



HARVARD MEDICAL SCHOOL
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Systematic Analysis of the ECG

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18 November 2024

Disclosures:

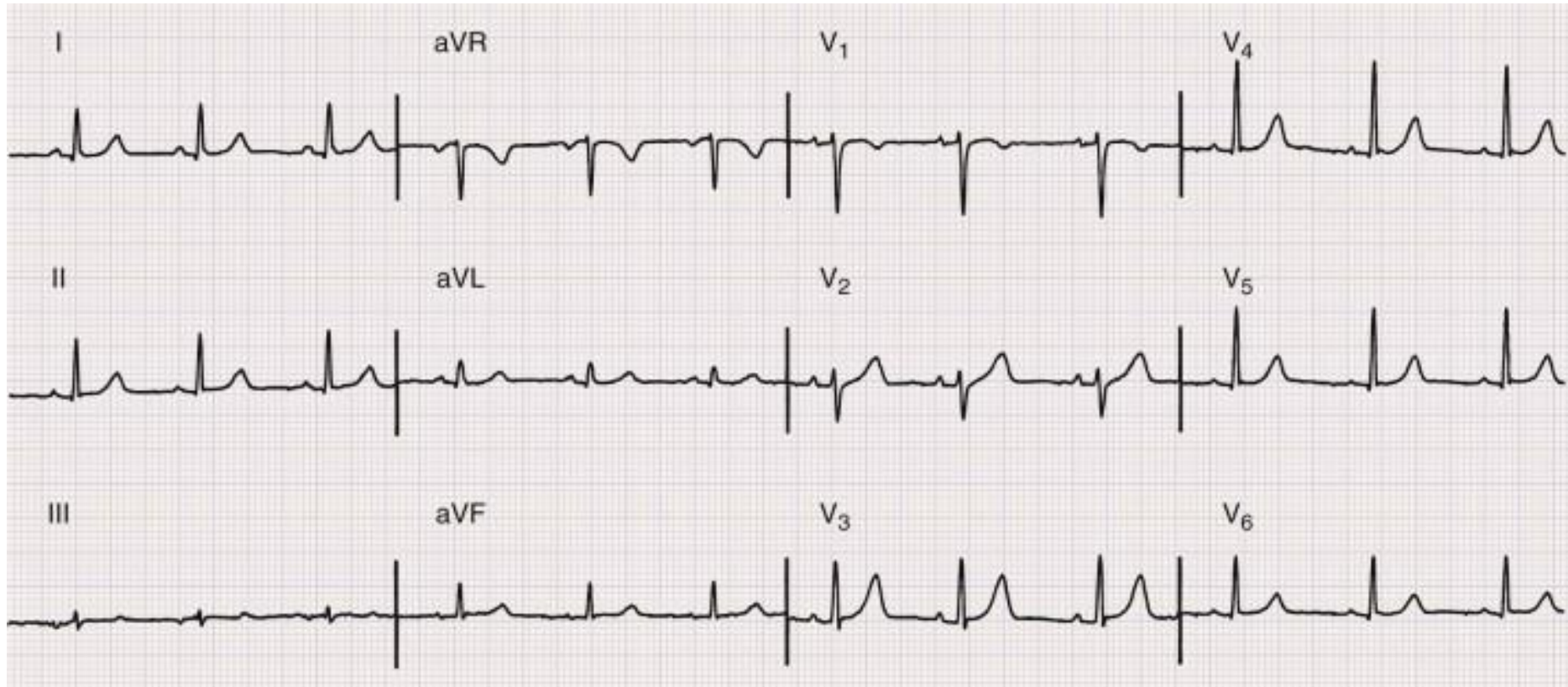
Research grant from Anumana; Consultant for Abbott, Anumana, Bristol-Myers Squibb, NeuTrace, Medtronic, Moderna, Pfizer, Voiant



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**CORRIGAN MINEHAN
HEART CENTER**

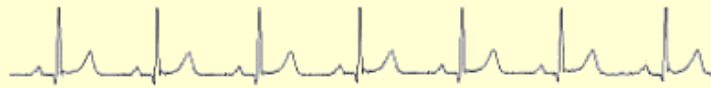
Introduction



ECG Wave-Maven

Self-Assessment Program for Students and Clinicians

Main Menu



What is ECG Wave-Maven?

Proficiency in electrocardiogram (ECG) interpretation is an essential skill for medical students, housestaff, and clinicians. However, medical school and postgraduate resources to develop and upgrade the necessary high level of "ECG literacy" are severely limited. Further, current textbook and classroom instructional materials do not adequately integrate ECG interpretation into specific contexts where waveform findings must be correlated with other clinical data. We have begun to address the limitations in traditional approaches to ECG pedagogy by creating the infrastructure for a unique web-based tutorial.

Note: this site requires cookies and javascript to be activated.

- Please choose one of the following:**
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 - [Browse with Diagnoses \(reference mode\)](#)
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Additional support from the George S. Kurland, MD Legacy Fund is gratefully acknowledged.
See our ECG Wave-Maven article published in: [Medical Education Online](#) Click [here](#) to read the article.

Learning Objectives

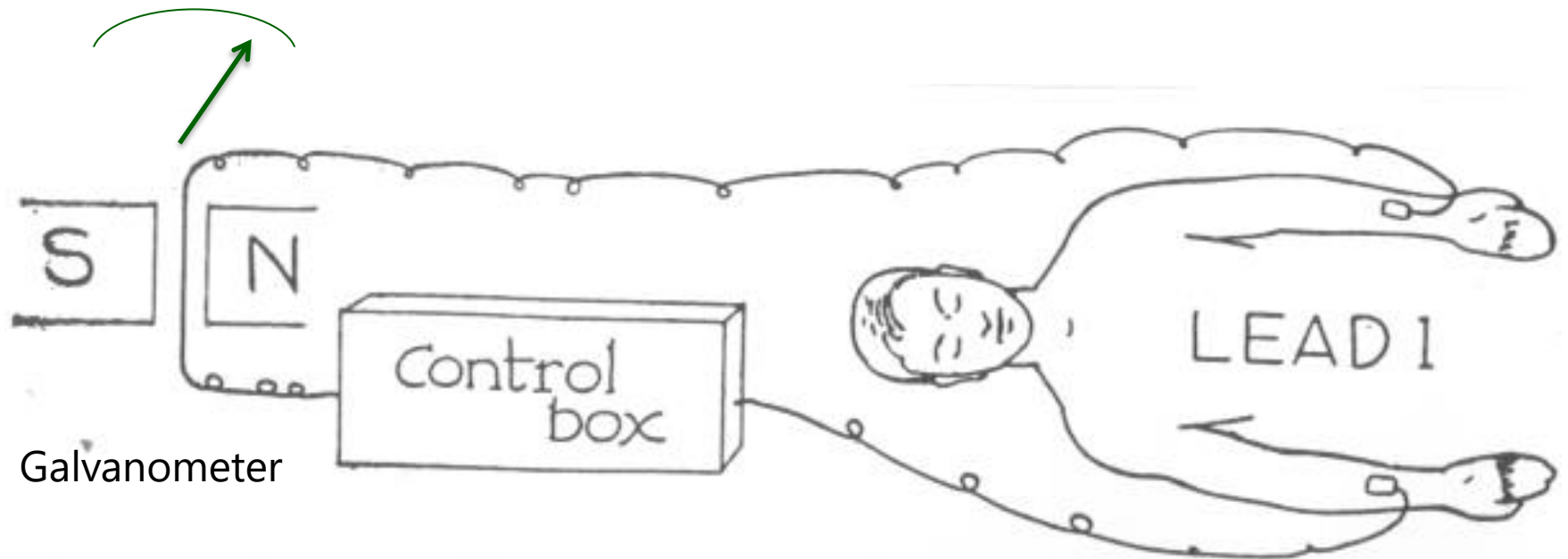
1. Describe a systematic method for interpreting a 12-lead ECG.
2. Identify the different types of heart block.
3. Identify the major types of atrial arrhythmias.

Session 1A: Basic ECG Physiology

Learning objectives:

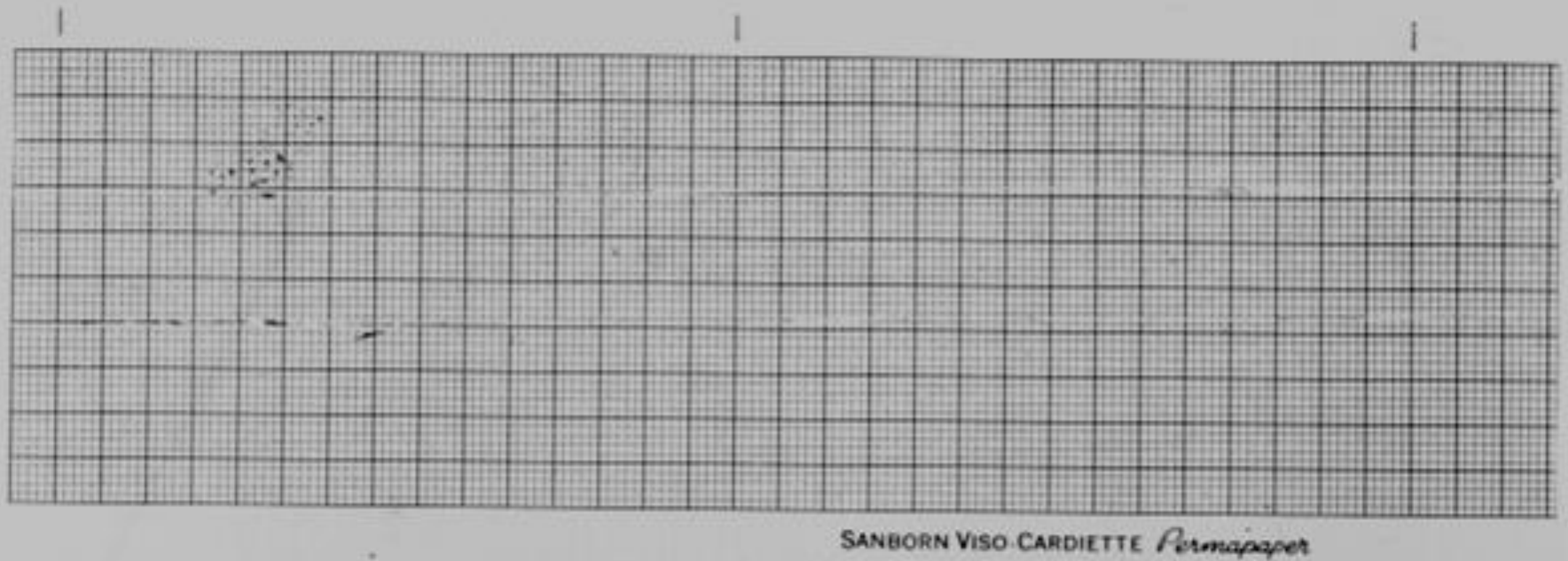
- Explain how an ECG indicates the direction and magnitude of electrical activity in the heart
- Identify the P wave, QRS complex, and T wave on a normal ECG
- Calculate heart rate, rhythm, axis and intervals (PR and QRS)

Basic ECG Physiology



Adapted from P. M. Yurchak, M.D.

ECG Recording



ECG Recording

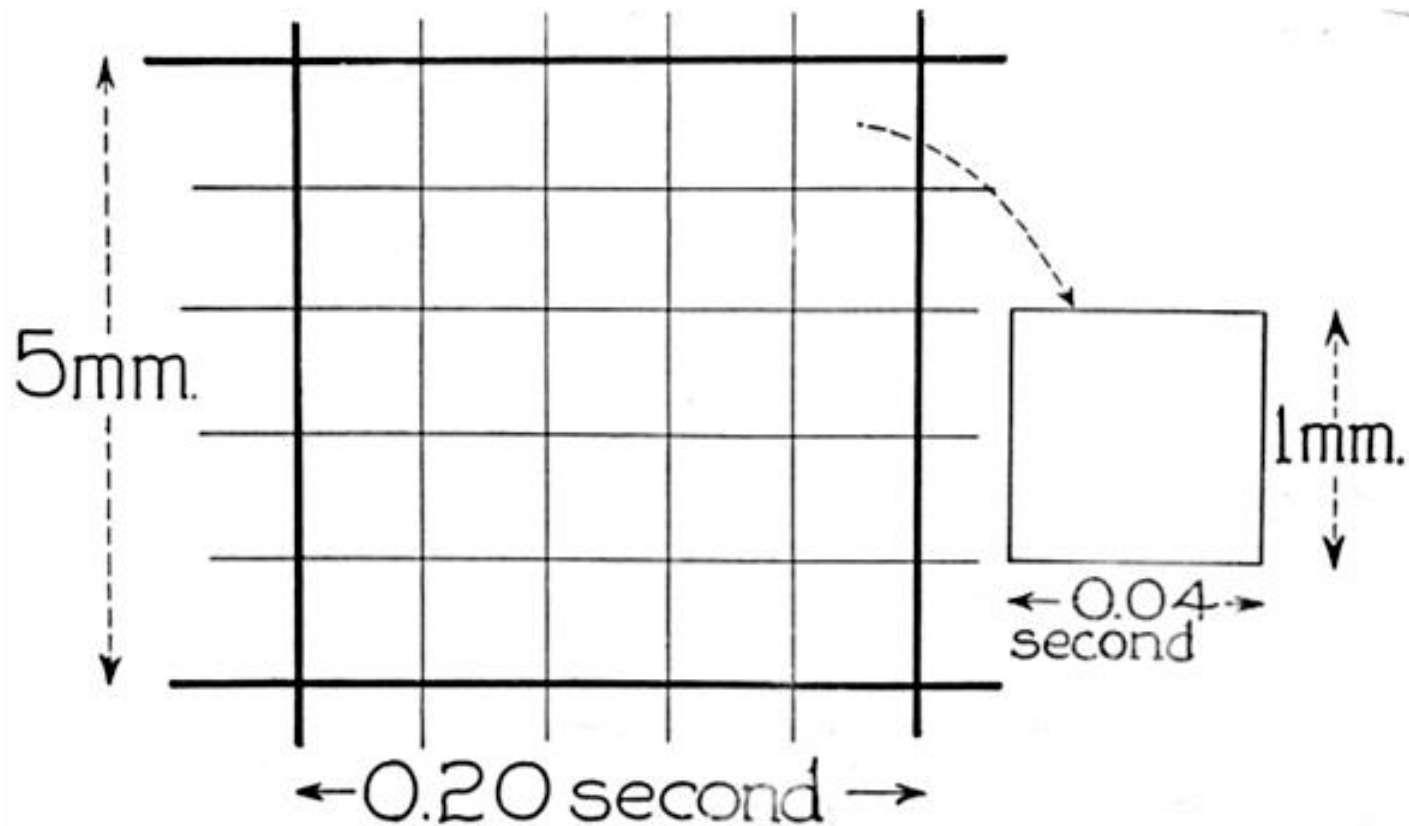


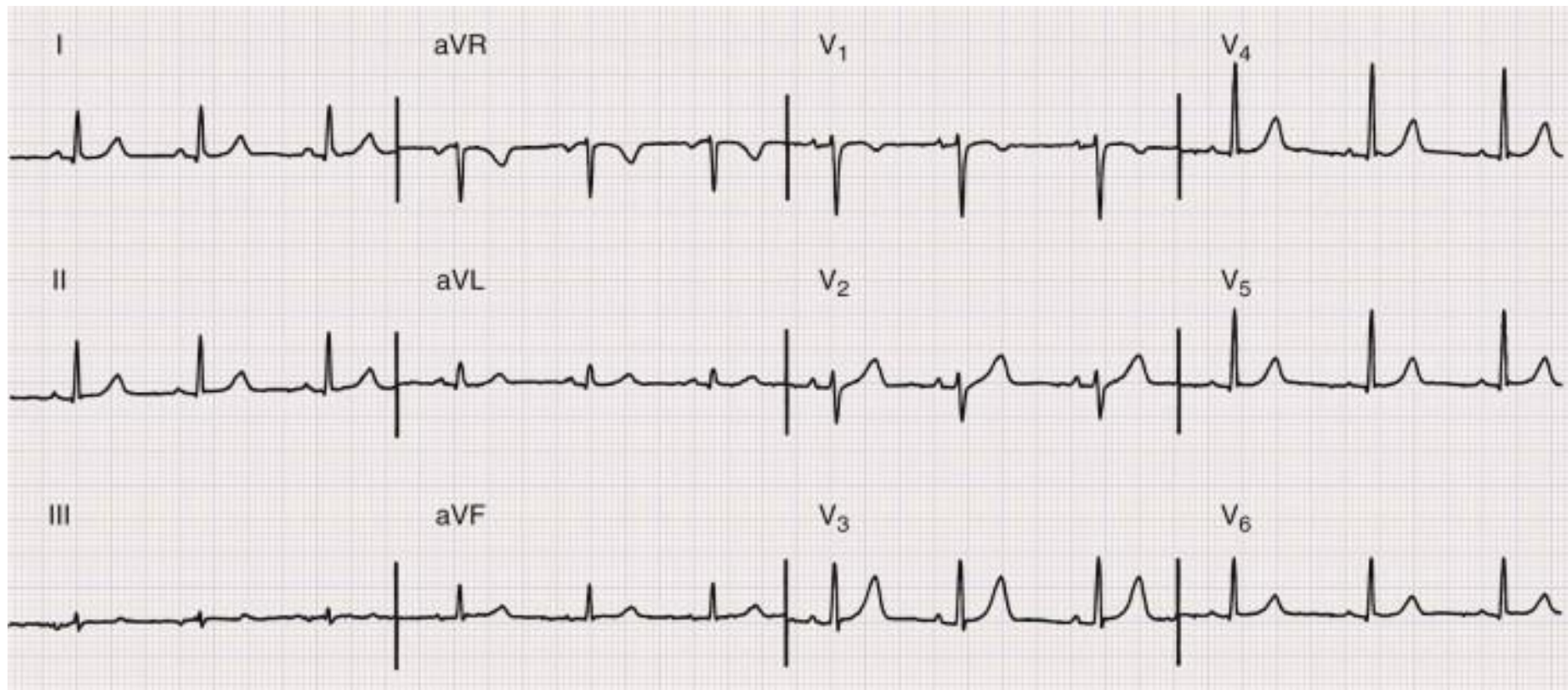
FIG. 11.—Time and amplitude lines of the electrocardiogram.



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ECG Recording



X-axis

→ Time

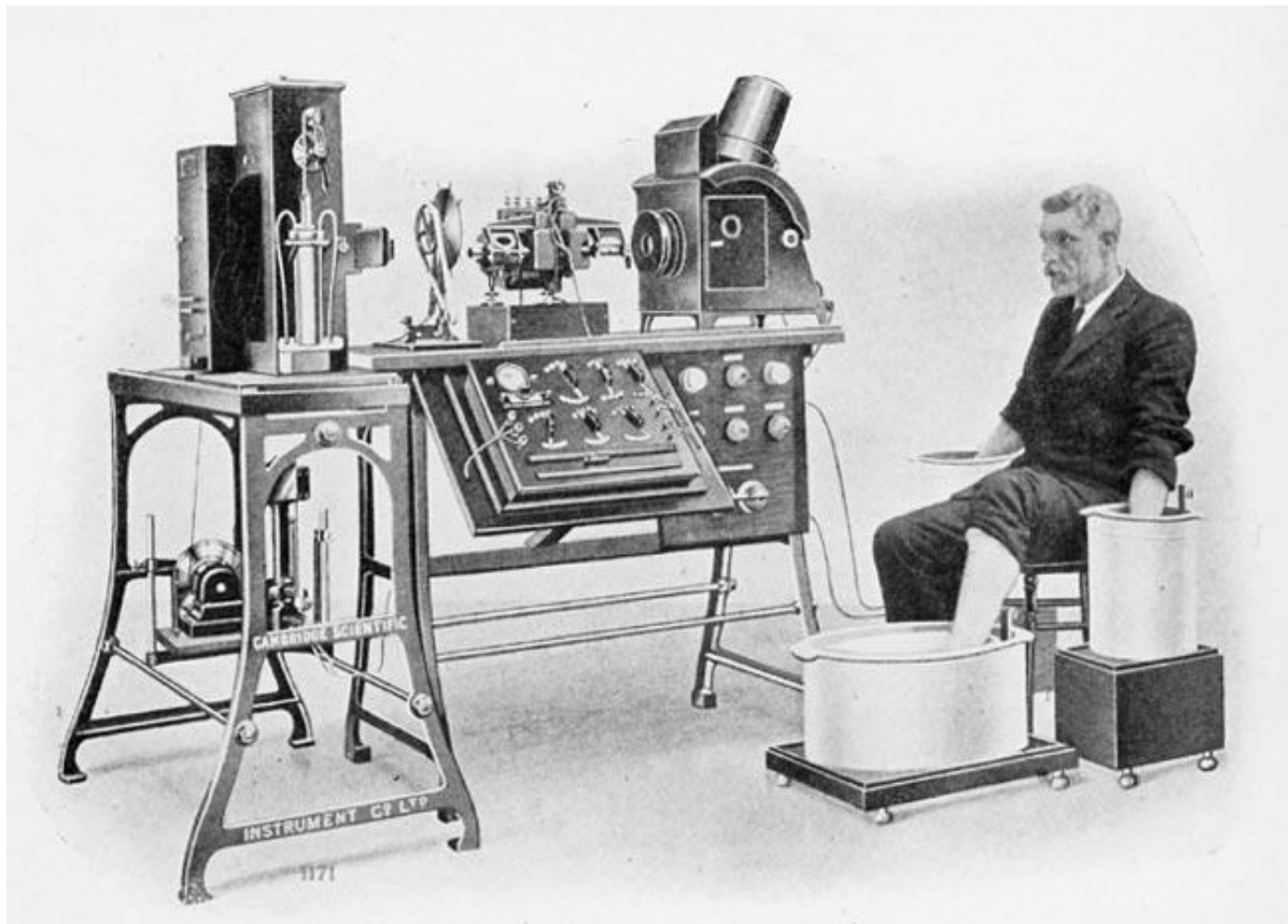
Y-axis

→ Voltage

Direction of deflection

→ Direction of depolarization vector

ECG in 1905

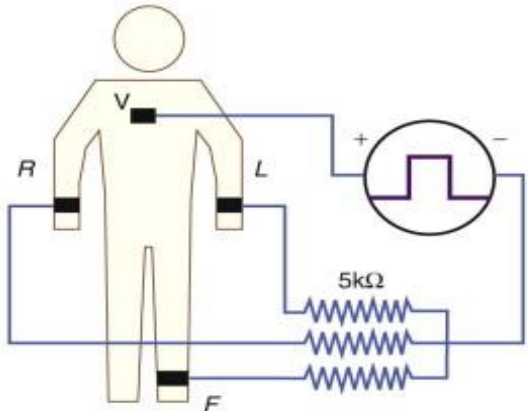
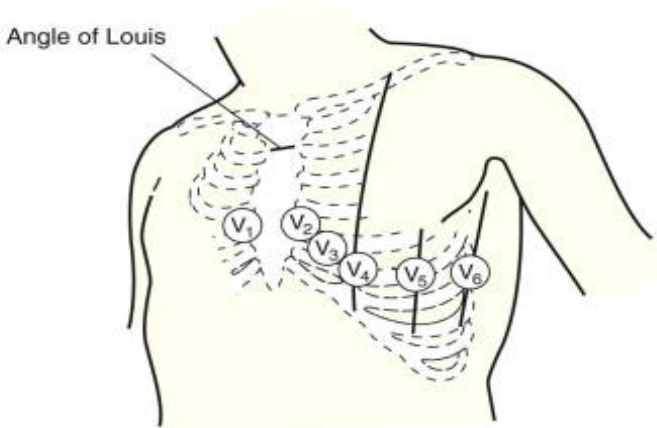
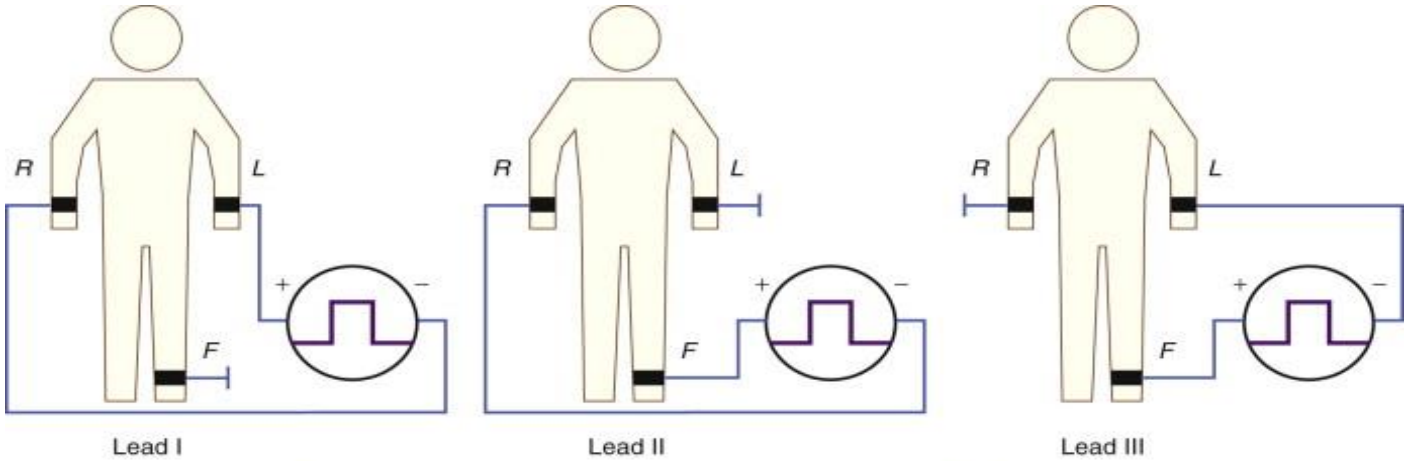


PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSSED IN JARS OF SALT SOLUTION

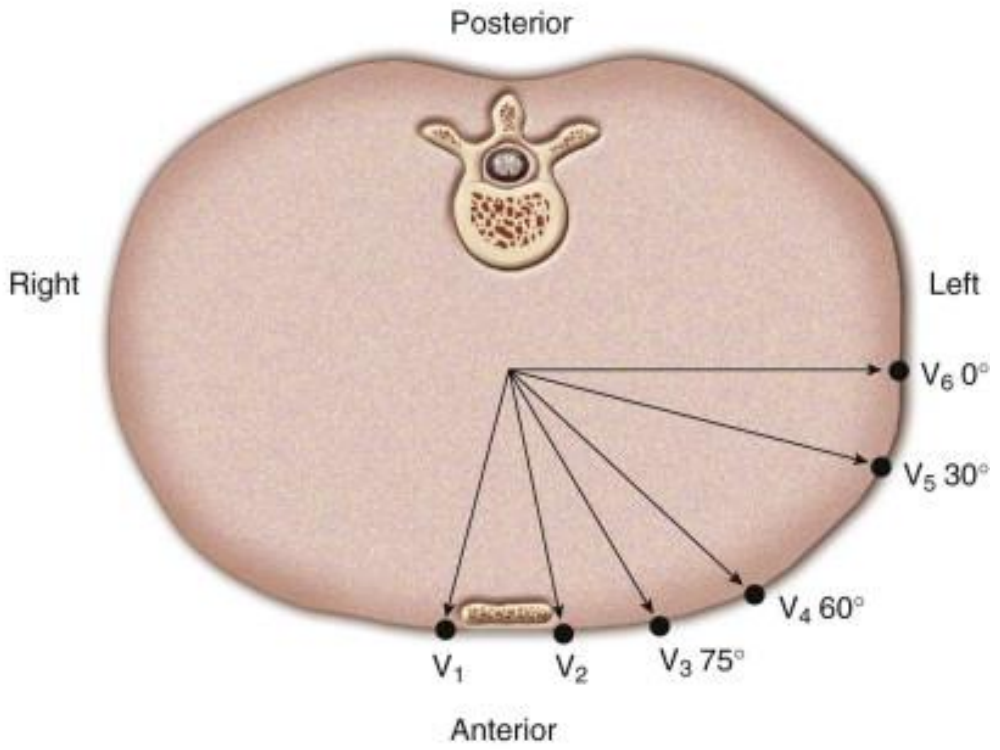
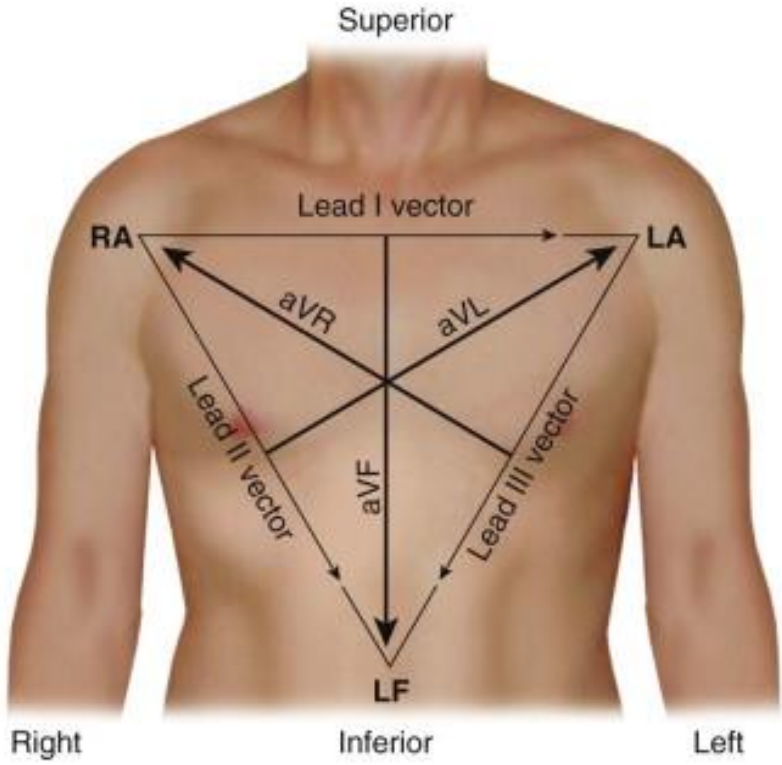
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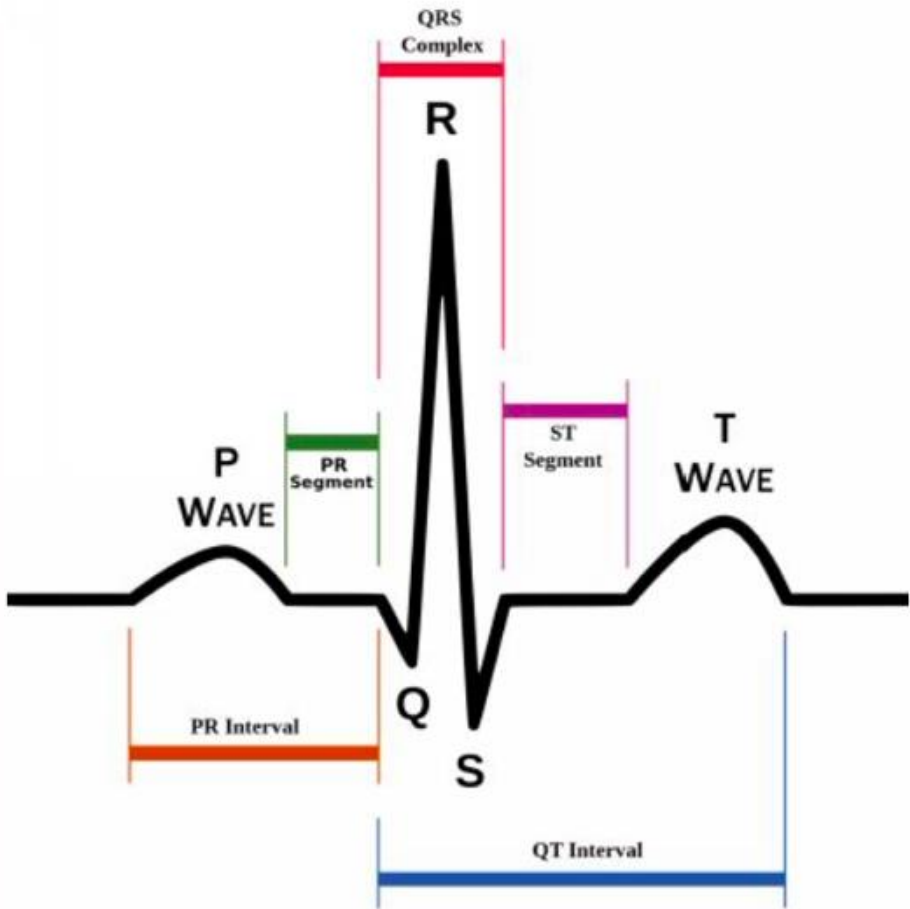
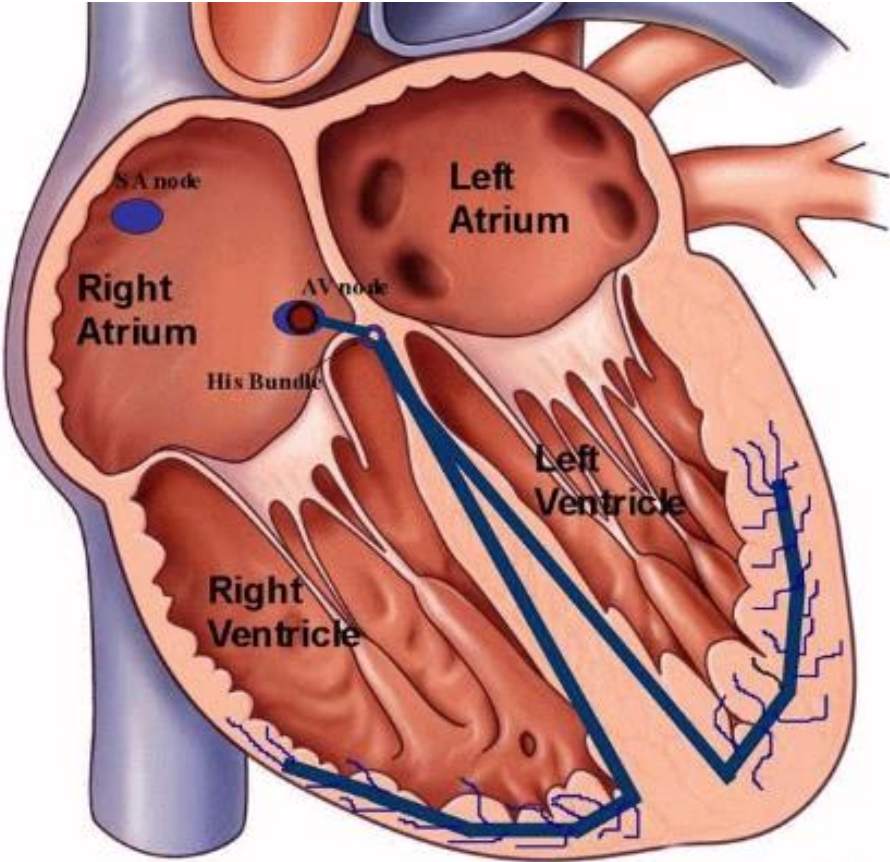
ECG in 2024



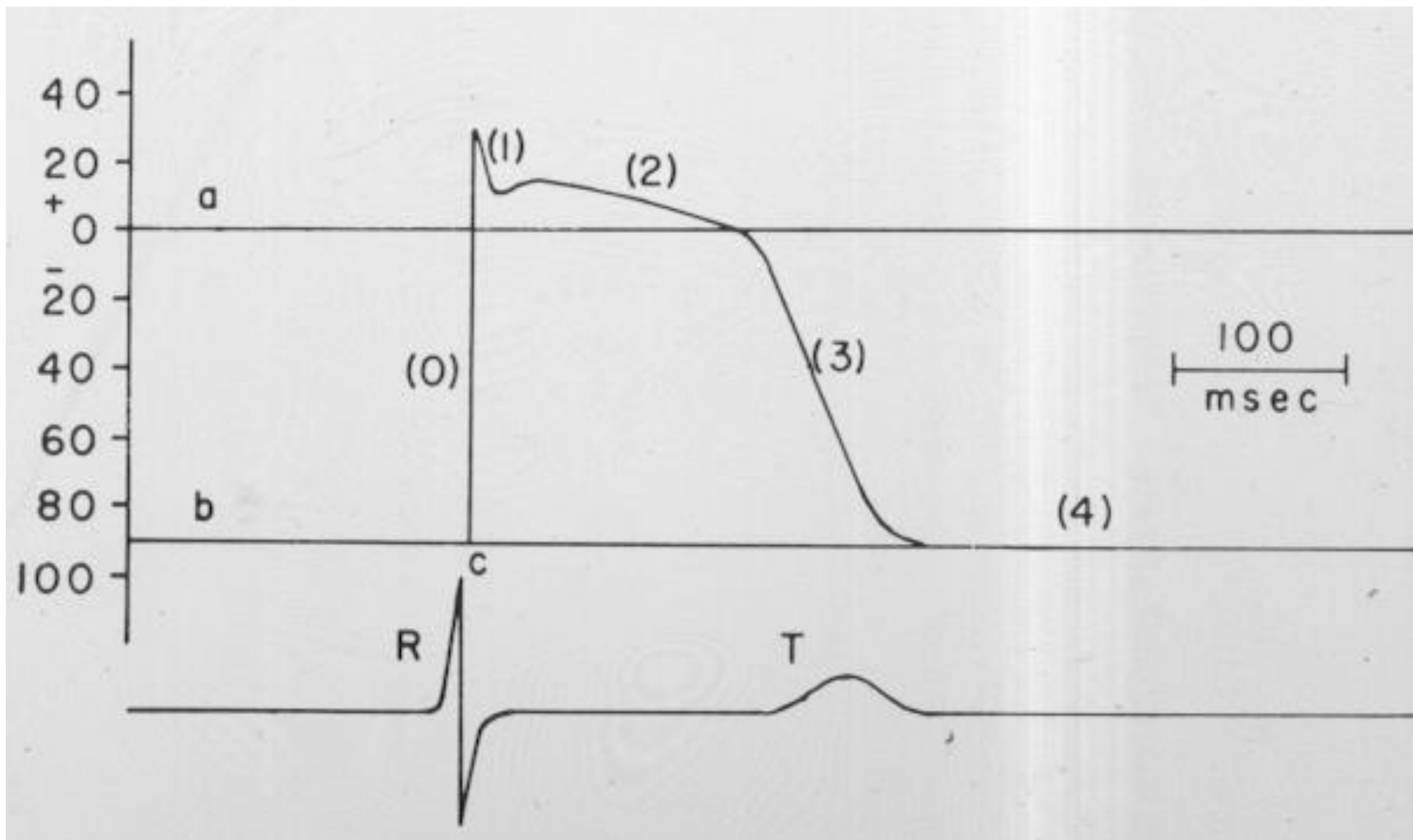
ECG Vectors



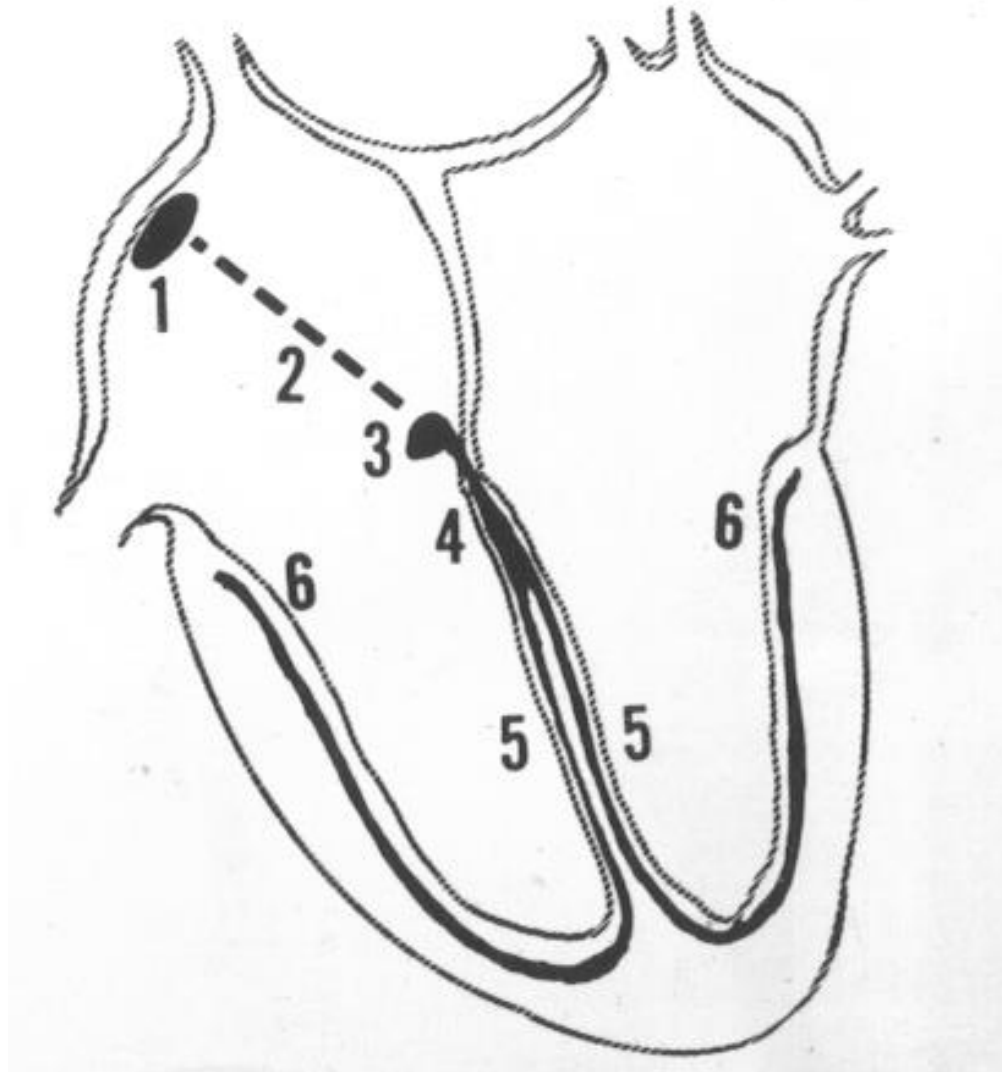
ECG Timing



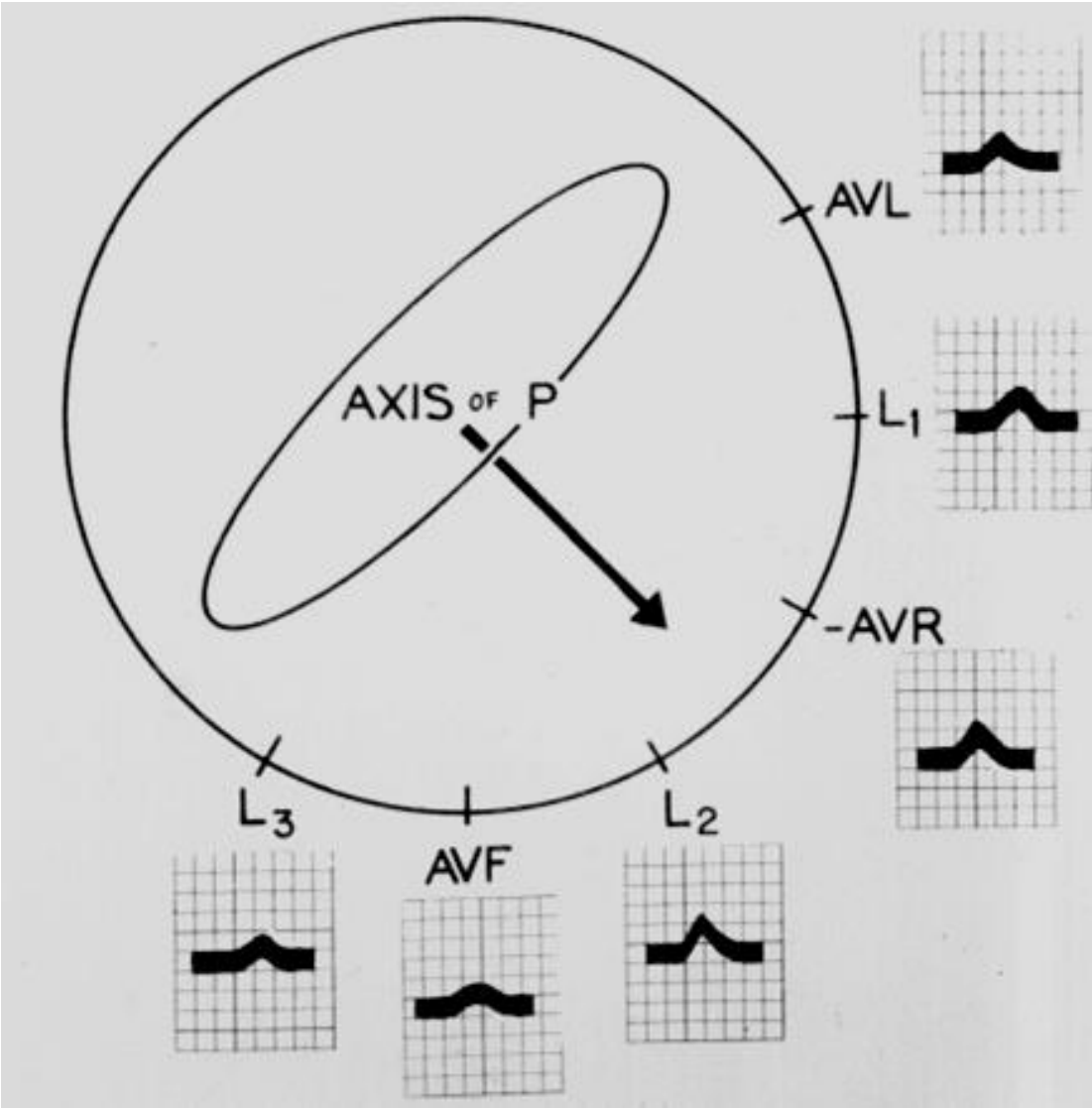
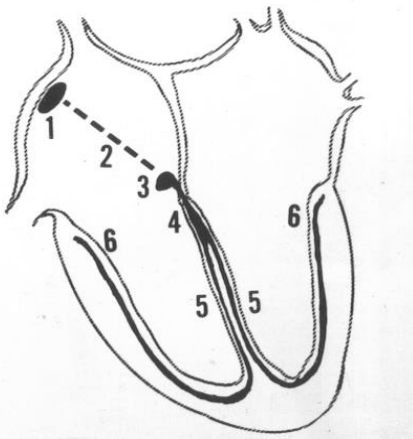
ECG Timing: the T Wave



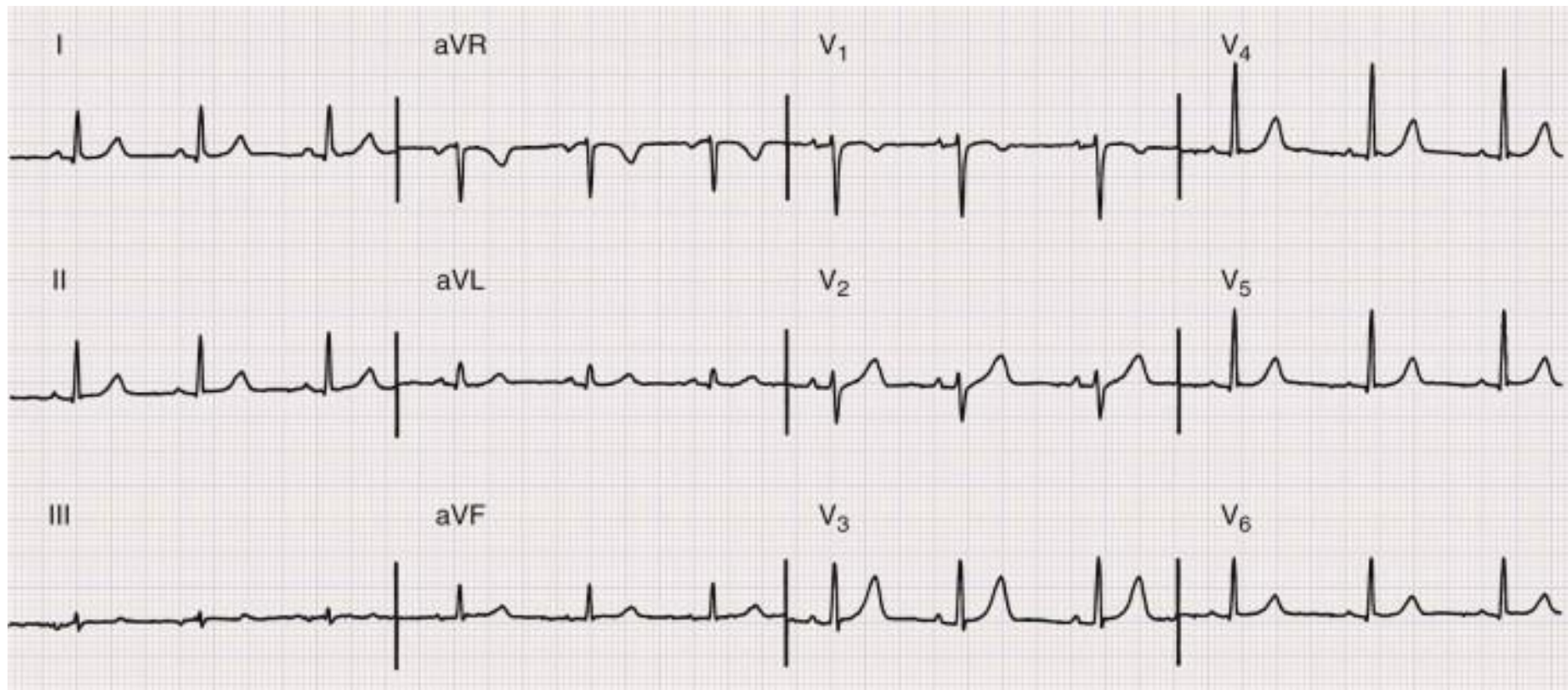
ECG Vectors: the P Wave



ECG Vectors: the P Wave



ECG Recording



X-axis

→ Time

Y-axis

→ Voltage

Direction of deflection

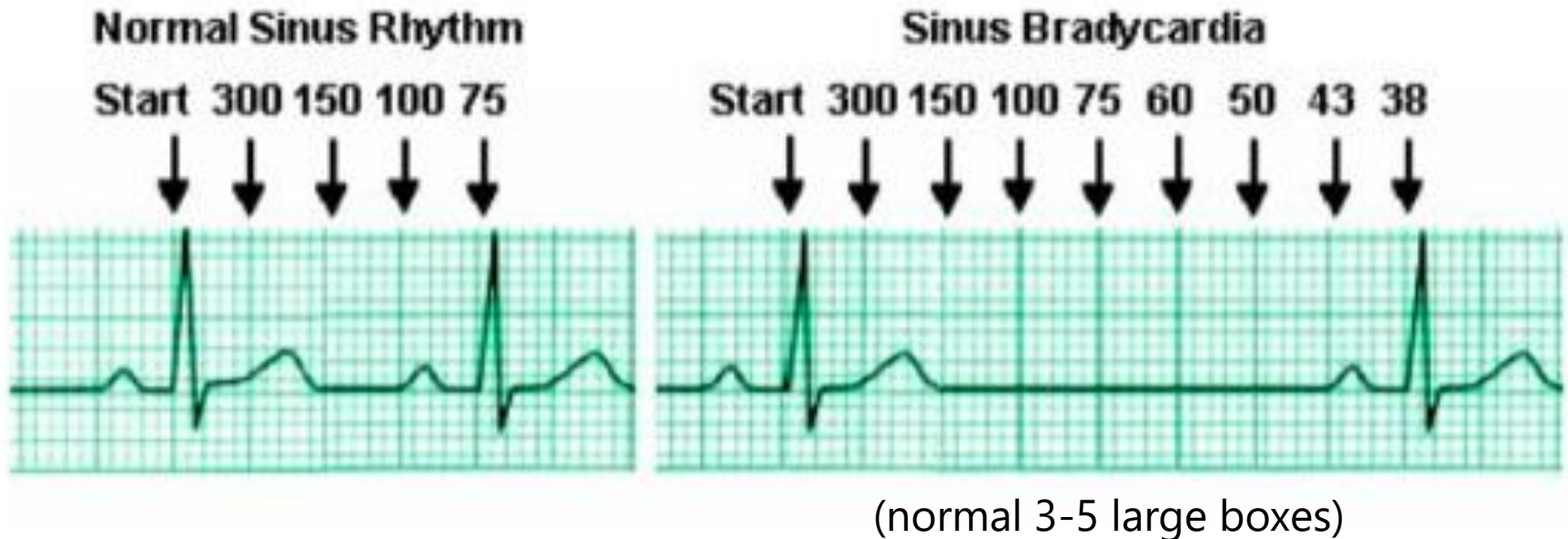
→ Direction of depolarization vector

ECG Interpretation

- Rate
- Rhythm
- Axis
- Intervals
- QRS morphology
- P wave morphology
- ST segments and T waves

Alternate: IRWAX system (<https://ecg.bidmc.harvard.edu>)

ECG: Rate



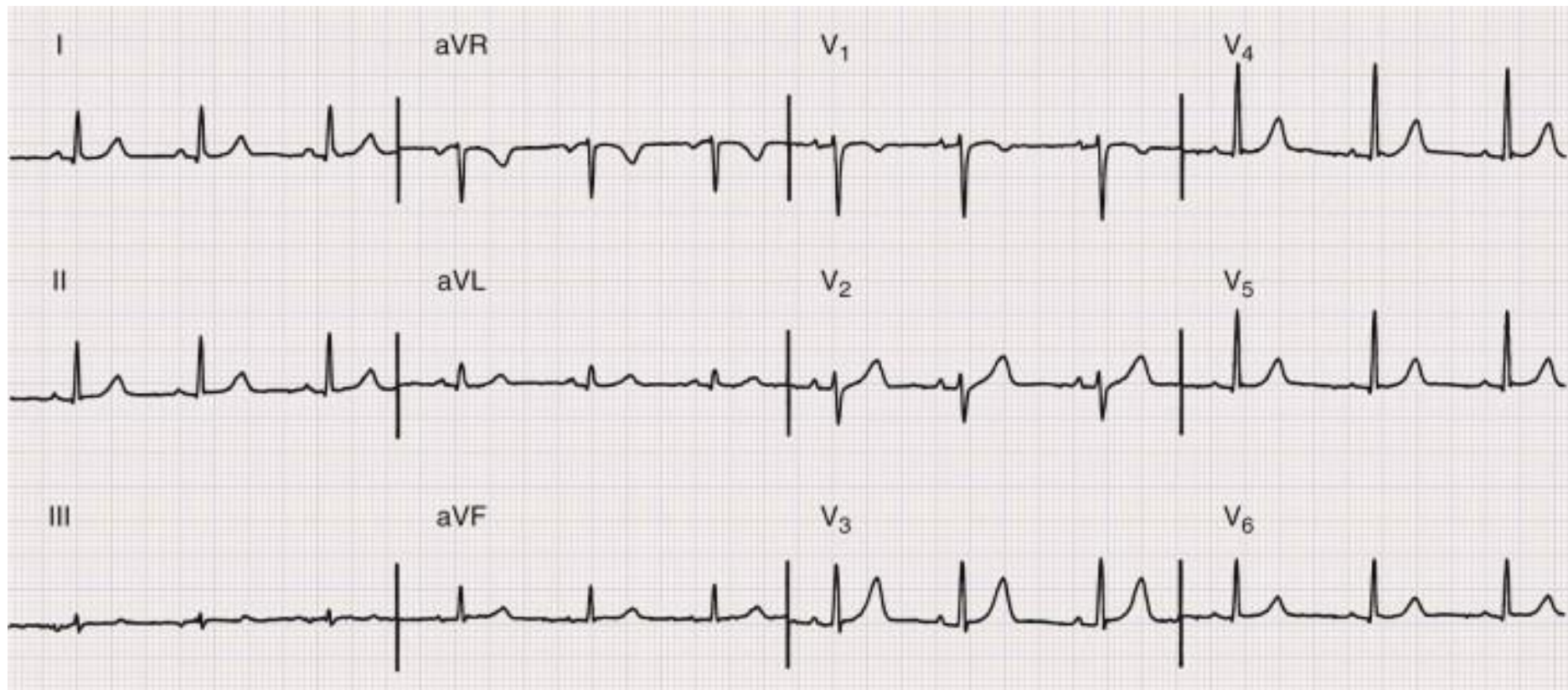
Regular rhythm:

- Rate = $300 / \text{number of } \underline{\text{large}} \text{ squares in between R waves}$
- Rate in msec = $60,000 / \text{bpm}$

Irregular rhythm:

- Rate = $\# \text{ complexes on the rhythm strip} \times 6$

ECG: Rhythm



Is normal sinus rhythm present or not?

Do you see a P wave?

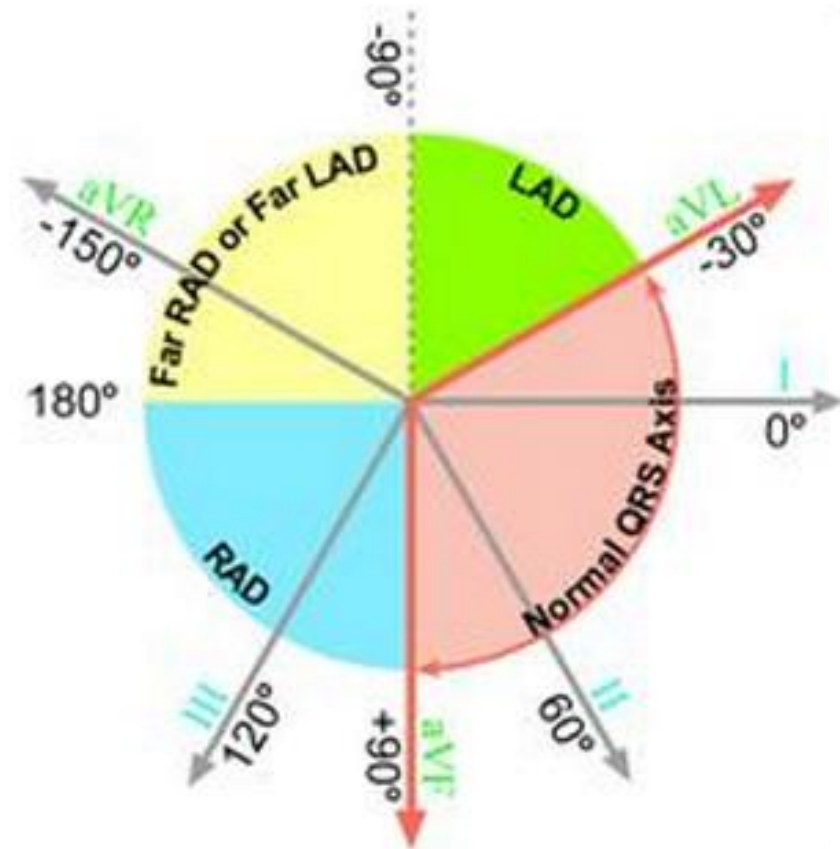
Is the axis of the P wave normal (upright in I and II)?

Does every P have a QRS and does every QRS have a P?

ECG: Axis

For the P and QRS, look at I and II

- If both (+): normal axis
- If (-) in I: right axis deviation
- If (-) in II: left axis deviation



ECG: Intervals

PR

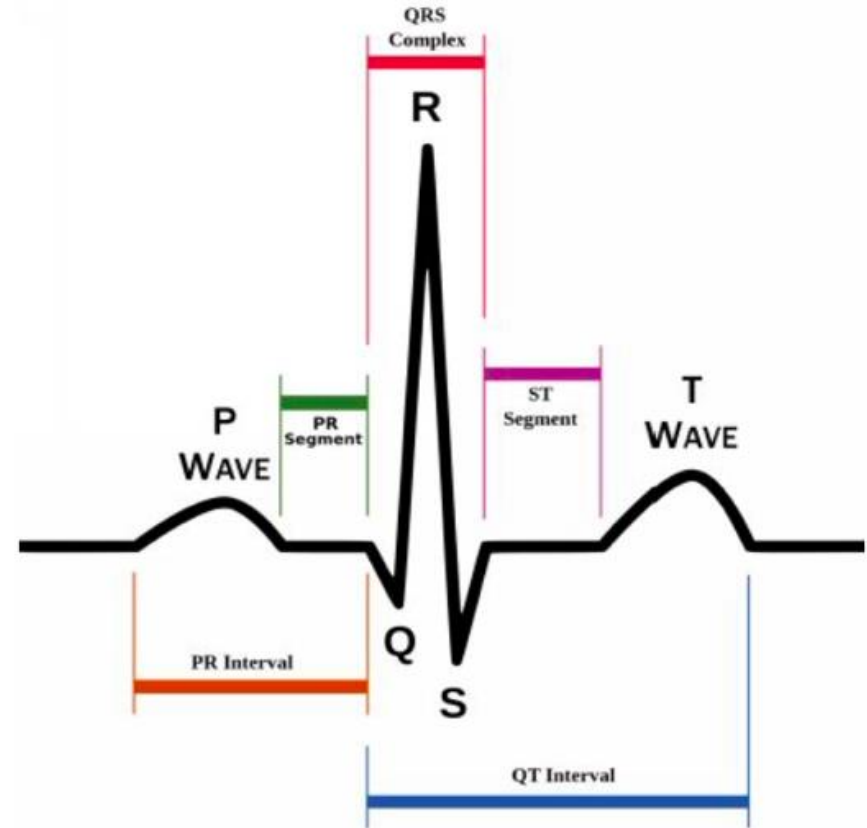
- 0.12 to 0.2 seconds
- > 0.2 = "1st degree AV Bloc

QRS

- < 0.12 = normal
- > 0.12 = "wide"

QT

- Ideally $< 400 - 450$ msec
- Shorter at faster HR



ECG: QT Interval

Heart Rate	Age Group (years)			
	18-29	30-39	40-49	50-60
115-84	0.30-0.37	0.30-0.37	0.31-0.37	0.31-0.37
83-72	0.32-0.39	0.33-0.39	0.33-0.40	0.33-0.40
71-63	0.34-0.41	0.35-0.41	0.35-0.41	0.35-0.42
62-56	0.36-0.42	0.36-0.43	0.37-0.43	0.37-0.43
55-45	0.38-0.42	0.38-0.44	0.37-0.41	0.36-0.46

ECG: Corrected QT Interval

The Bazett Formula (for HR 60-100 bpm):

$$QT_c = \frac{\text{OBSERVED QT}}{\sqrt{\text{R - R INTERVAL (sec)}}}$$

QT Interval: How Long is Too Long?

- 99th percentile for women: 480 msec
- 99th percentile for men: 470 msec

Session 1B: Heart Block

Learning objectives:

- Identify the different degrees of heart block
 - Distinguish between the different types of second degree heart block
- Correlate ECG findings with anatomic level of heart block

Types of Heart Block

Block type	Key ECG Finding	Level of Block
1 st degree	PR prolongation	Atrium, AV node
2 nd degree (Mobitz I/Wenckebach)	Progressive PR prolongation, Intermittent drop of ventricular conduction, Grouped ventricular beats	AV node
2 nd degree (Mobitz II)	Intermittent drop of ventricular conduction without a change in PR*, Grouped ventricular beats**	Below AV node
3 rd degree (complete)	AV dissociation (more A beats than V beats)	Below AV node

* PR may be normal

** QRS may be widened indicating infra-Hisian block, or normal with intra-Hisian block

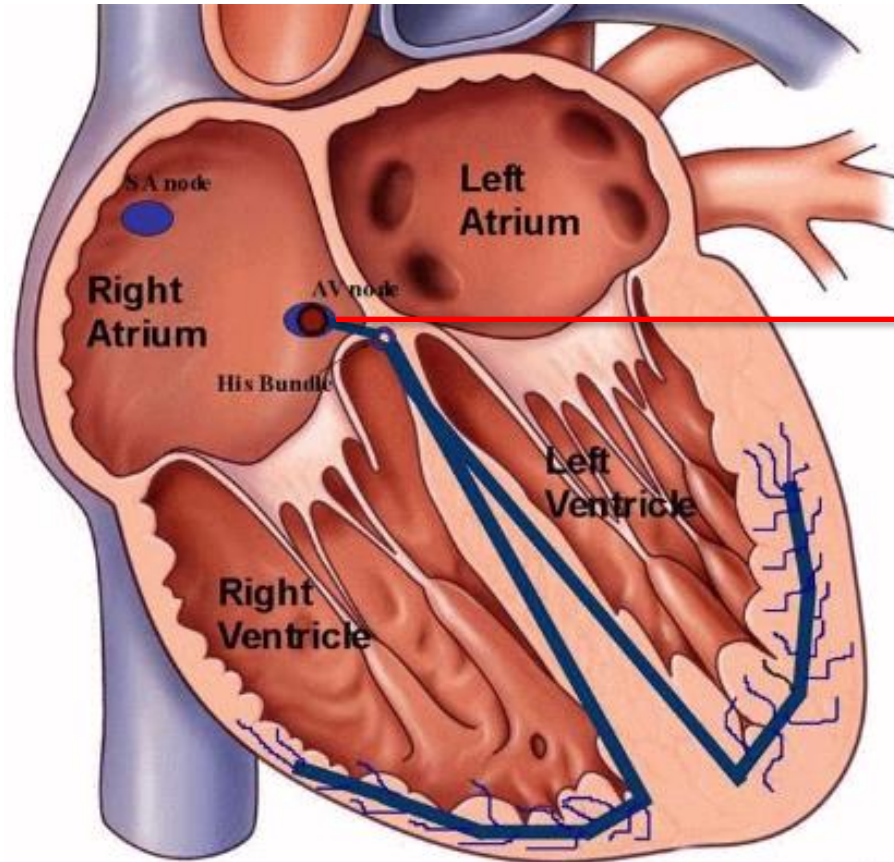


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Types of Heart Block

Important to determine level of block, as this will determine the need for pacing support



Block at/above AV node:
Less ominous

Block below AV node:
More ominous



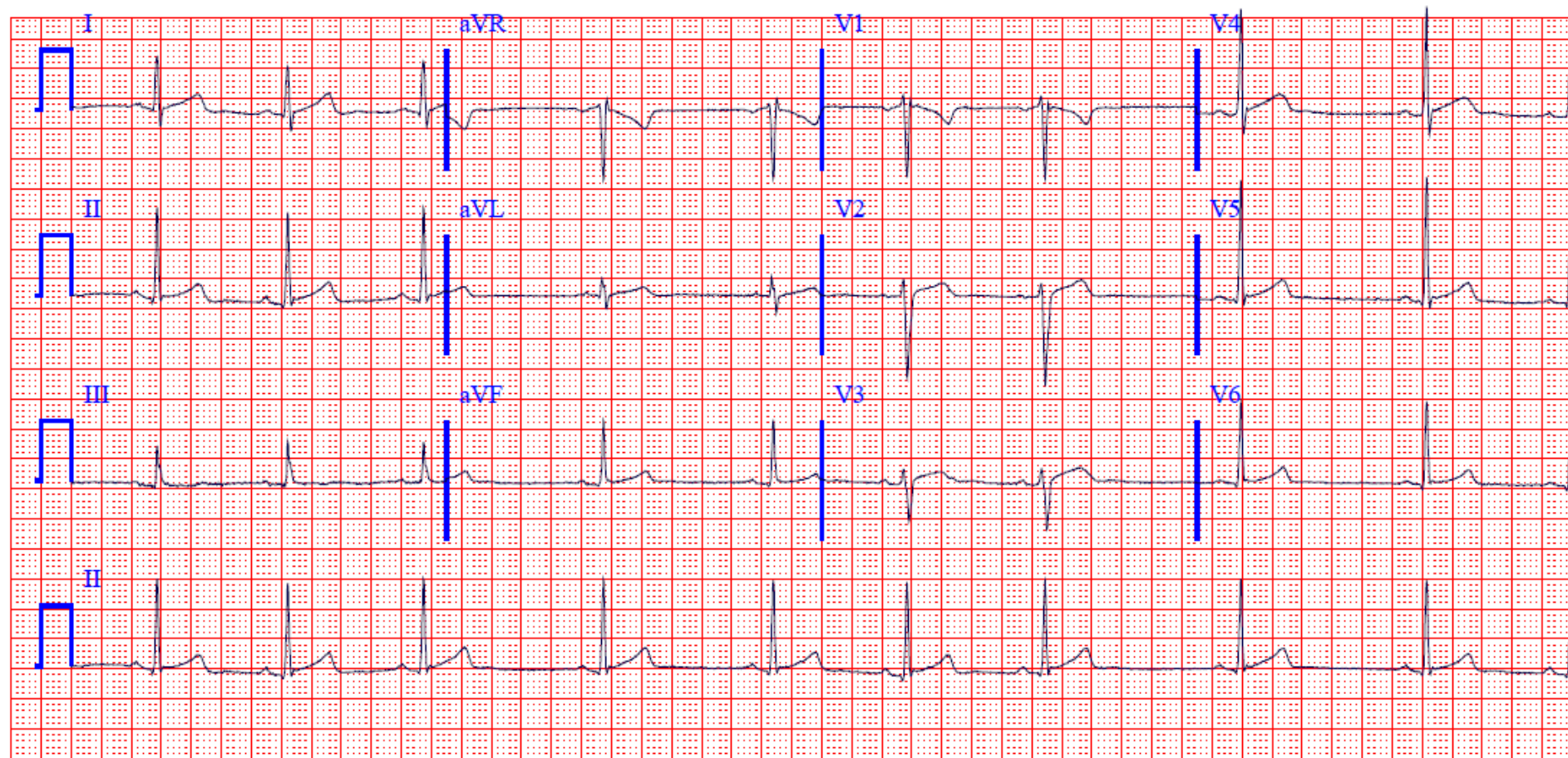
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Question 1

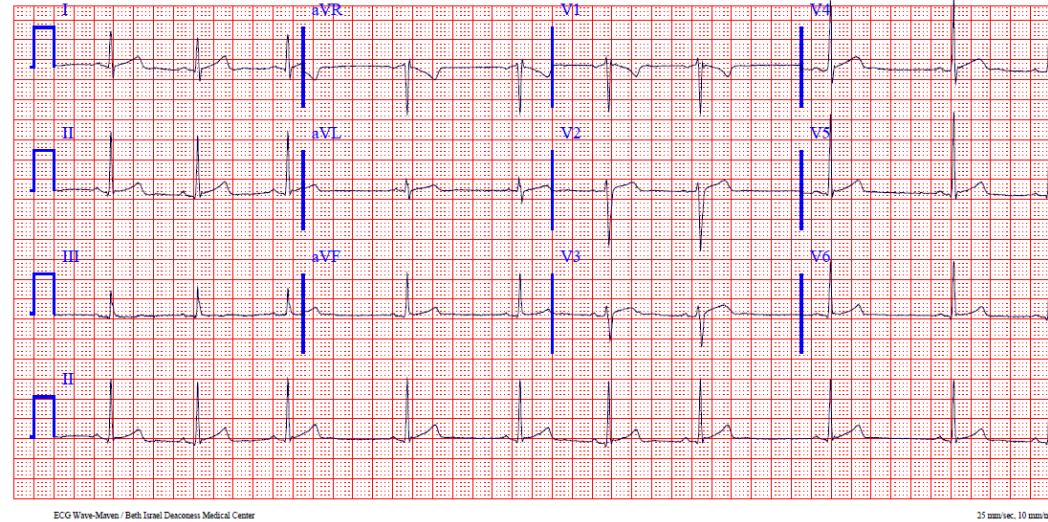
48-year-old man with coronary artery disease and prior coronary artery bypass surgery who presents to a routine outpatient visit with intermittent palpitations. No presyncopal symptoms or syncopal events.

Question 1: What is the rhythm?



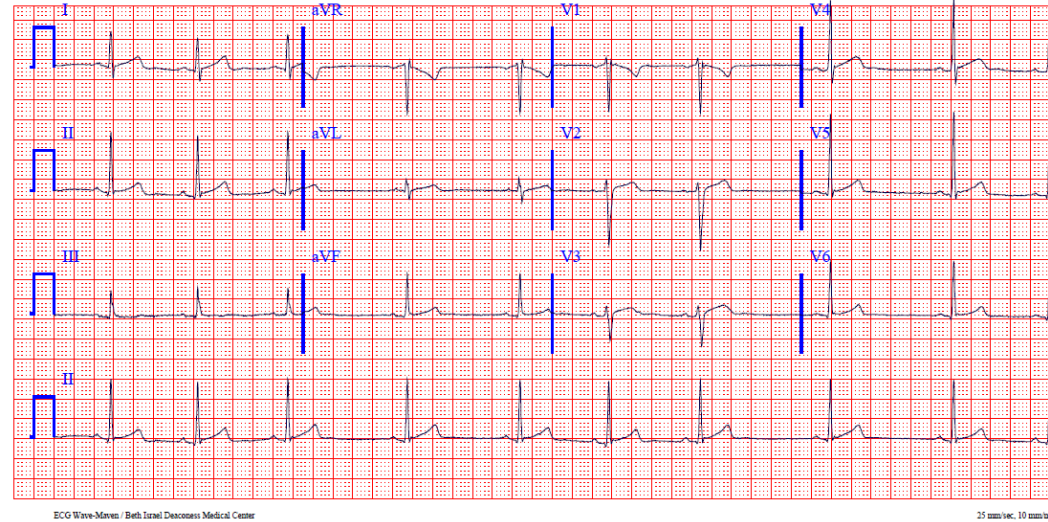
Question 1: What is the rhythm?

- A. Normal sinus rhythm
- B. Sinus bradycardia
- C. Atrial fibrillation
- D. Atrial flutter
- E. Normal sinus rhythm with long QT interval
- F. Normal sinus rhythm with sinus arrhythmia



Question 1: What is the rhythm?

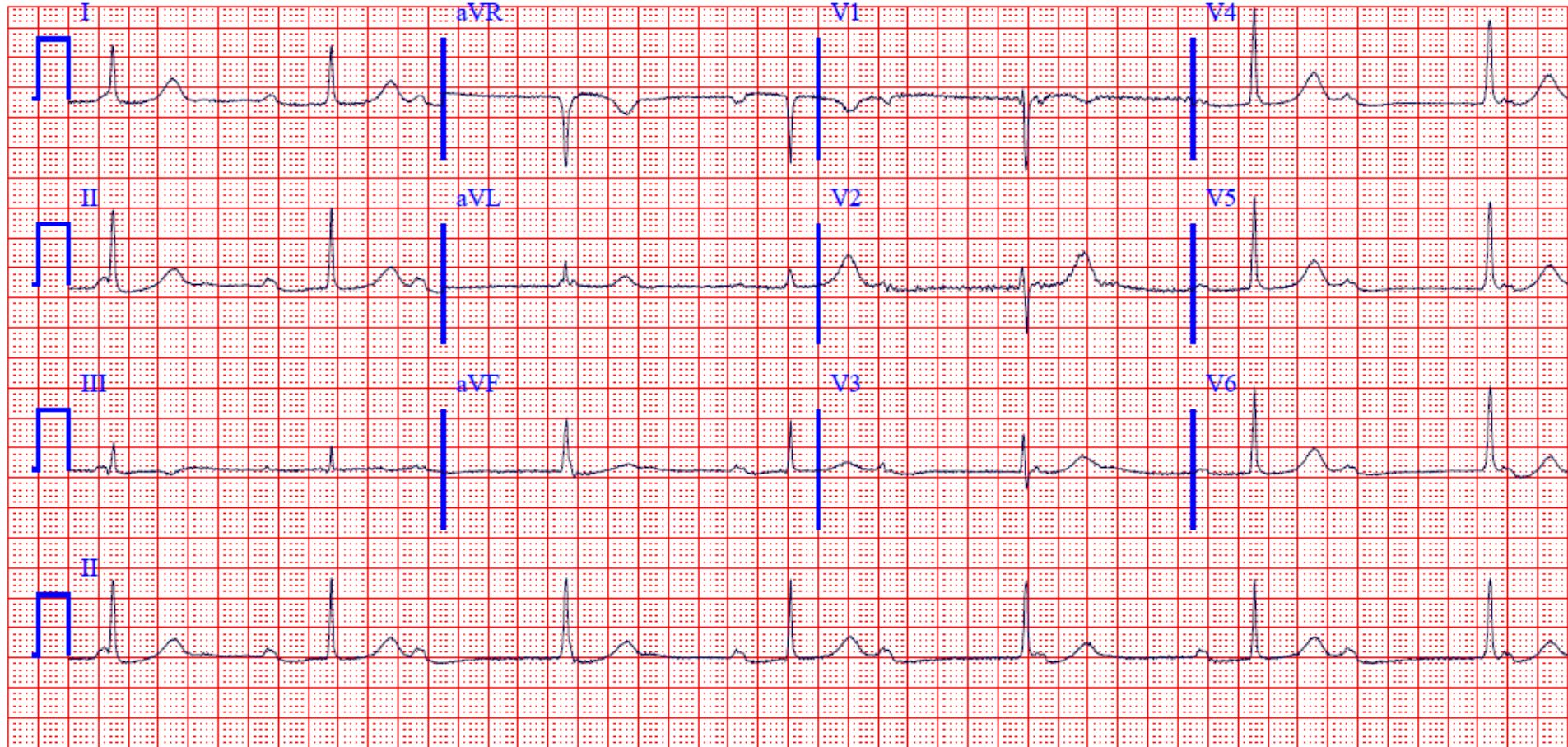
- A. Normal sinus rhythm
- B. Sinus bradycardia
- C. Atrial fibrillation
- D. Atrial flutter
- E. Normal sinus rhythm with long QT interval
- F. **Normal sinus rhythm with sinus arrhythmia**



Question 2

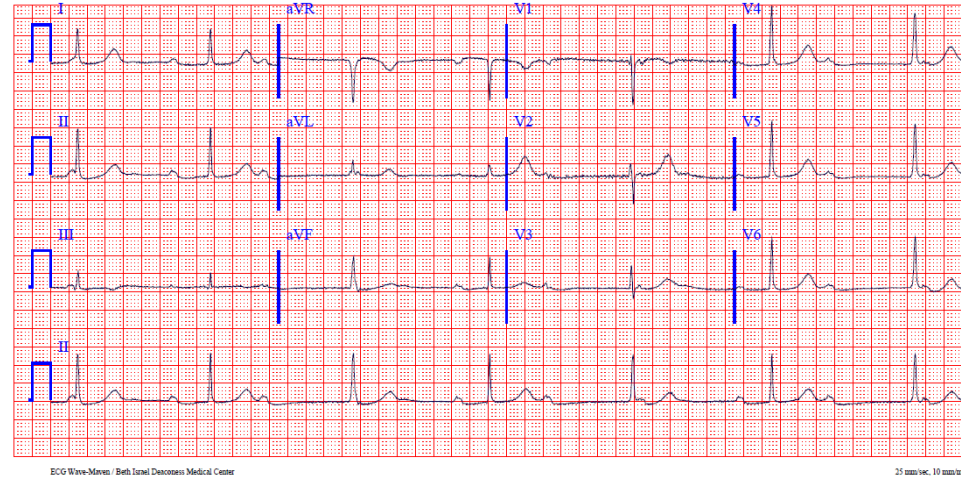
71-year-old woman who is brought to the ED by her daughter after being found briefly unresponsive in a chair. No fall, no trauma. Patient reports that she feels “fine” and wishes to return home.

Question 2: What is the rhythm?



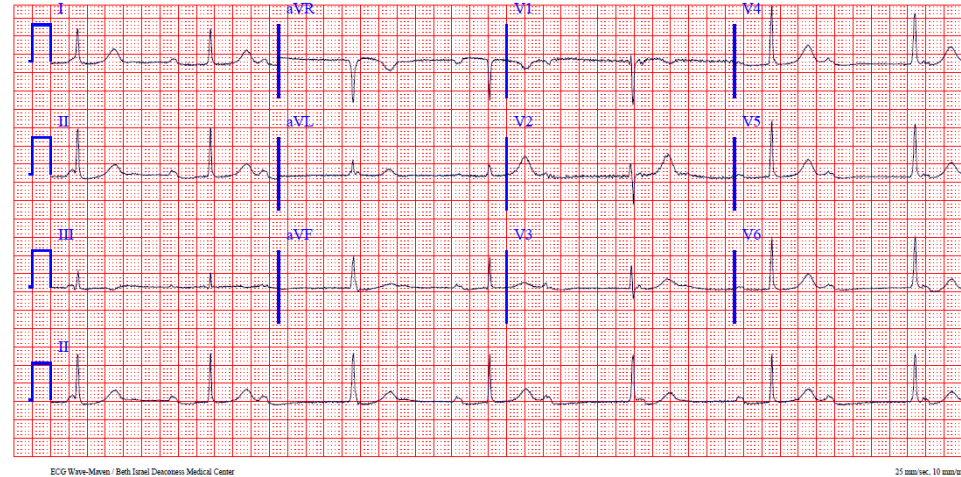
Question 2: What is the rhythm?

- A. Normal sinus rhythm
- B. 1st degree AV block
- C. 2nd degree AV block (Wenckebach)
- D. 2nd degree AV block (Mobitz II)
- E. Complete heart block



Question 2: What is the rhythm?

- A. Normal sinus rhythm
- B. 1st degree AV block
- C. 2nd degree AV block (Wenckebach)
- D. 2nd degree AV block (Mobitz II)
- E. Complete heart block



Question 3

59-year-old woman with no prior medical history admitted for observation after traumatic leg fracture sustained in MVA (passenger). No concerning exam or laboratory findings. Routine telemetry was performed after surgical repair of her fracture.

Question 3: What is the rhythm?



Question 3: What is the rhythm?

- A. Normal sinus rhythm
- B. 1st degree AV block
- C. 2nd degree AV block (Wenckebach)
- D. 2nd degree AV block (Mobitz II)
- E. Complete heart block



Question 3: What is the rhythm?

- A. Normal sinus rhythm
- B. 1st degree AV block
- C. 2nd degree AV block (Wenckebach)
- D. 2nd degree AV block (Mobitz II)
- E. Complete heart block



Session 1C: Atrial Arrhythmias

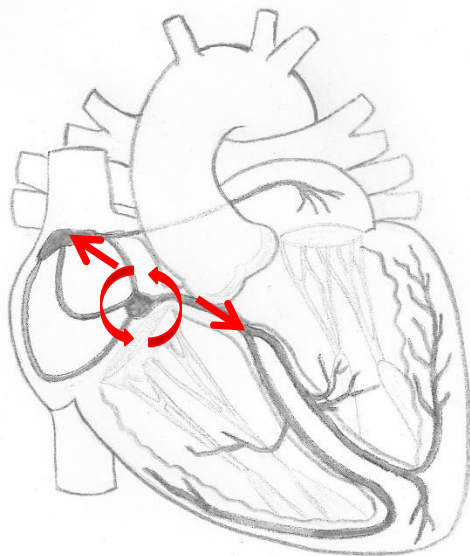
Learning objectives:

- Identify the different types of atrial arrhythmias
- Correlate ECG findings with the mechanism of atrial arrhythmias

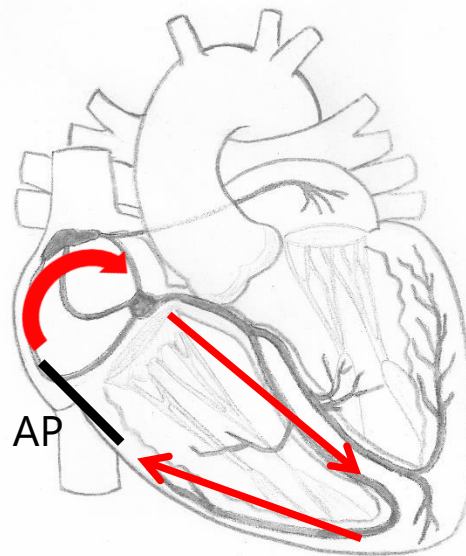
We will focus on atrial arrhythmias today

SVT will be discussed in a future session on narrow-complex tachycardias

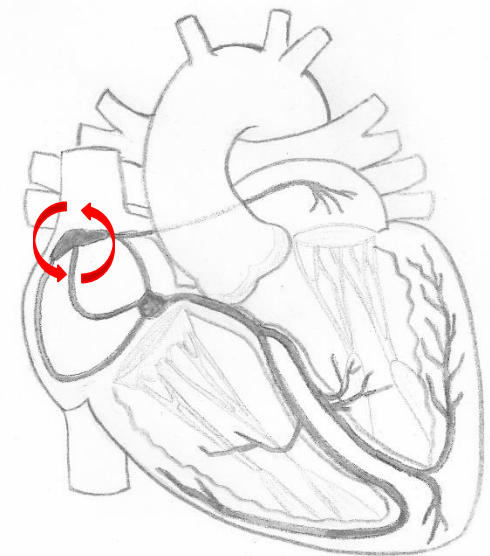
AVNRT



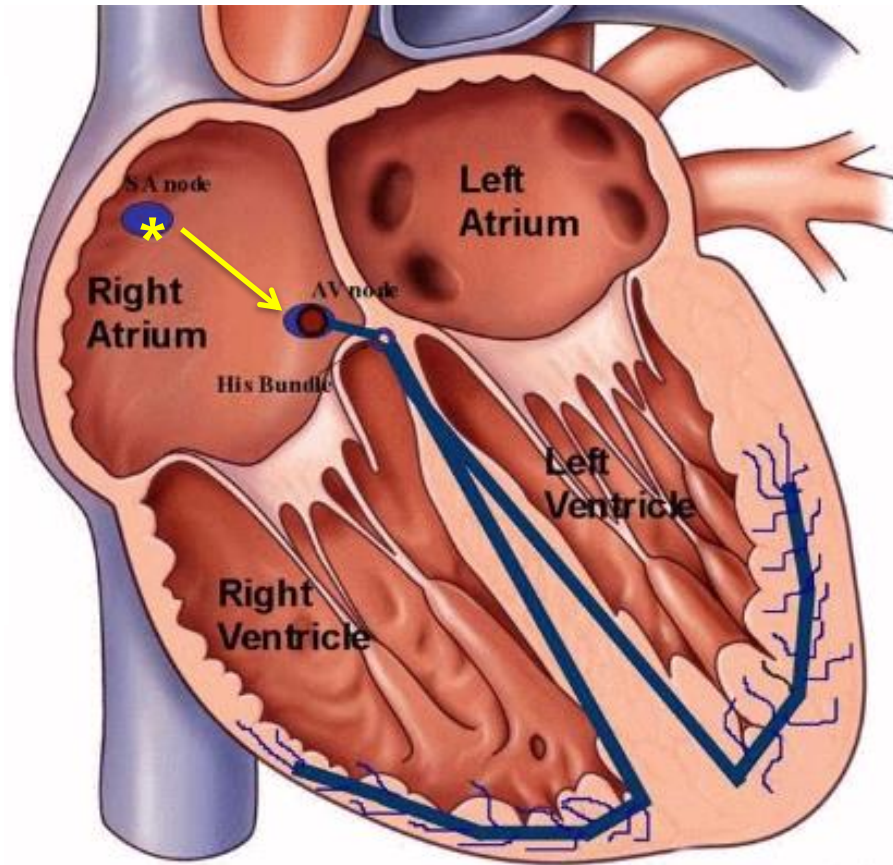
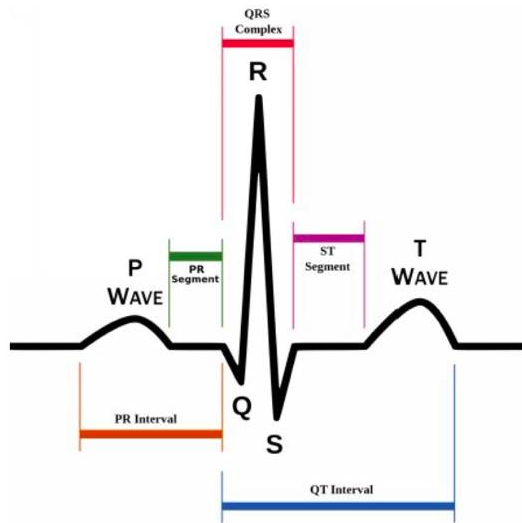
AVRT



AT



Normal Sinus Rhythm



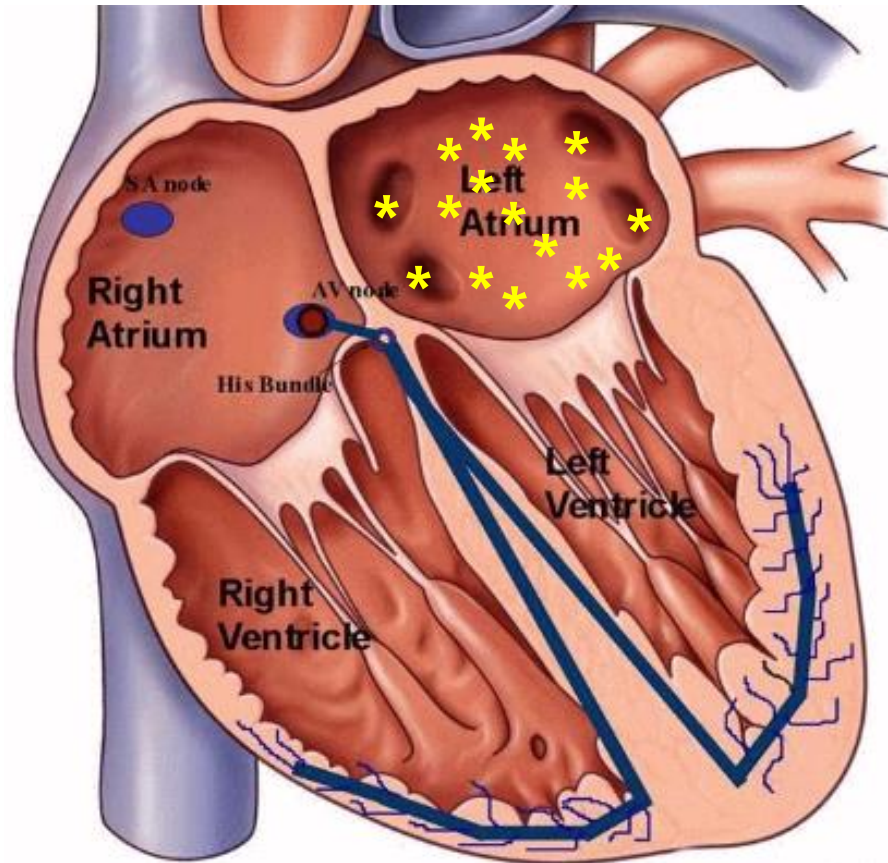
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Atrial Fibrillation

Most common sustained arrhythmia in adults

Associated with increase in stroke risk



Chaotic electrical activity in the pulmonary veins



SA node overdrive suppressed,

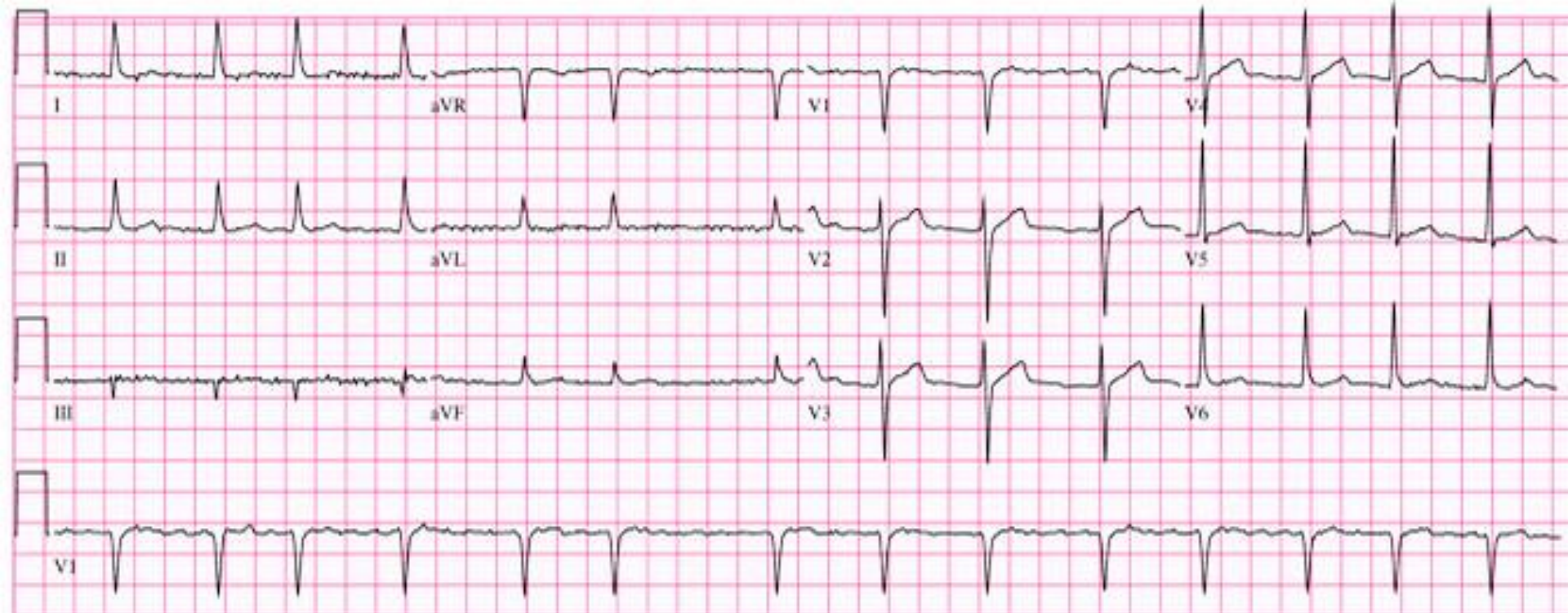
AV node is inundated with irregular electrical impulses



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Question 4: What is the rhythm?

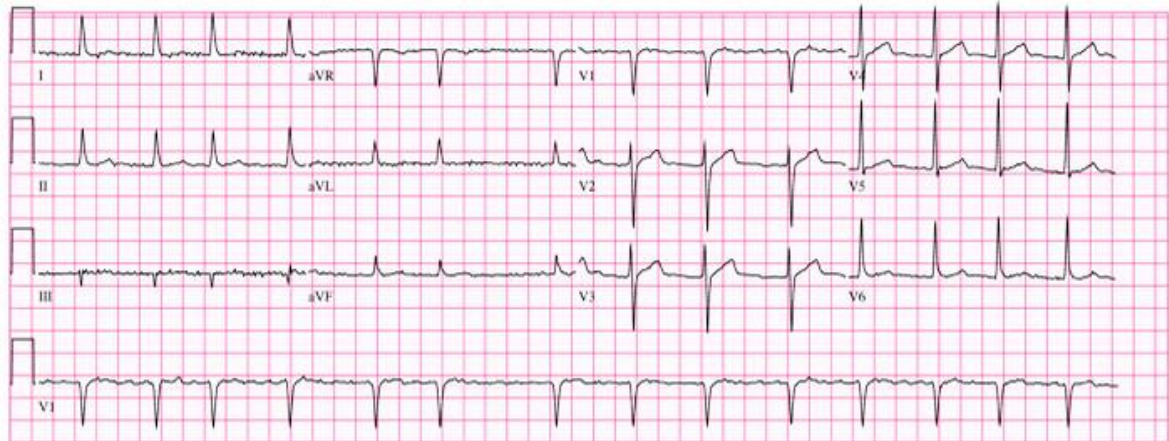


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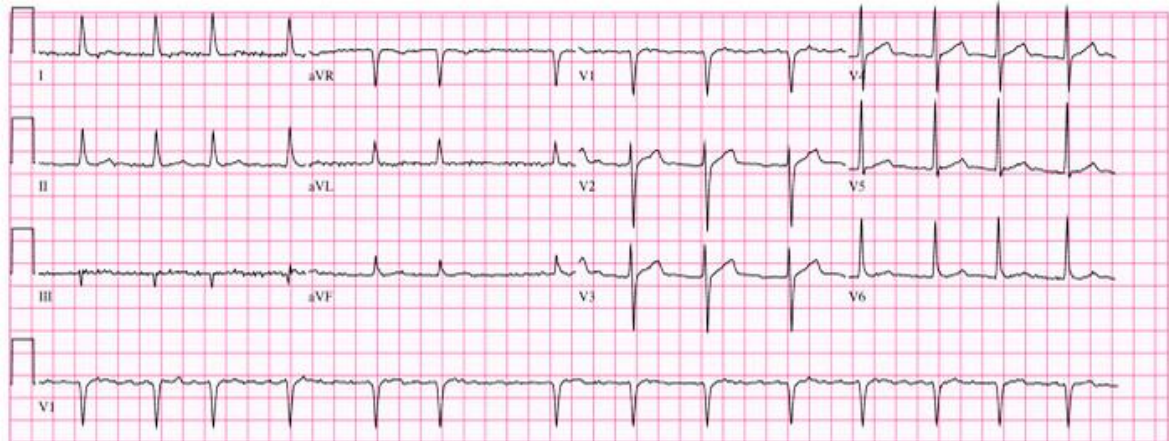
Question 4: What is the rhythm?

- A. Sinus rhythm
- B. Atrial fibrillation
- C. Atrial flutter, atypical
- D. Atrial flutter, typical
- E. Atrial tachycardia

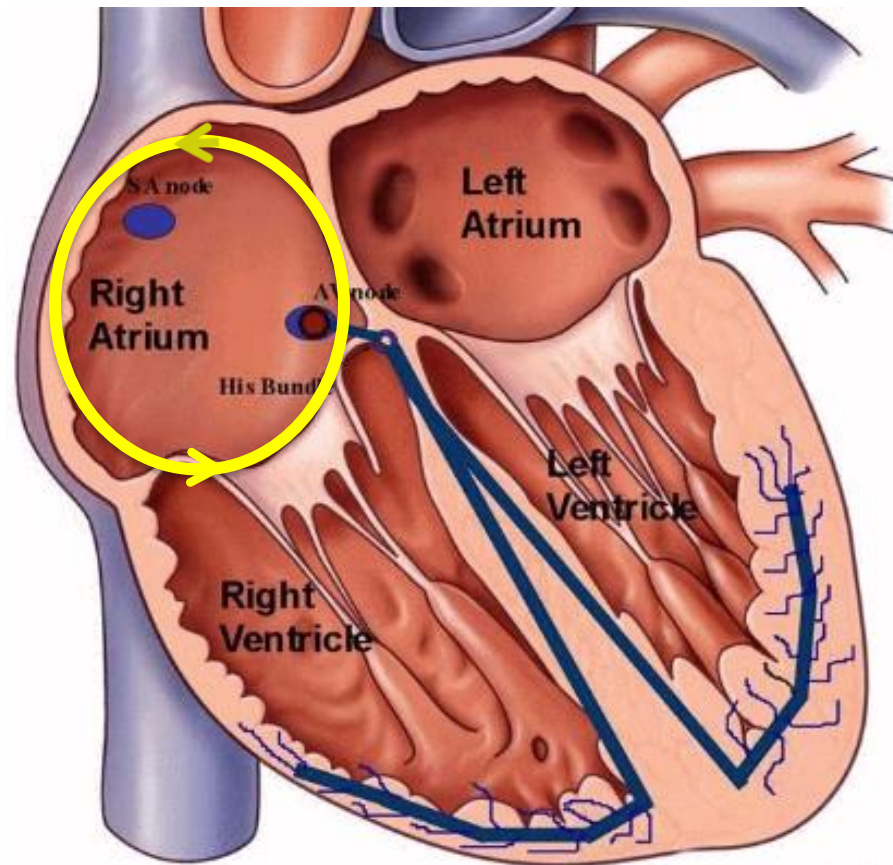


Question 4: What is the rhythm?

- A. Sinus rhythm
- B. **Atrial fibrillation**
- C. Atrial flutter, atypical
- D. Atrial flutter, typical
- E. Atrial tachycardia



Typical Atrial Flutter



Atrial circuit



SA node
overdrive
suppressed

AV node
inundated with
rapid, regular
impulses

“typical” atrial flutter: cavotricuspid isthmus-dependent, counterclockwise

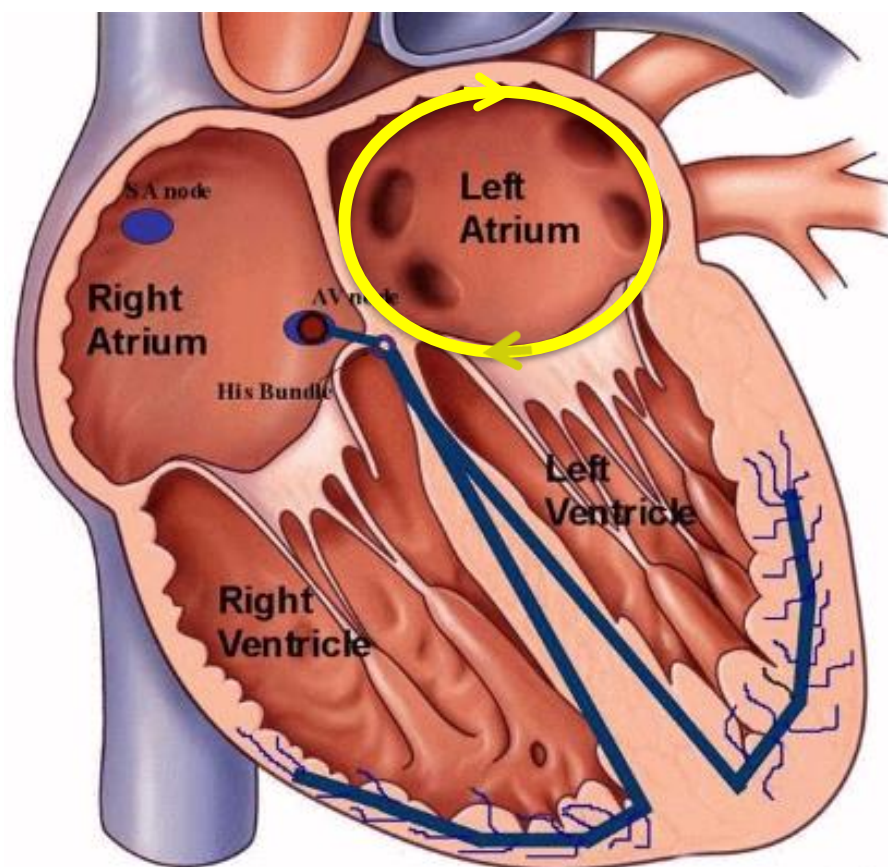
...clockwise is also observed



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Left Atrial Flutter



Atrial circuit

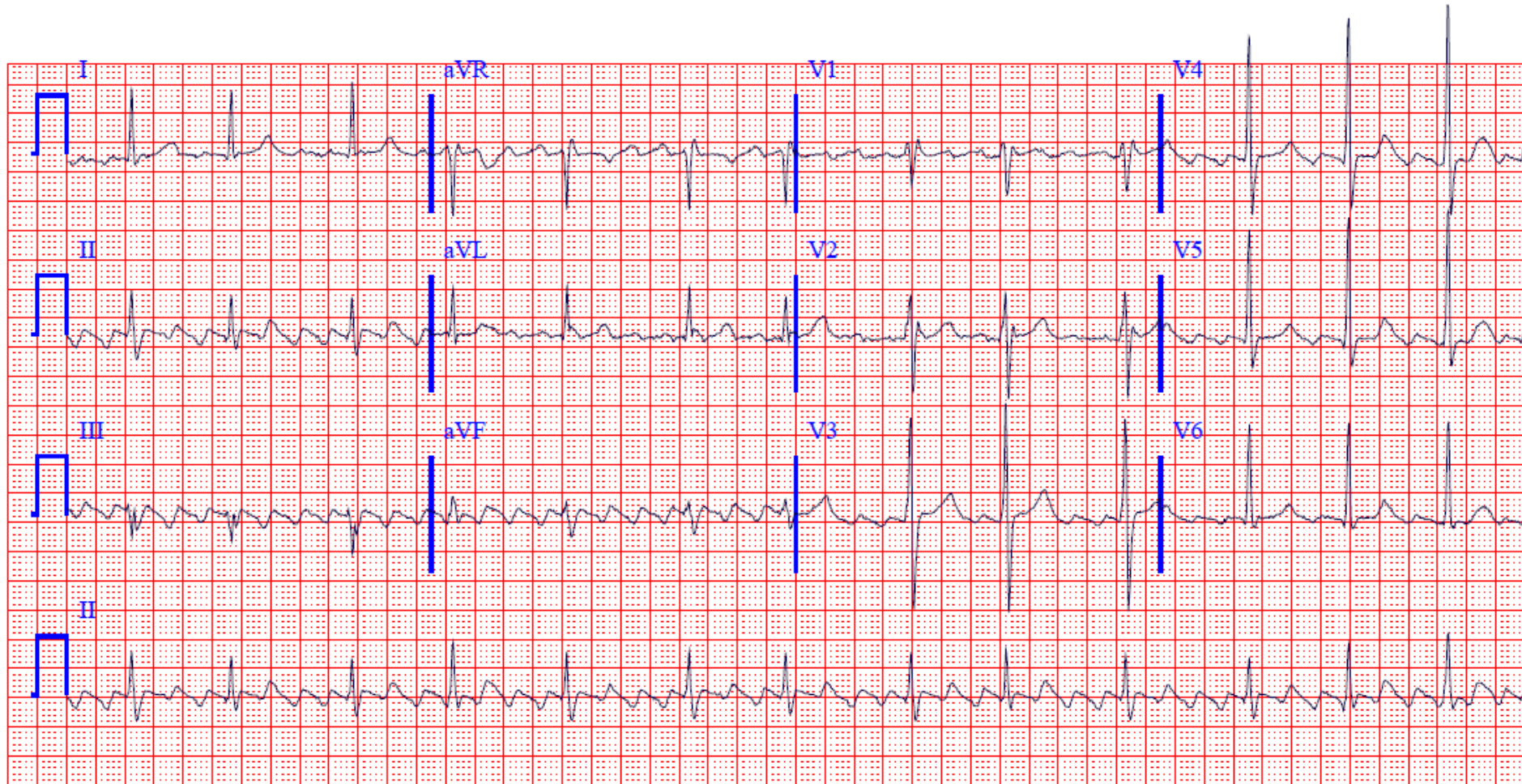


SA node
overdrive
suppressed

AV node
inundated with
rapid, regular
impulses

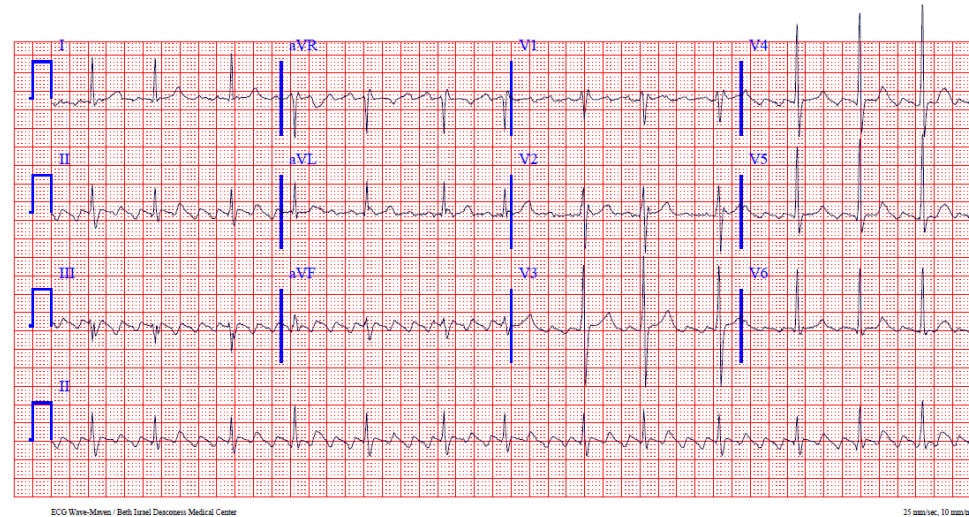
- Waveform different than "isthmus-dependent" flutter
- Isoelectric line may be visible between atrial waves

Question 5: What is the rhythm?



Question 5: What is the rhythm?

- A. Sinus rhythm
- B. Atrial fibrillation
- C. Atrial flutter, atypical
- D. Atrial flutter, typical
- E. Atrial tachycardia



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25 mm/sec, 10 mm/mV

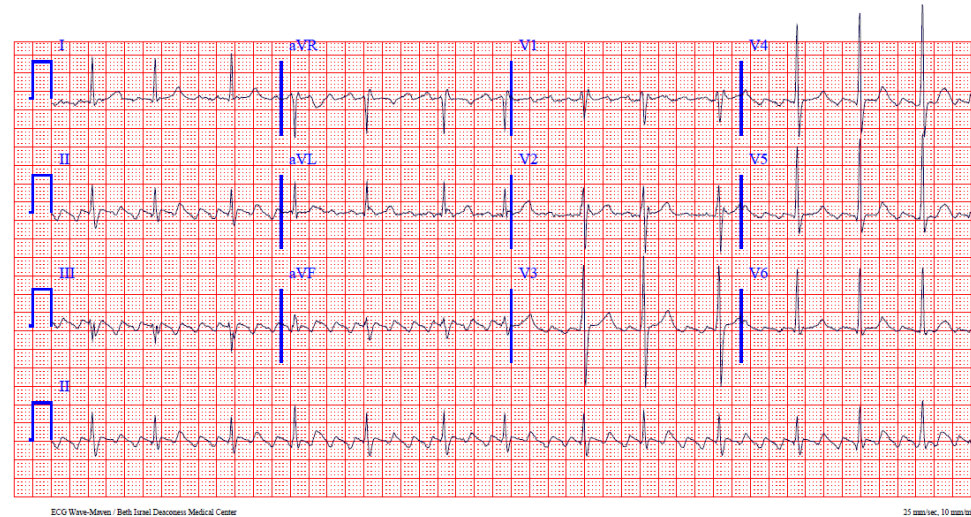


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Question 5: What is the rhythm?

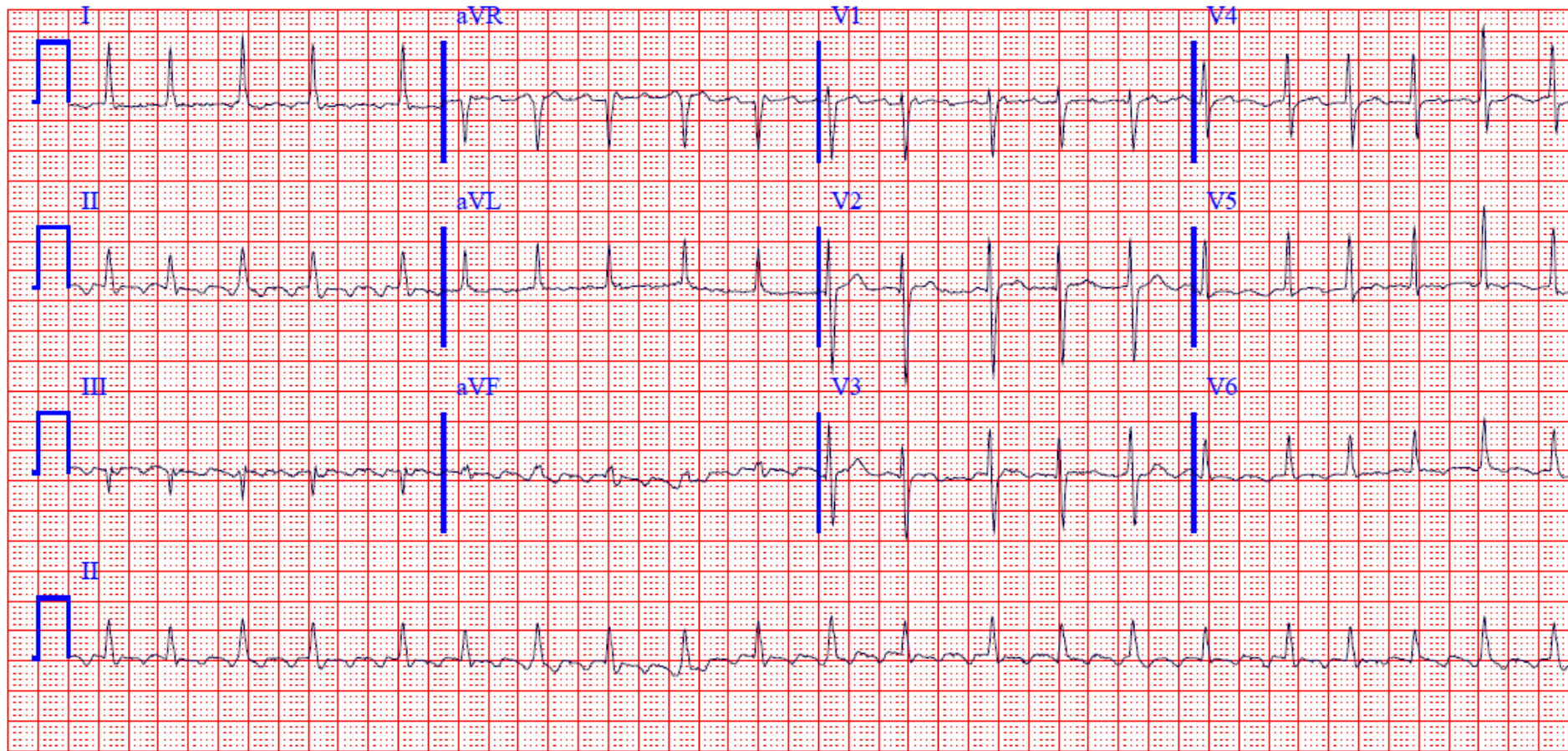
- A. Sinus rhythm
- B. Atrial fibrillation
- C. Atrial flutter, atypical
- D. **Atrial flutter, typical**
- E. Atrial tachycardia



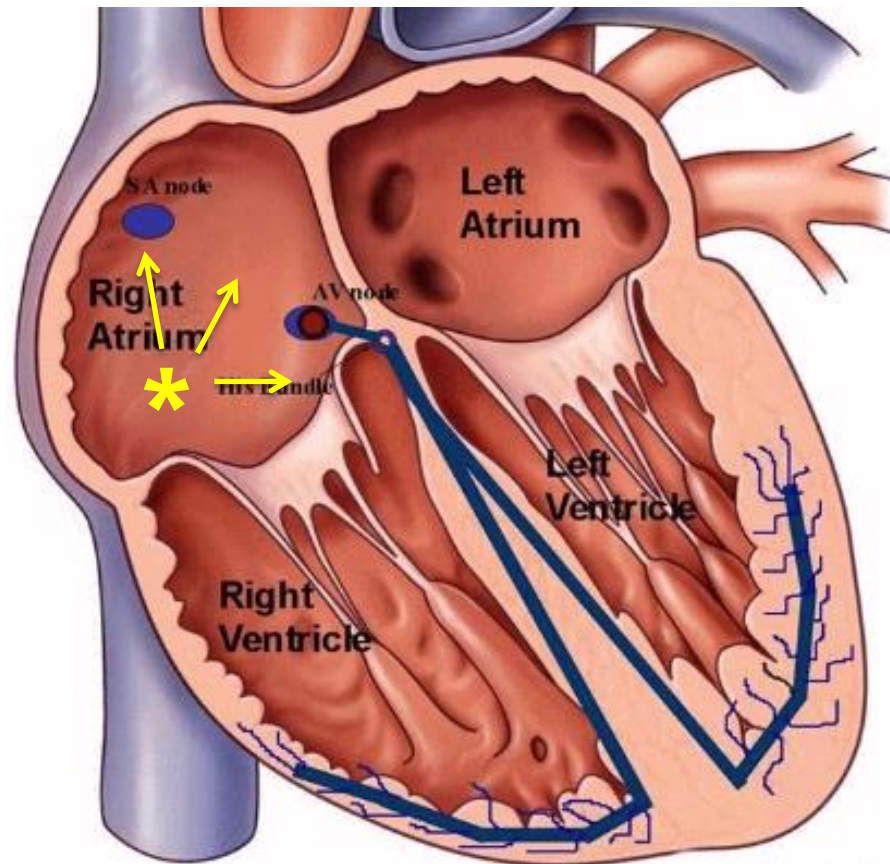
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Atypical (Left-Sided) Atrial Flutter



Atrial Tachycardia



Atrial focus
(left or right)

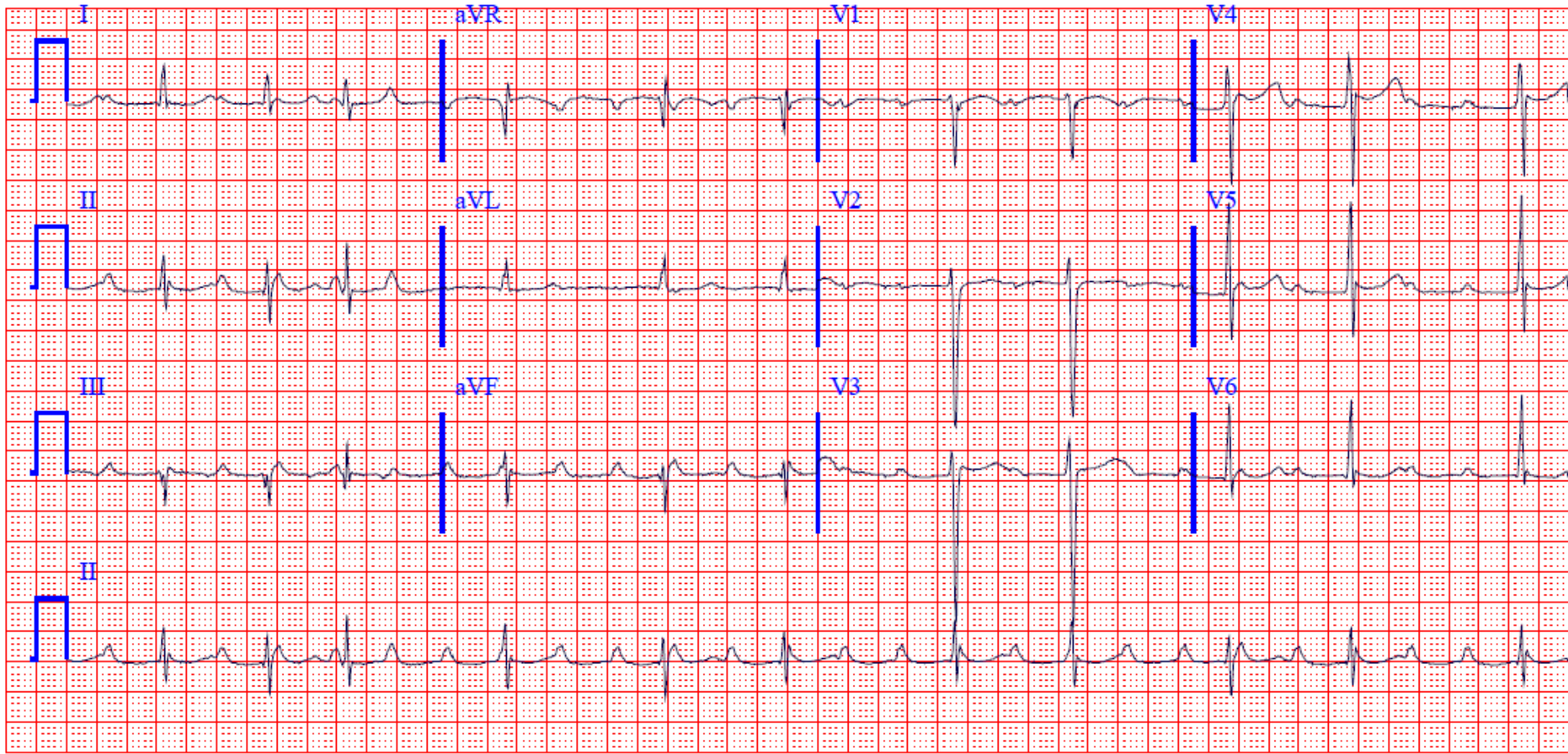


SA node
overdrive
suppressed

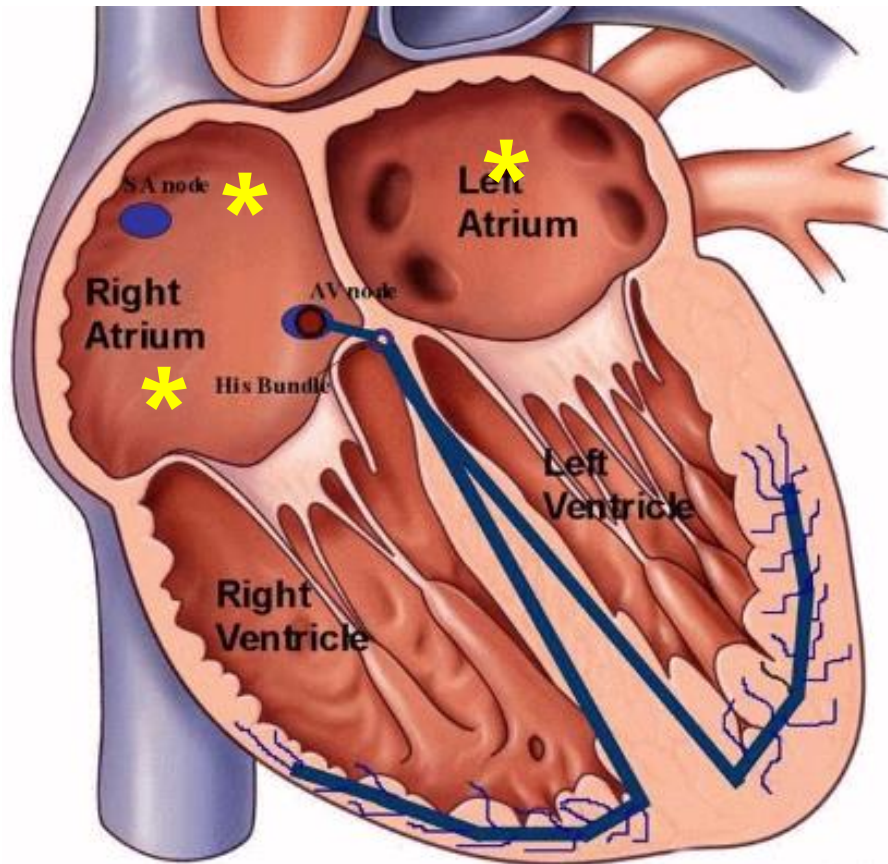
AV node
inundated with
rapid, regular
impulses

Atrial waves may mimic the waveform associated with atrial flutter
Atrial tachycardia rates defined to be less than 250 bpm

Atrial Tachycardia



Multifocal Atrial Tachycardia



Multiple atrial foci
(left or right)

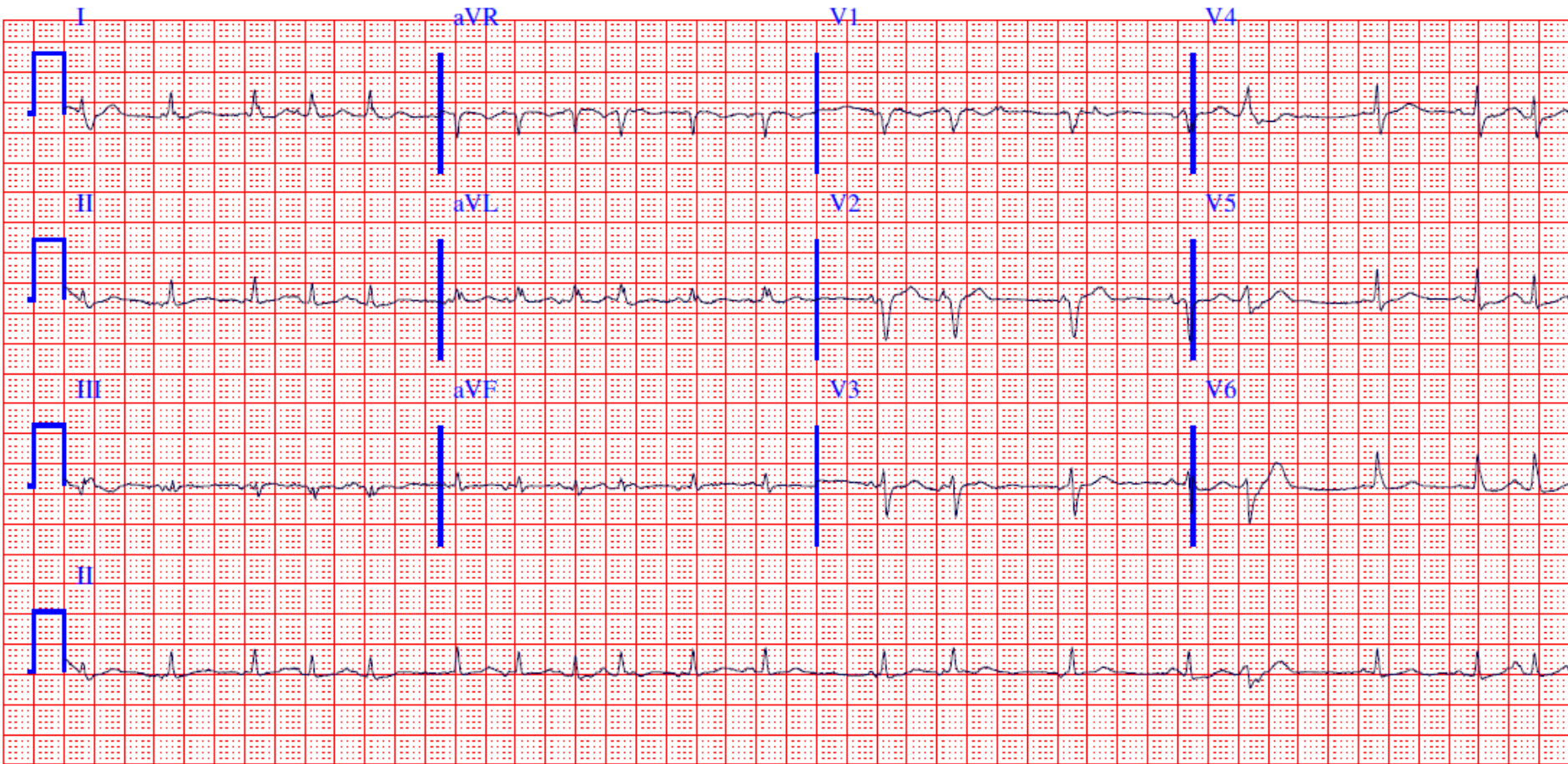


SA node
overdrive
suppressed

AV node
inundated with
rapid, regular
impulses

Multiple, abnormal P wave morphologies may be visible

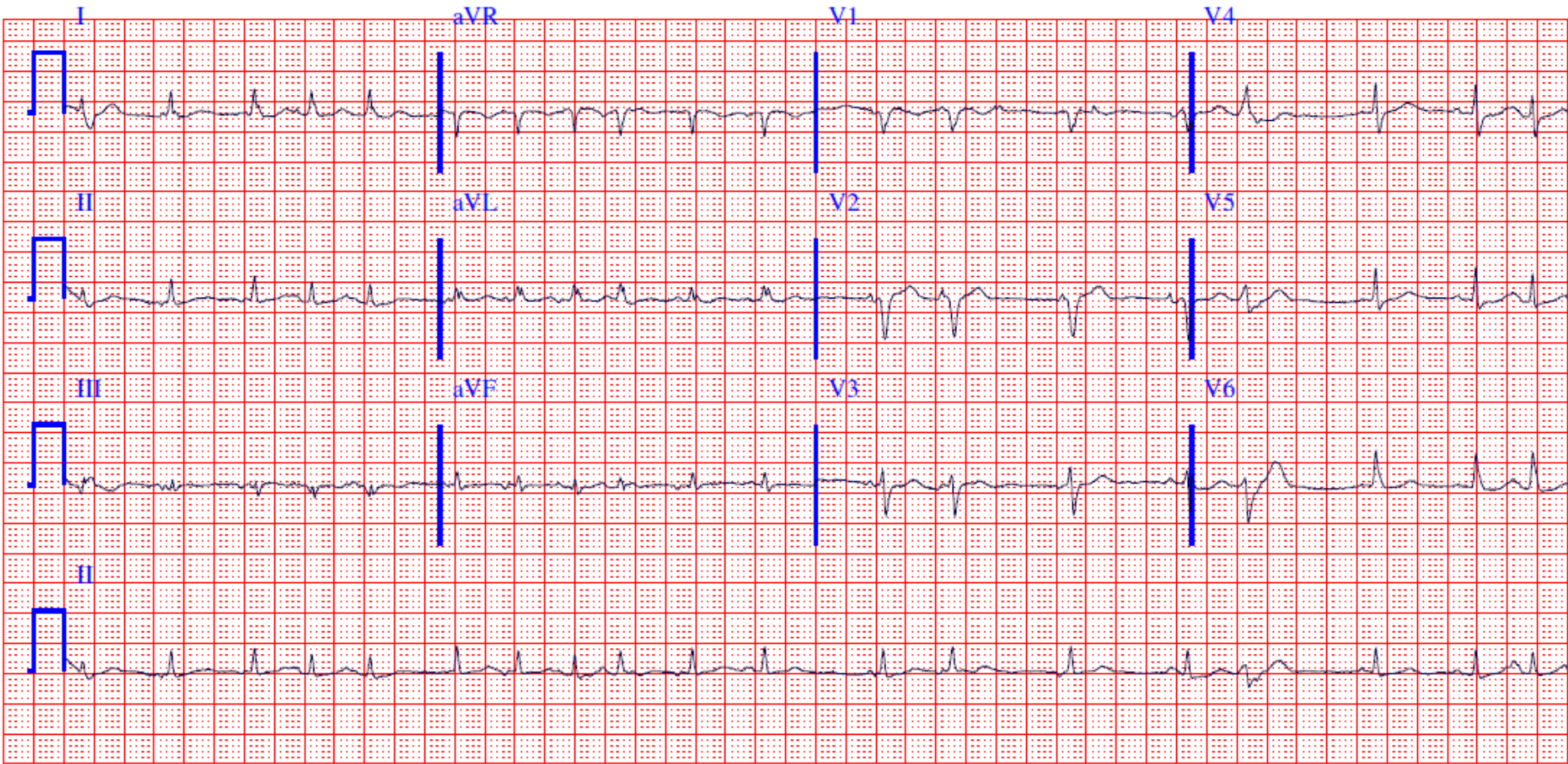
Multifocal Atrial Tachycardia



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25 mm/sec, 10 mm/mV

Multifocal Atrial Tachycardia



ECG Wave-Maven / Beth Israel Deaconess Medical Center

25 mm/sec, 10 mm/mV

Three atrial morphologies in three leads

Thank you



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