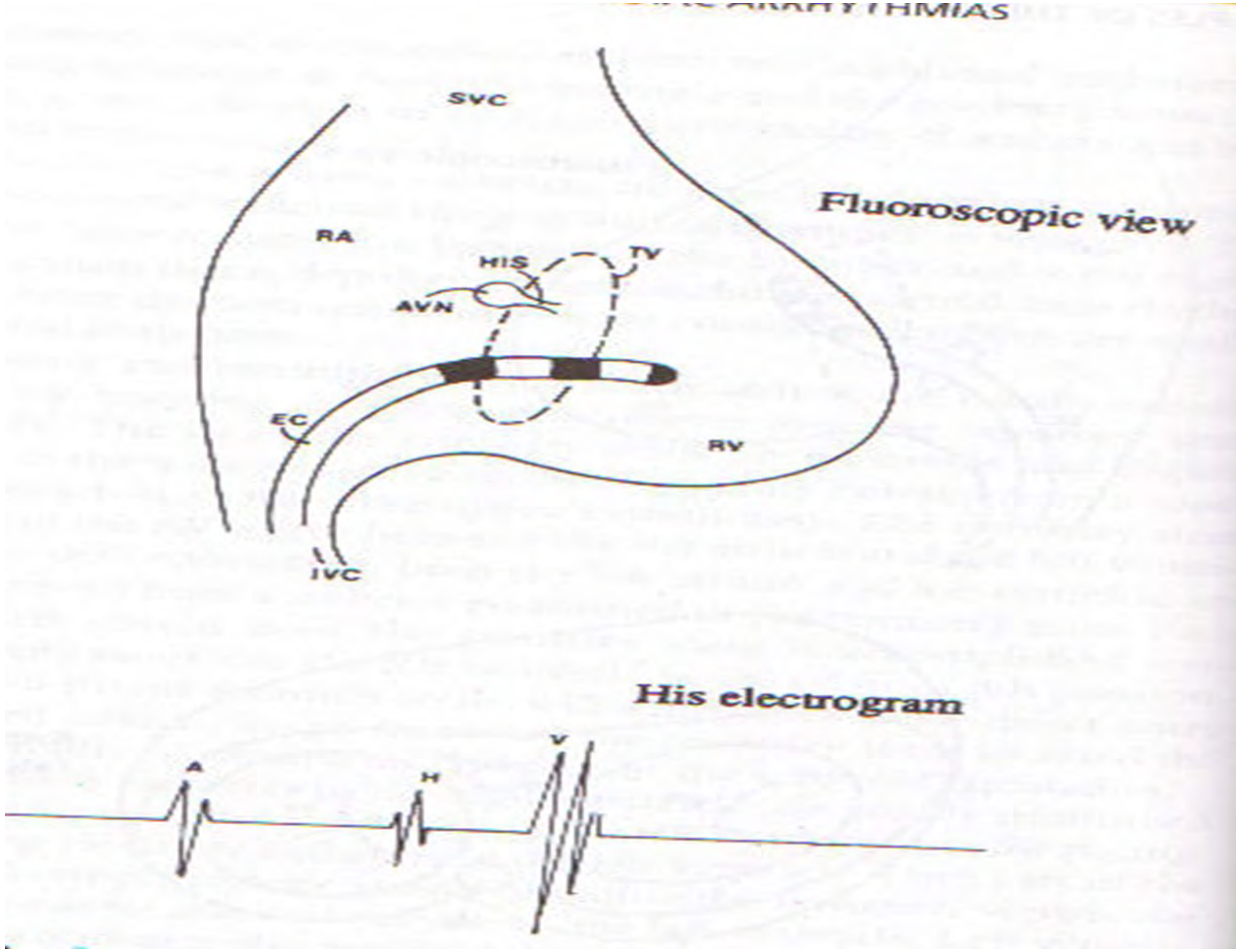
1. QRS Width	BBB—site of block anywhere Normal QRS—block in AV node or His bundle
2. PR of Conducted P Wave	>0.30 seconds—block in AV node ≤0.16 seconds—block in HPS or His bundle
3. Atropine or Exercise	Improve conduction—block in AV node Worsen conduction—block in HPS or His bundle
4. CSP	Worsen conduction—block in AV node Improve conduction—block in HP or His bundle

Josephson. Clinical Cardiac Electrophsyiology, fourth edition.



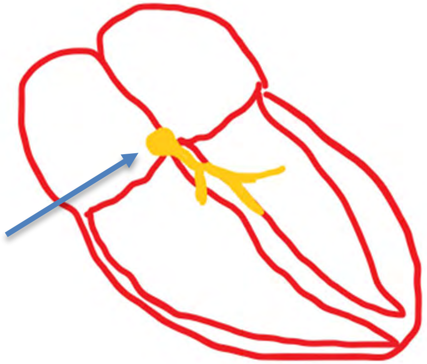
Josephson. Clinical Cardiac Electrophsyiology, fourth edition.

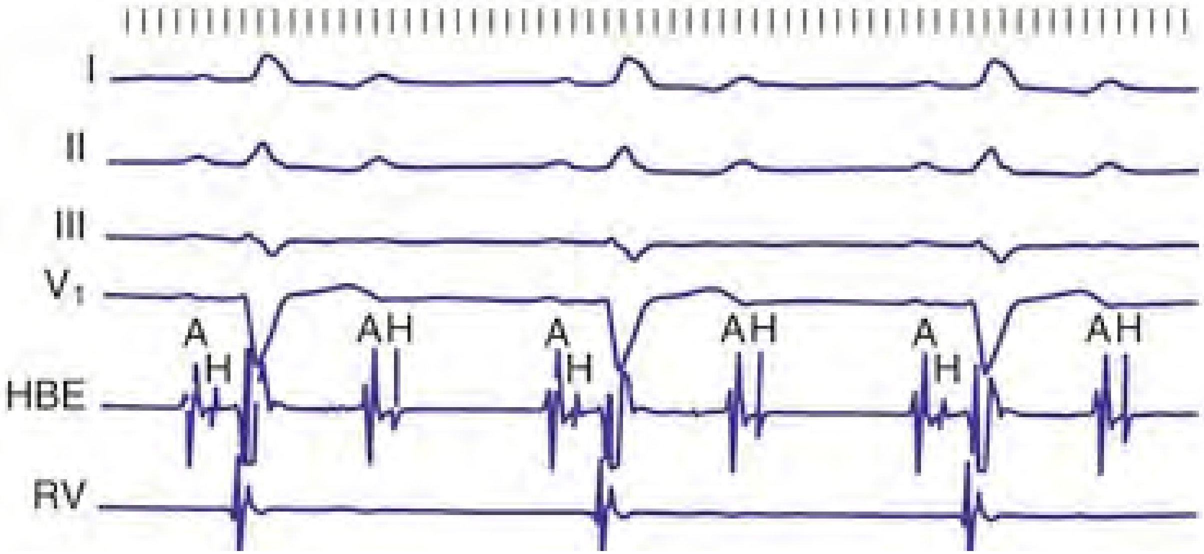
EP study



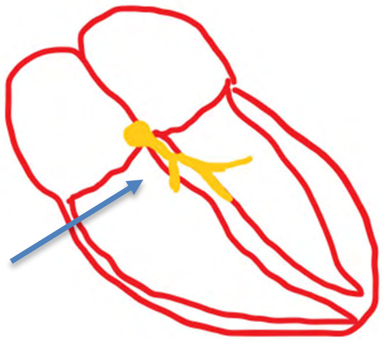
SVC
Fluoroscopic view
RA
HIS
TV
AVN
EC
RV
IVC
His electrogram
A
H
V


I
II
aVF
V1
1HIS 1,2
1HIS 3,4
1RV 1,2
1RV 3,4
S1
595
S1
600
S1
600
S1
600
S1

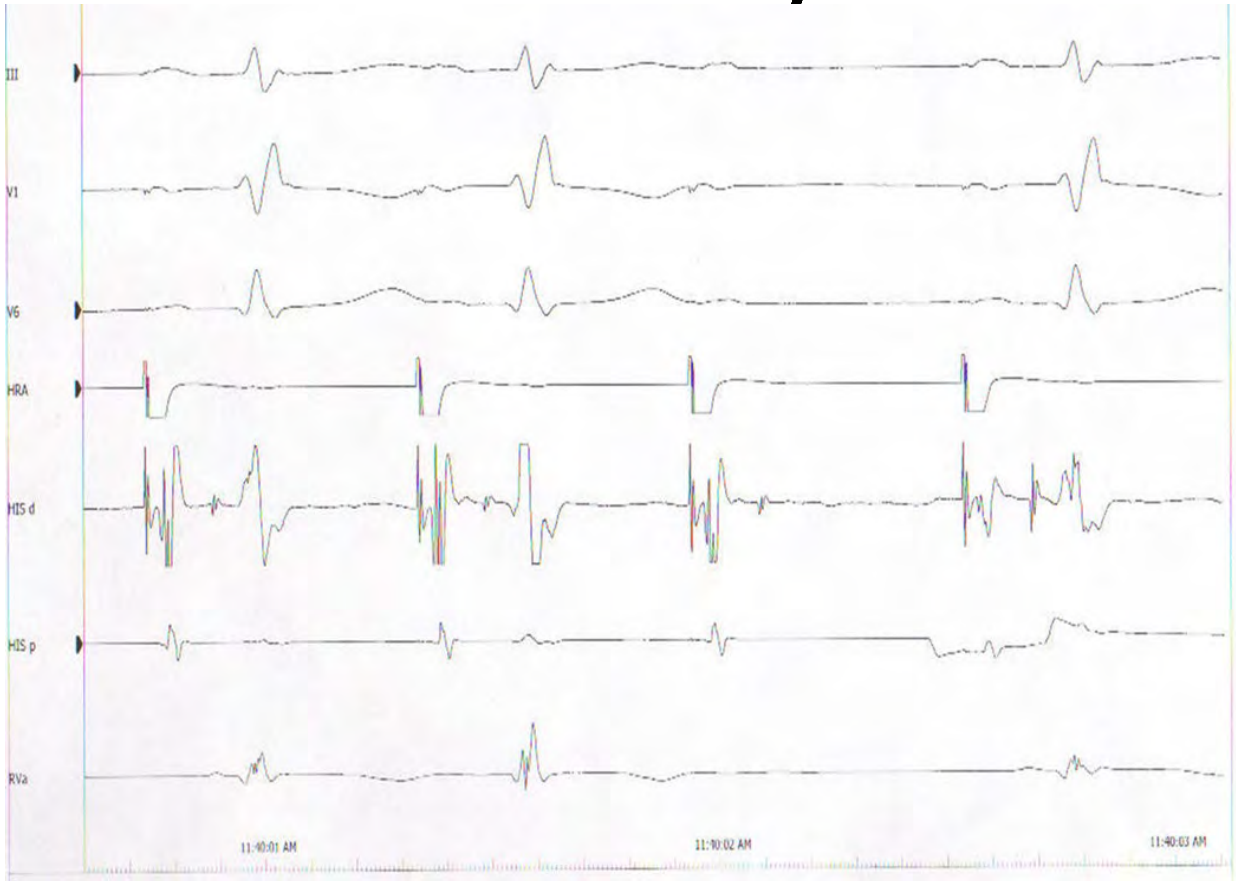




(From Josephson ME: Clinical cardiac electrophysiology: techniques and interpretations, ed 3, Philadelphia, 2002, Lippincott–Williams & Wilkins, pp 92-109.)



EP study



What is the level of AV block?

1) Suprahisian
2) Infrahisian
3) None, this normal AV conduction

Bonus Question

What is the most likely level of AV block?

Physiologic AV Block

- First and second degree AV block may occur physiologically at an ***AV Nodal*** level:
  - in response to premature atrial impulses or atrial tachyarrhythmias
  - in settings of increased vagal tone (e.g., sleep, Valsalva maneuver, well-trained athletes)


sSpO2 93
PVC 0
NBP ?/?(?)
PULSE 64
PlsNBP ?
RESP 14
169
S0415

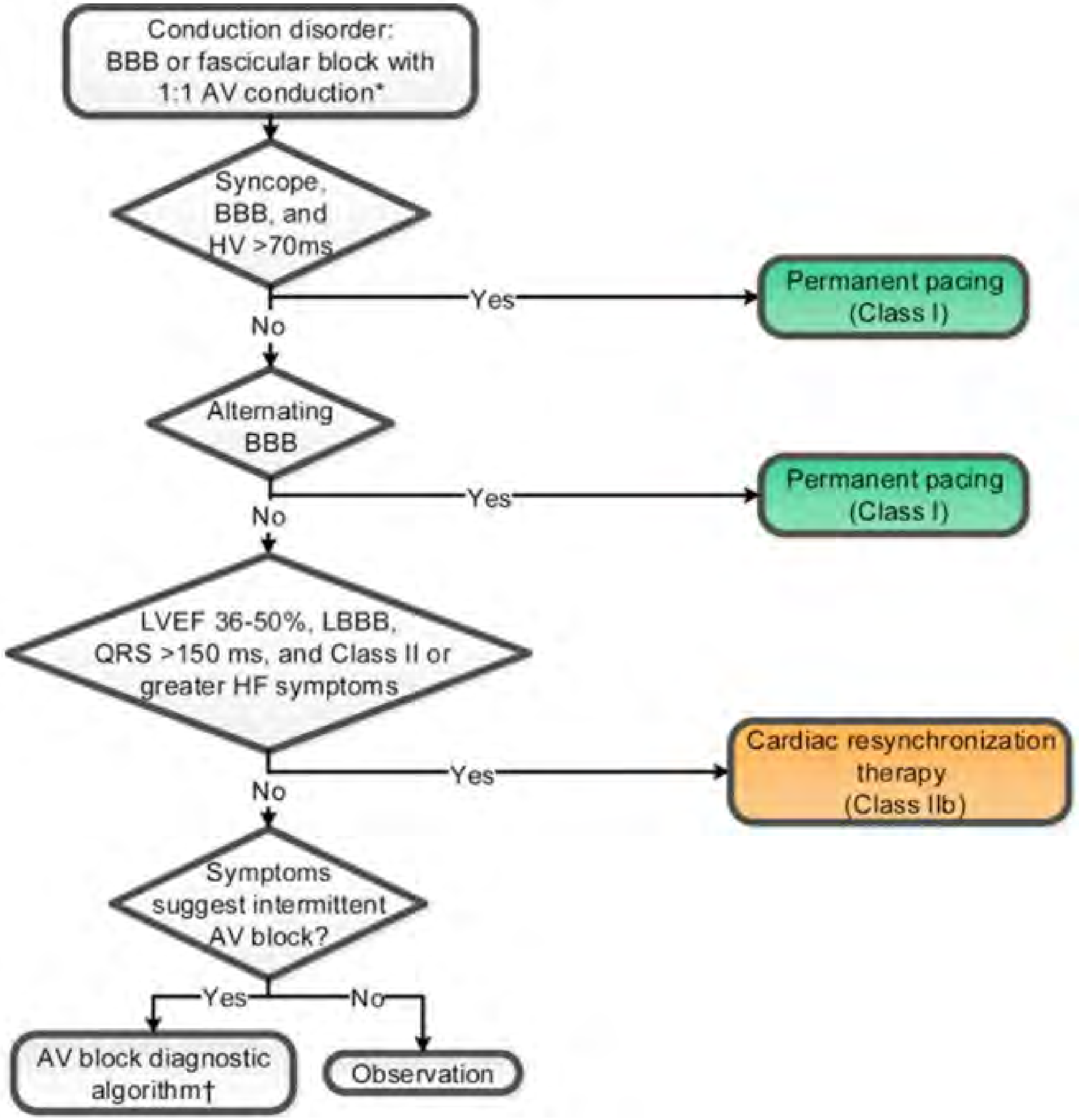
Does the patient need a ppm?

1) Reversible (ischemia, drugs) or not
2) Anatomical level of block
3) Symptoms due to bradycardia

2018 Guidelines

- Acquired second-degree Mobitz type II AVB, high-grade AVB, or third-degree AVB not caused by reversible or physiologic causes, permanent pacing is recommended regardless of symptoms.
- For all other types of AVB, in the absence of conditions associated with progressive AV conduction abnormalities, permanent pacing should generally be considered only in the presence of symptoms that correlate with AVB.

2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines, and the Heart Rhythm Society



2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines, and the Heart Rhythm Society

From: **Dual-Chamber Pacing or Ventricular Backup Pacing in Patients With an Implantable Defibrillator: The Dual Chamber and VVI Implantable Defibrillator (DAVID) Trial**

JAMA. 2002;288(24):3115-3123. doi:10.1001/jama.288.24.3115

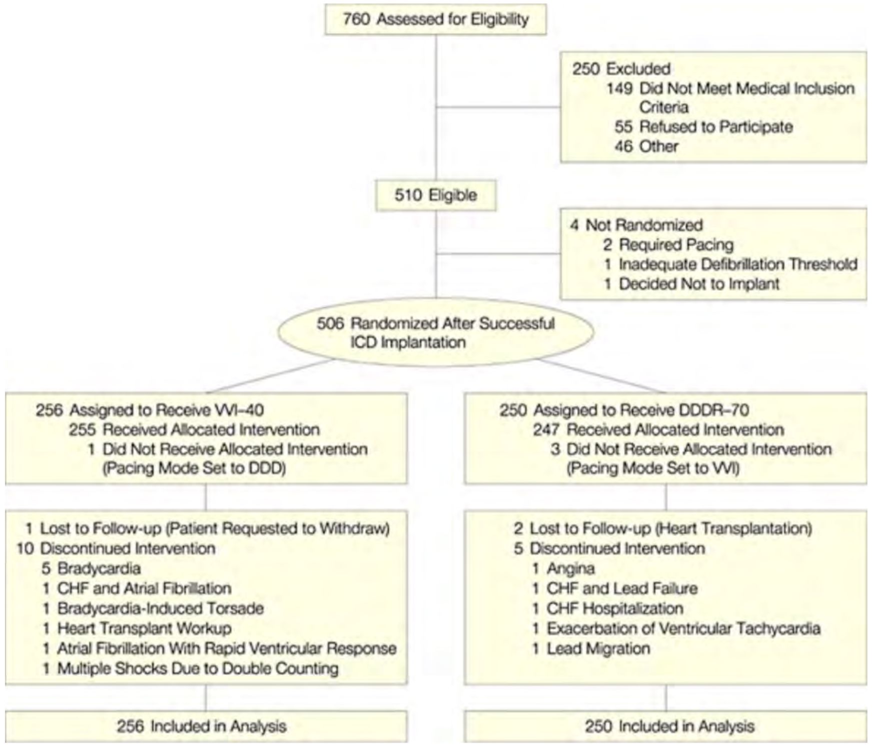


Figure Legend:

CHF indicates congestive heart failure; ICD, implantable cardioverterdefibrillator. Many other patients would have been assessed and eligible,but for reasons related to a hospital's bulk purchase agreements, anothermanufacturer's device was to be used.

The JAMA Network

From: **Dual-Chamber Pacing or Ventricular Backup Pacing in Patients With an Implantable Defibrillator: The Dual Chamber and VVI Implantable Defibrillator (DAVID) Trial**

JAMA. 2002;288(24):3115-3123. doi:10.1001/jama.288.24.3115

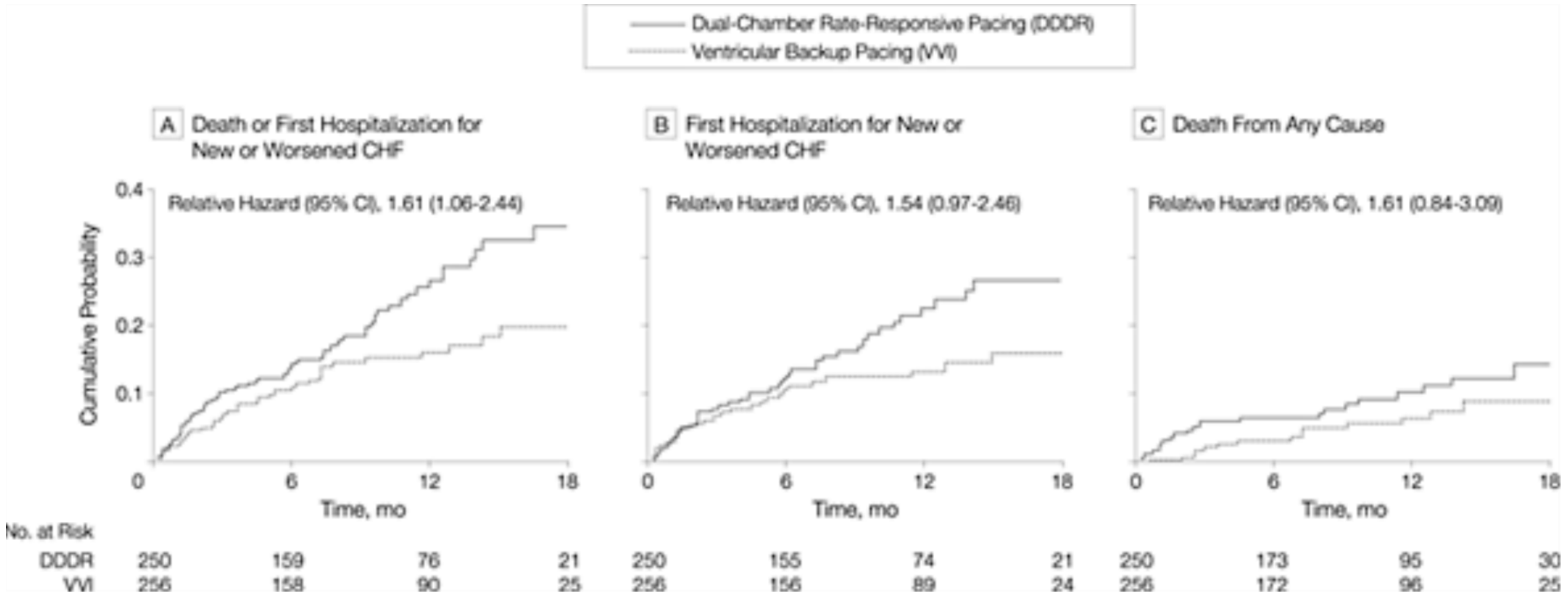
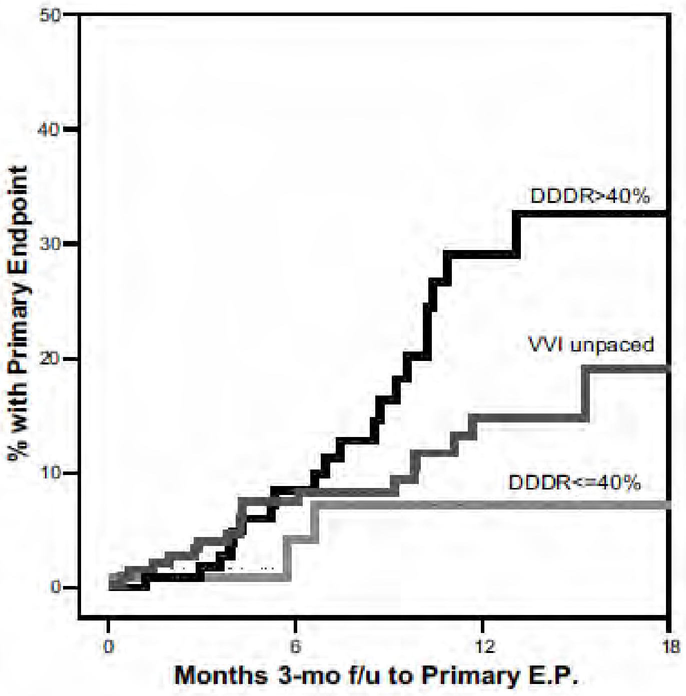


Figure Legend:

For all plots, time zero is the day of randomization. CI indicatesconfidence interval. A, Survival to death or first hospitalization for congestiveheart failure (CHF). Unadjusted P = .02; adjustedfor sequential monitoring, P = .03. B, Survival tofirst hospitalization for CHF. Patients are censored at death. Log-rank P = .07. C, Survival to death from any cause. Log-rank P = .15.



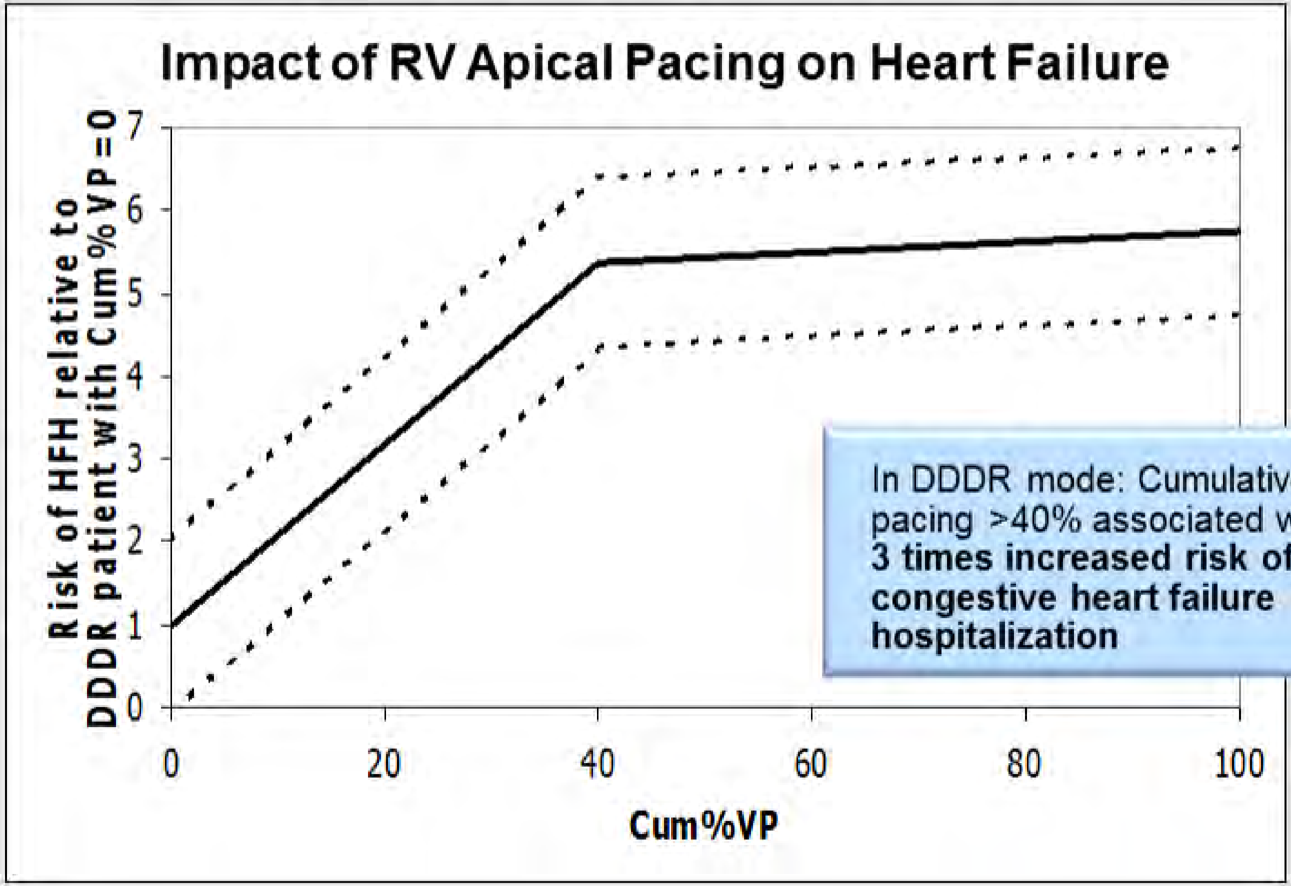
N at risk:	0	6	12	18	
	126	70	26	3	DDDR>40%
	195	118	47	5	VVIunpaced
	59	35	16	4	DDDR≤40%

DDDR>40% vs. DDDR<40% p = .03
DDDR>40% vs. VVI unpaced p = .07

Figure 1 Kaplan-Meier plots of the composite outcome of death or hospitalization for congestive heart failure for DDDR-70 >40% right ventricular pacing, DDDR-70 <40% right ventricular pacing, and VVI-40 paced groups. Time is from 3-month follow-up.

Sharma AD, Rizo-Patron C, Hallstrom AP, et al. Percent right ventricular pacing predicts outcomes in the DAVID trial. Heart Rhythm 2005;2:830–4

MOST trial Sub-study



In DDDR mode: Cumulative RV pacing >40% associated with **3 times increased risk of congestive heart failure hospitalization**

Sweeney MO, et al. Circulation 2003;107:2932-2937

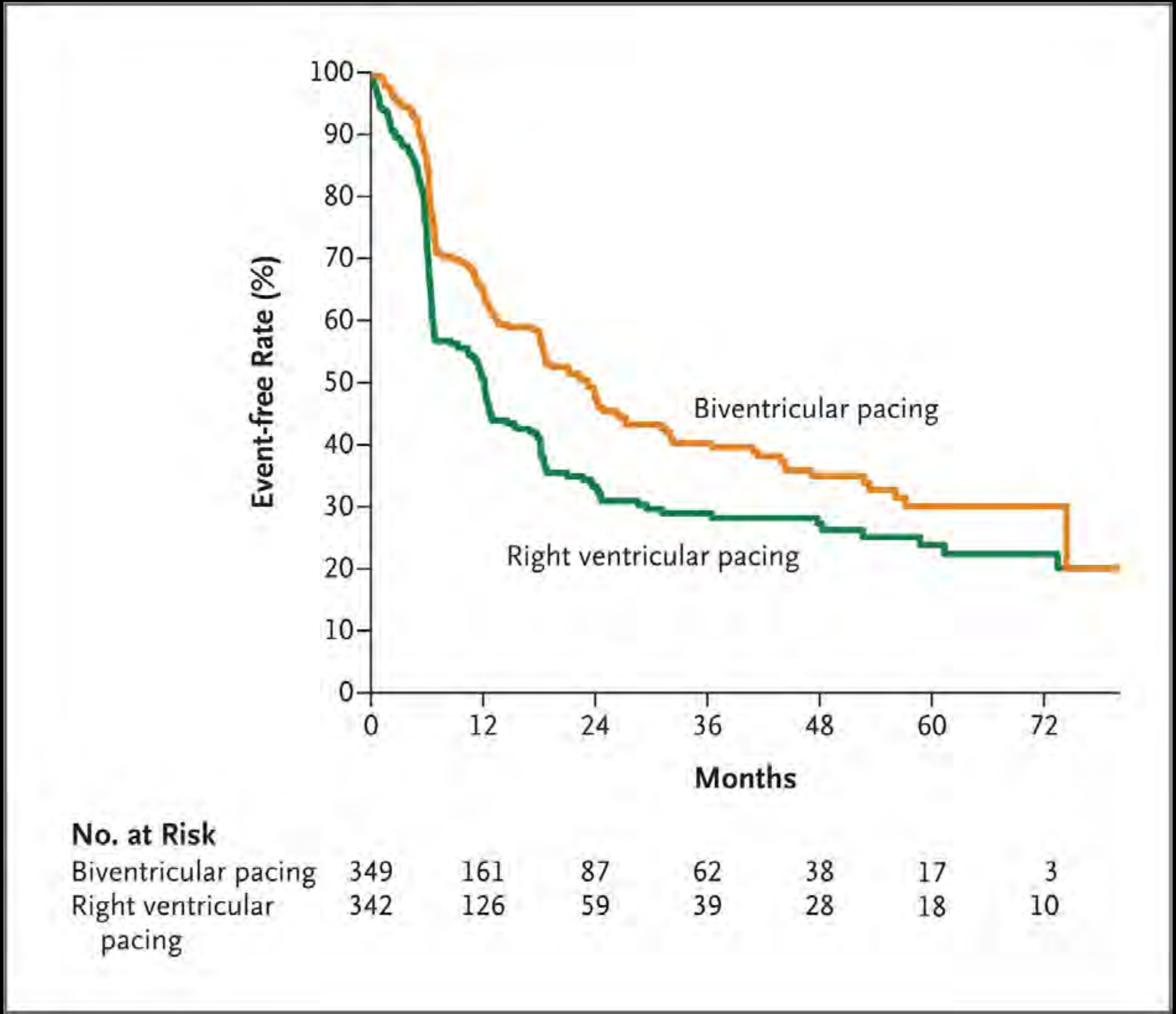
BLOCK-HF

- AV block necessitating pacing
- Second or third degree AV block
- First degree with symptoms similar to pacemaker syndrome
- Documented Wenckebach or PR interval >300 msec when paced at 100 bpm
- LVEF Less than or equal 50%
- NYHA class I, II, III
- No previous pacemaker or ICD

Endpoints

- Primary: composite of
  - ➢ All-cause mortality.
  - ➢ HF-related urgent care, defined as:
    - HF hospitalization requiring IV therapy or,
    - Any unplanned visit requiring IV HF therapy
  - ➢ Increase in LVESI by ≥15%
- Secondary:
- All cause death /urgent care visit for HF
- All cause death /hospitalization for HF
- All cause death
- Hospitalization for HF

Freedom from a Primary-Outcome Event.

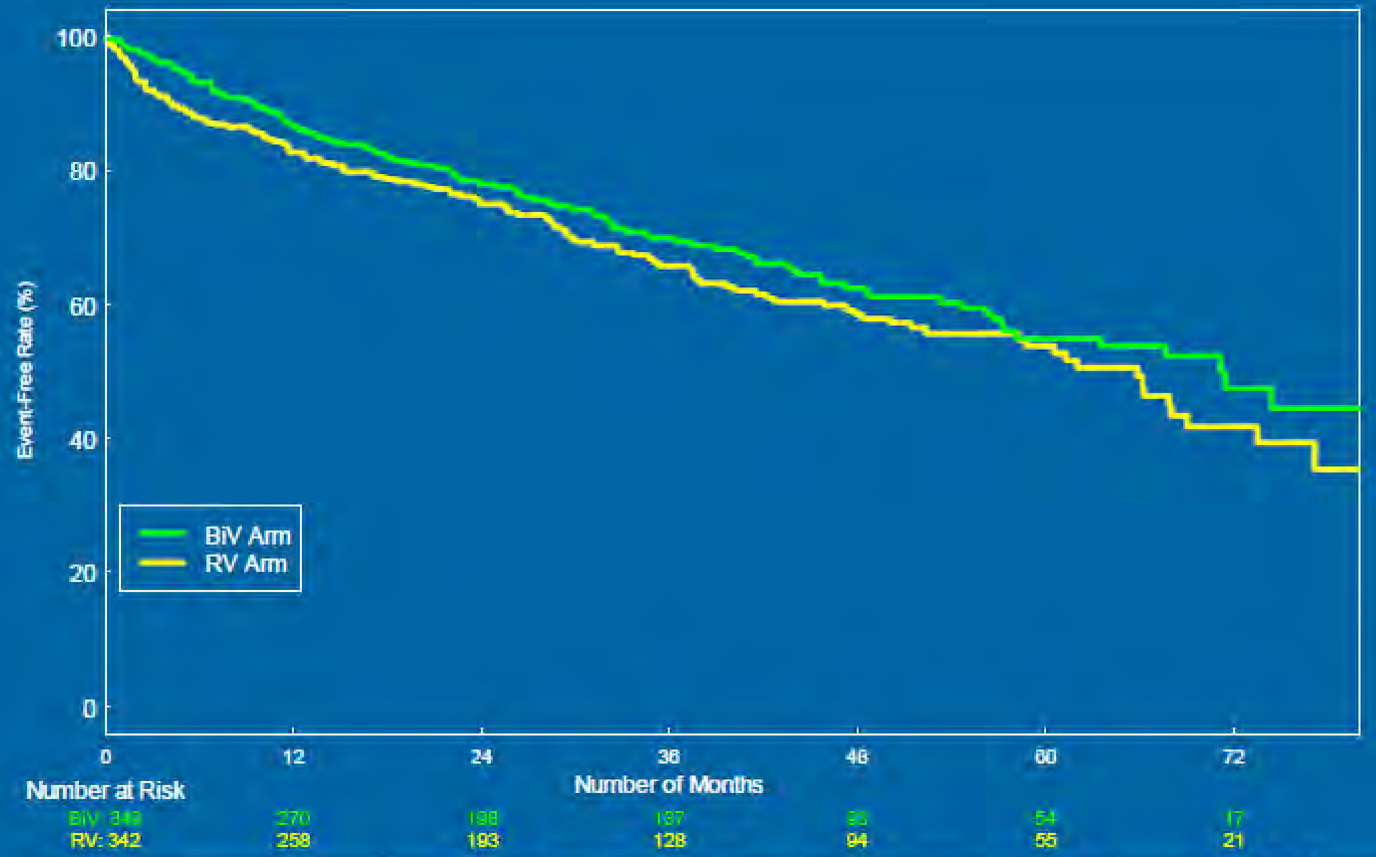


Cohort	Estimated HR (95% CI)	Probability HR < 1	Threshold
All Randomized Subjects	0.74 (0.60, 0.90)	0.9978	0.9775
CRT-P Only	0.73 (0.58, 0.91)		
CRT-D Only	0.75 (0.57, 1.02)		

Curtis AB et al. N Engl J Med 2013;368:1585-1593

The NEW ENGLAND JOURNAL of MEDICINE

Secondary Endpoint: Mortality/HF hospitalization



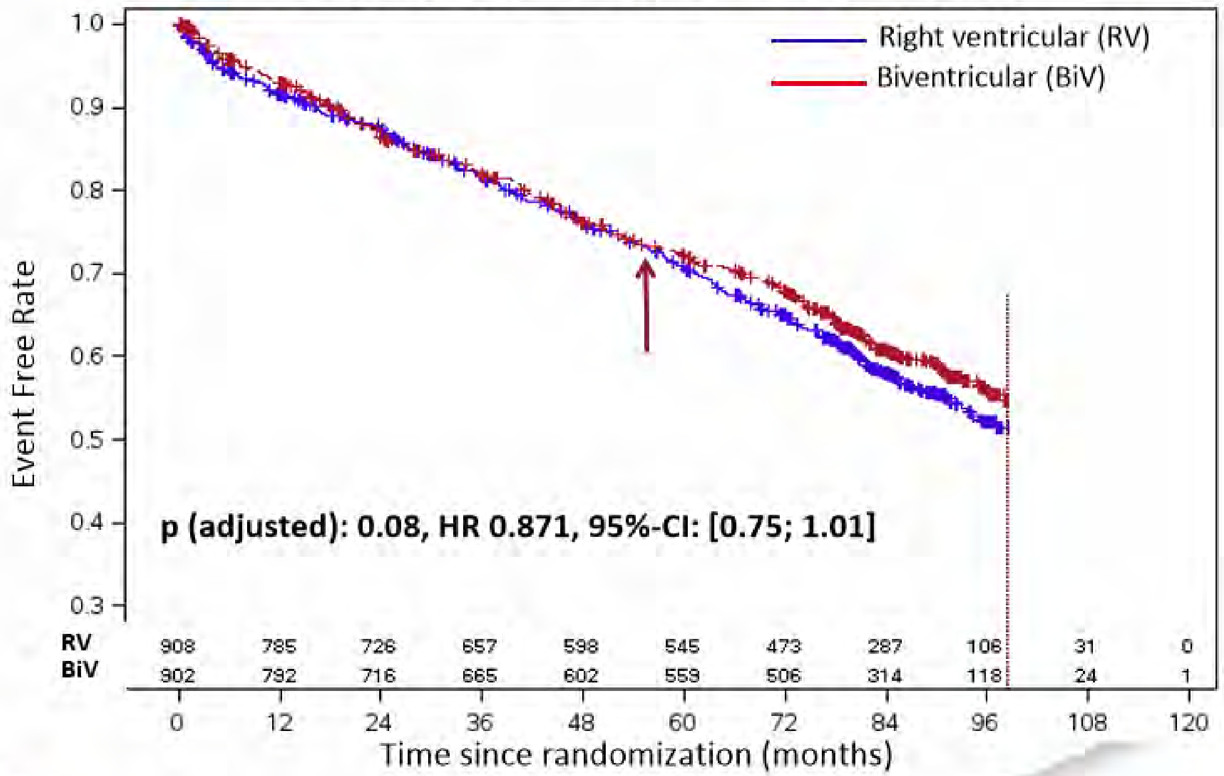
Cohort	Estimated HR (95% CI)	Probability HR < 1	Threshold
All Randomized Subjects	**0.78 (0.61, 0.99)**	**0.9802**	0.95
CRT-P Only	0.77 (0.58, 1.00)		
CRT-D Only	0.80 (0.58, 1.13)		

Conclusion

- In patients with AV block and LV EF of ≤ 50%, BiV pacing compared to RV pacing leads to a significant 26% reduction in combined endpoint of mortality, HF related urgent care and increase in LVESI.
- Furthermore, there is a 27% RRR in the composite endpoint of HF urgent care and all cause mortality.

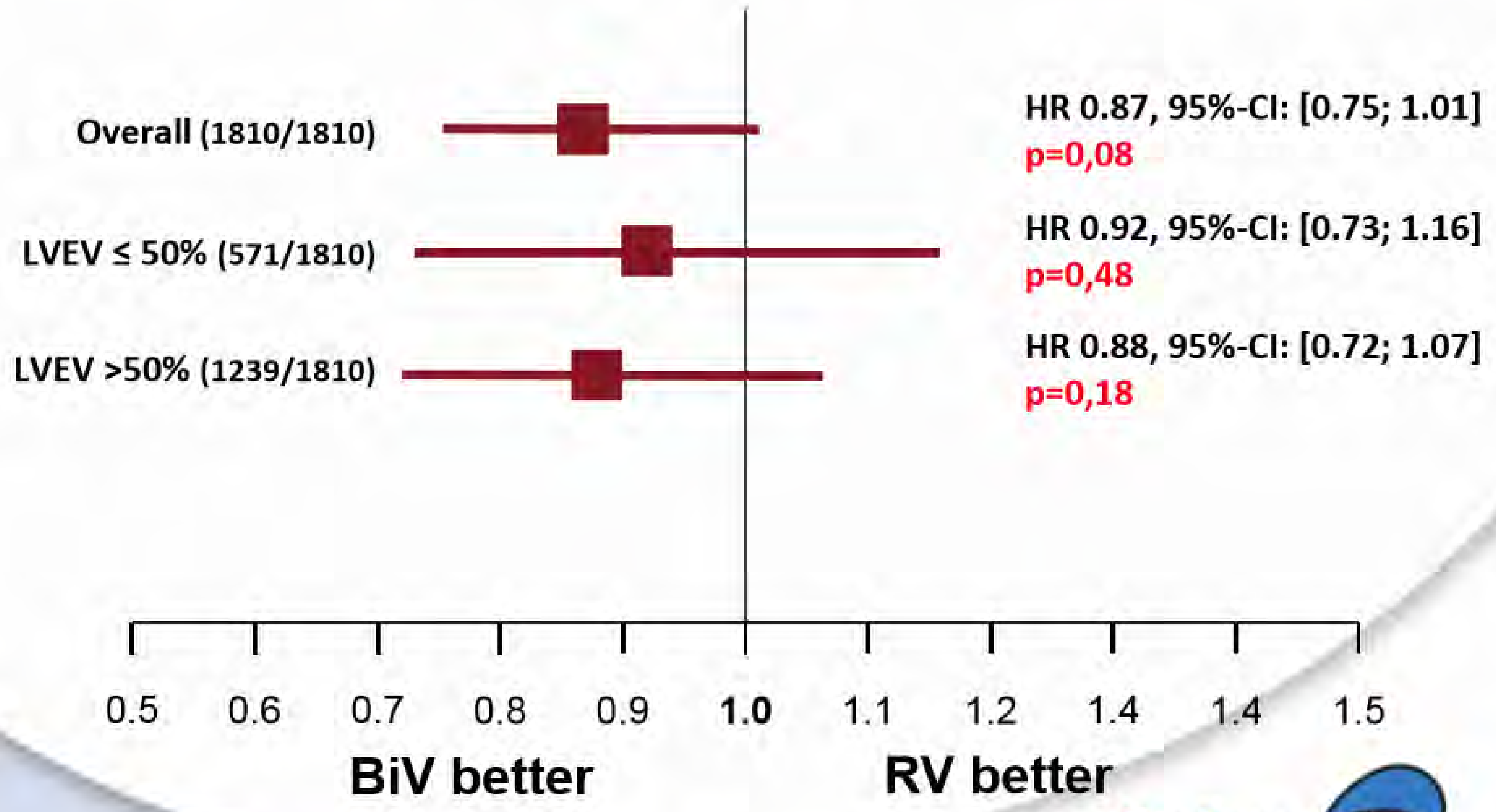
MORTALITY/HF HOSPITALIZATION

1810 patients / LVEF 55.4±12.2%



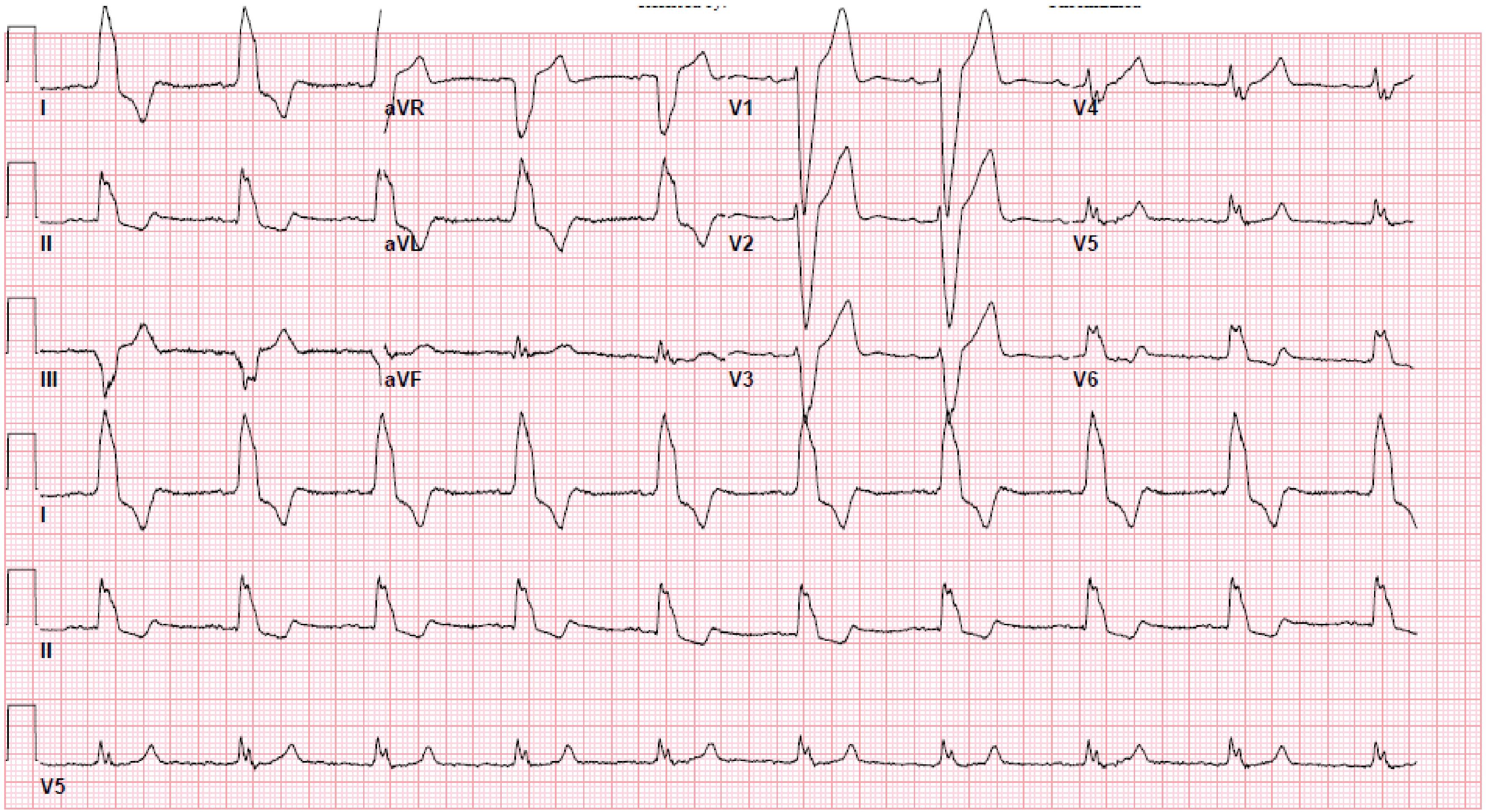
BioPace

MORTALITY / HF HOSPITALIZATION



BioPace

Thank You



52 yo male with history of HTN. Presents with syncope, EKG shown above, what is the next step:

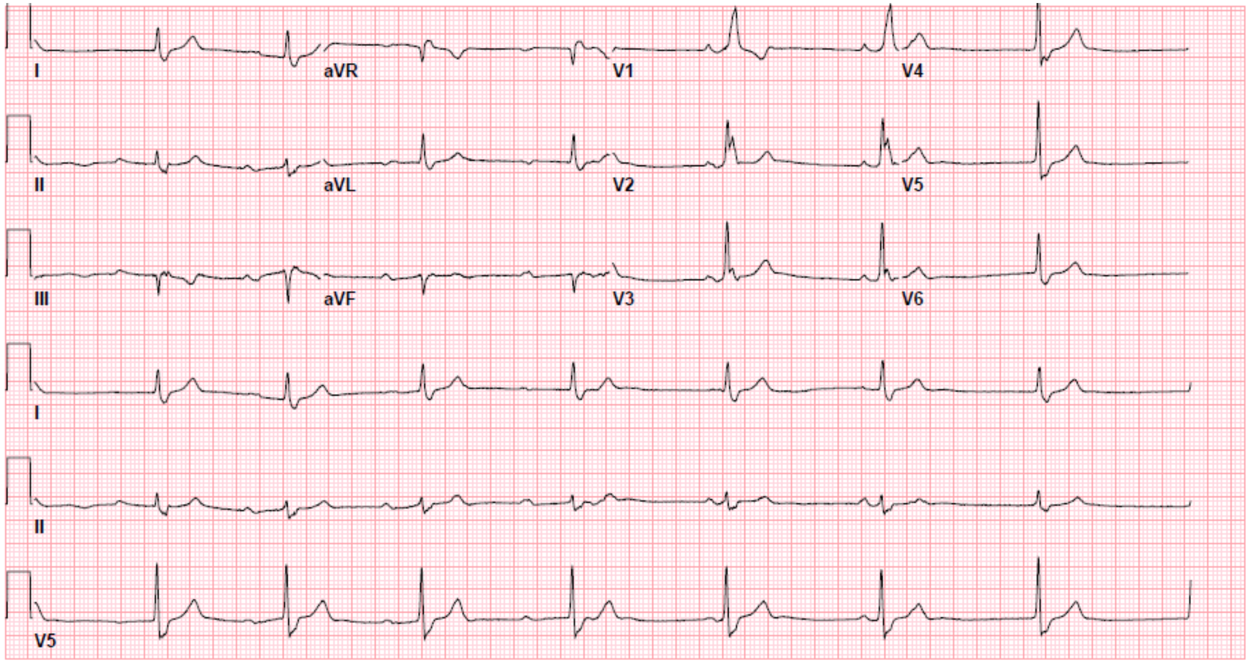
1- Pacemaker
2- Implantable loop recorder
3- EPS

LBBB and syncope

- The risk of developing AVB increases up to 17% in patients with syncope and BBB during 42 months follow-up.

McAnulty JH, Rahimtoola SH, Murphy E, DeMots H, Ritzmann L, Kanarek PE, et al. Natural history of "high-risk" bundle-branch block: Final report of a prospective study. N Engl J Med. 1982;307:137–43.

- 80 year old male with history of HTN admitted with stroke, has PAF. Noticed to have bradycardia on telemetry. EKG shown below:

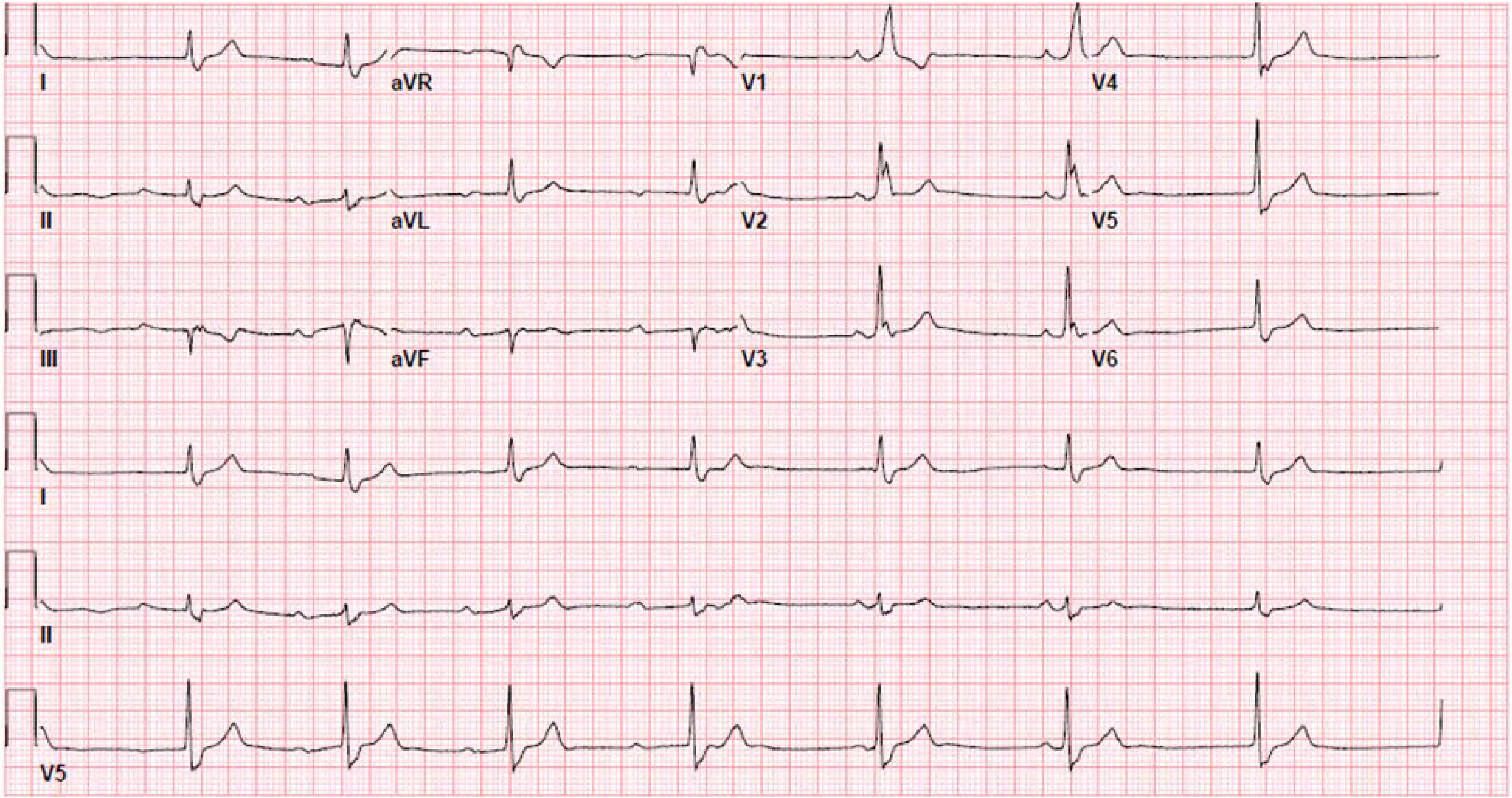


Best next step is:

1- Pacemaker

2- EPS

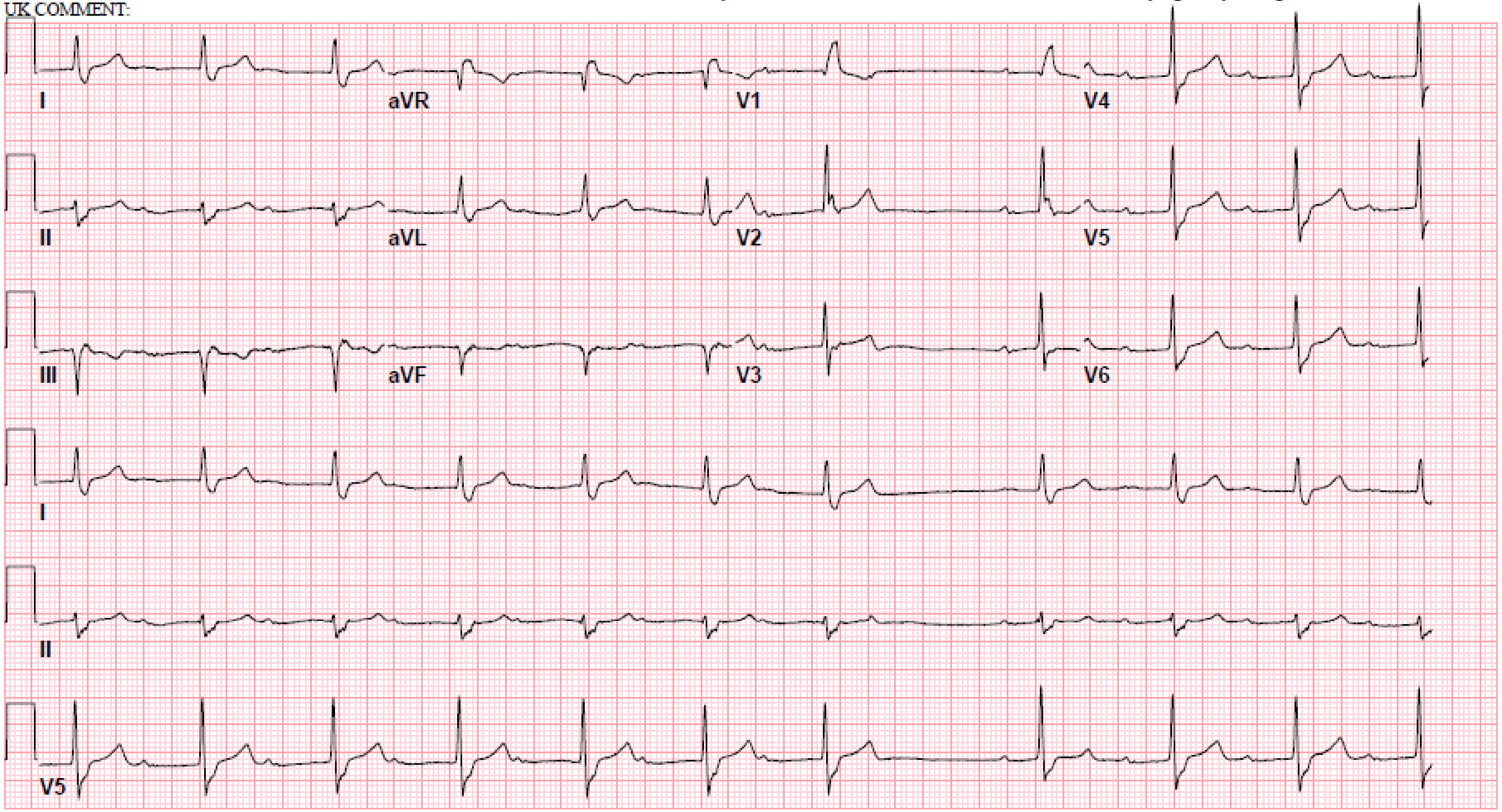
3- Do nothing



I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
I
II
V5

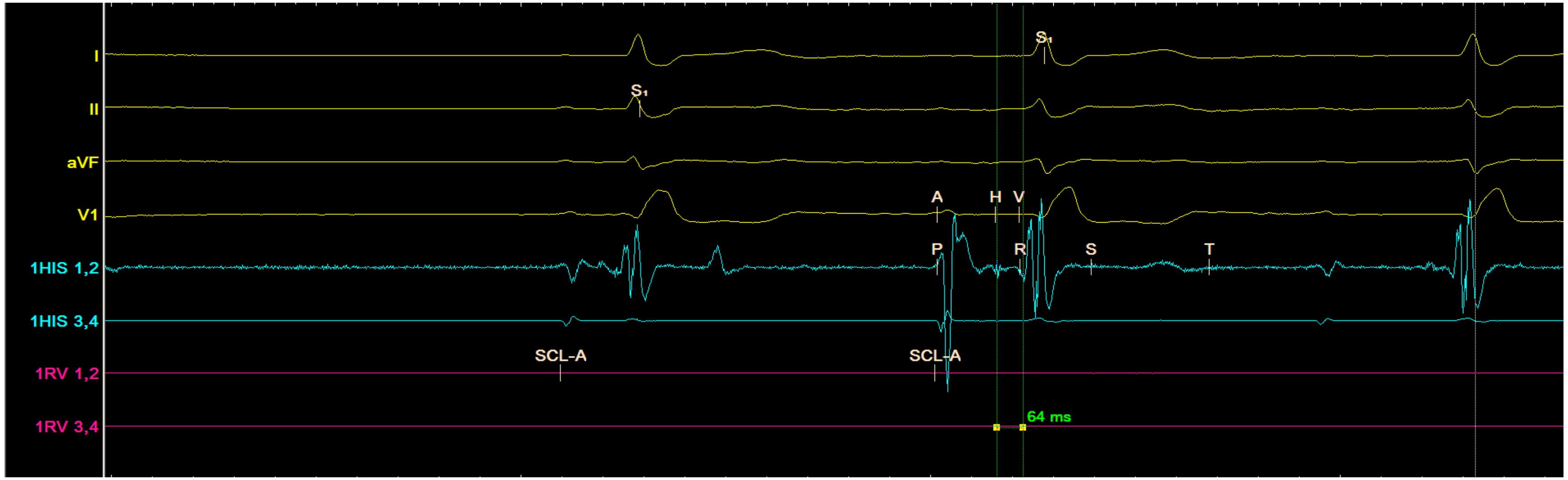
Referred by: Electronically signed by: Craig Chasen

UK COMMENT:



25mm/s 10mm/mV 150Hz 8.0 SP2 12SL 239 CID: 28

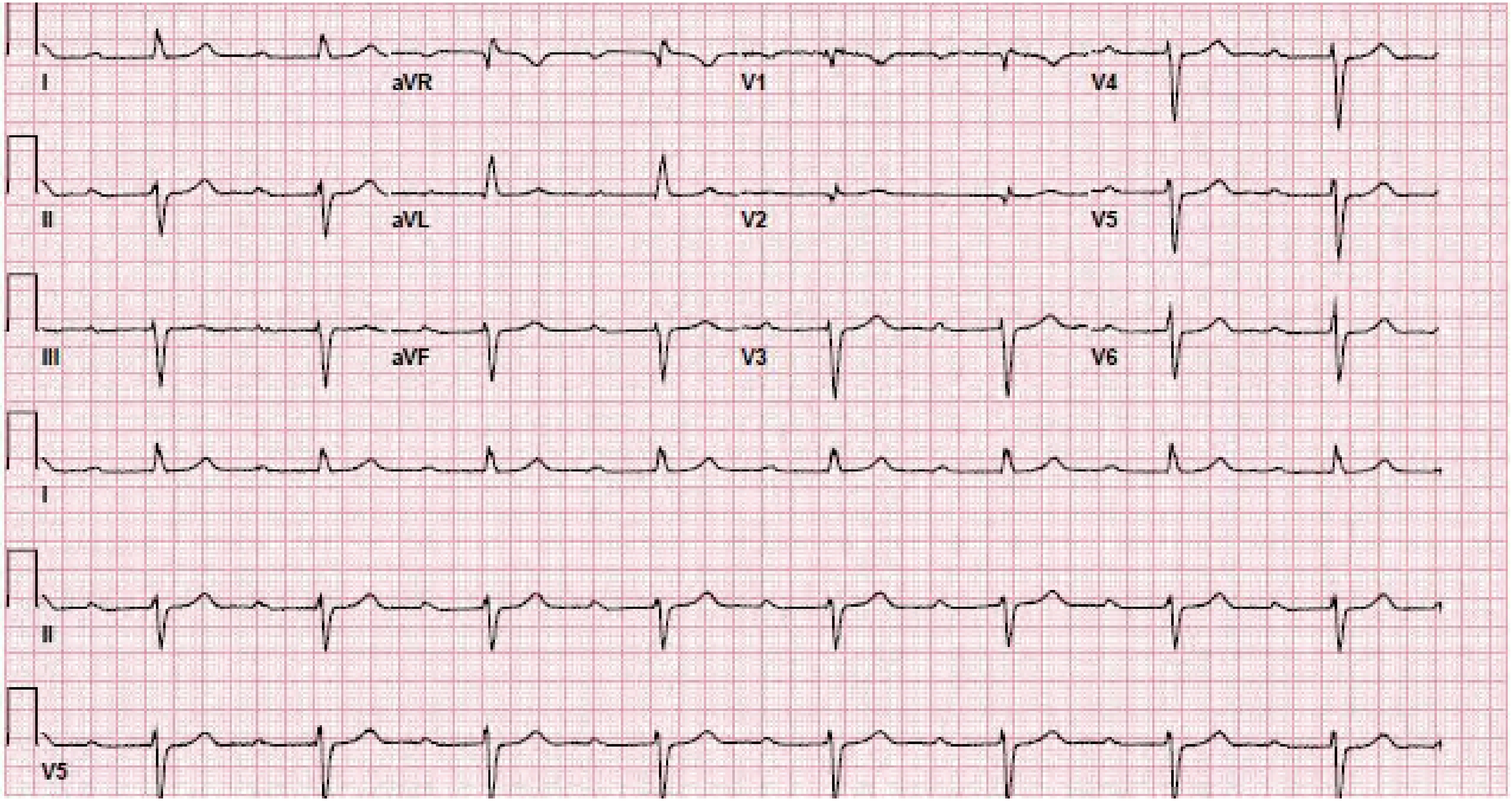
EID:2410 EDT: 09:45 15-JUL-2017 ORDER: 001ZNBZWK ACCOUNT: 0235867047182

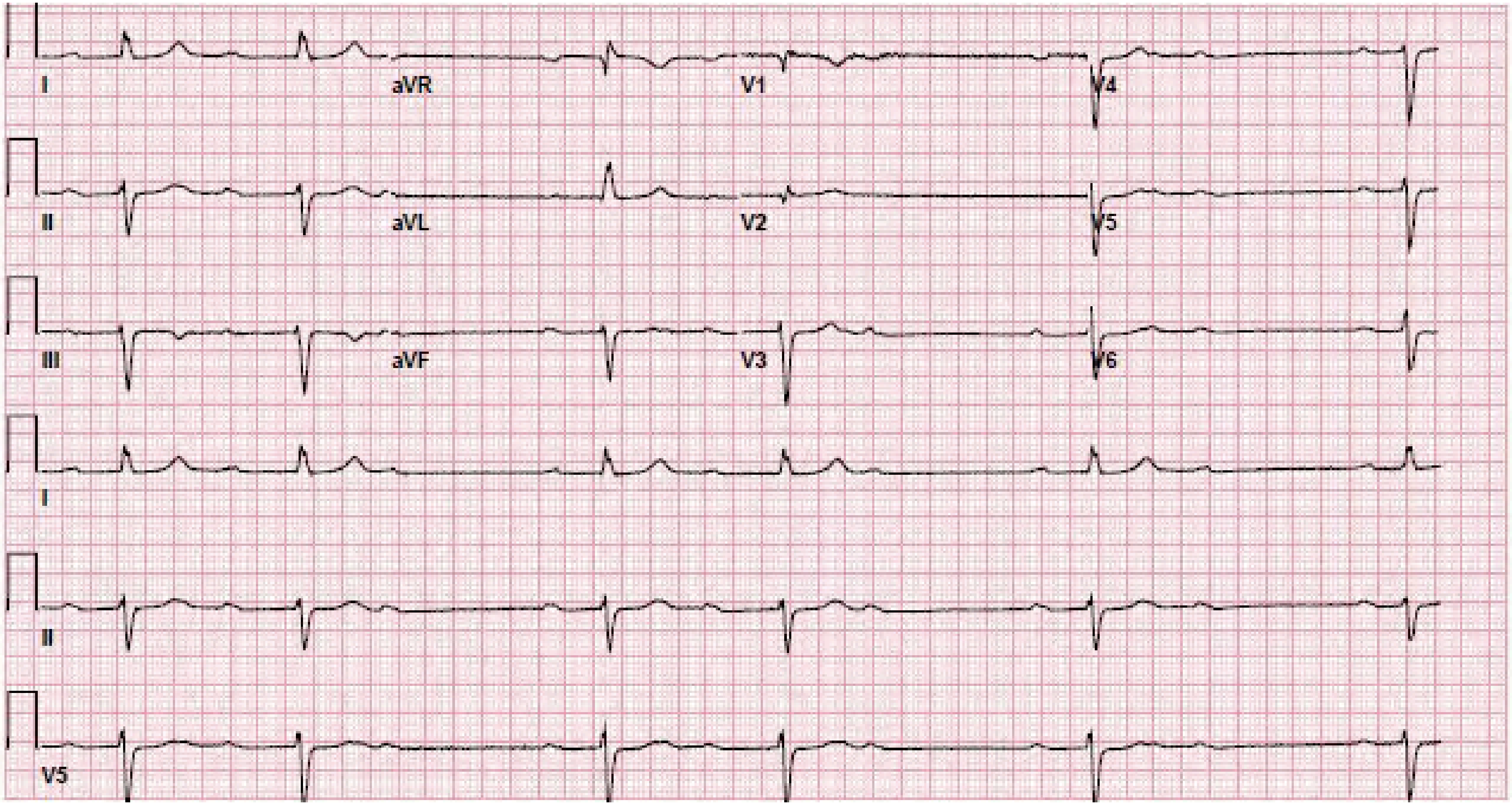


I
II
aVF
V1
1HIS 1,2
1HIS 3,4
1RV 1,2
1RV 3,4
S₁
S₁
A
H
V
P
R
S
T
SCL-A
SCL-A
64 ms

Case

- 62 year old male with history of HTN, CKD III, HLD, DM II, OSA, and aortic valve replacement presented to with pre-syncope.


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
I
II
V5



I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
I
II
V5

Next step in management?

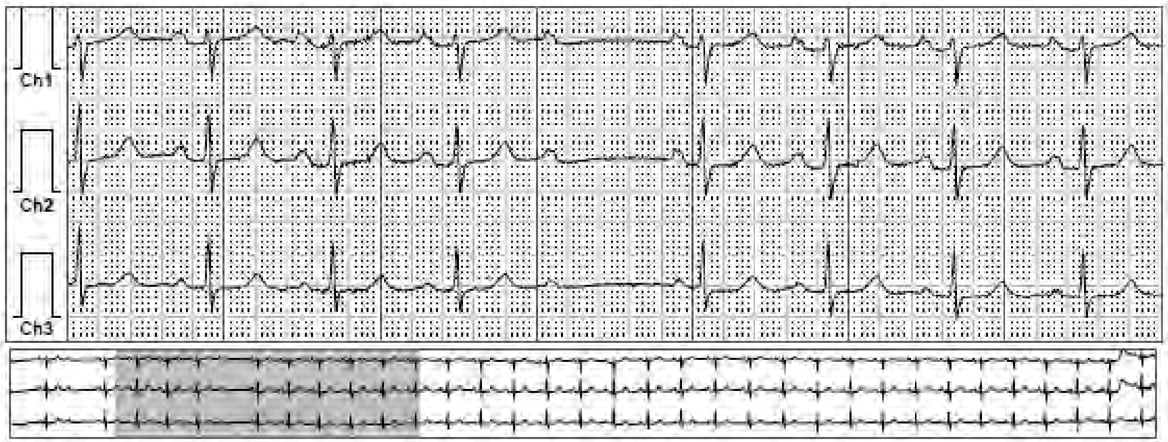
1- EPS

2- PPM

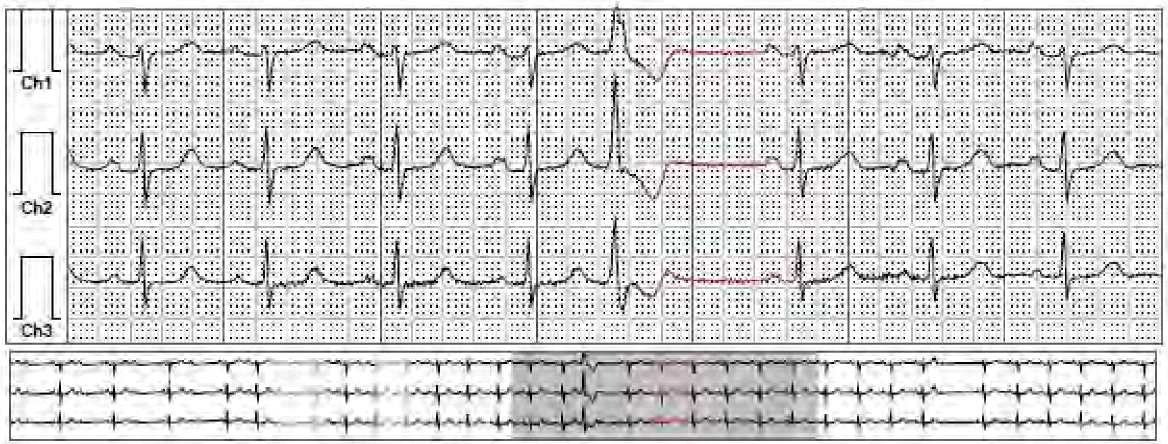
3- Do nothing

Case

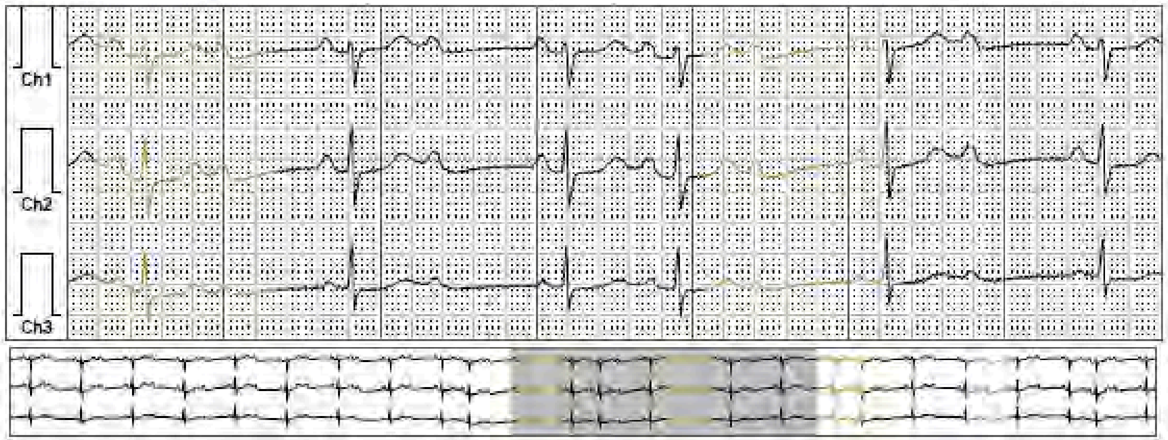
- 69 year old lady with h/o HTN has been c/o fatigue and dizziness for last 3 months. Baseline EKG shows sinus rhythm and is unremarkable. Holter monitor was ordered.



5:59:31 PM D1 71 BPM Size x1,x1,x1 PVC Strip 2 of 32



8:25:30 PM D1 50 BPM Size x1,x1,x1 Atrial Trigeminy Strip 3 of 32



What is the best next step?

1- Pacemaker

2- EPS

3- Exercise stress test

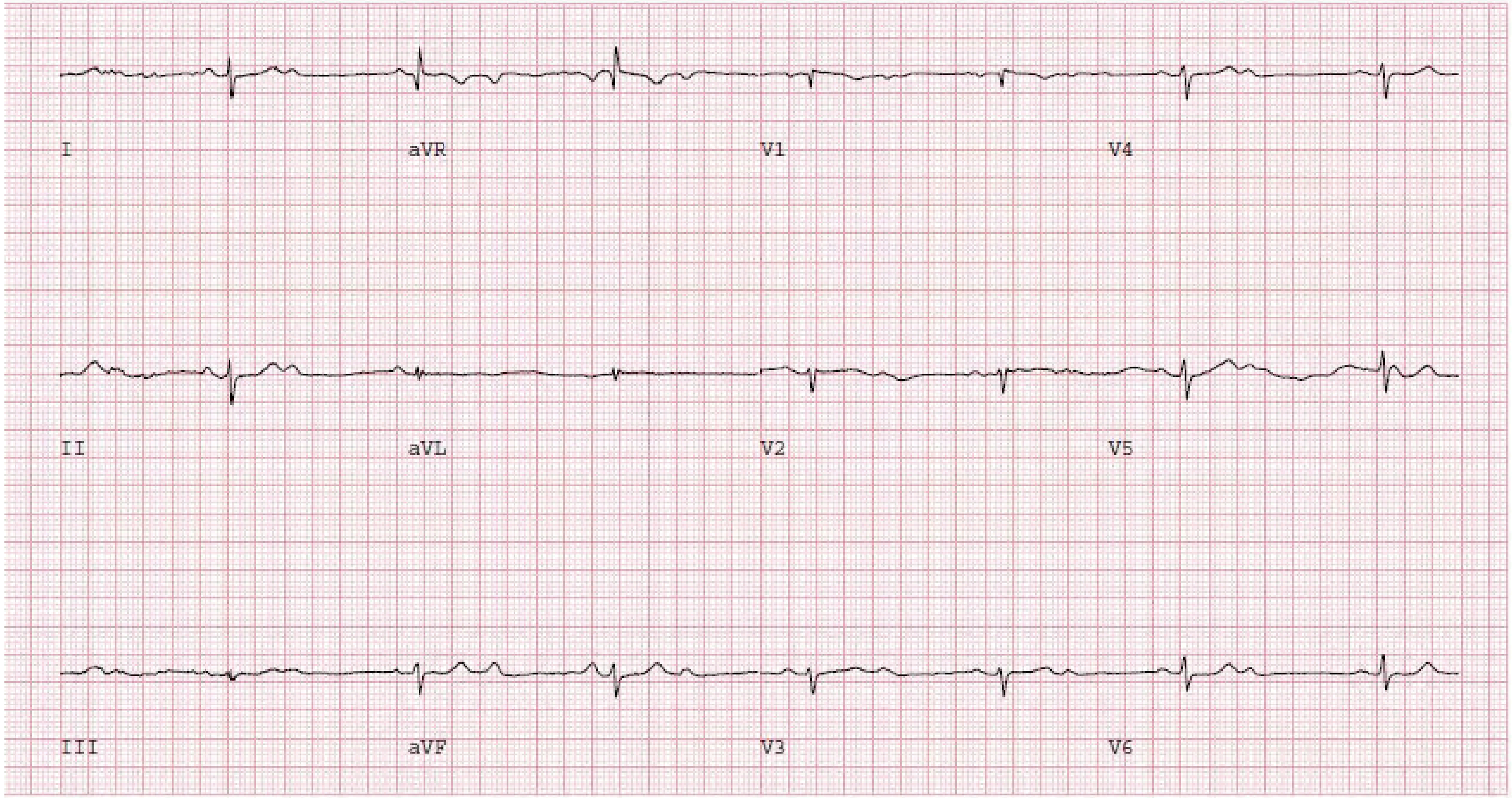
4- Reassure patient

[redacted]
11/30/2017
3:27:27pm

49 bpm
166/80 mmHg

PRETEST
SUPINE
36:58

BRUCE
0.0 mph
0.0 %



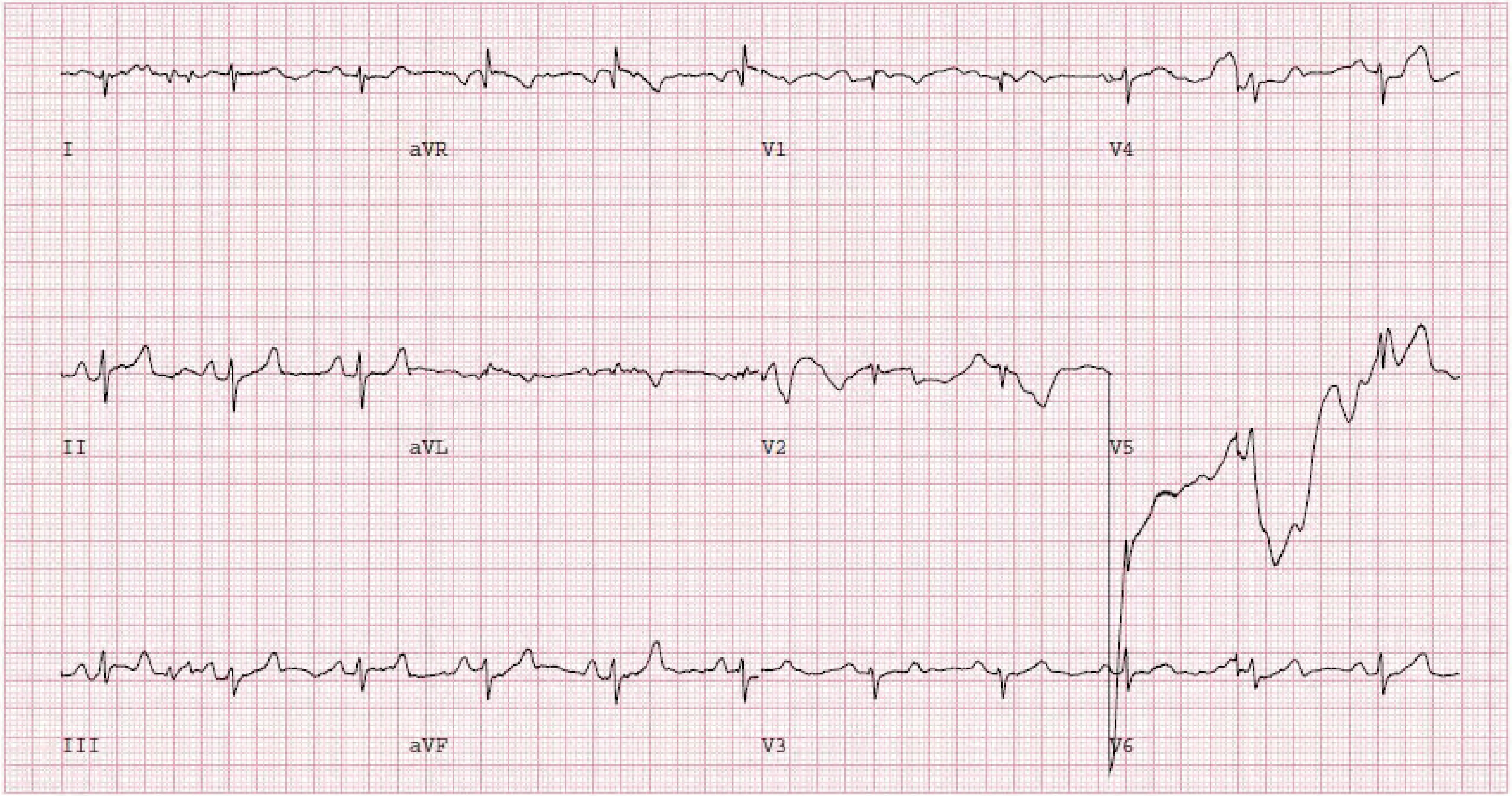
[redacted]

Patient ID: 016381295
11/30/2017
3:30:58pm

65 bpm
166/90 mmHg

EXERCISE
STAGE 1
02:50

BRUCE
1.7 mph
10.0 %



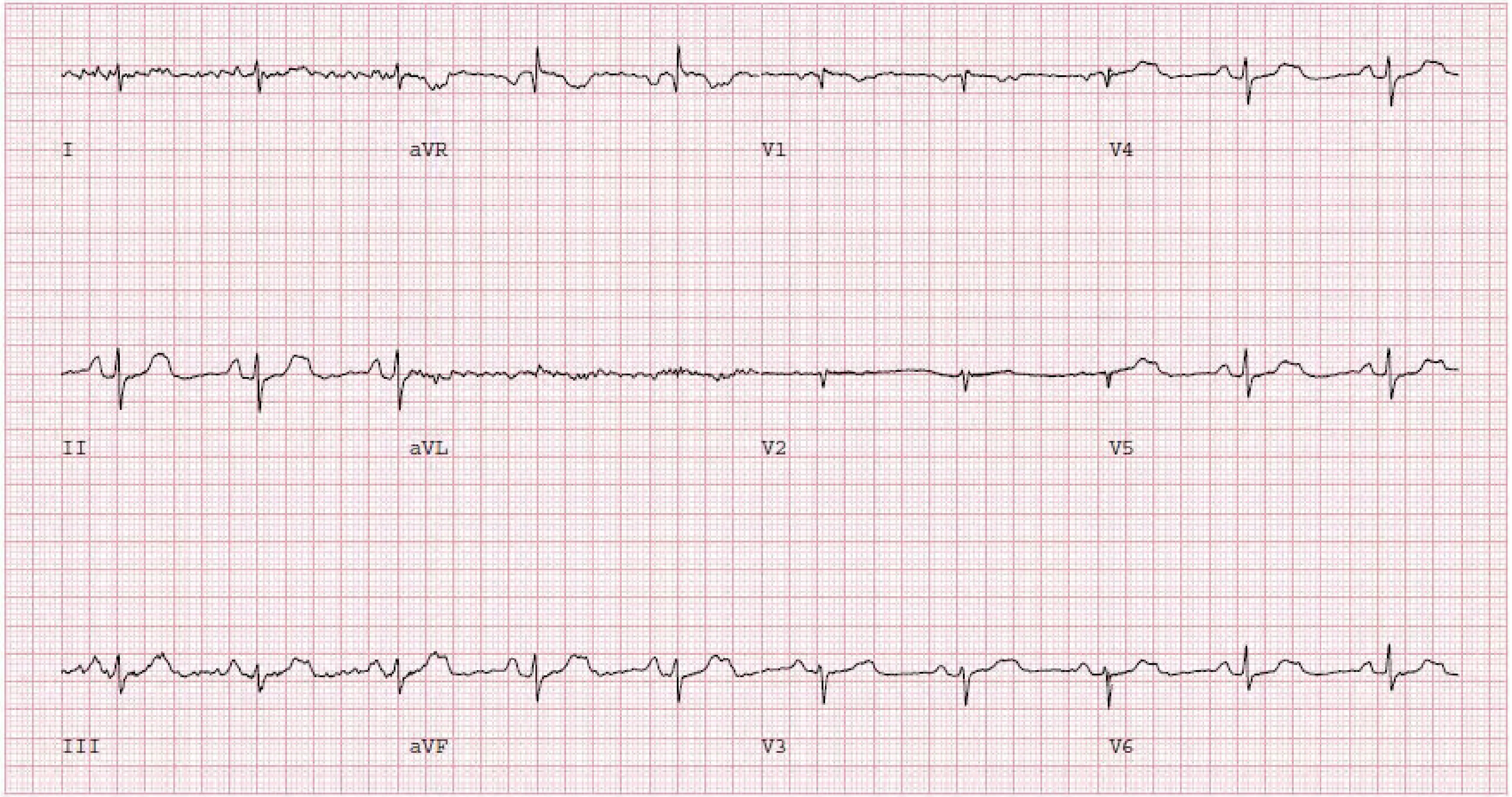
GE

[redacted]
3:34:48pm

61 bpm

RECOVERY
01:00

BRUCE
0.0 mph
0.0 %

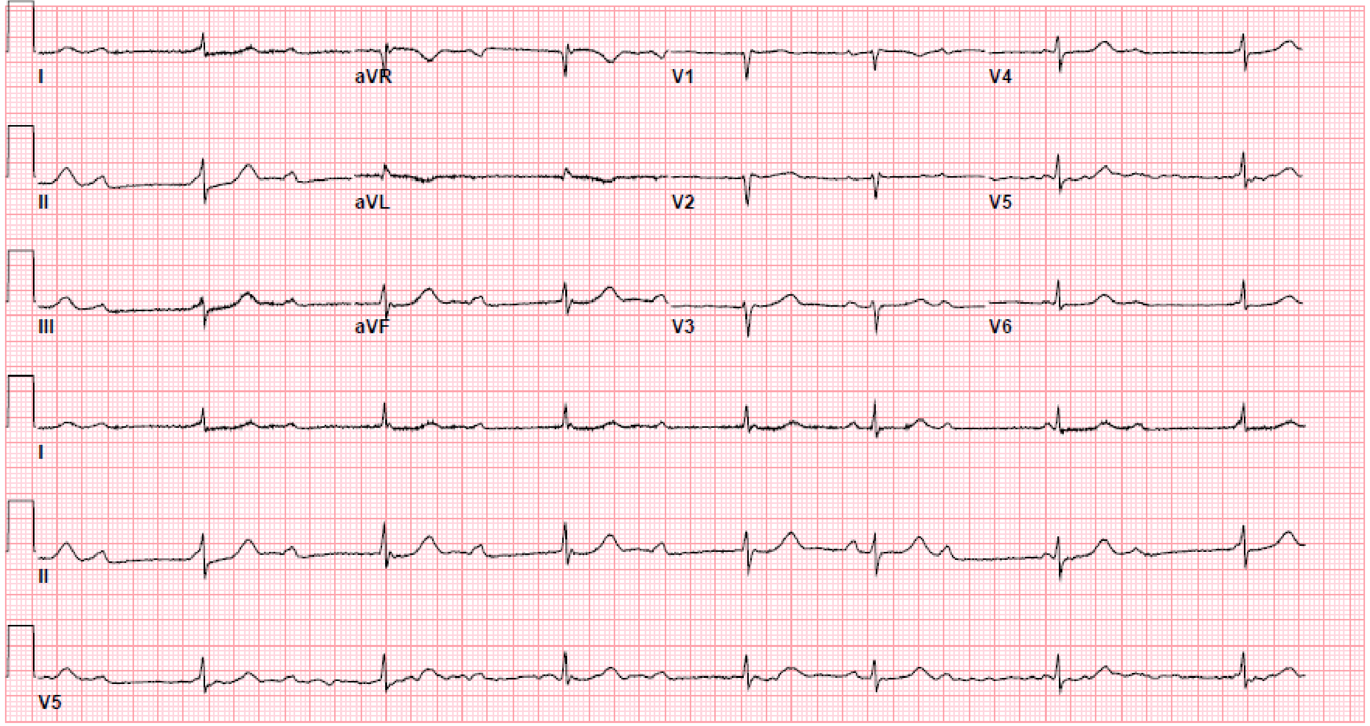


GE

Referred by:

Electronically signed by: Chien-Suu Kuo MD

UK ER COMM: STEMI- Y/N: ATT INITS: TIME:



Basic Pacing Concepts

Yousef Darrat MD
8/6/2021

Objectives

- Identify the components of pacing systems and their respective functions
- Define basic electrical terminology
- Describe the relationship of amplitude and pulse width defined in the strength duration curve
- Explain the importance of sensing
- Understand the need for and types of sensors used in rate responsive pacing
- Discuss sources of electromagnetic interference (EMI) and patient/clinician guidelines related to these sources

Lets start simple

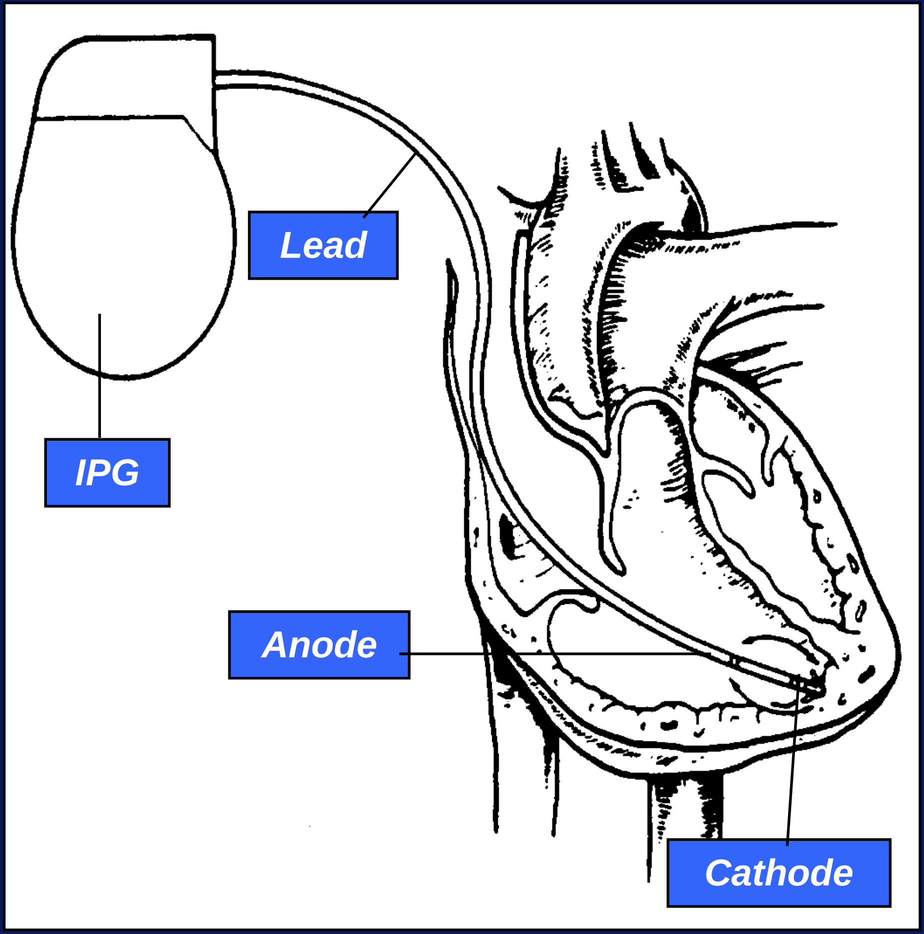
Pacemaker Components Combine with Body Tissue to Form a Complete Circuit

- **Pulse generator: power source or battery**
- **Leads or wires containing:**

  Cathode (negative electrode)

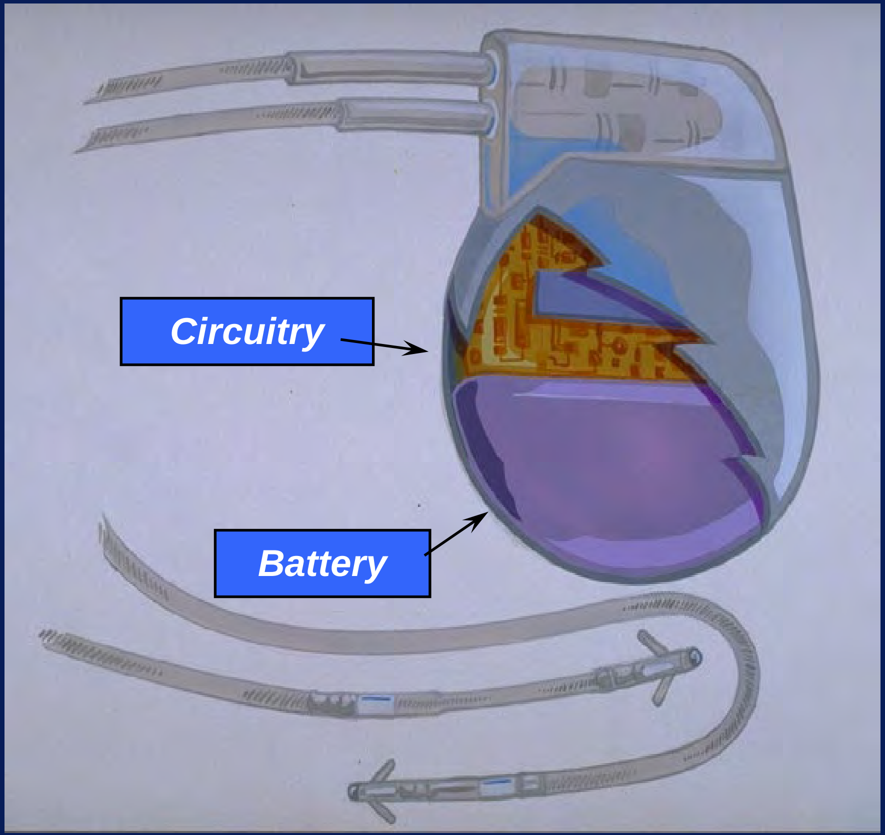
  and

  Anode (positive electrode)



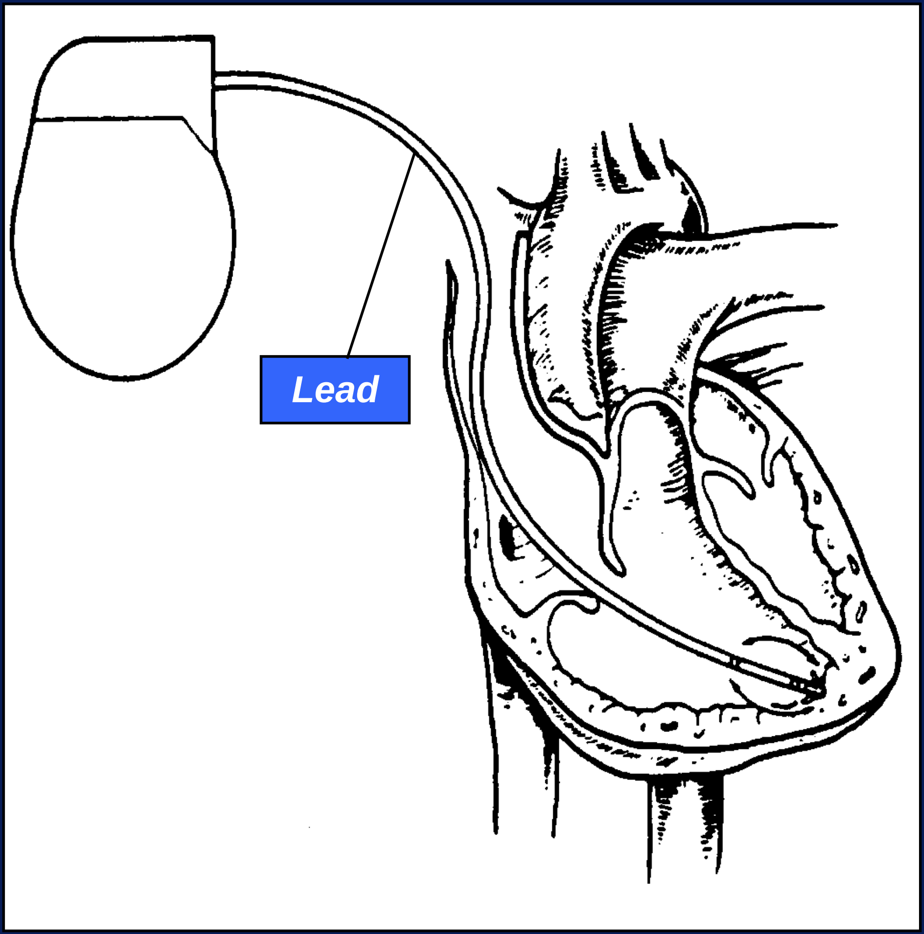
The Pulse Generator:

- Contains a battery that provides the energy for sending electrical impulses to the heart
- Houses the circuitry that controls pacemaker operations



Leads Are Insulated Wires That:

- Deliver electrical impulses from the pulse generator to the heart
- Sense cardiac depolarization



Types of Leads

- **Endocardial or transvenous leads**
- **Myocardial/Epicardial leads**

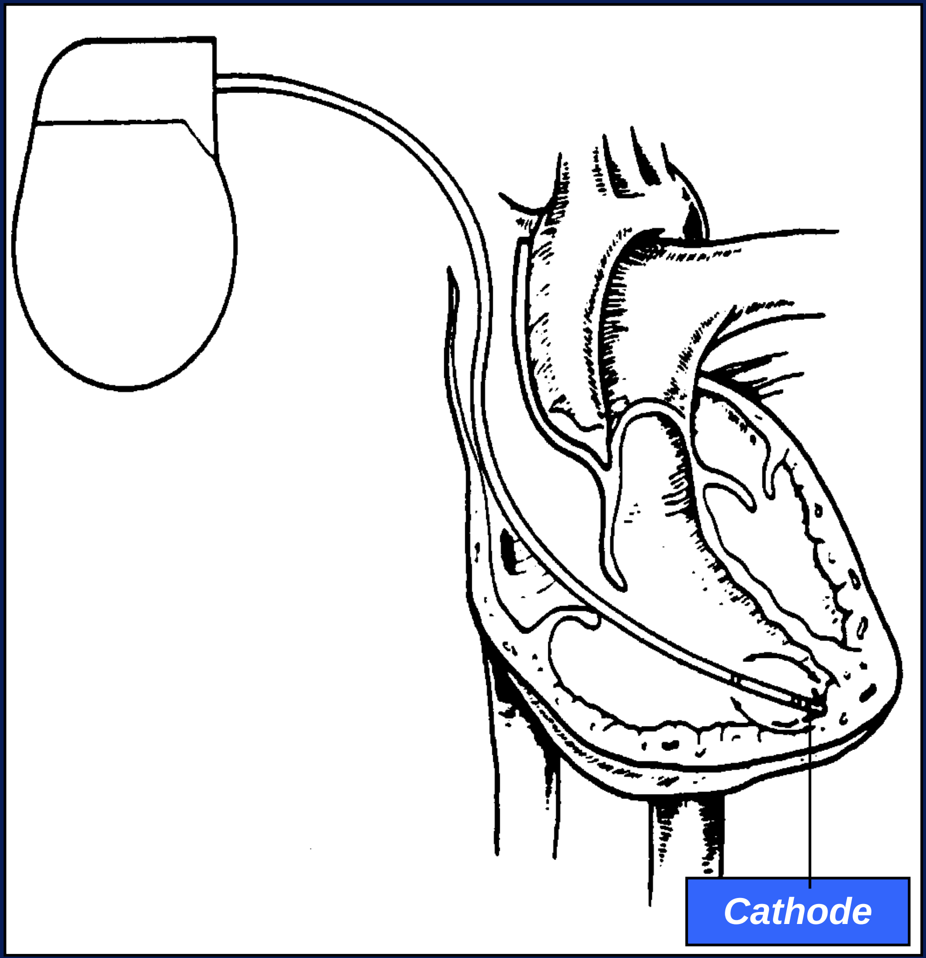
Transvenous Leads

Bipolar Vs Unipolar Configuration

- In unipolar configuration, the electrode stimulating the cardiac chamber typically is the cathode of the pacing circuit. It must be in direct contact with the myocardium.
- In bipolar configuration, both the anode and the cathode are in contact with the heart.

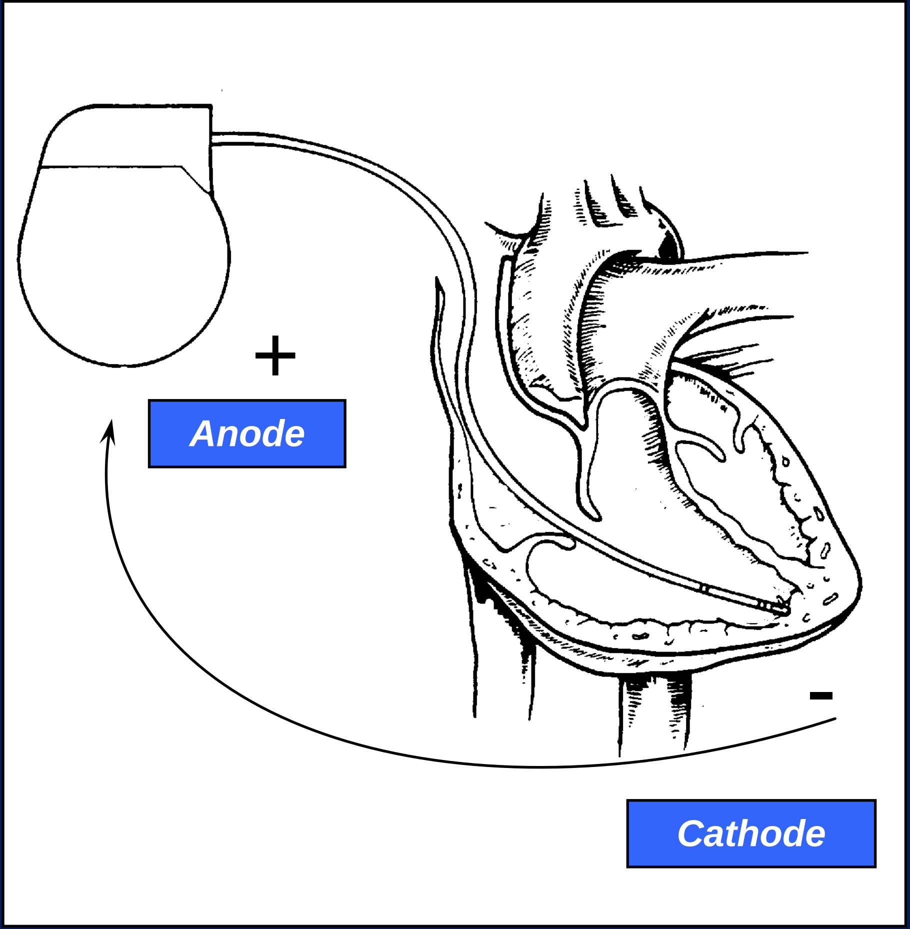
Bipolar leads

- Cathode: -vely charged
- Anode: +vely charged



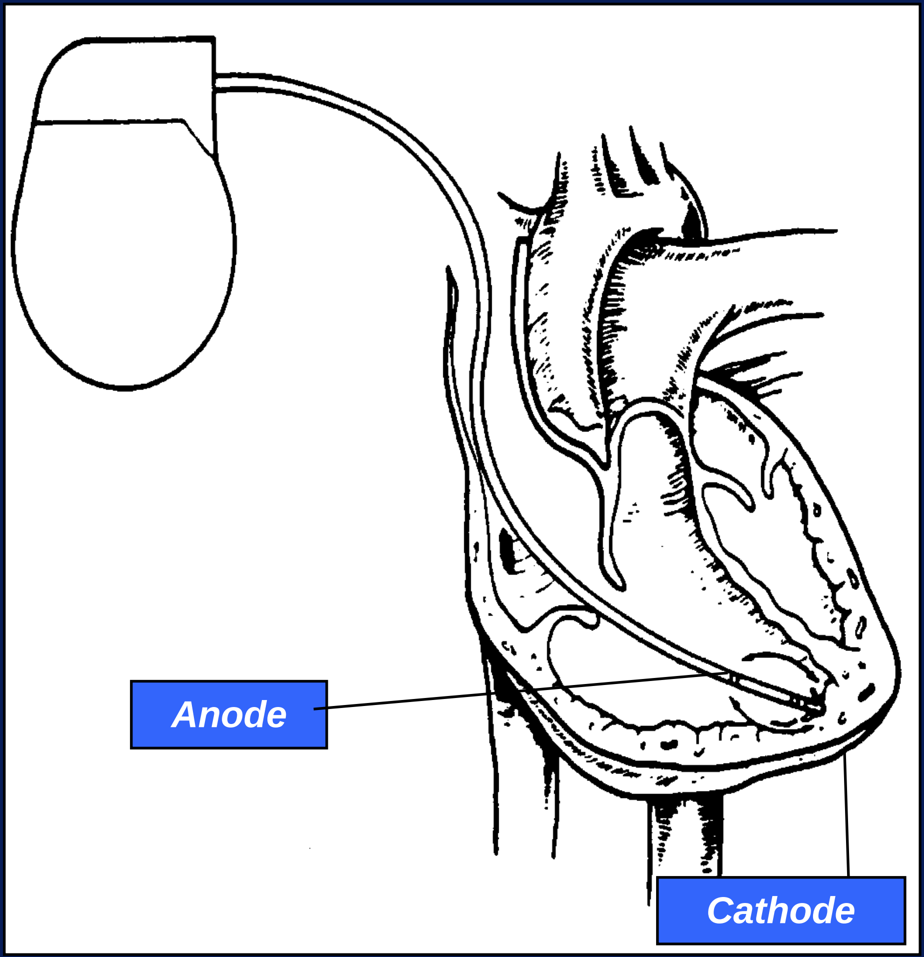
A Unipolar Pacing System Contains a Lead with Only One Electrode Within the Heart; In This System, the Impulse:

- Flows through the tip electrode (cathode)
- Stimulates the heart
- Returns through body fluid and tissue to the IPG (anode)



A Bipolar Pacing System Contains a Lead with Two Electrodes Within the Heart. In This System, the Impulse:

- Flows through the tip electrode located at the end of the lead wire
- Stimulates the heart
- Returns to the ring electrode above the lead tip



Most Pacemakers Perform Four Functions:

- Stimulate cardiac depolarization
- Sense intrinsic cardiac function
- Respond to increased metabolic demand by providing rate responsive pacing
- Provide diagnostic information stored by the pacemaker

Electrical Concepts

Every Electrical Pacing Circuit Has the Following Characteristics:

- Voltage
- Current
- Impedance

Voltage

- Voltage is the force or "push" that causes electrons to move through a circuit
- In a pacing system, voltage is:
  - Measured in volts
  - Provided by the pacemaker battery
  - Often referred to as amplitude

Current

- The flow of electrons in a completed circuit
- In a pacing system, current is:
  - Measured in mA (milliamps)
  - Represented by the letter "I"
  - Determined by the amount of electrons that move through a circuit

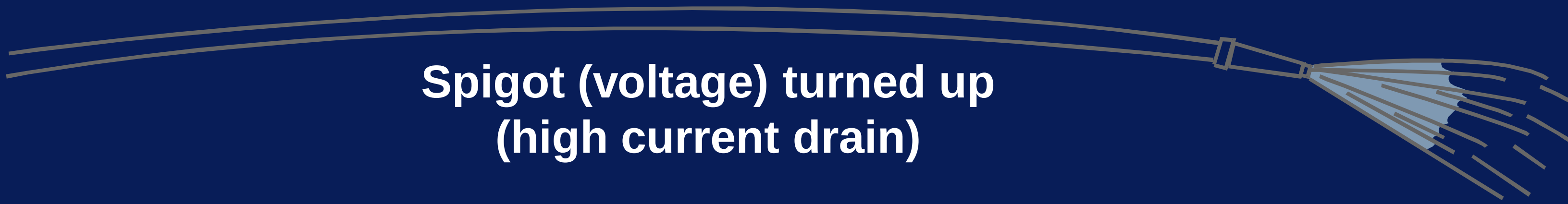
Impedance

- The opposition to current flow
- In a pacing system, impedance is:
  - Measured in ohms
  - Represented by the letter "R" (Ω for numerical values)
  - The measurement of the sum of all resistance to the flow of current

Voltage, Current, and Impedance Are Interdependent

- The interrelationship of the three components can be likened to the flow of water through a hose
  - Voltage represents the force with which . . .
  - Current (water) is delivered through . . .
  - A hose, or lead, where each component represents the total impedance:
    - The nozzle, representing the electrode
    - The tubing, representing the lead wire

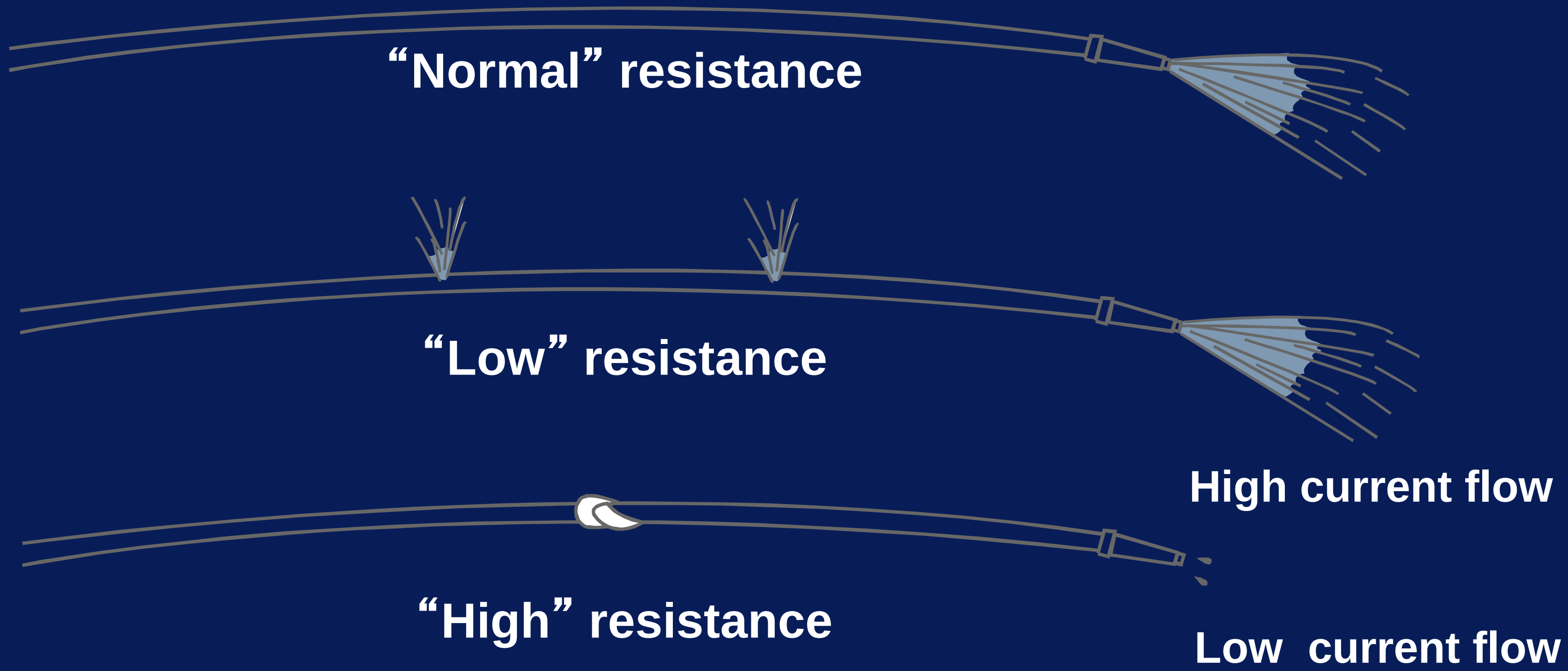
Voltage and Current Flow



Spigot (voltage) turned up
(high current drain)

Spigot (voltage) turned low
(low current drain)

Resistance and Current Flow



Impedance Changes Affect Pacemaker Function and Battery Longevity

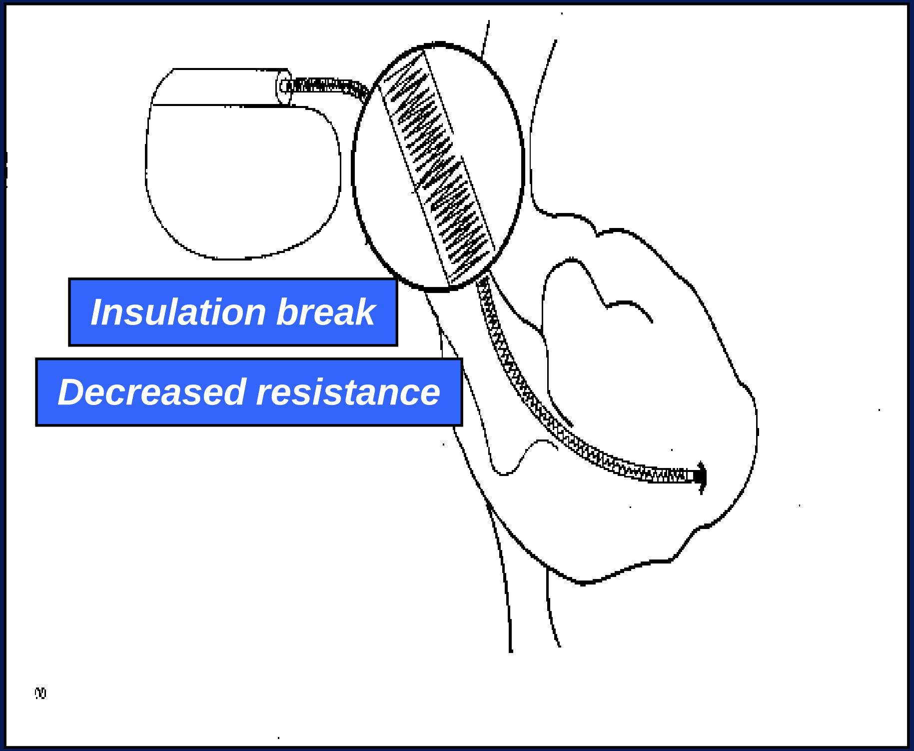
- High impedance reading reduces battery current drain and increases longevity
- Low impedance reading increases battery current drain and decreases longevity
- Impedance reading values range from 300 to 1,000 Ω
  - High impedance leads will show impedance reading values greater than 1,000 ohms

Lead Impedance Values Will Change Due to:

- Insulation breaks
- Wire fractures

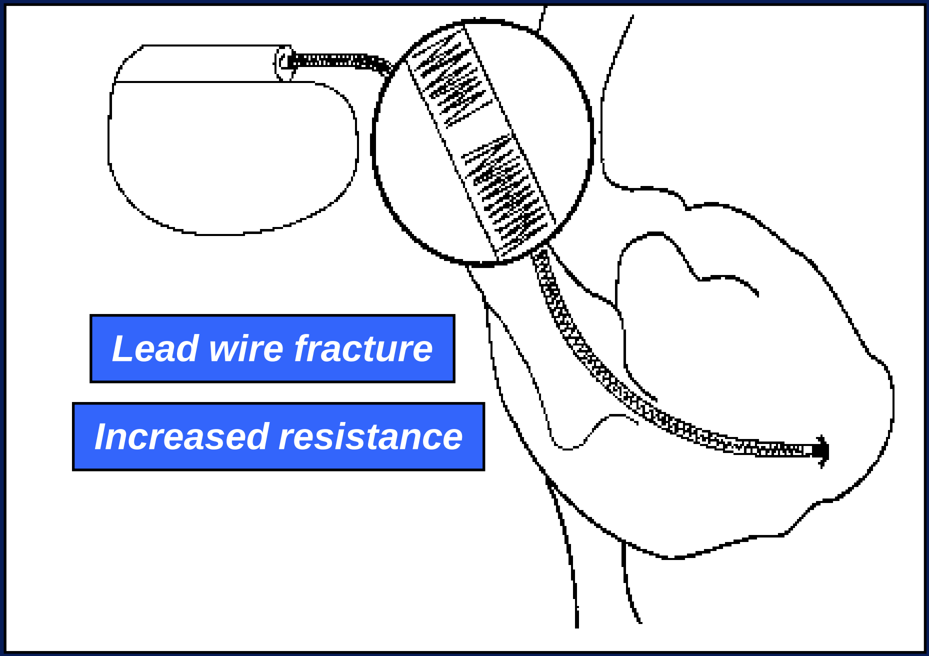
An Insulation Break Around the Lead Wire Can Cause Impedance Values to Fall

- Insulation breaks expose the wire to body fluids which have a low resistance and cause impedance values to fall
- Current drains through the insulation break into the body which depletes the battery
- An insulation break can cause impedance values to fall below 300 Ω



A Wire Fracture Within the Insulating Sheath May Cause Impedance Values to Rise

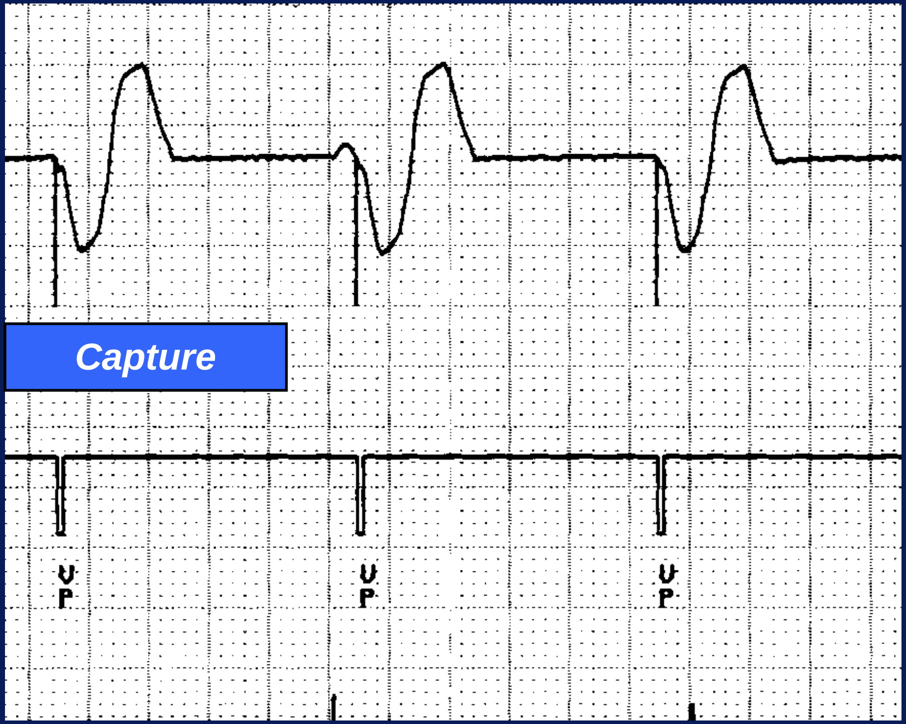
- Impedance values across a break in the wire will increase
- Current flow may be too low to be effective
- Impedance values may exceed 3,000 Ω

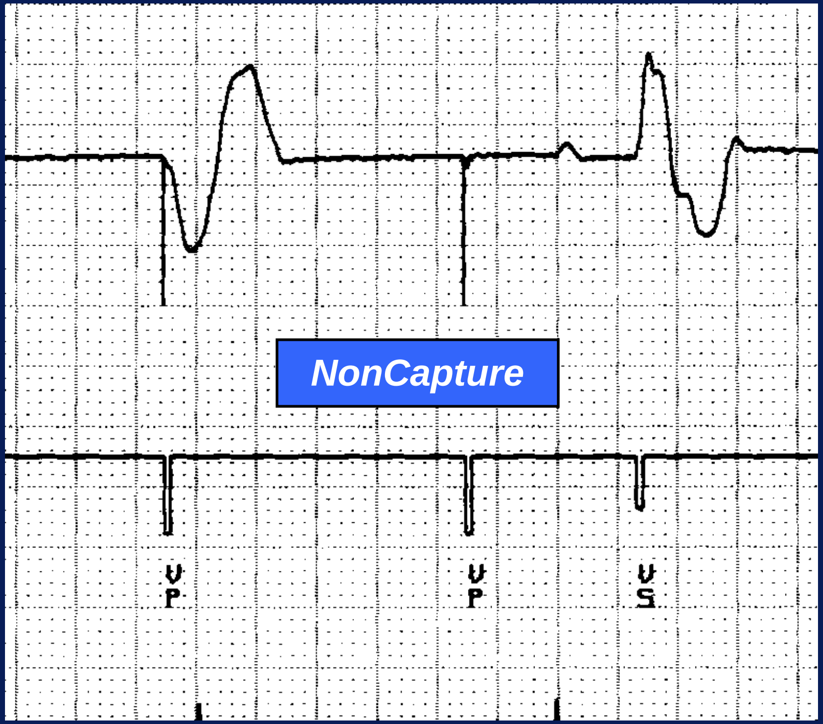


Stimulation

Stimulation Threshold

- The minimum electrical stimulus needed to consistently capture the heart





VVI / 60

Two Settings Are Used to Ensure Capture:

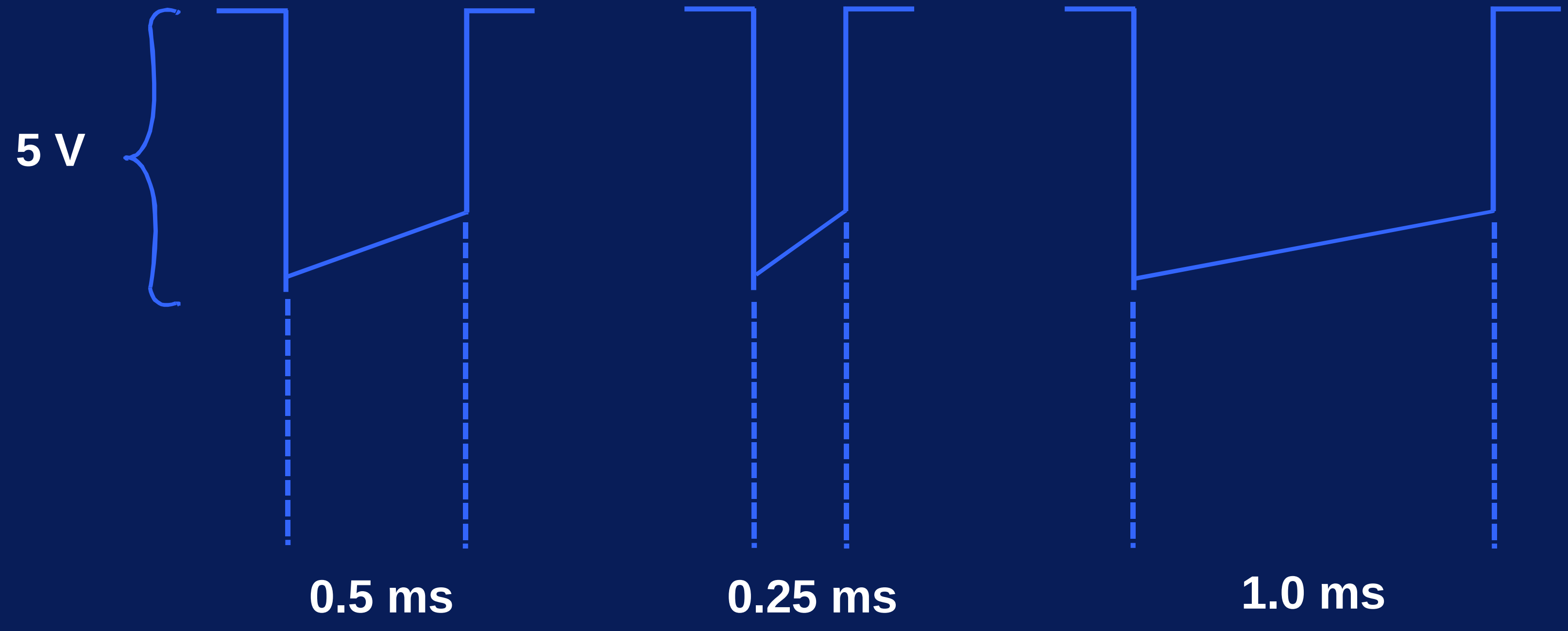
- Amplitude
- Pulse width

Amplitude is the Amount of Voltage Delivered to the Heart By the Pacemaker

- Amplitude reflects the strength or height of the impulse:
  - The amplitude of the impulse must be large enough to cause depolarization (i.e., to "capture" the heart)

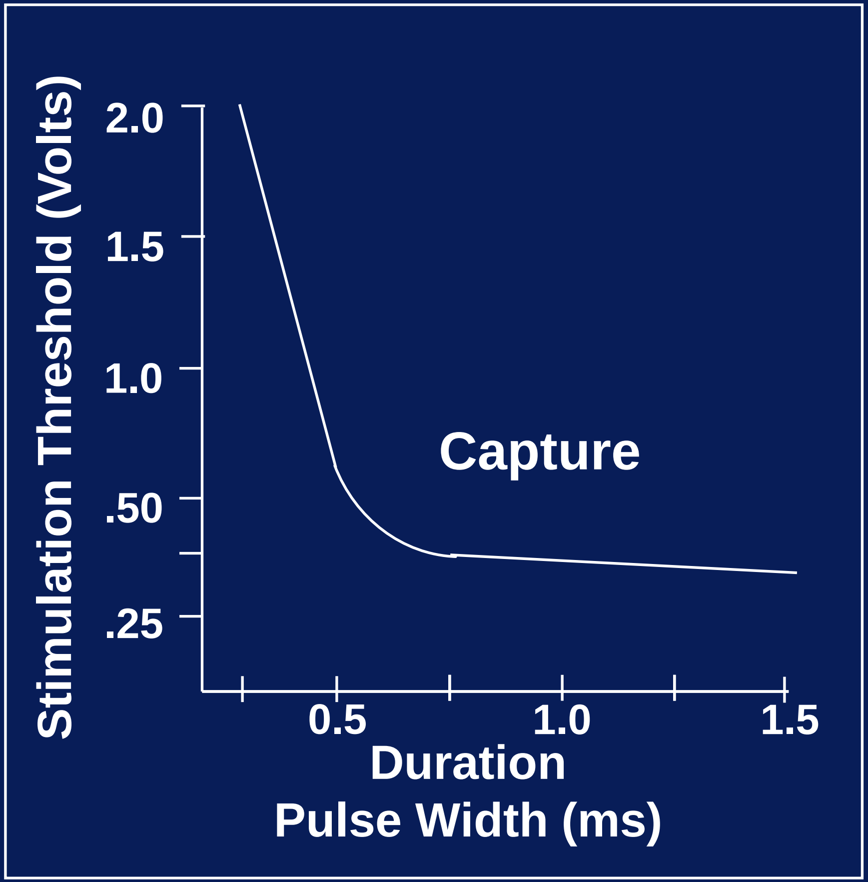
Pulse Width Is the Time (Duration) of the Pacing Pulse

- Pulse width is expressed in milliseconds (ms)
- The pulse width must be long enough for depolarization to disperse to the surrounding tissue



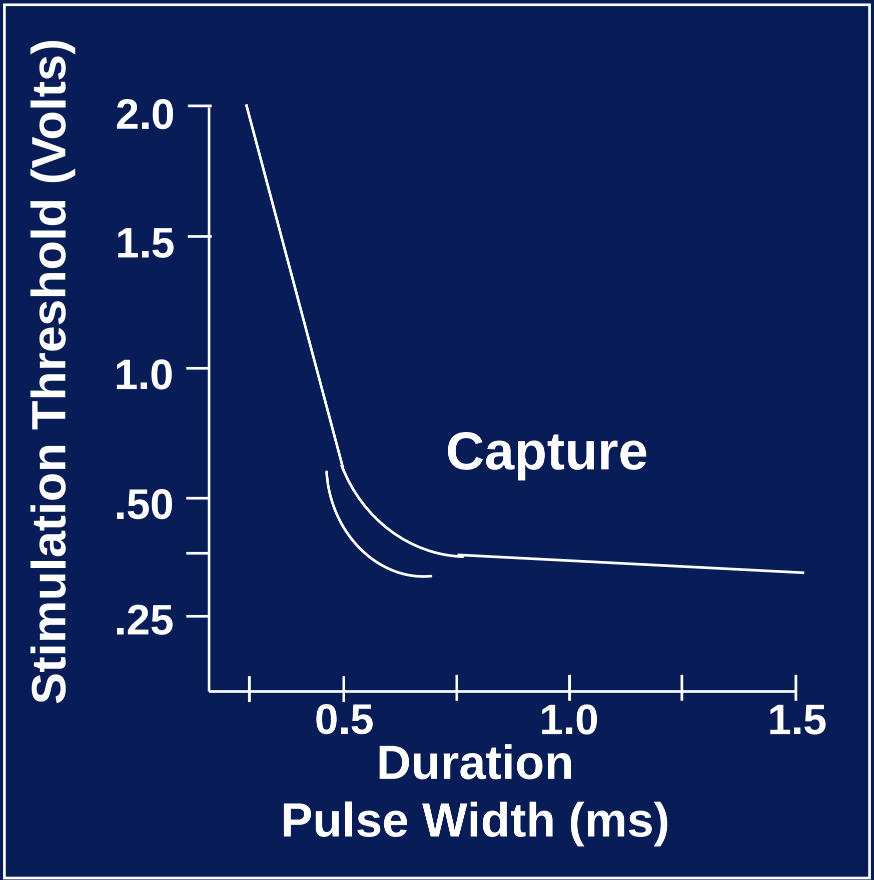
The Strength-Duration Curve

- The strength-duration curve illustrates the relationship of amplitude and pulse width
  - Values on or above the curve will result in capture



Clinical Usefulness of the Strength-Duration Curve

- Adequate safety margins must be achieved due to:
  - Acute or chronic pacing system
  - Daily fluctuations in threshold



Sensing

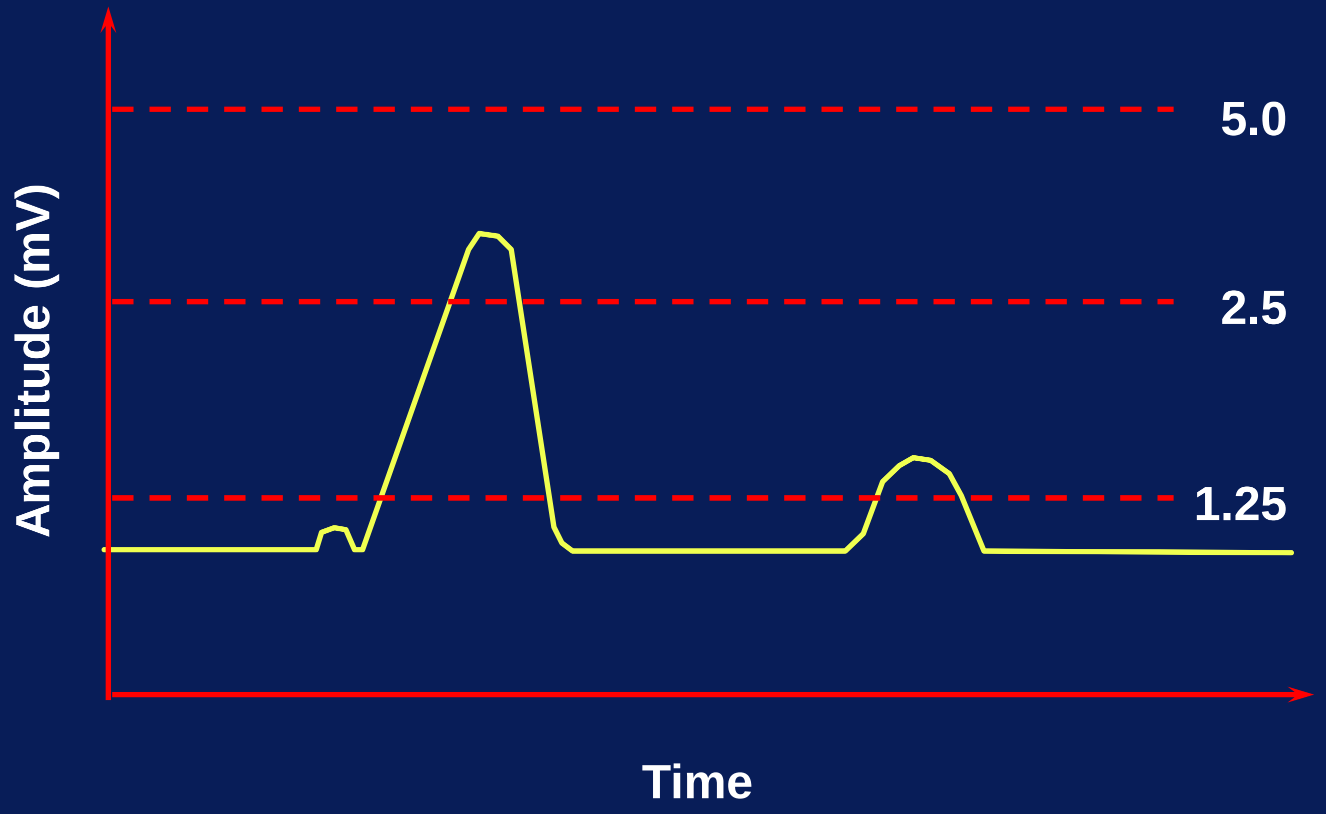
Sensing

- Sensing is the ability of the pacemaker to "see" when a natural (intrinsic) depolarization is occurring
  - Pacemakers sense cardiac depolarization by measuring changes in electrical potential of myocardial cells between the anode and cathode

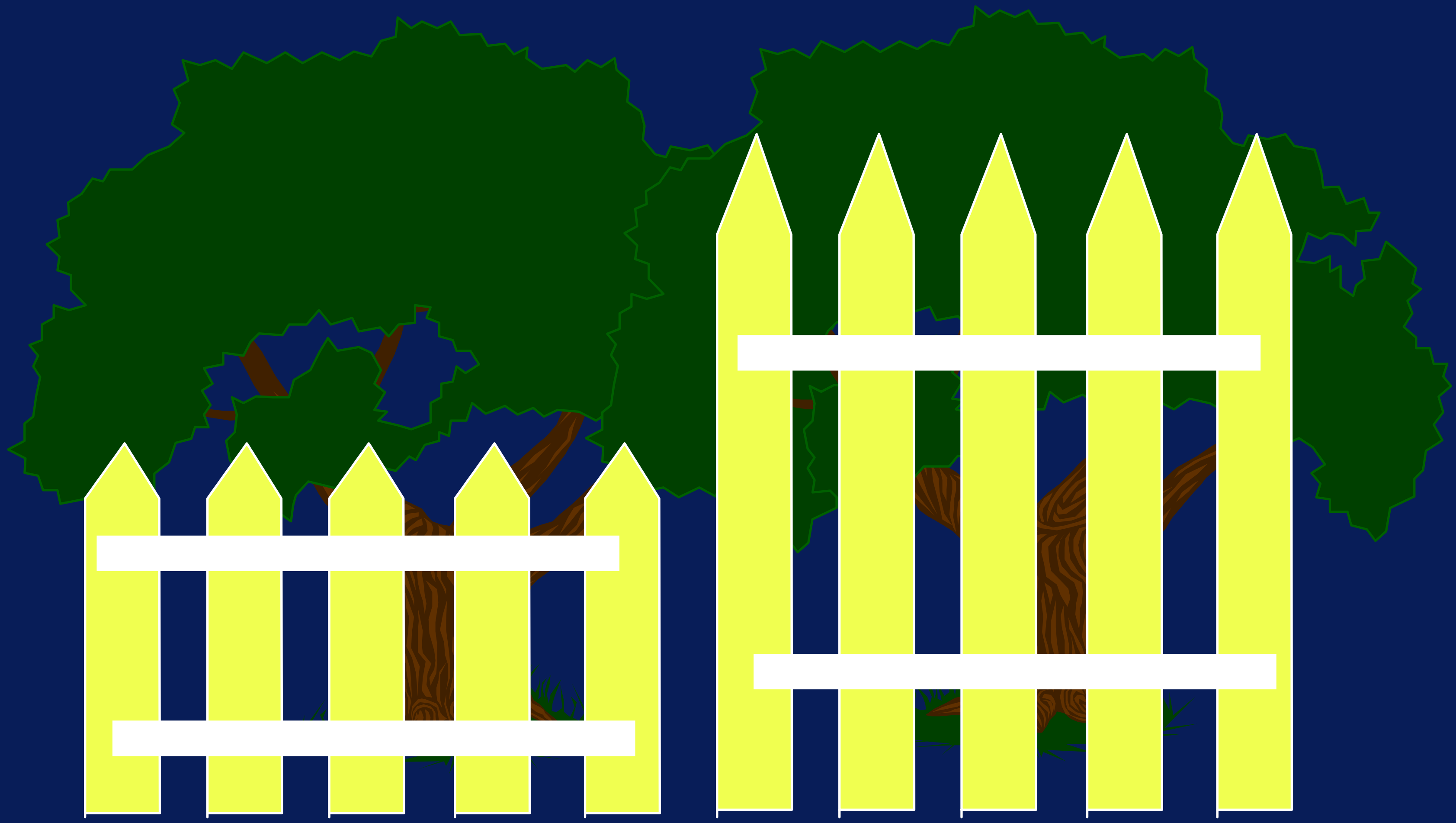
Accurate Sensing...

- Ensures that undersensing will not occur – the pacemaker will not miss P or R waves that should have been sensed
- Ensures that oversensing will not occur – the pacemaker will not mistake extra-cardiac activity for intrinsic cardiac events
- Provides for proper timing of the pacing pulse – an appropriately sensed event resets the timing sequence of the pacemaker

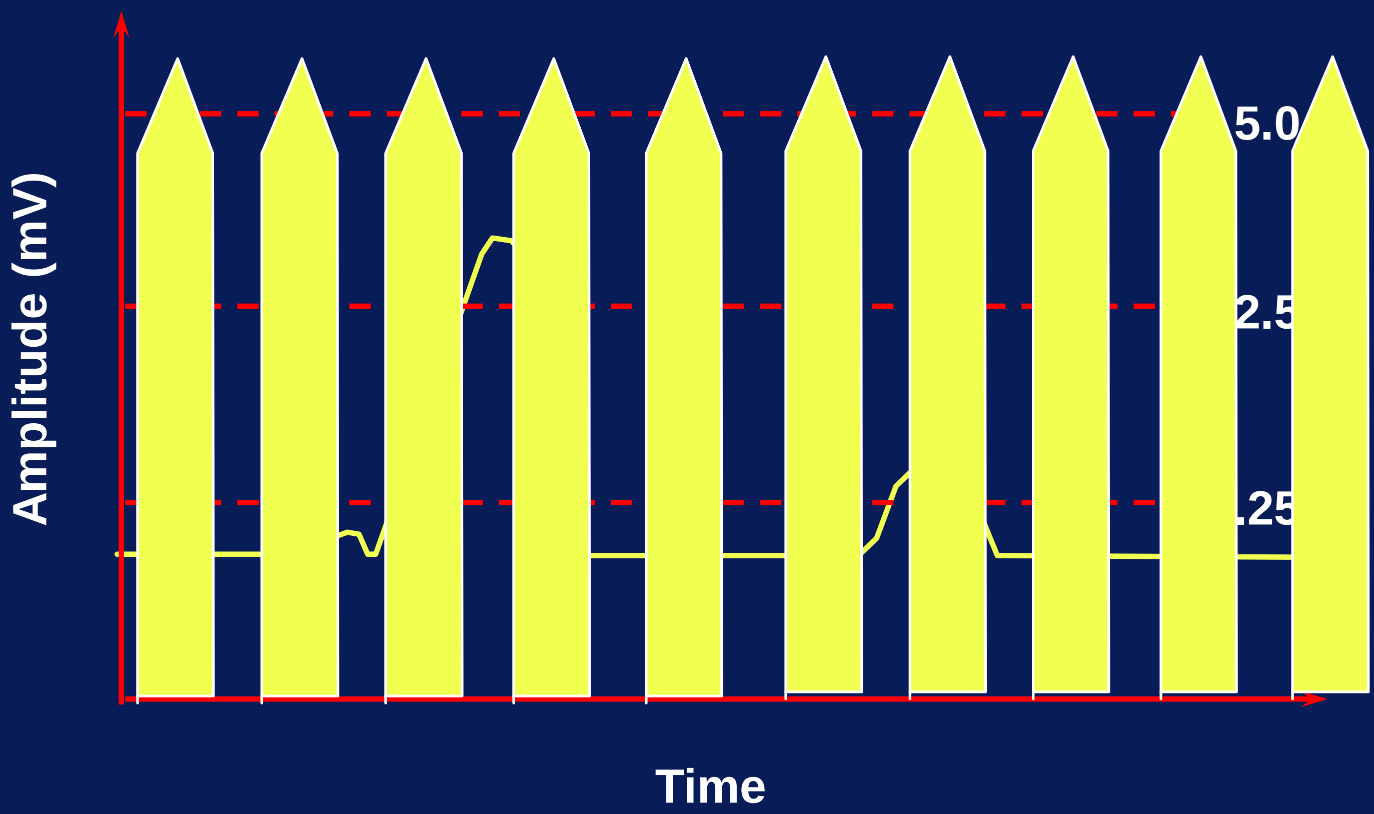
Sensitivity



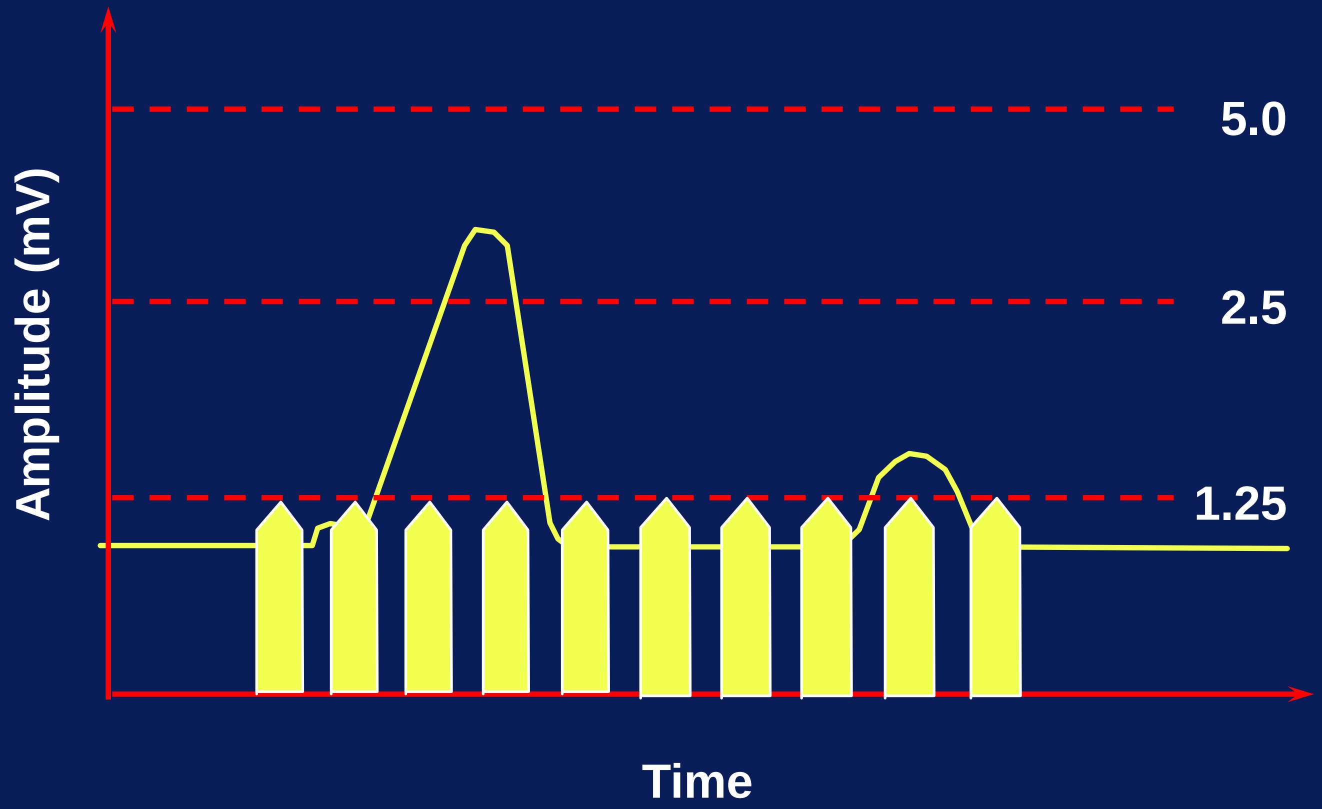
Sensitivity – The Greater the Number, the *Less* Sensitive the Device to Intracardiac Events



Sensitivity



Sensitivity



Accurate Sensing Requires That Extraneous Signals Be Filtered Out

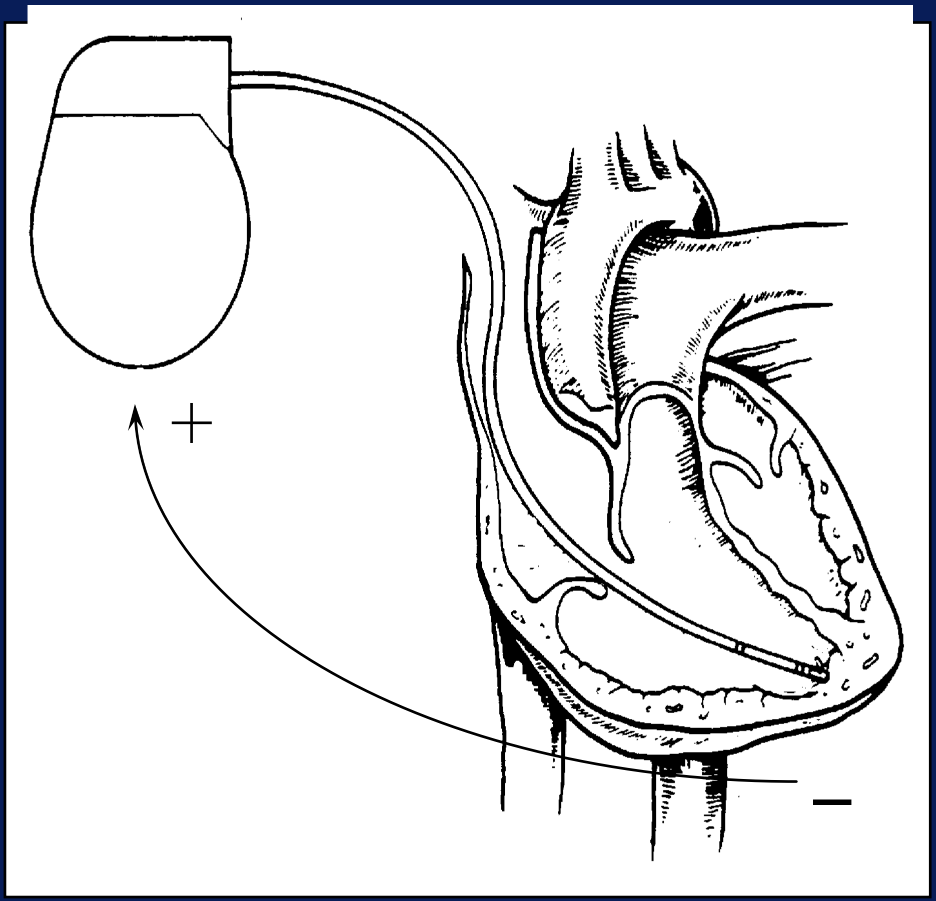
- Allow appropriate sensing of P waves and R waves and reject inappropriate signals
- Unwanted signals most commonly sensed are:
  - T waves
  - Far-field events (R waves sensed by the atrial channel)
  - Skeletal myopotentials (e.g., pectoral muscle myopotentials)

Factors That May Affect Sensing Are:

- Positioning of the lead
- Lead polarity (unipolar vs. bipolar)
- Lead integrity
  - Insulation break
  - Wire fracture
- EMI – Electromagnetic Interference

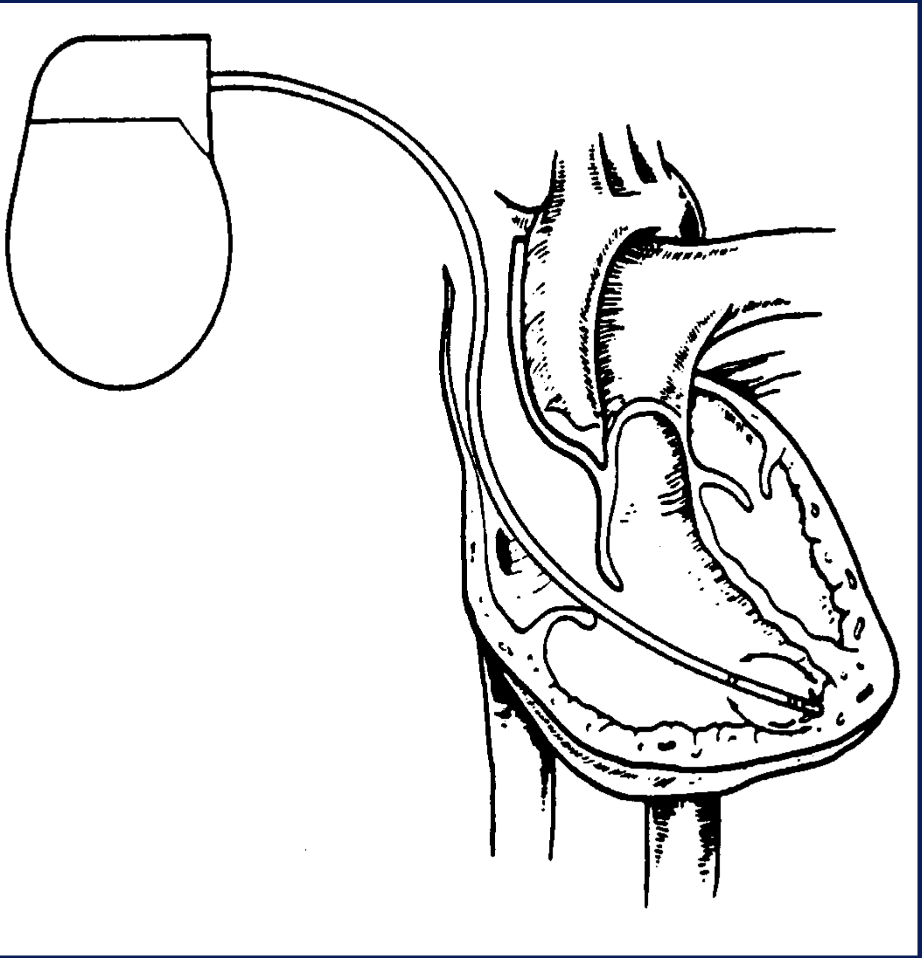
Unipolar Sensing

- Produces a large potential difference due to:
  - A cathode and anode that are farther apart than in a bipolar system

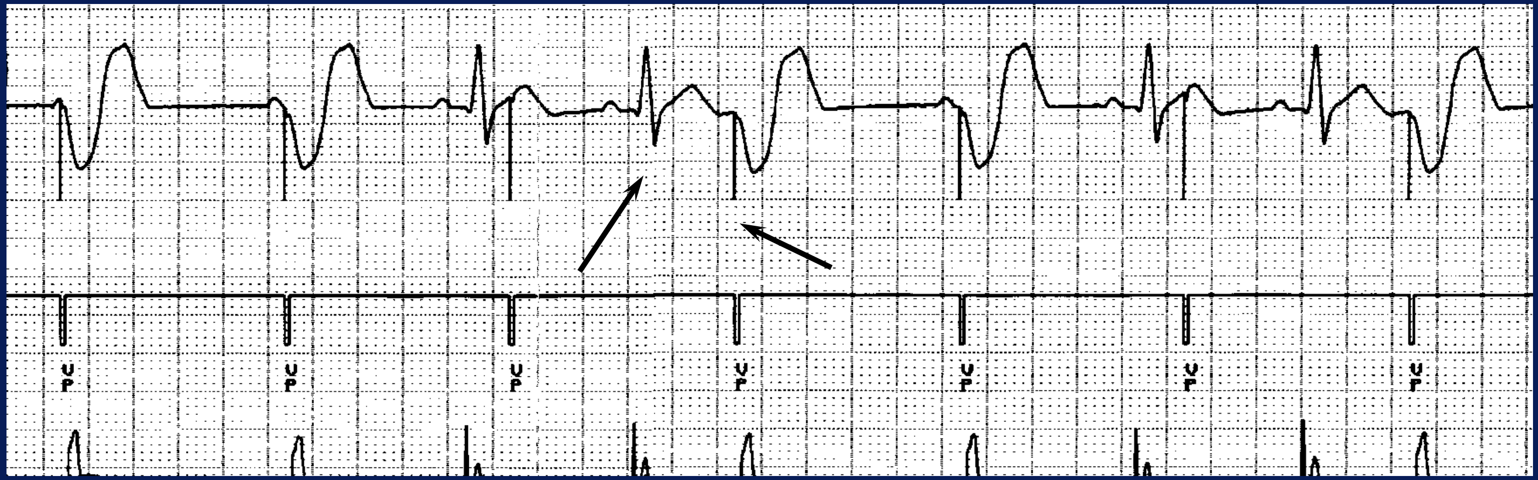


Bipolar Sensing

- Produces a smaller potential difference due to the short interelectrode distance
  - Electrical signals from outside the heart such as myopotentials are less likely to be sensed



What is the sensing problem?



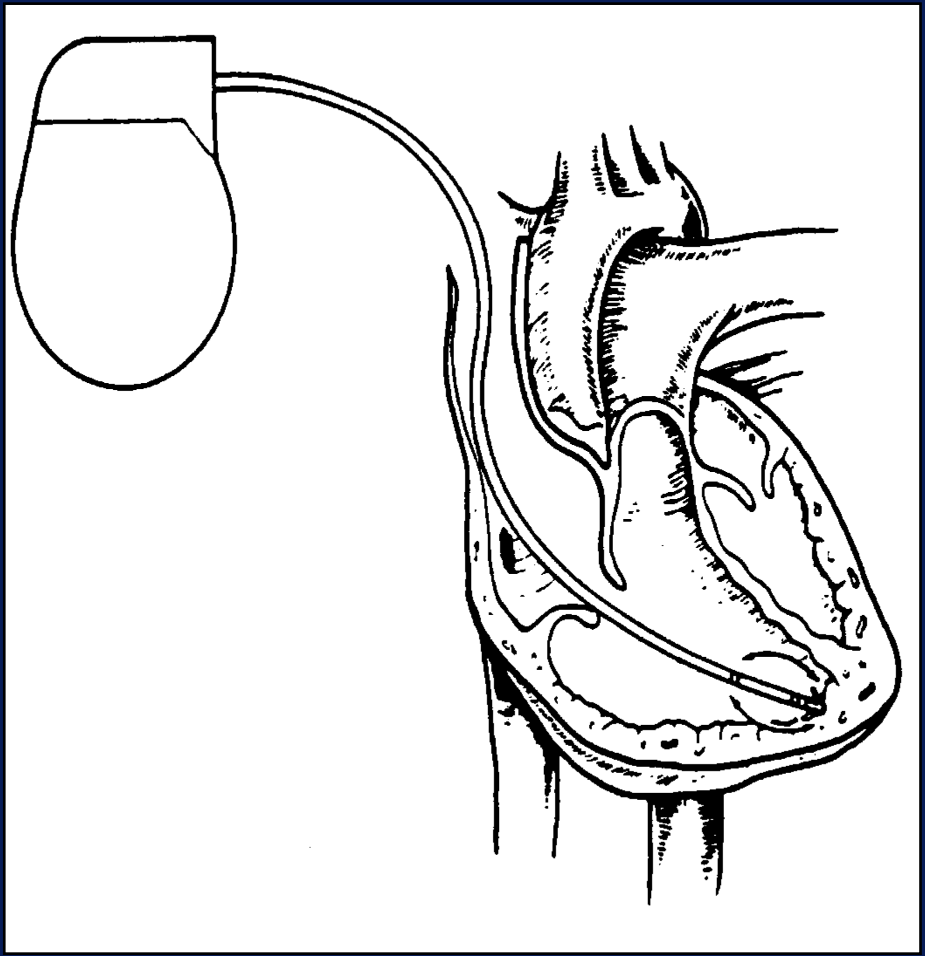
VVI / 60

What is the sensing problem?

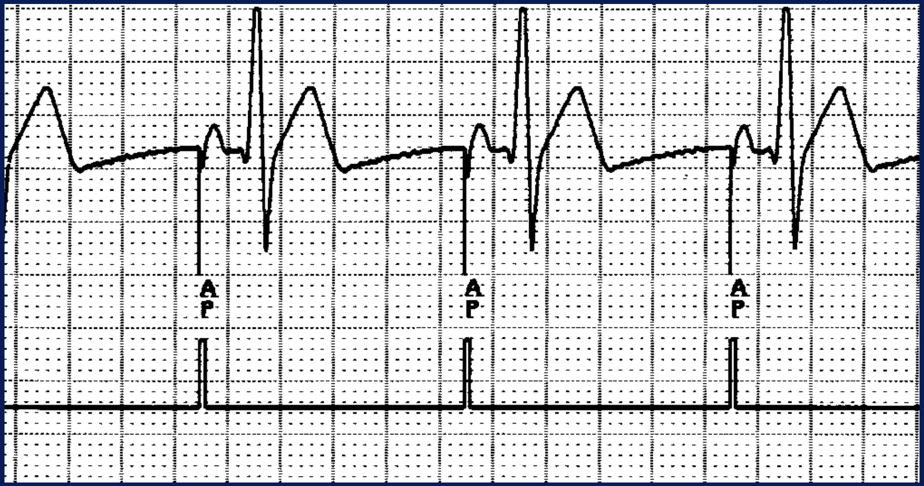
VVI / 60

Single-Chamber System

- The pacing lead is implanted in the atrium *or* ventricle, depending on the chamber to be paced and sensed

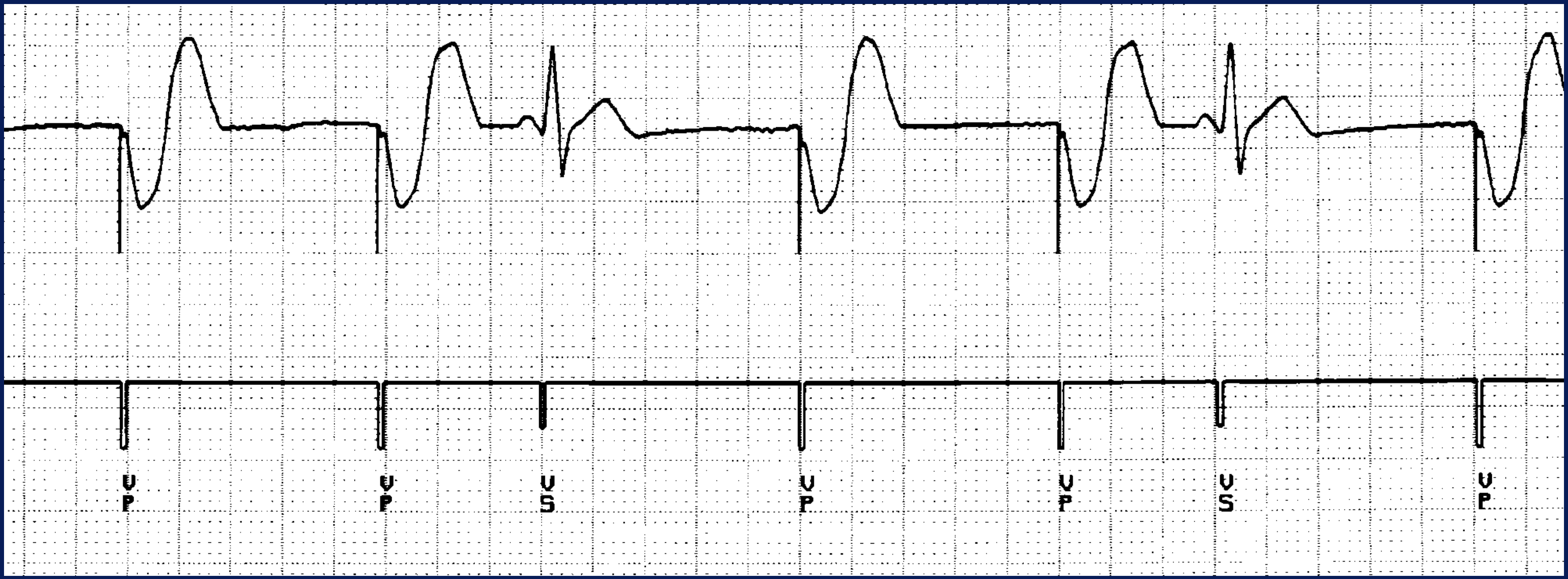


Paced Rhythm Recognition



AAI / 60

Paced Rhythm Recognition



VVI / 60

Advantages and Disadvantages of Single-Chamber Pacing Systems

Advantages

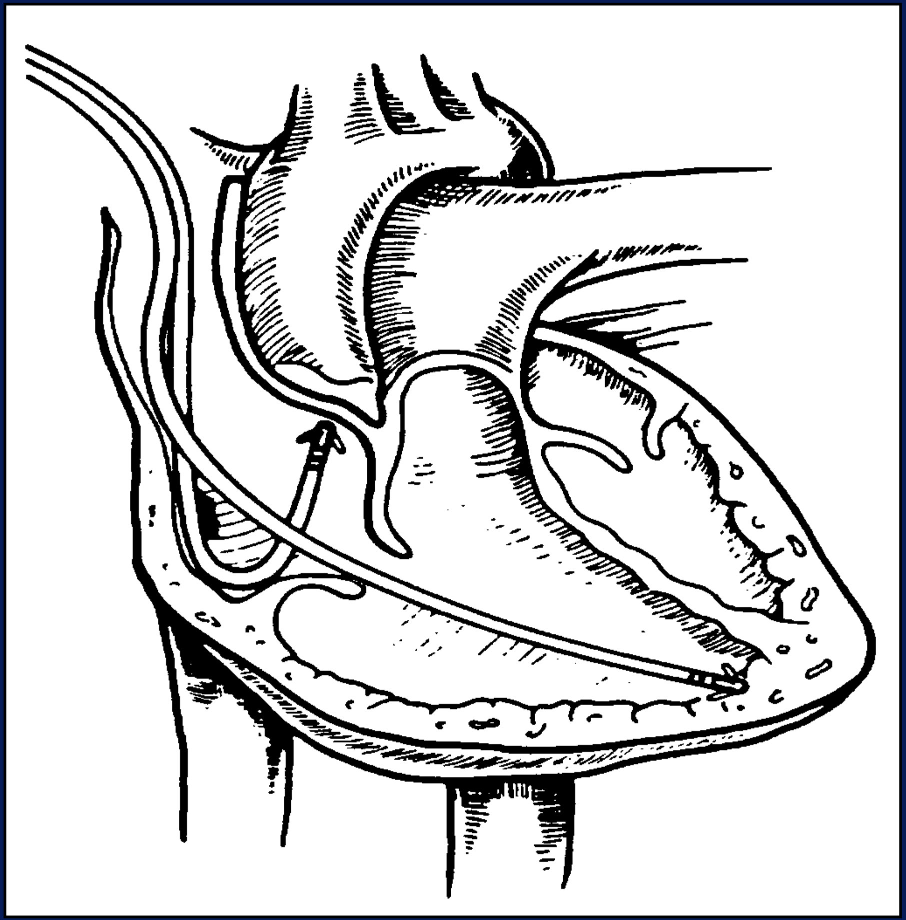
- Implantation of a single lead

Disadvantages

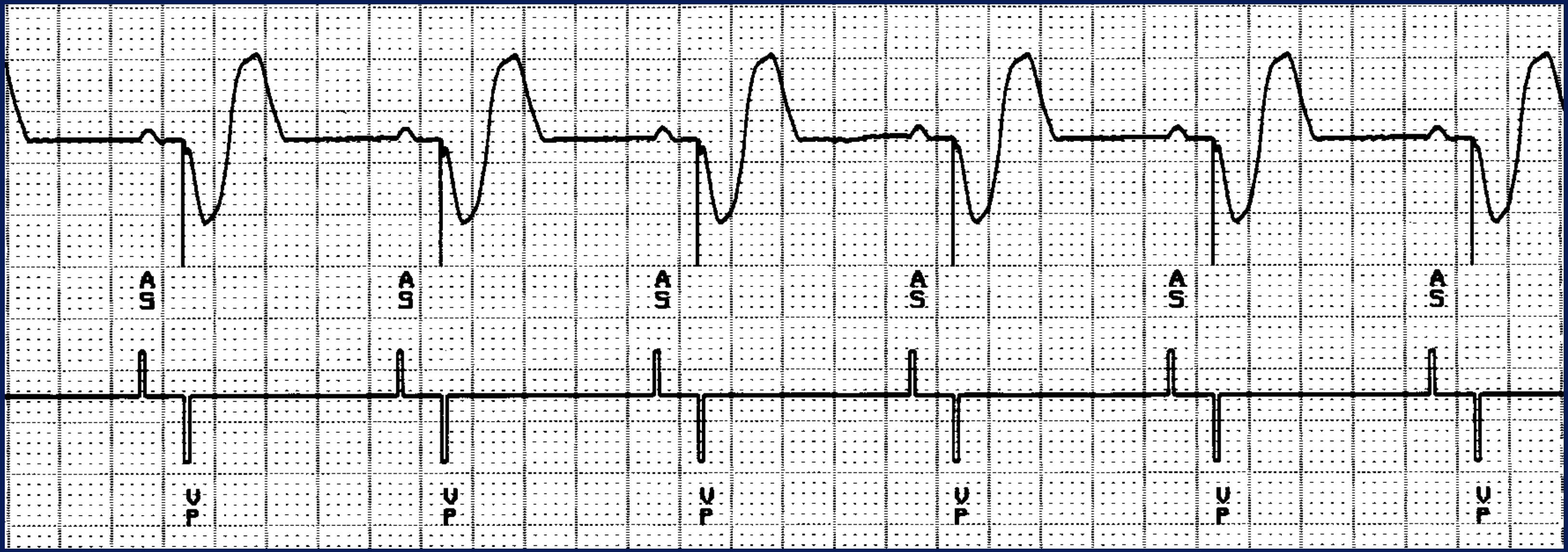
- Single ventricular lead does not provide AV synchrony
- Single atrial lead does not provide ventricular backup if A-to-V conduction is lost

Dual-Chamber Systems Have Two Leads:

- One lead implanted in the atrium
- One lead implanted in the ventricle

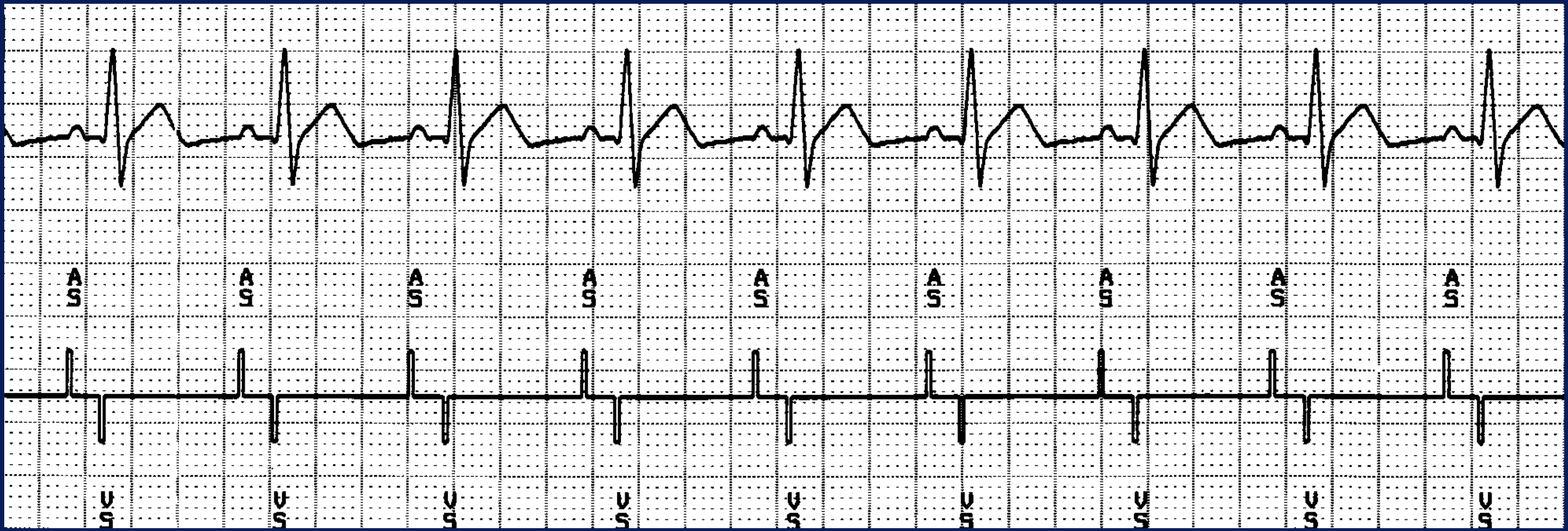


Paced Rhythm Recognition



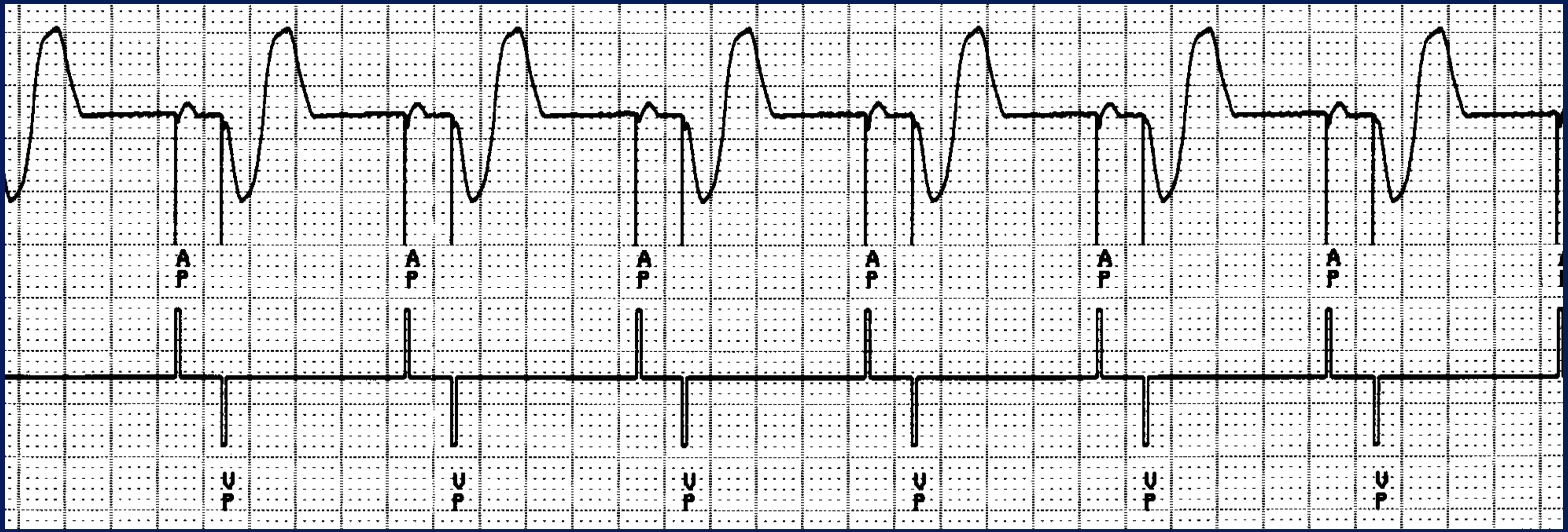
DDD / 60 / 120

Paced Rhythm Recognition



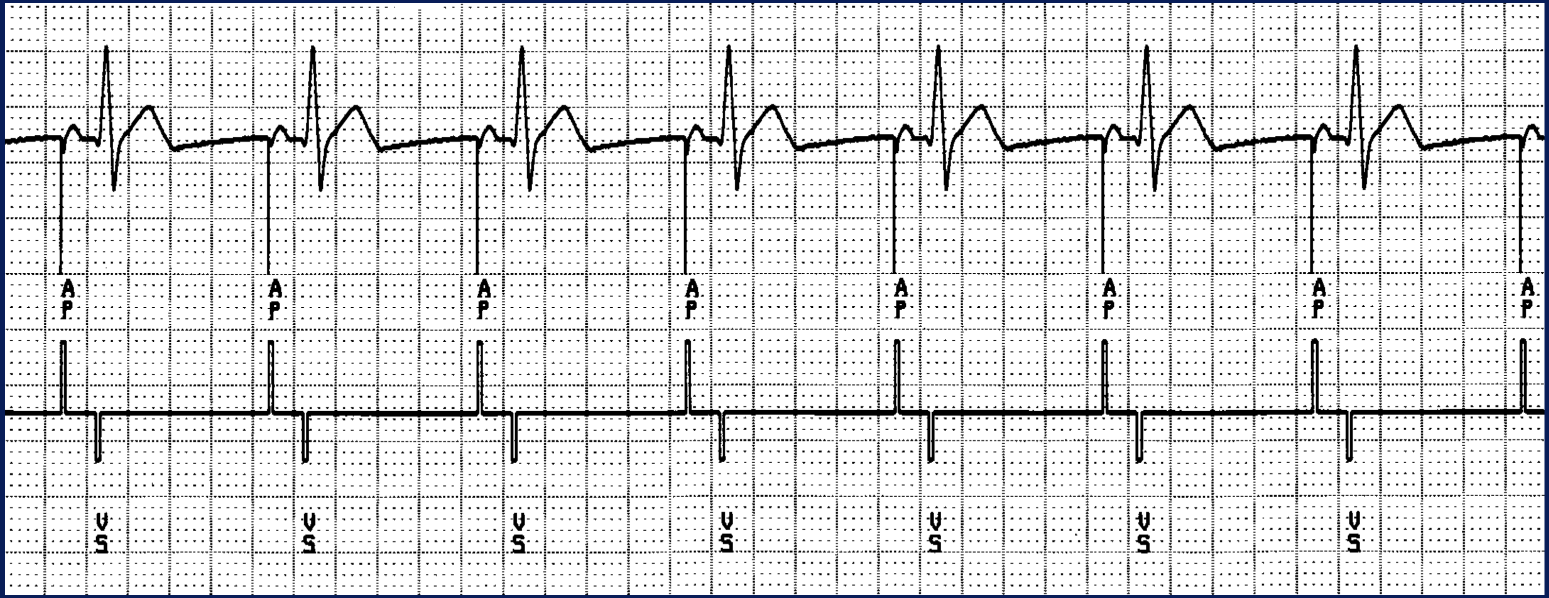
DDD / 60 / 120

Paced Rhythm Recognition



DDD / 60 / 120

Paced Rhythm Recognition



DDD / 60 / 120

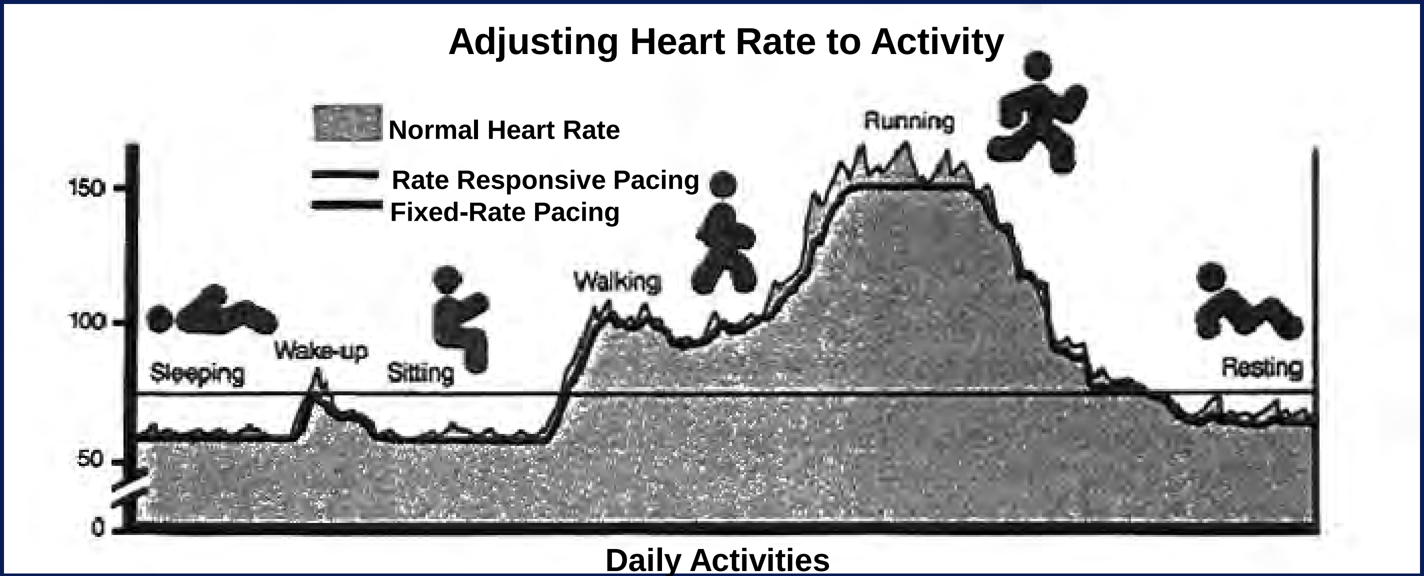
Rate Responsive Pacing

Rate Response

- Rate responsive (also called rate modulated) pacemakers provide patients with the ability to vary heart rate when the sinus node cannot provide the appropriate rate
- Rate responsive pacing is indicated for:
  - Patients who are chronotropically incompetent (heart rate cannot reach appropriate levels during exercise or to meet other metabolic demands)
  - Patients in chronic atrial fibrillation with slow ventricular response

Rate Responsive Pacing

- When the need for oxygenated blood increases, the pacemaker ensures that the heart rate increases to provide additional cardiac output

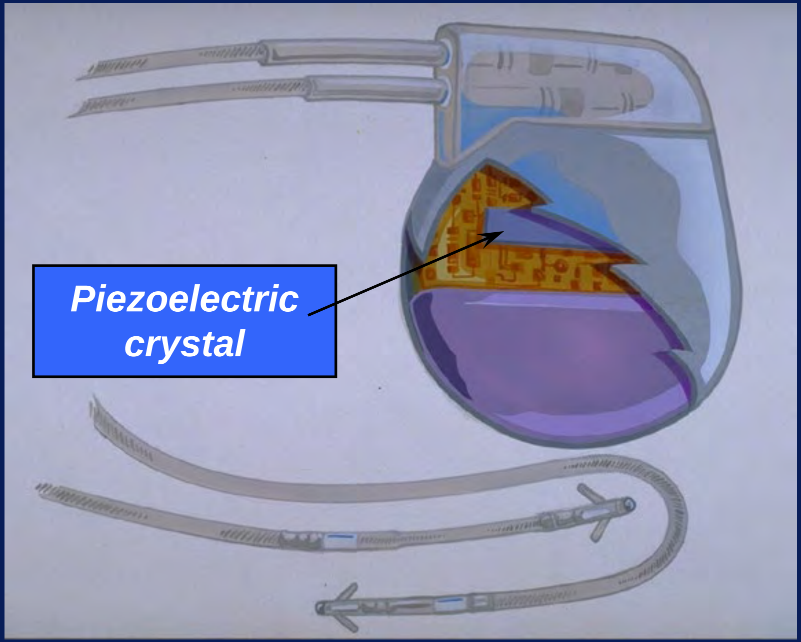


A Variety of Rate Response Sensors Exist

- Those most accepted in the market place are:
  - Activity sensors that detect physical movement and increase the rate according to the level of activity
  - Minute ventilation sensors that measure the change in respiration rate and tidal volume via transthoracic impedance readings

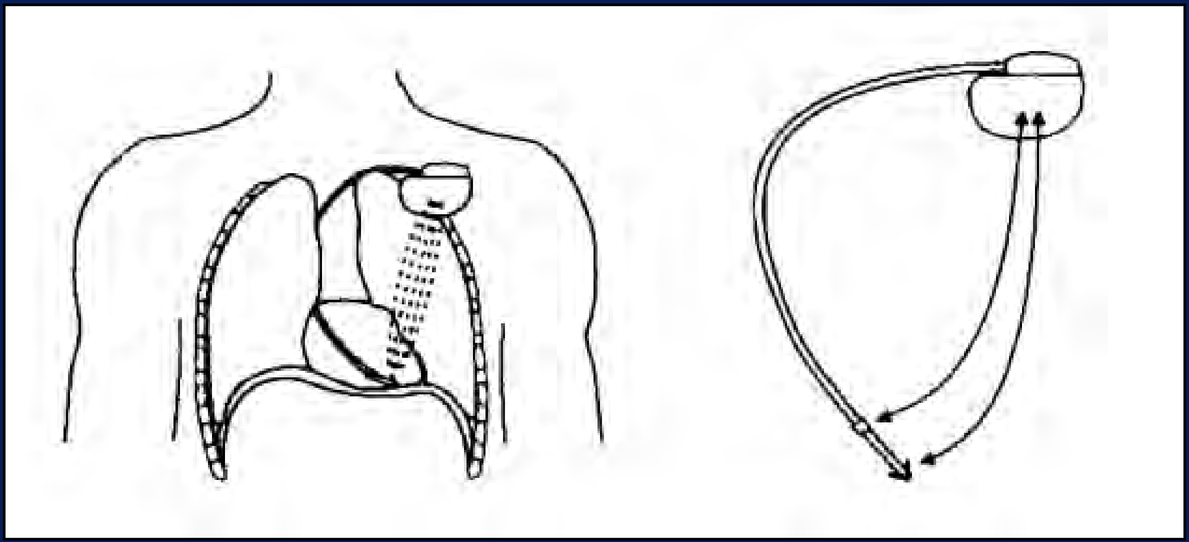
Rate Responsive Pacing

- Activity sensors employ a *piezoelectric crystal* that detects mechanical signals produced by movement
- The crystal translates the mechanical signals into electrical signals that in turn increase the rate of the pacemaker



Rate Responsive Pacing

- Minute ventilation can be measured by measuring the changes in electrical impedance across the chest cavity to calculate changes in lung volume over time

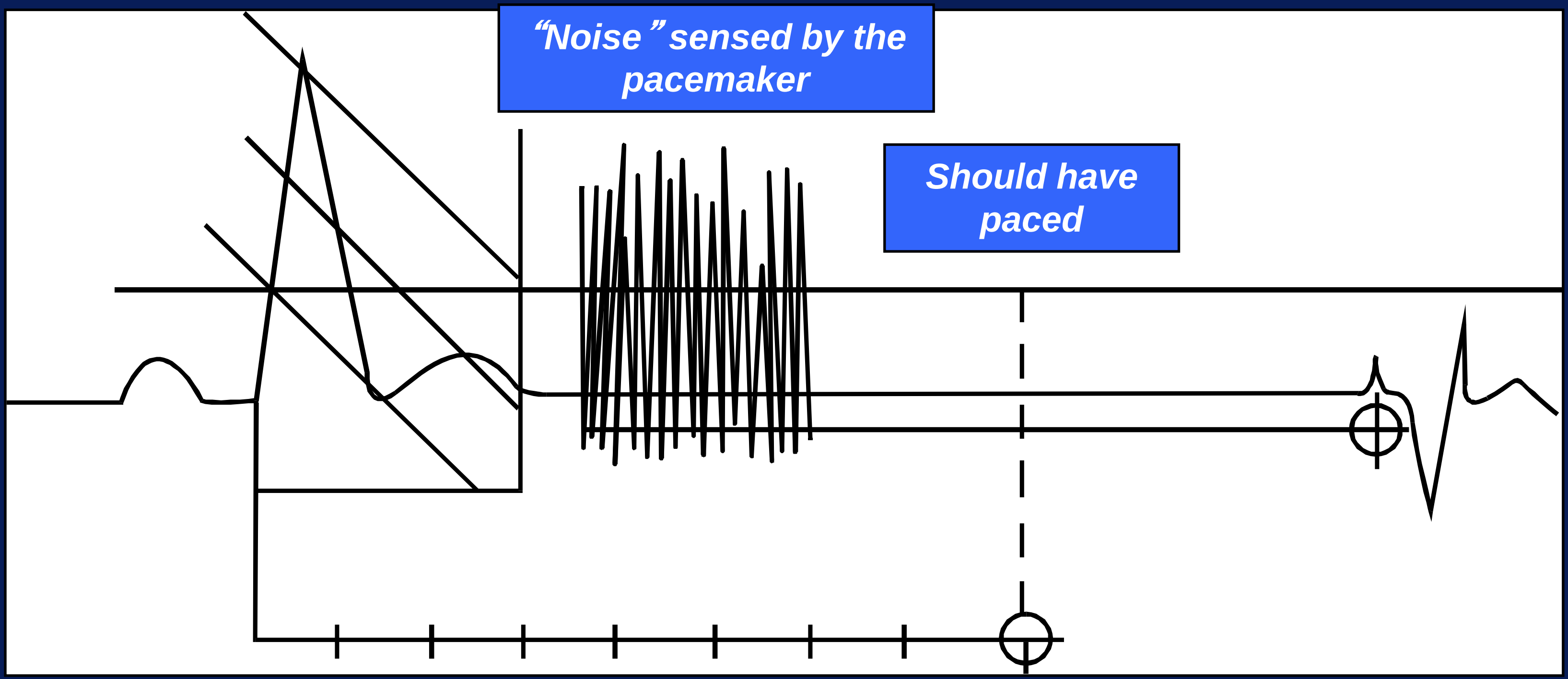


Electromagnetic Interference

Electromagnetic Interference (EMI)

- Interference is caused by electromagnetic energy with a source that is outside the body
- Few sources of EMI are found in the home or office but several exist in hospitals

EMI



Sources of EMI Are Found Most Commonly in Hospital Environments

- Sources of EMI that interfere with pacemaker operation include surgical/therapeutic equipment such as:
  - Electrocautery
  - Transthoracic defibrillation
  - Extracorporeal shock-wave lithotripsy
  - Therapeutic radiation
  - RF ablation
  - TENS units
  - MRI

Electrocautery is the Most Common Hospital Source of Pacemaker EMI

- Outcomes
  - Oversensing–inhibition
  - Undersensing (noise reversion)
  - Power on Reset
  - Permanent loss of pacemaker output (if battery voltage is low)

- Precautions
  - Reprogram mode to VOO/DOO, or place a magnet over device
  - Strategically place the grounding plate
  - Limit electrocautery bursts to 1-second burst every 10 seconds
  - Use bipolar electrocautery forceps

Sources of EMI Are Found More Rarely in:

- Home, office, and shopping environments
- Industrial environments with very high electrical outputs
- Transportation systems with high electrical energy exposure or with high-powered radar and radio transmission
  - Engines or subway braking systems
  - Airport radar
  - Airplane engines
- TV and radio transmission sites

Summary of Basic Pacing Concepts Module

- Pacing systems
- Electrical concepts
- Stimulation thresholds
- Sensing
- Electromagnetic Interference (EMI)
- Rate response