Electrocardiography

Saeed Oraii MD, Cardiologist

Interventional Electrophysiologist

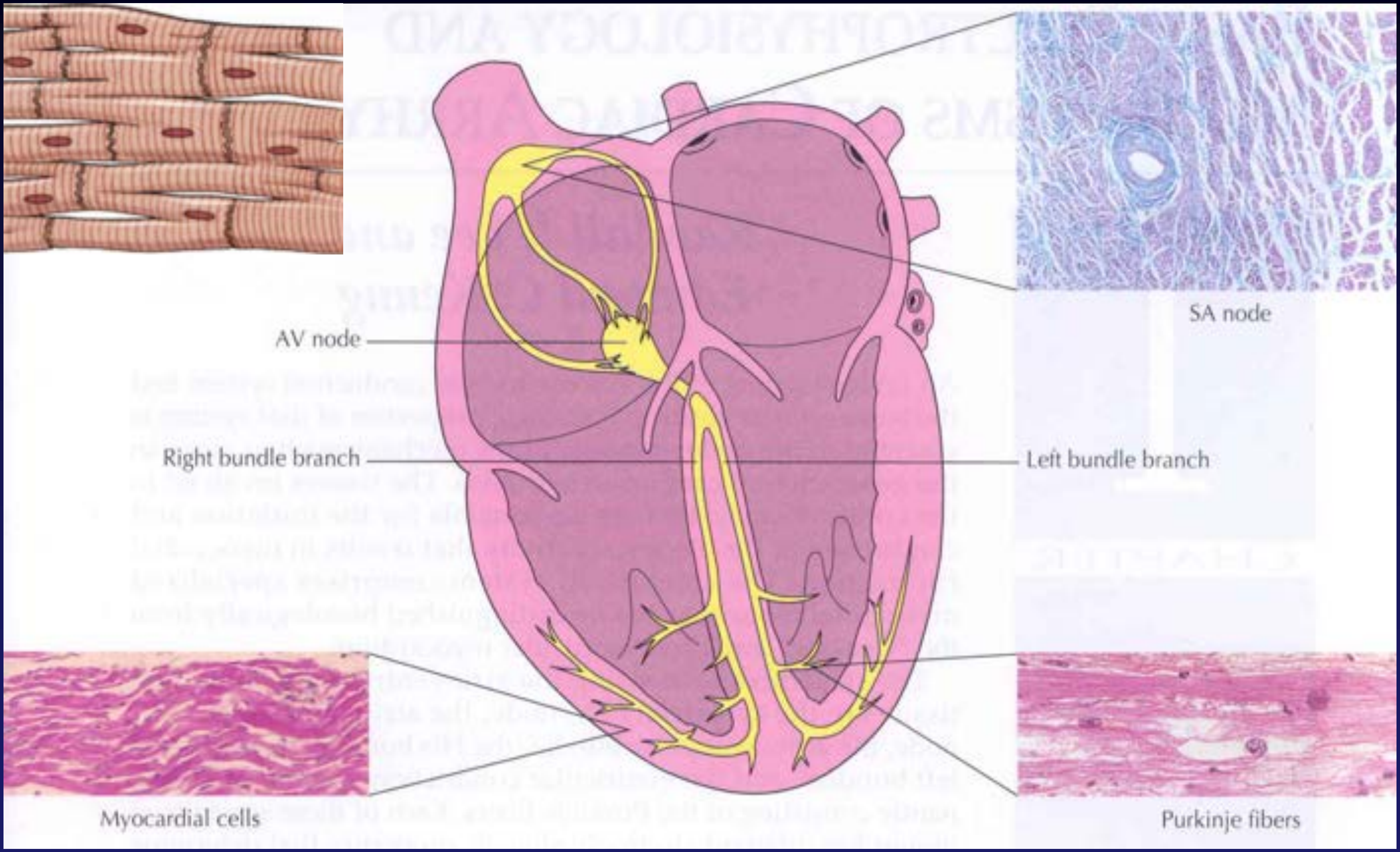
Tehran Arrhythmia Clinic

ECG

A graphic recording of electrical potentials generated by the heart

A noninvasive, inexpensive and highly versatile test

Normal Pathway of Electrical Conduction



Normal Impulse Conduction

Sinoatrial node

↓

AV node

↓

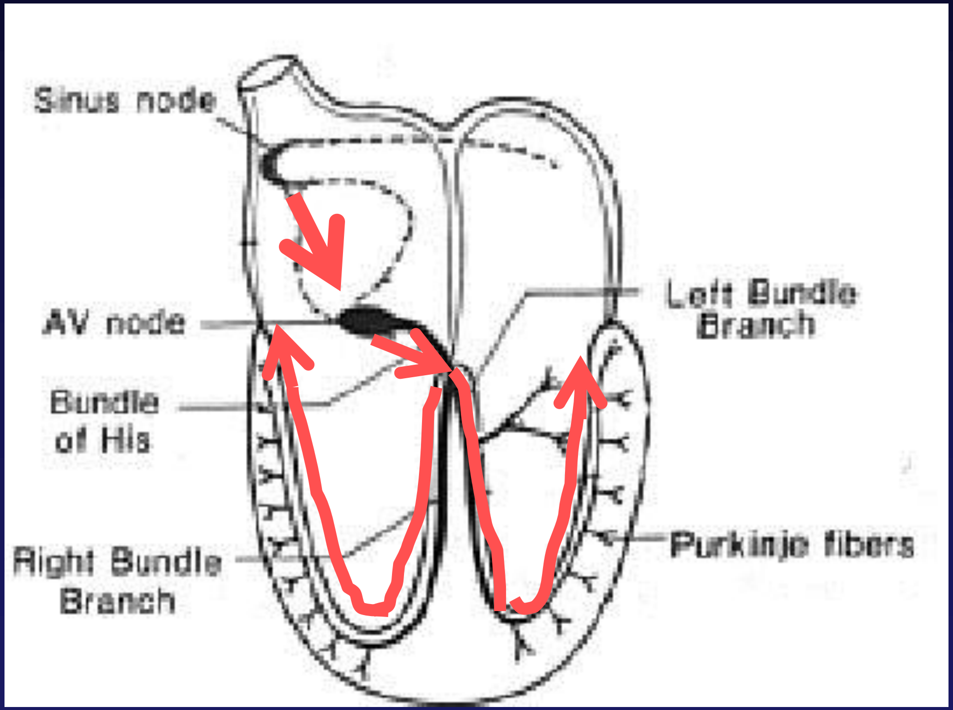
Bundle of His

↓

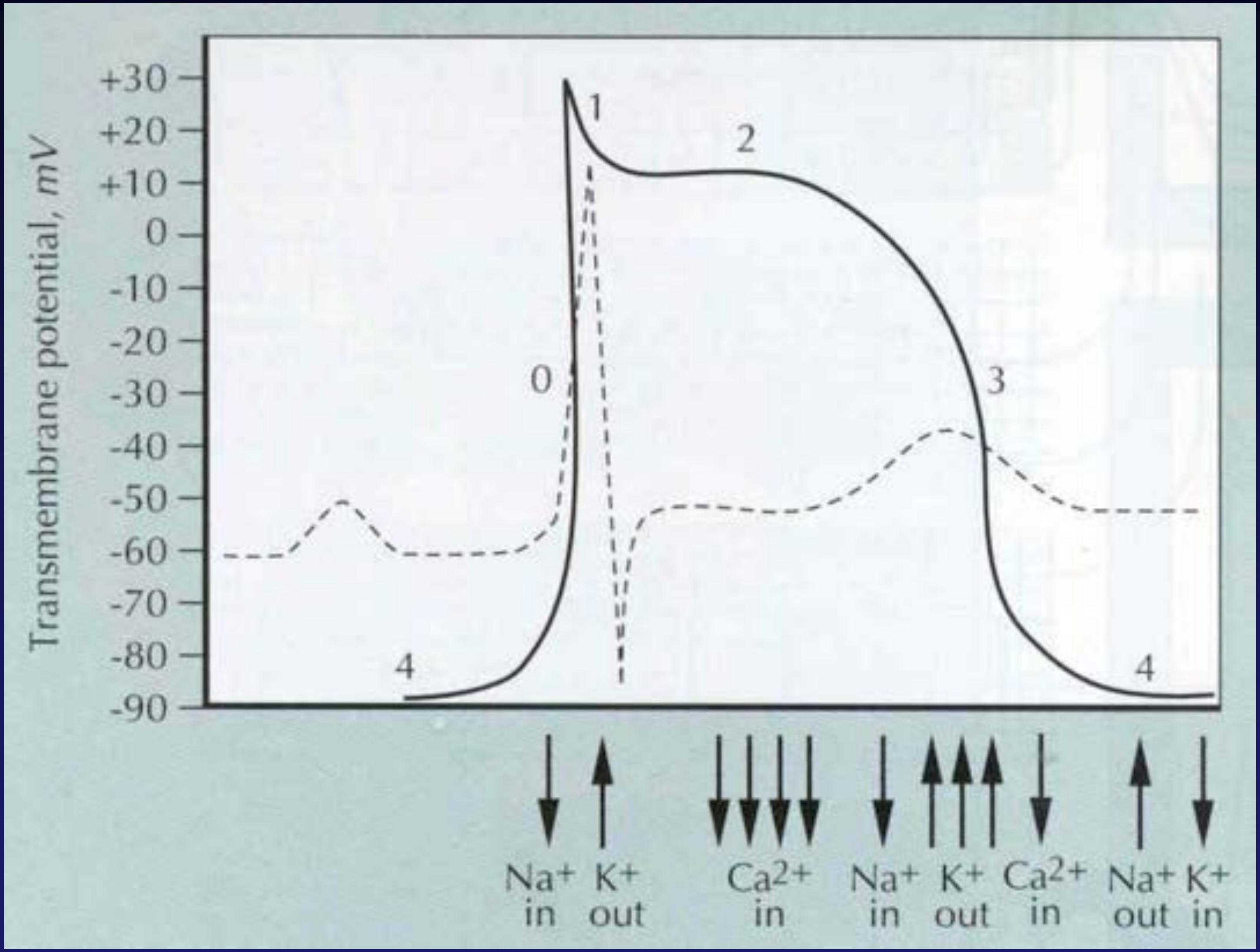
Bundle Branches

↓

Purkinje fibers



Cardiac Action Potential



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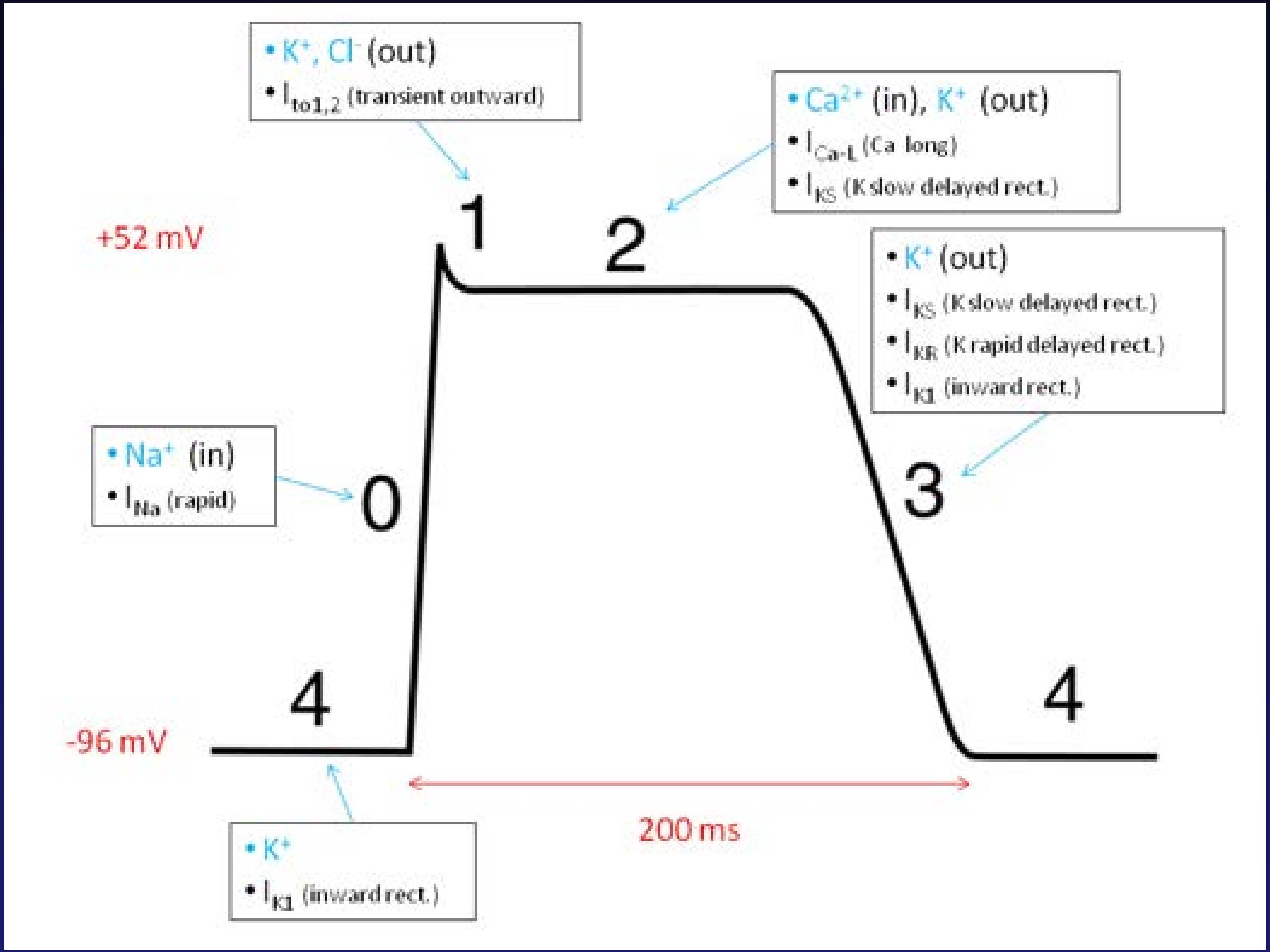
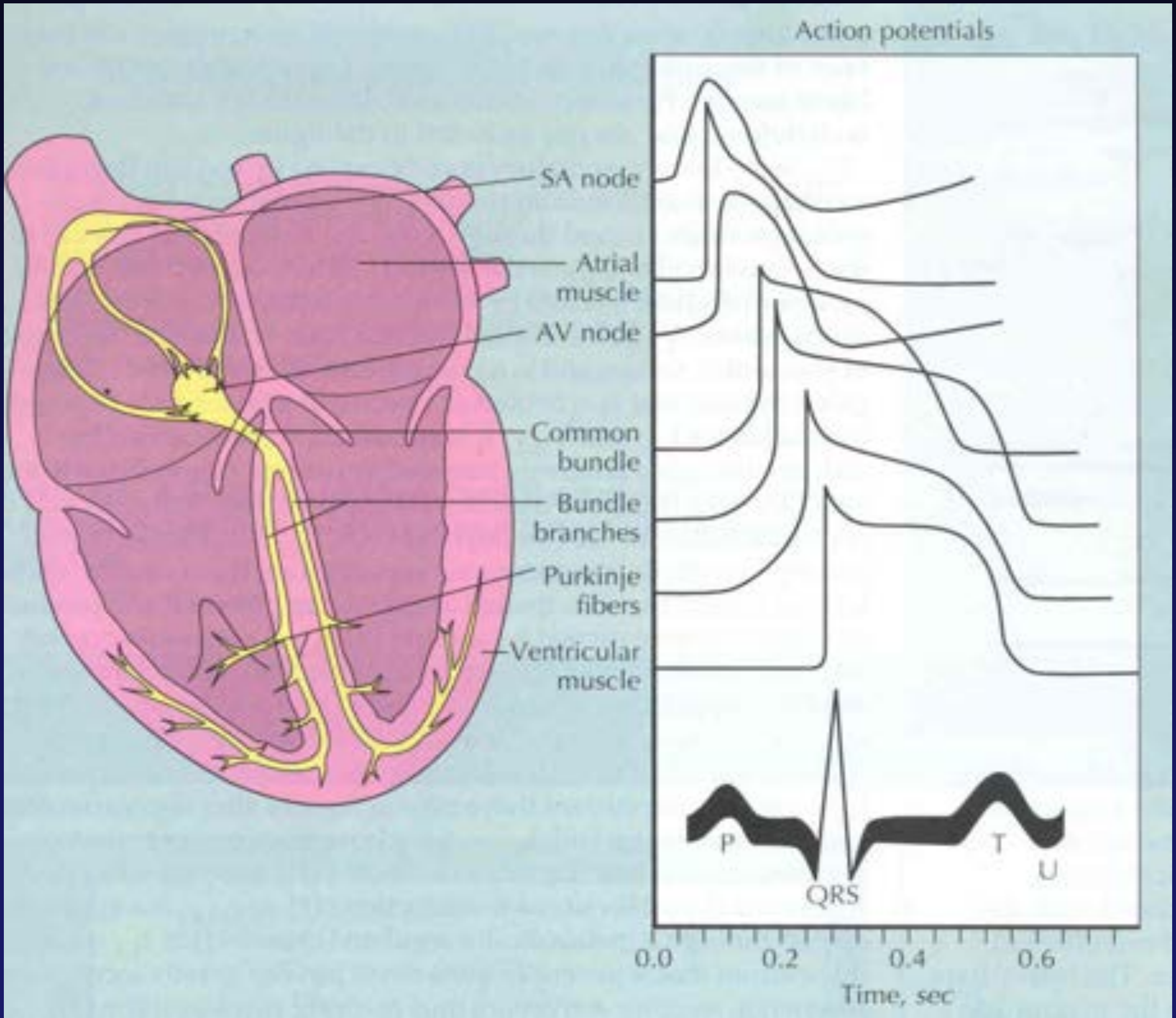
Cardiac Action Potential



Cardiac action potentials from different locations have different shapes



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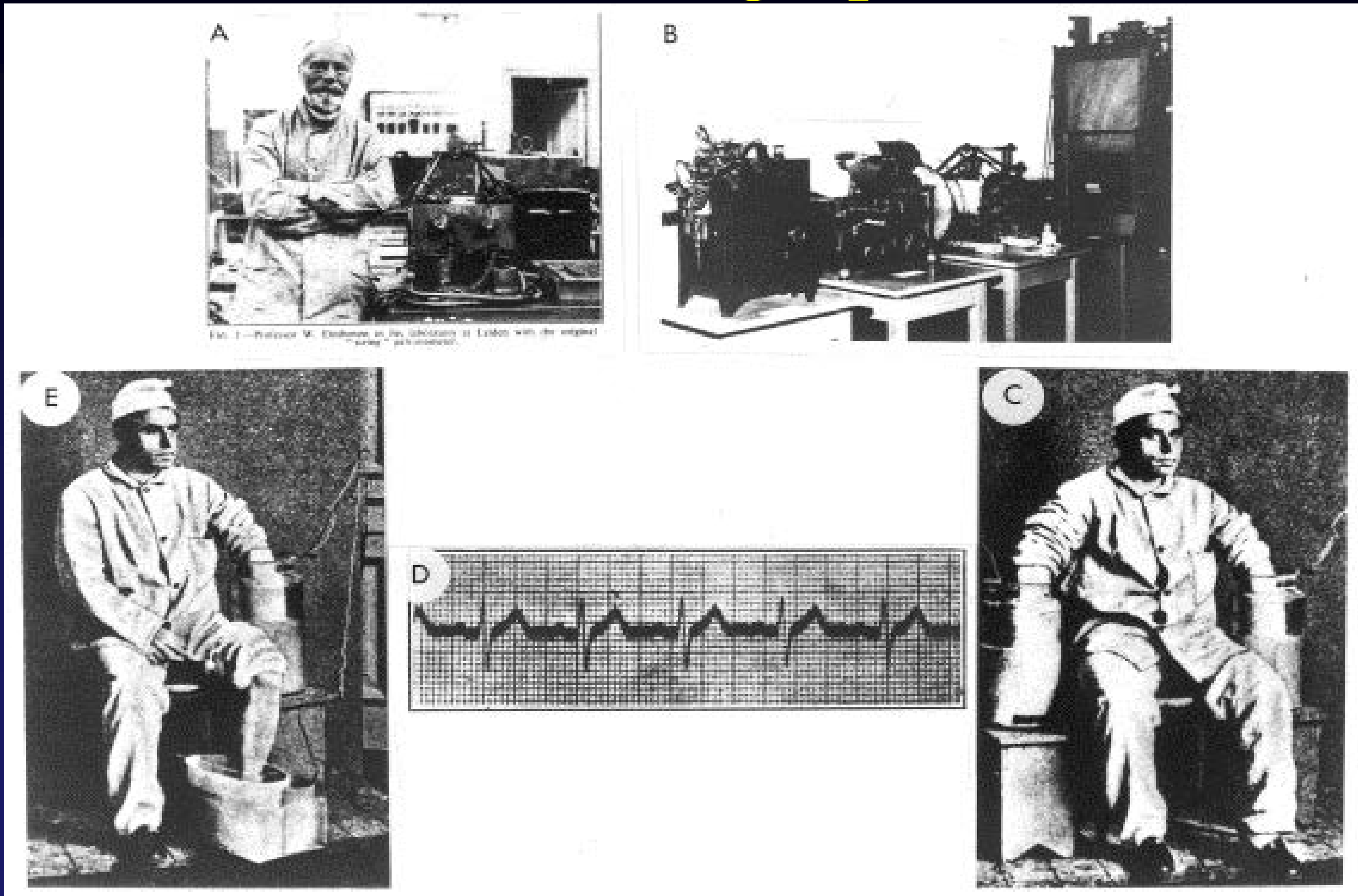
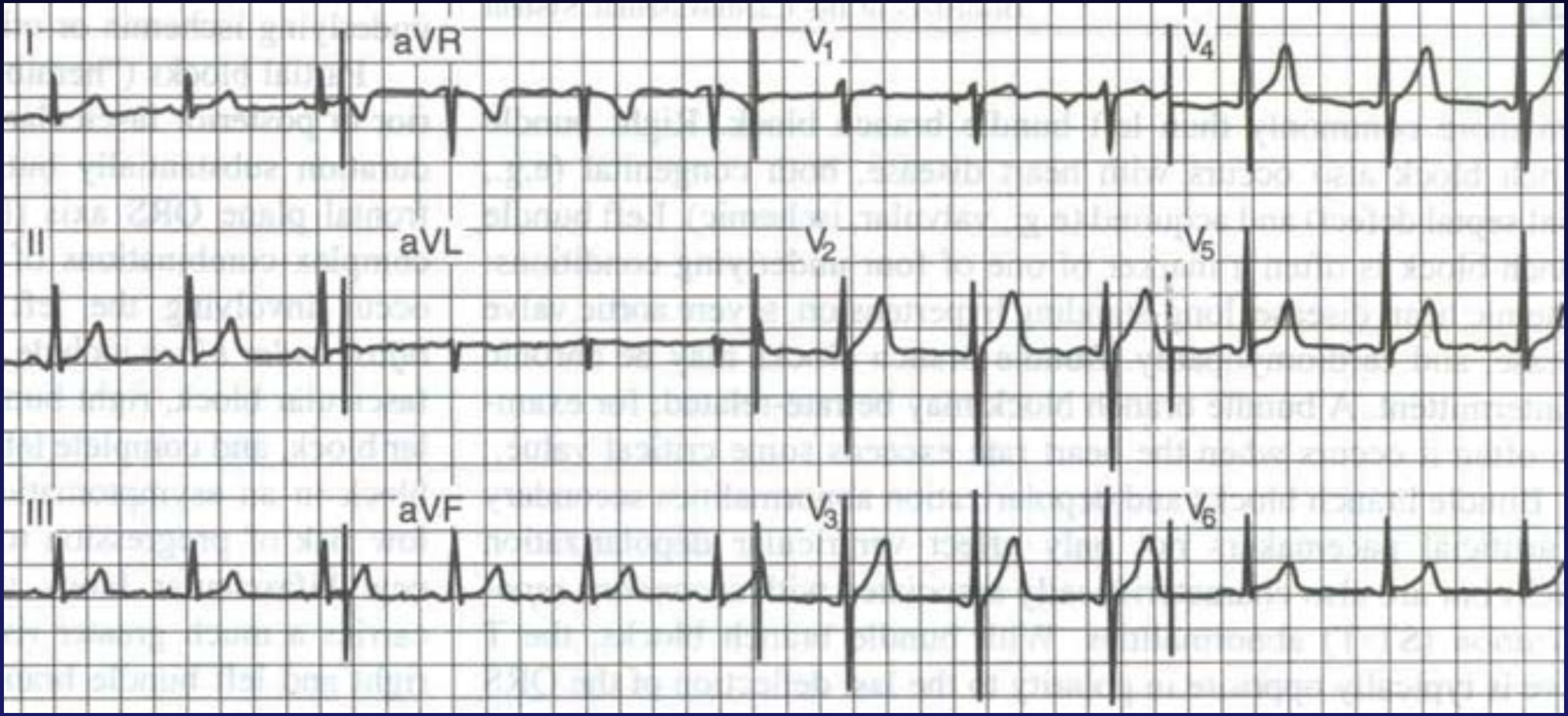
Electrophysiology

- Electric currents that spread through the heart are produced by three components
  - Cardiac pacemaker cells
  - Specialized conduction tissue
  - The heart muscle
- ECG only records the depolarization and repolarization potentials generated by atrial and ventricular myocardium.

Electrocardiograph 1903

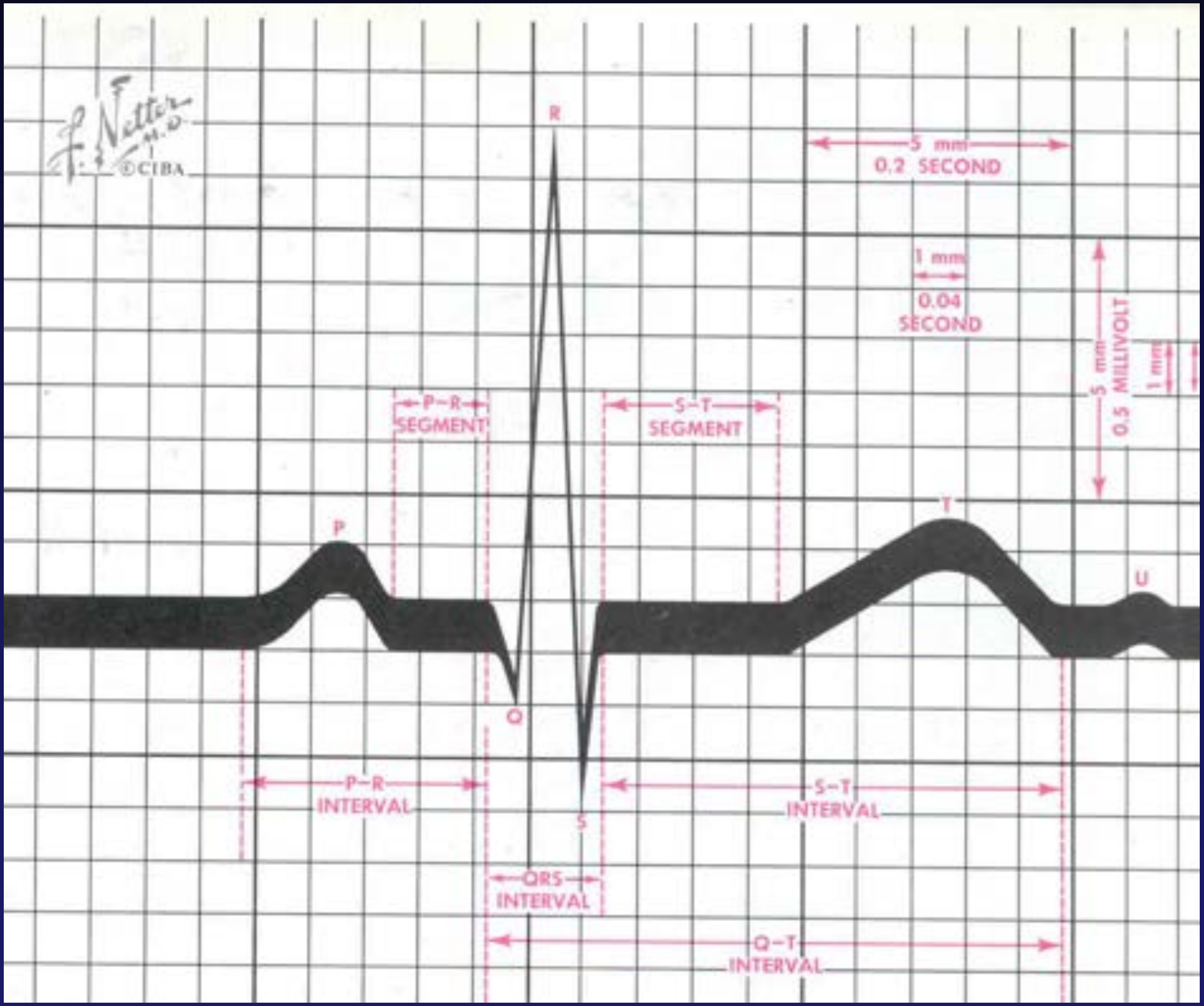


Normal Electrocardiogram

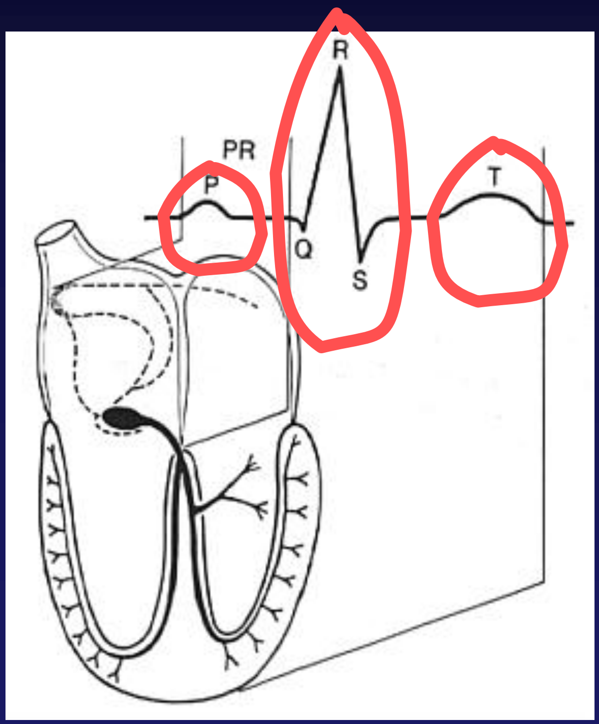


ECG Waveforms

Labeled alphabetically beginning with the P wave

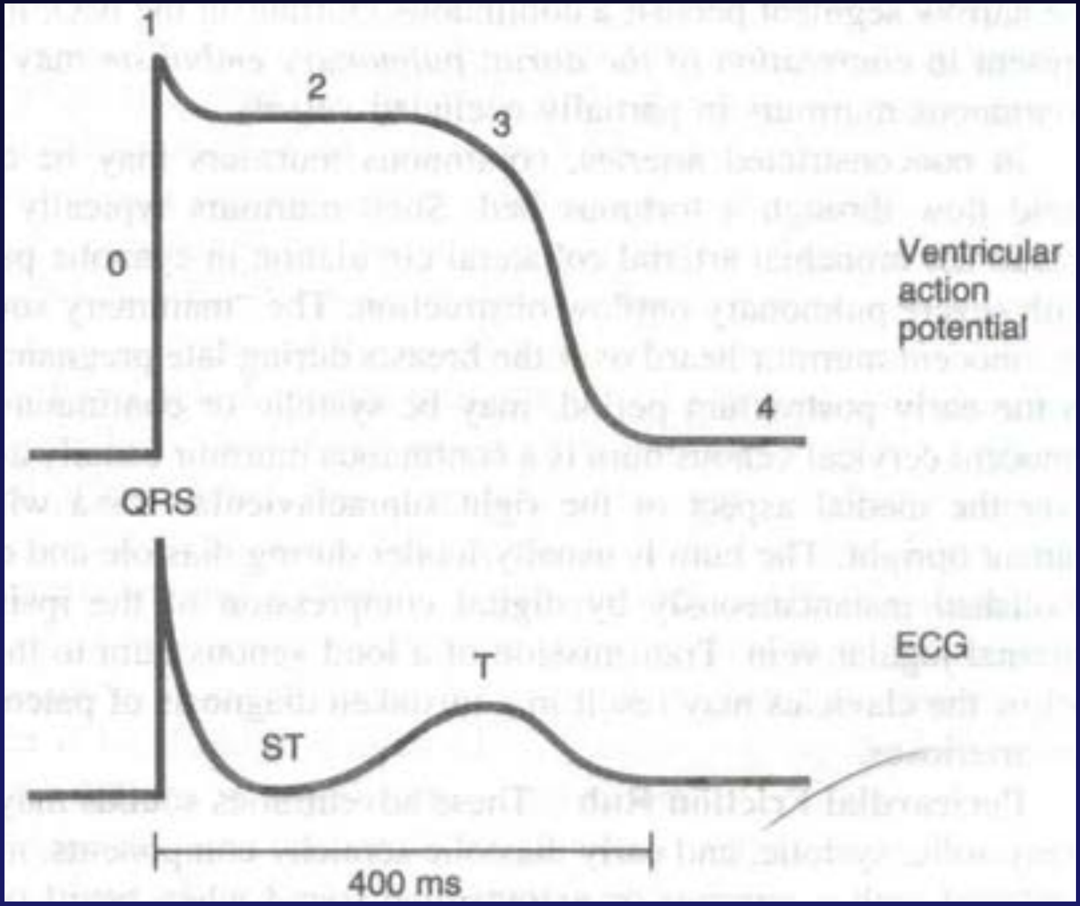


The "PQRST"



- P wave - Atrial depolarization
- QRS - Ventricular depolarization
- T wave - Ventricular repolarization

QRS-T Cycle Corresponds to Different Phases of Ventricular Action Potential



The PR Interval

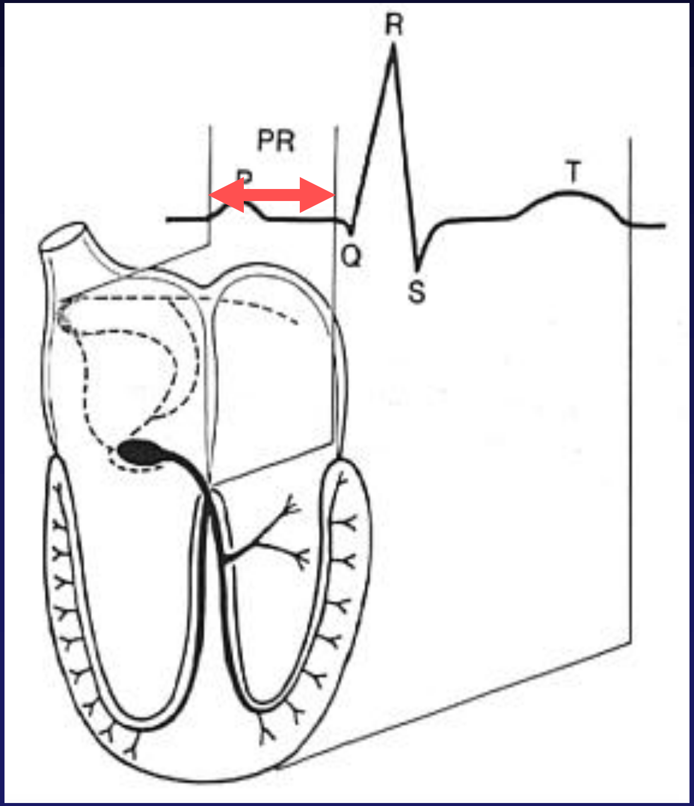
Atrial depolarization

+

delay in AV junction

(AV node/Bundle of His)

(delay allows time for the atria to contract before the ventricles contract)



Impulse Conduction & the ECG

Sinoatrial node

↓

AV node

↓

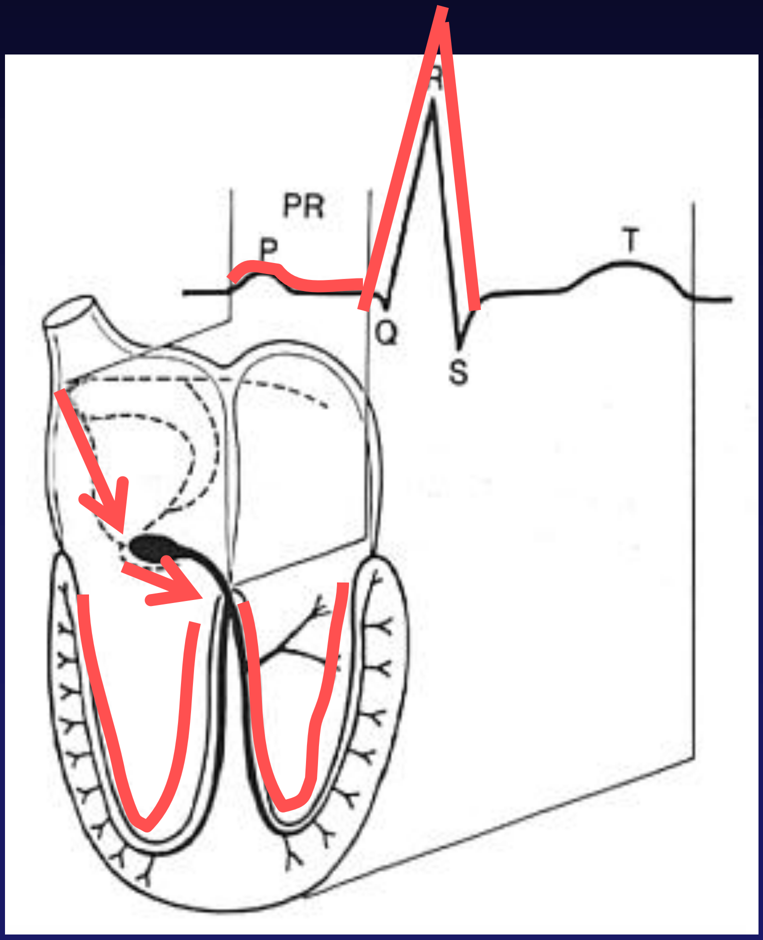
Bundle of His

↓

Bundle Branches

↓

Purkinje fibers



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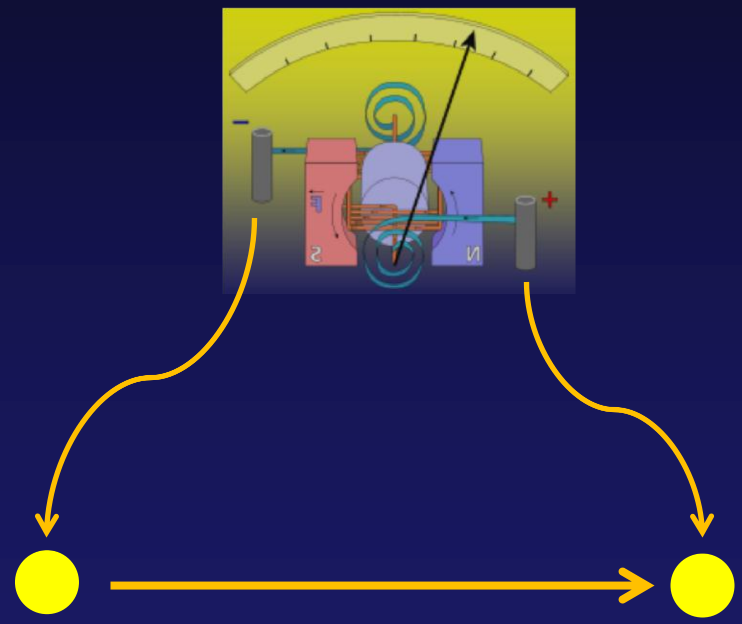
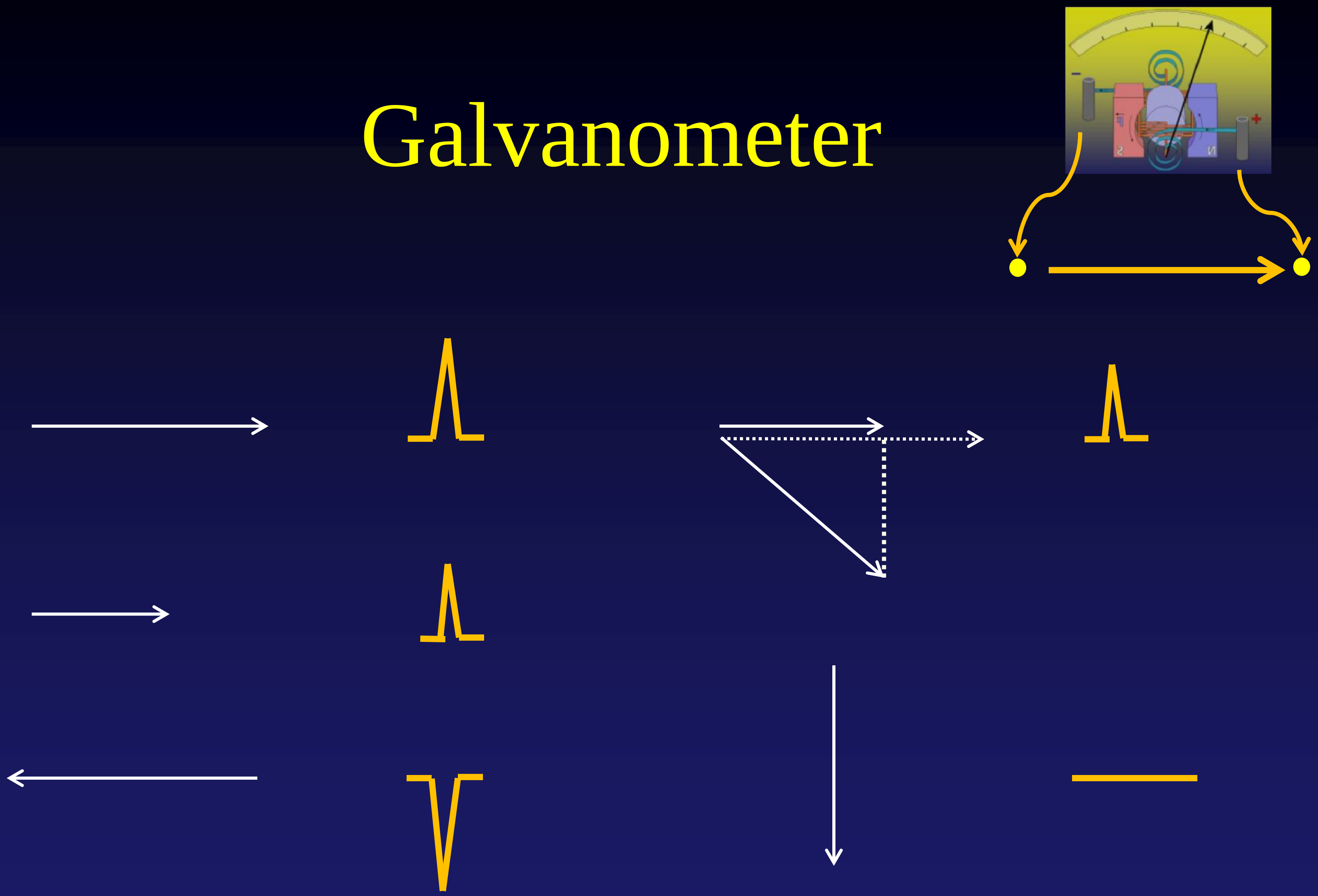
ECG Concept
Galvanometer



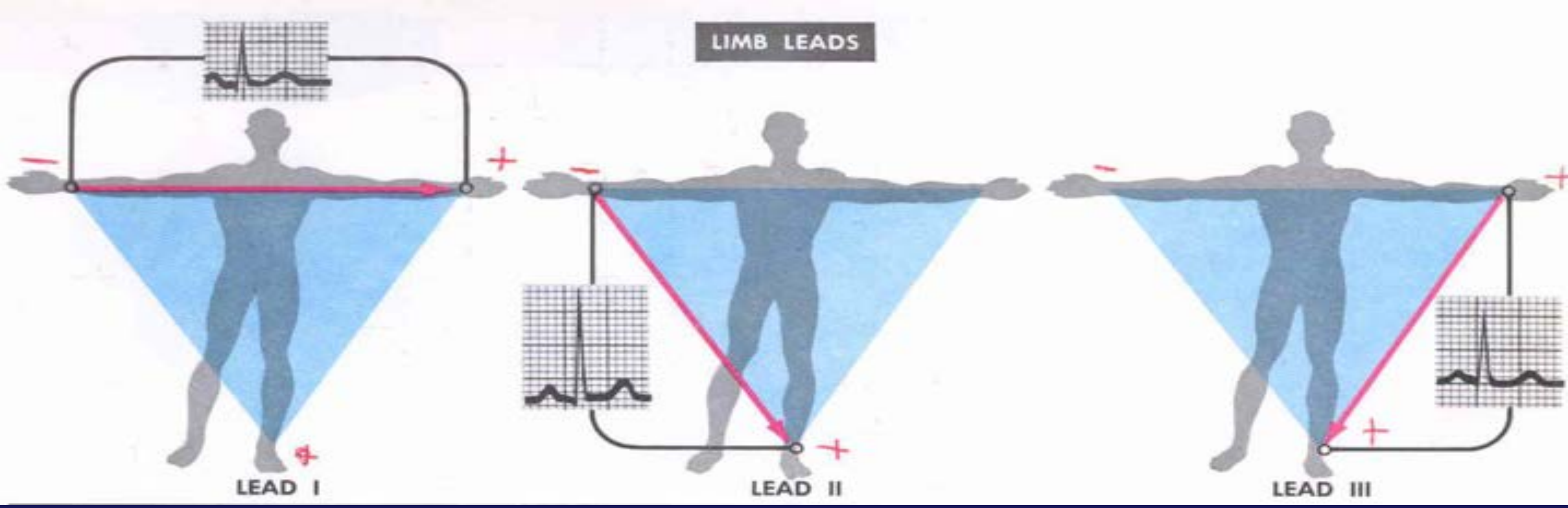
Vector Concept

- Cardiac depolarization and repolarization waves have direction and magnitude.
- They can, therefore, be represented by vectors.
- ECG records the complex spatial and temporal summation of electrical potentials from multiple myocardial fibers conducted to the surface of the body.

Galvanometer



Bipolar Limb Leads



Lead I

Lead II

Lead III

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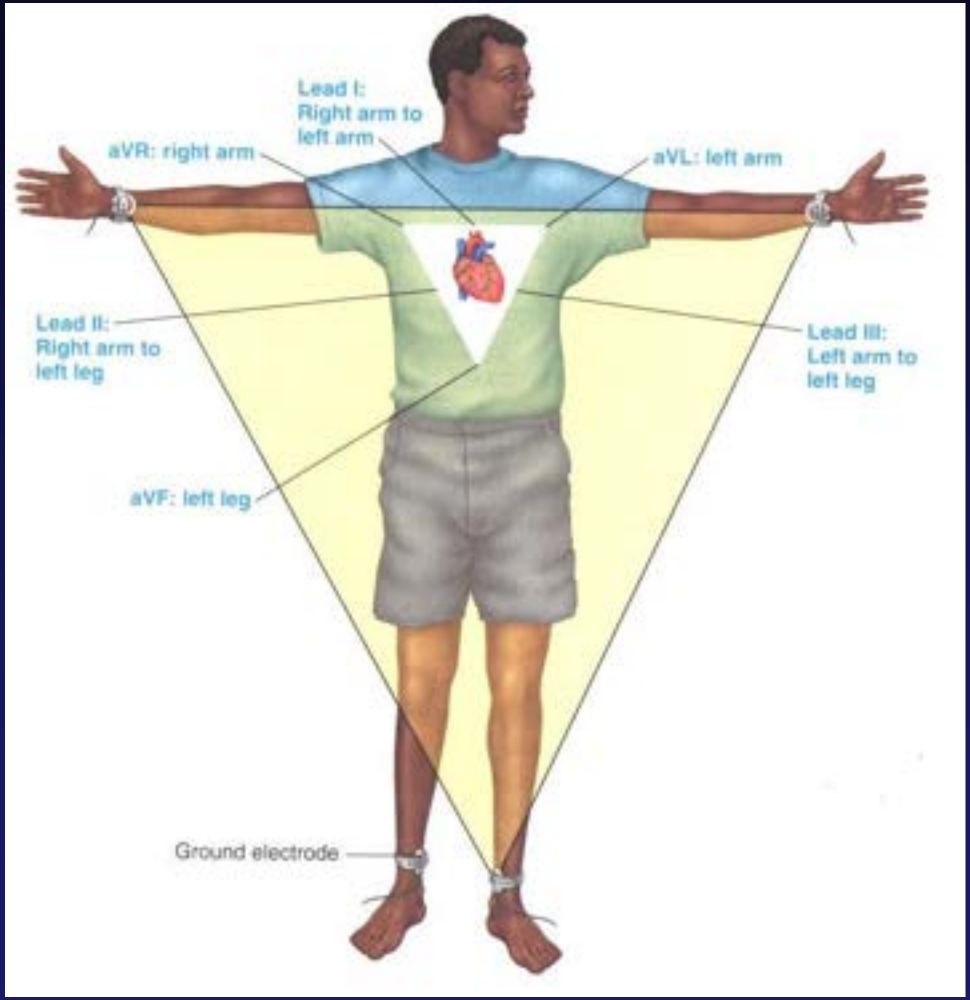
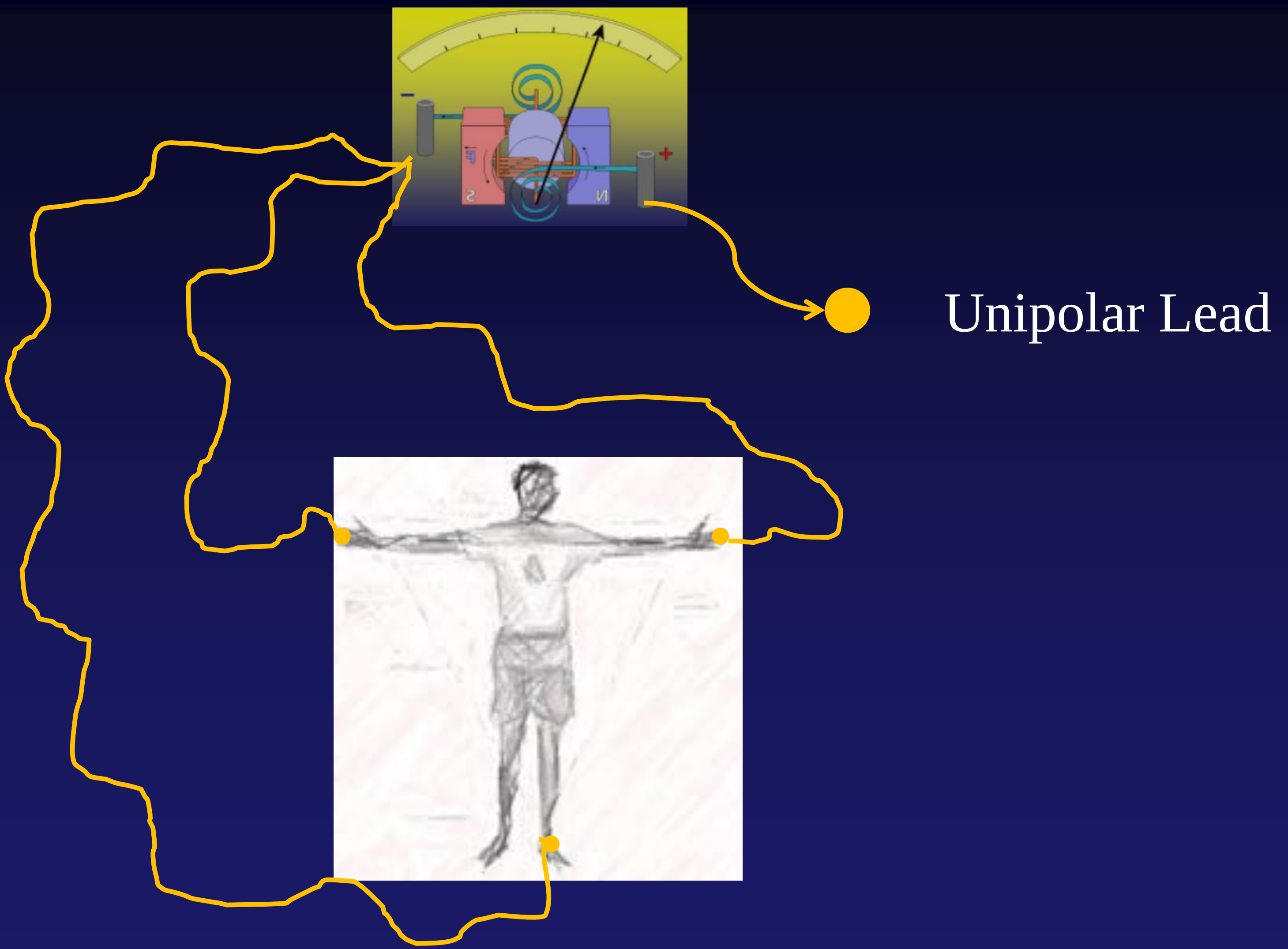
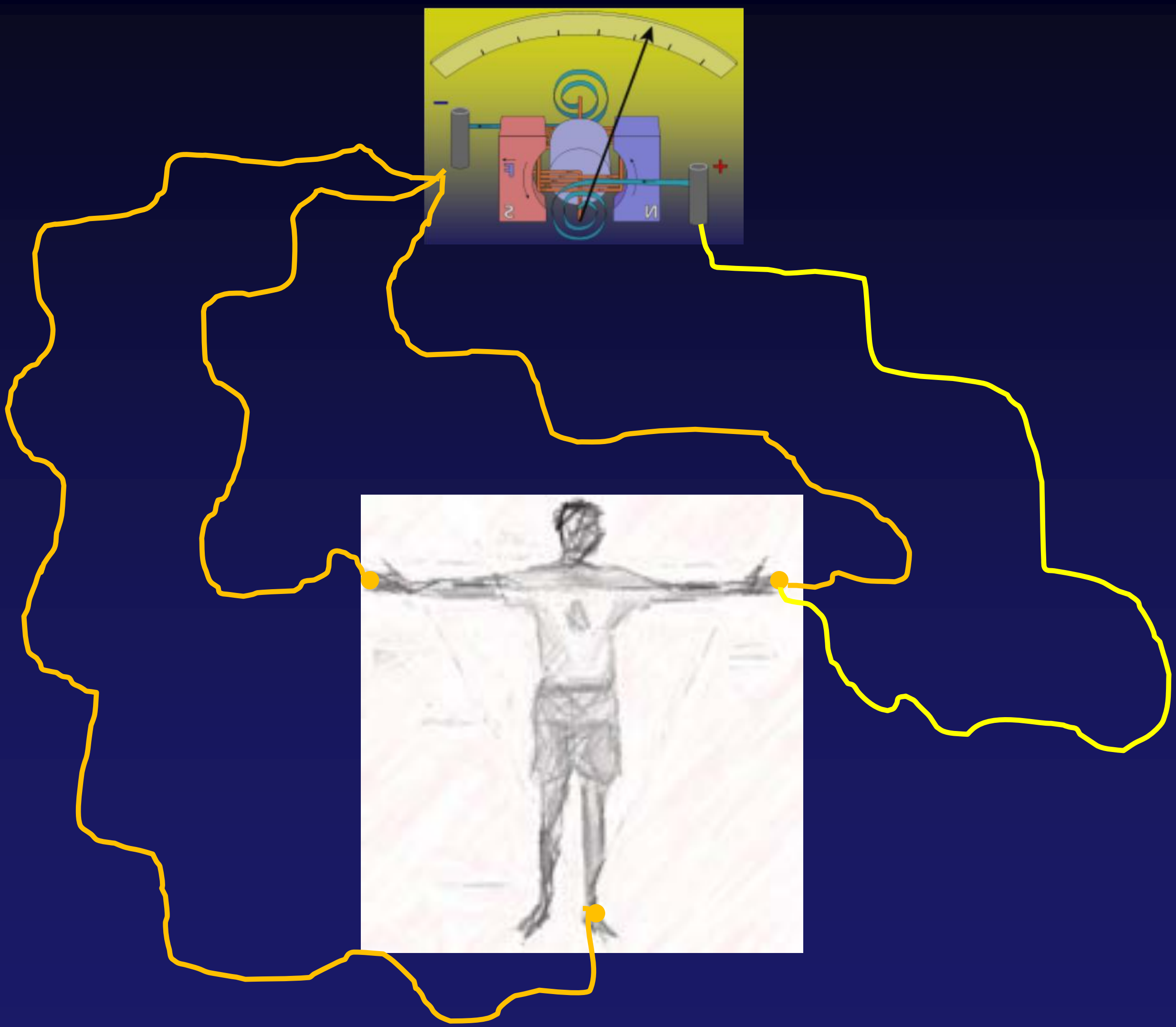
Einthoven Triangle



Central Terminal of Wilson

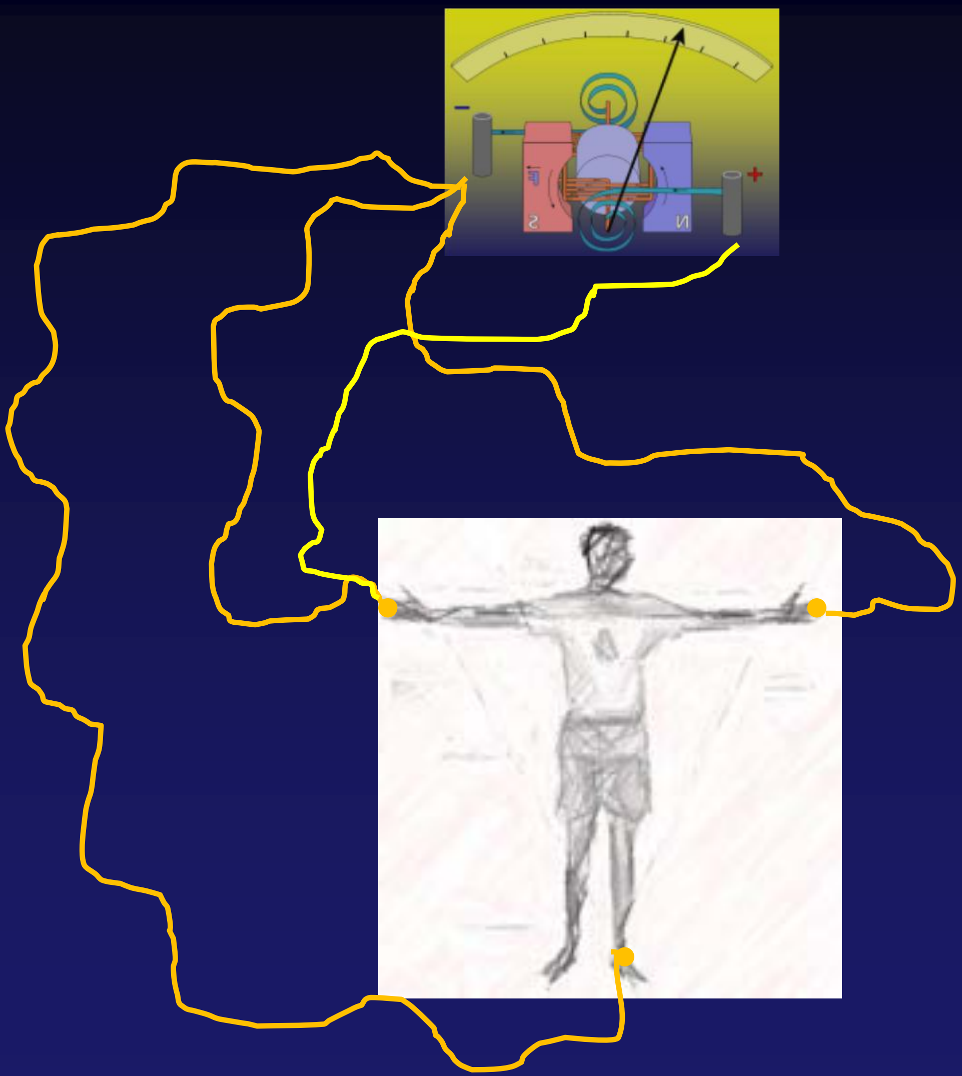


Unipolar Limb Leads



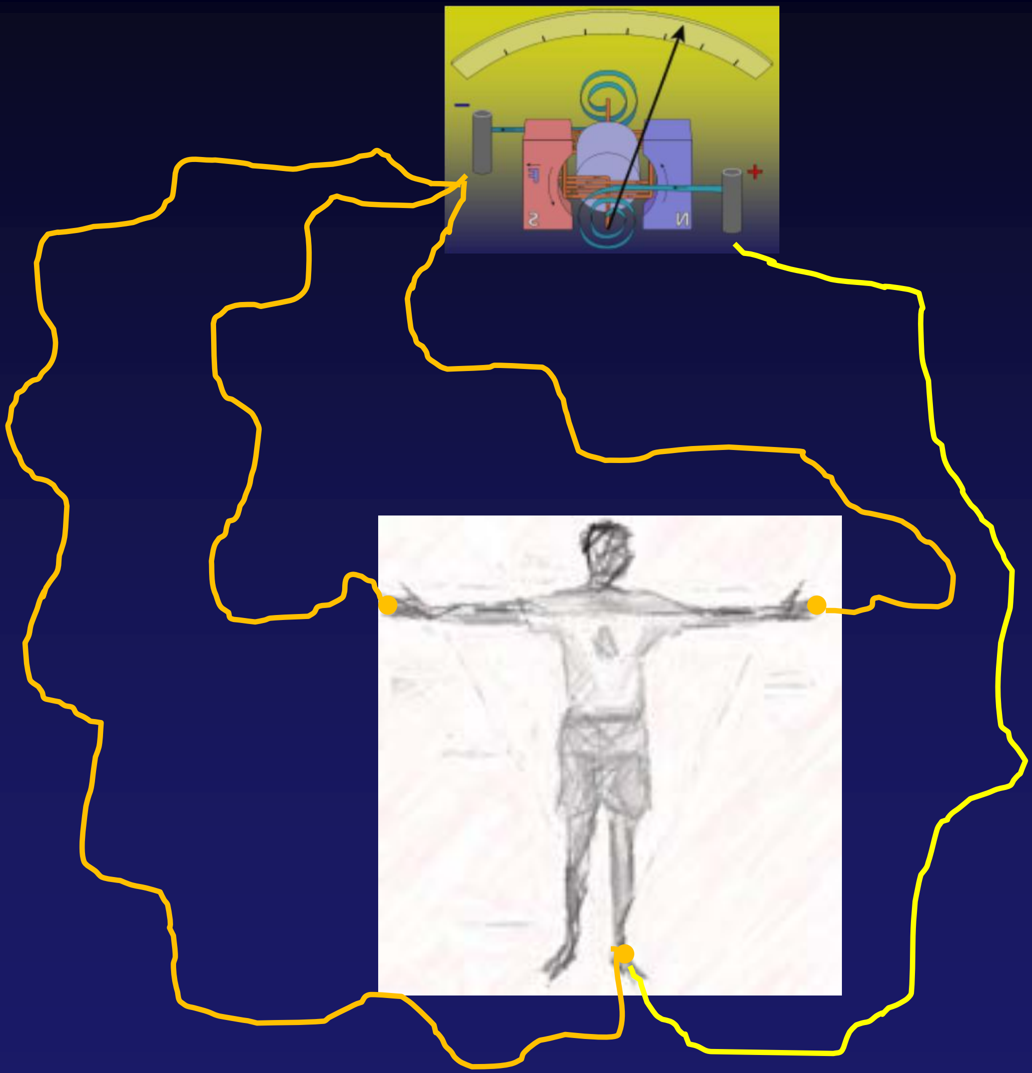
Lead
VL

Unipolar Limb Leads



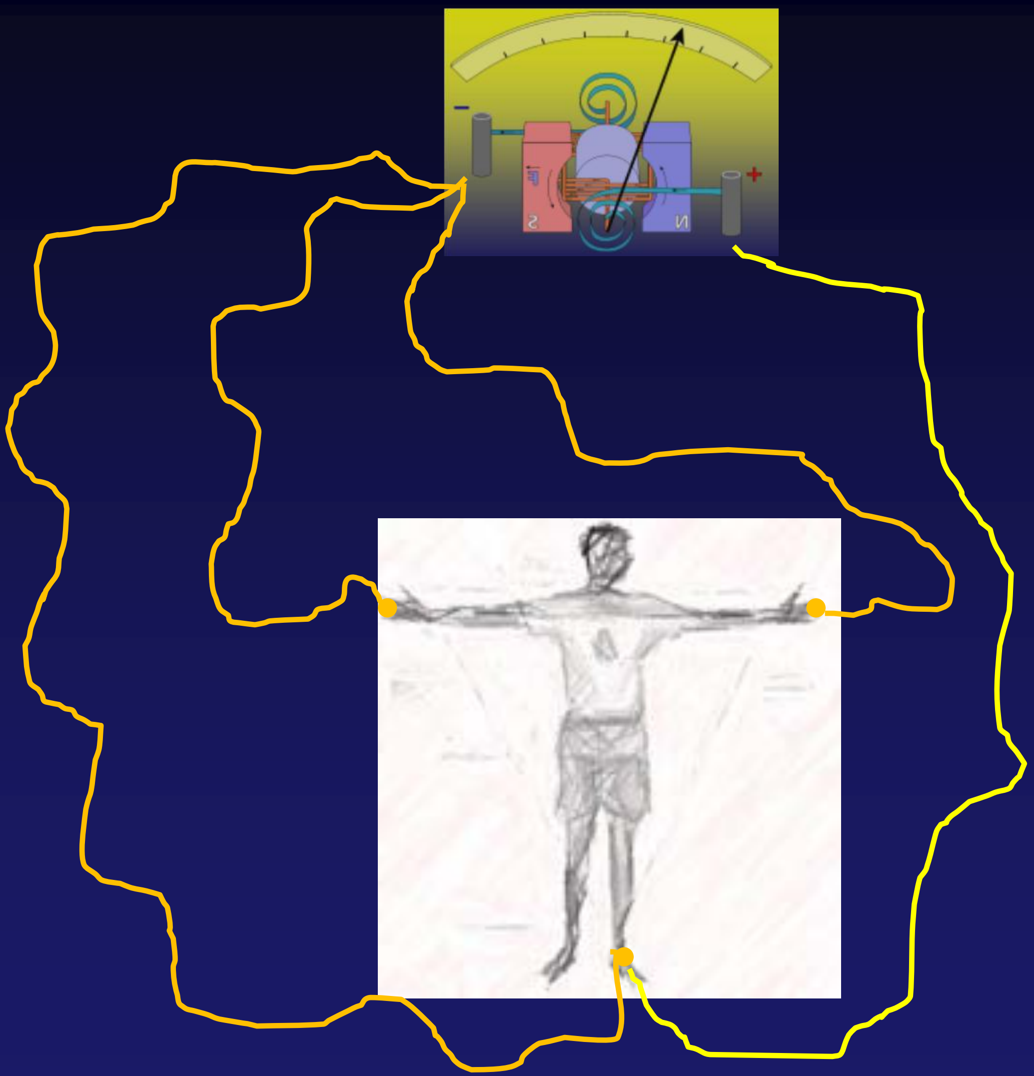
Lead
VR

Unipolar Limb Lead



Lead
VF

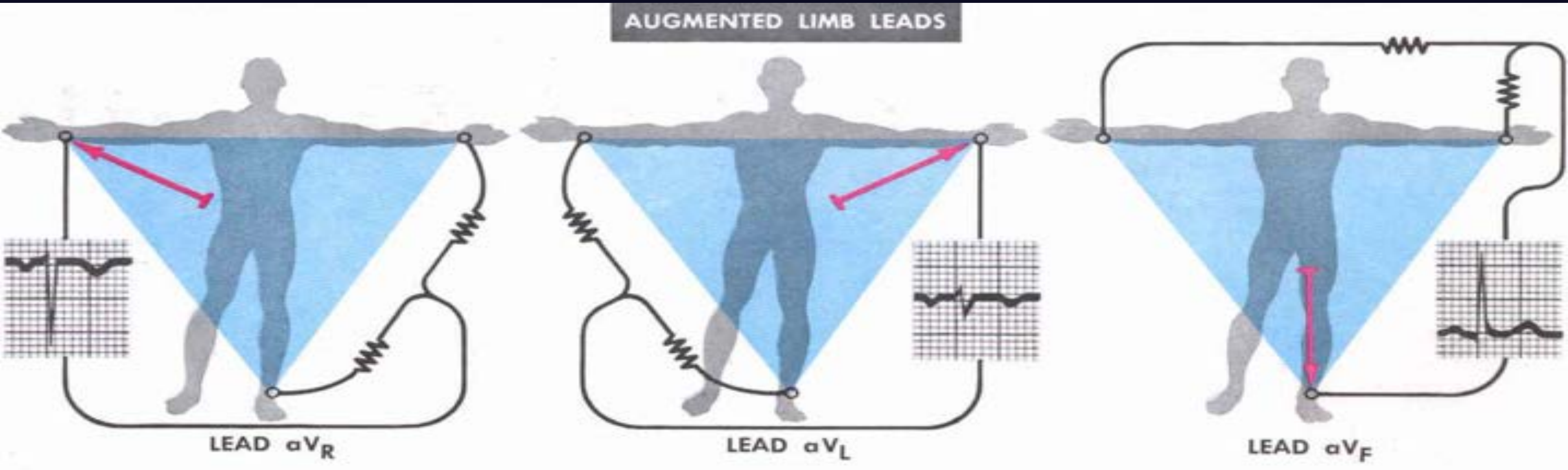
Unipolar Limb Lead



Lead
VF

augmented
VF or
aVF

Unipolar Limb Leads

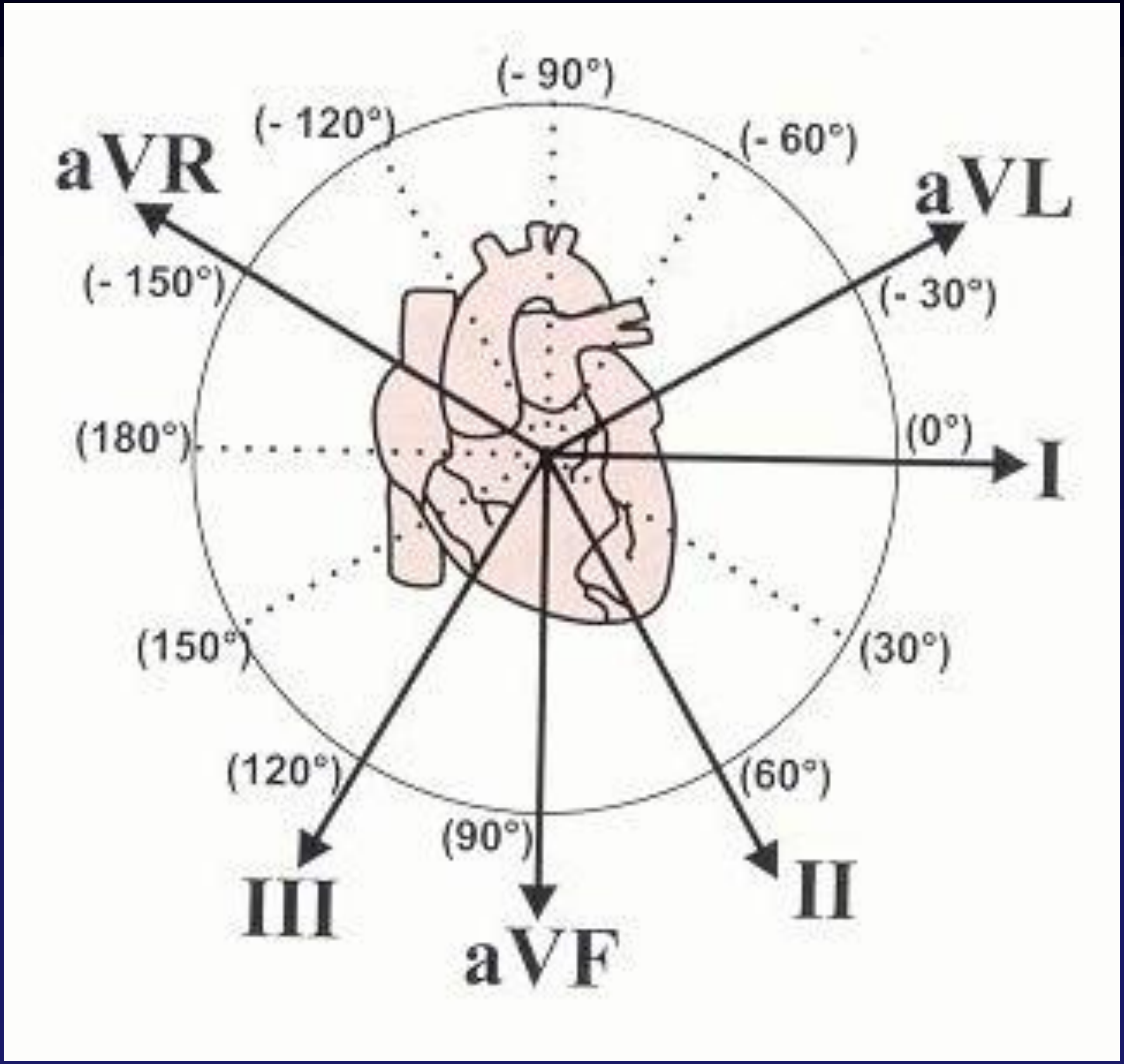


Lead aVR

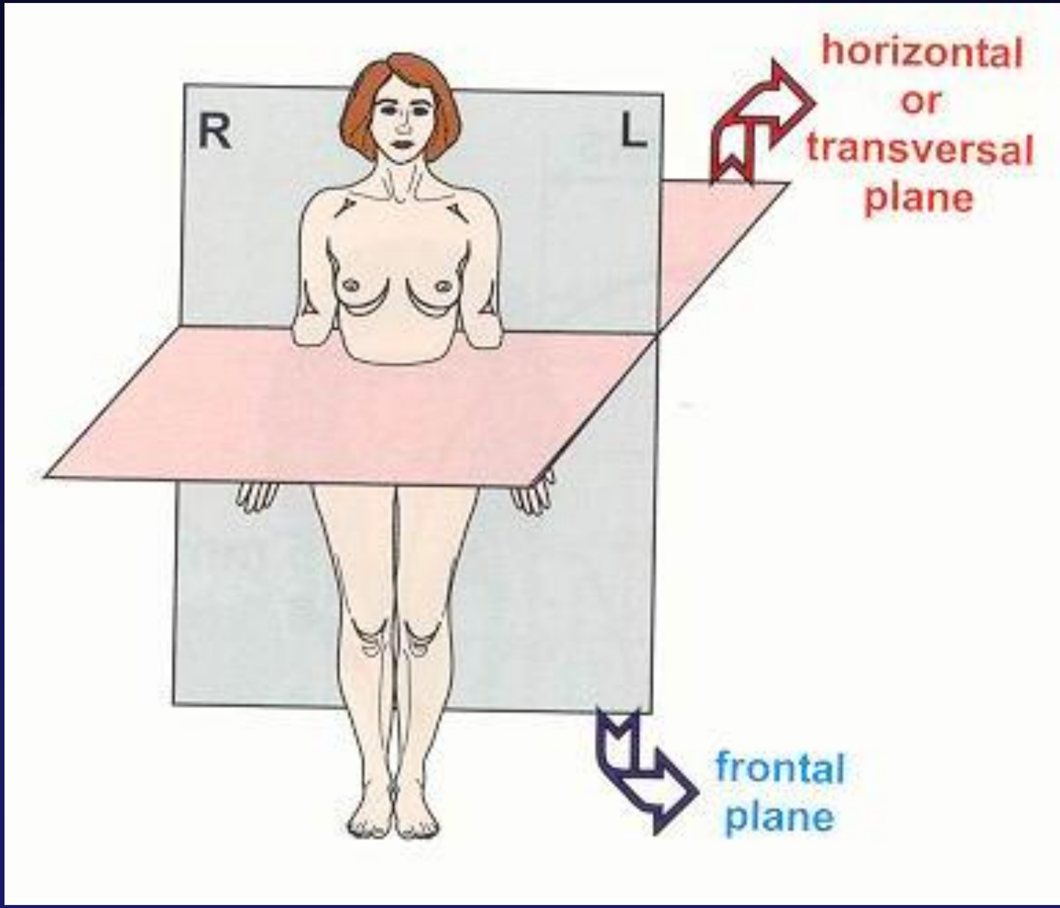
Lead aVL

Lead aVF

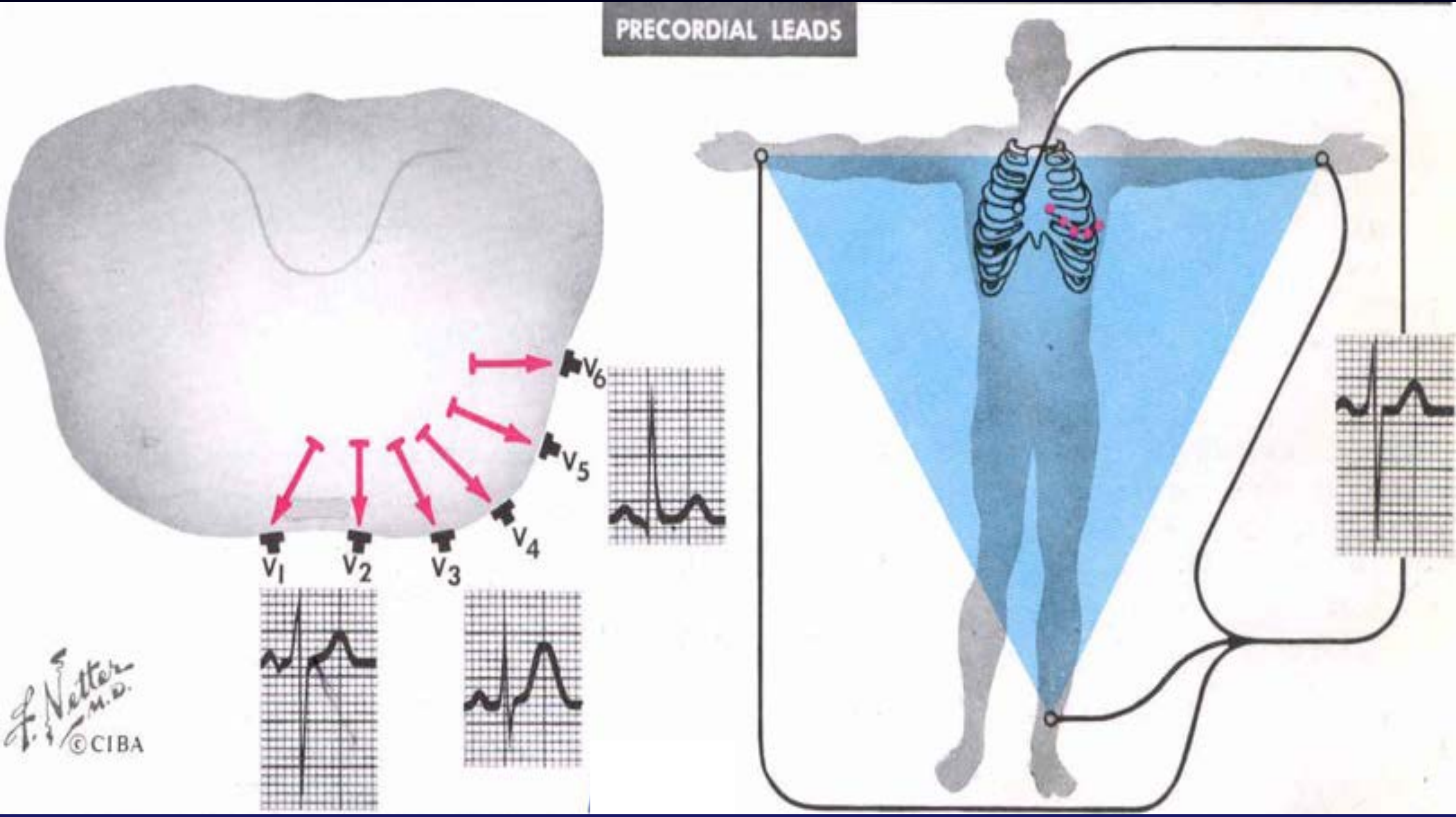
Limb Leads Directions



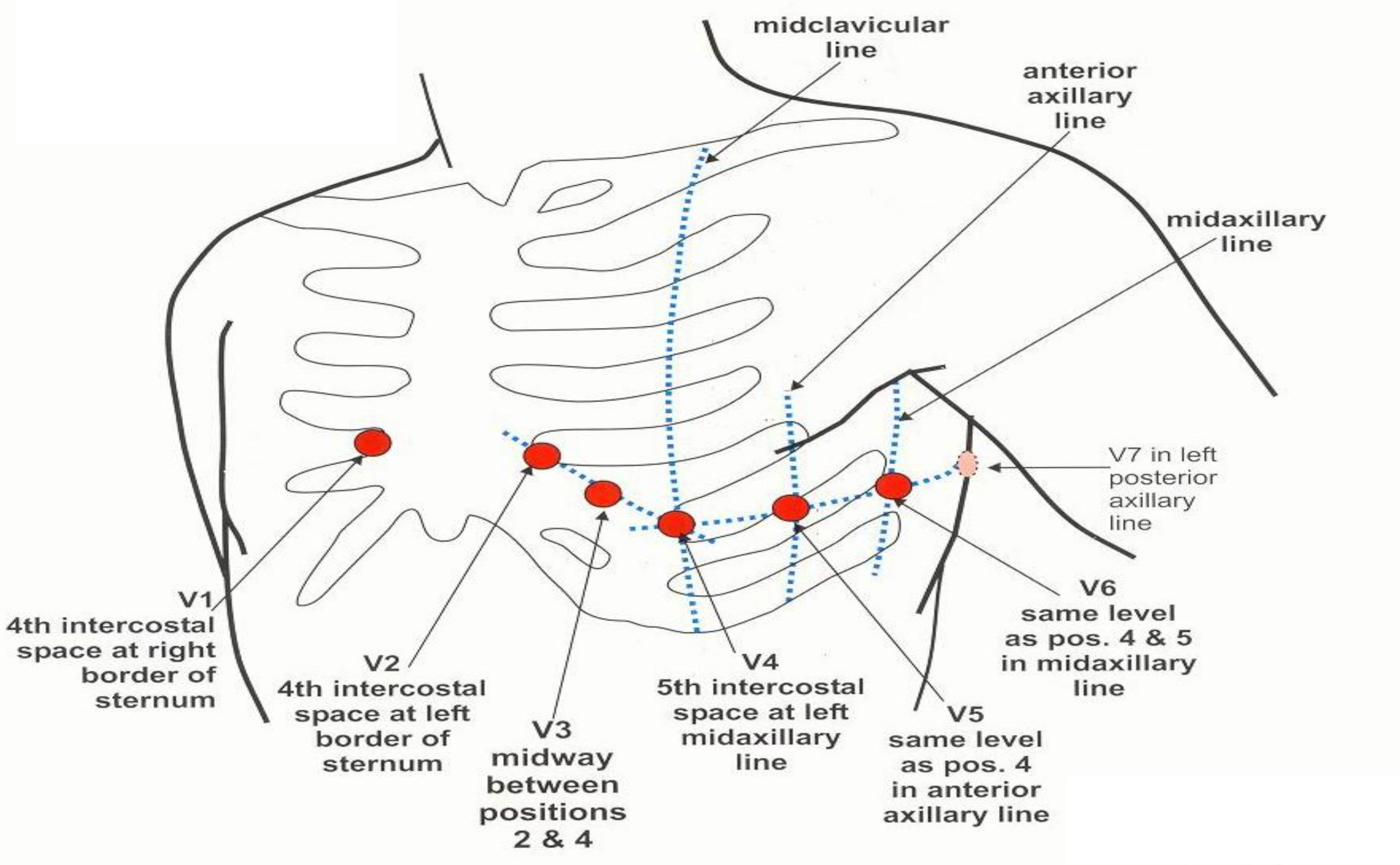
3-D Representation of Cardiac Electrical Activity



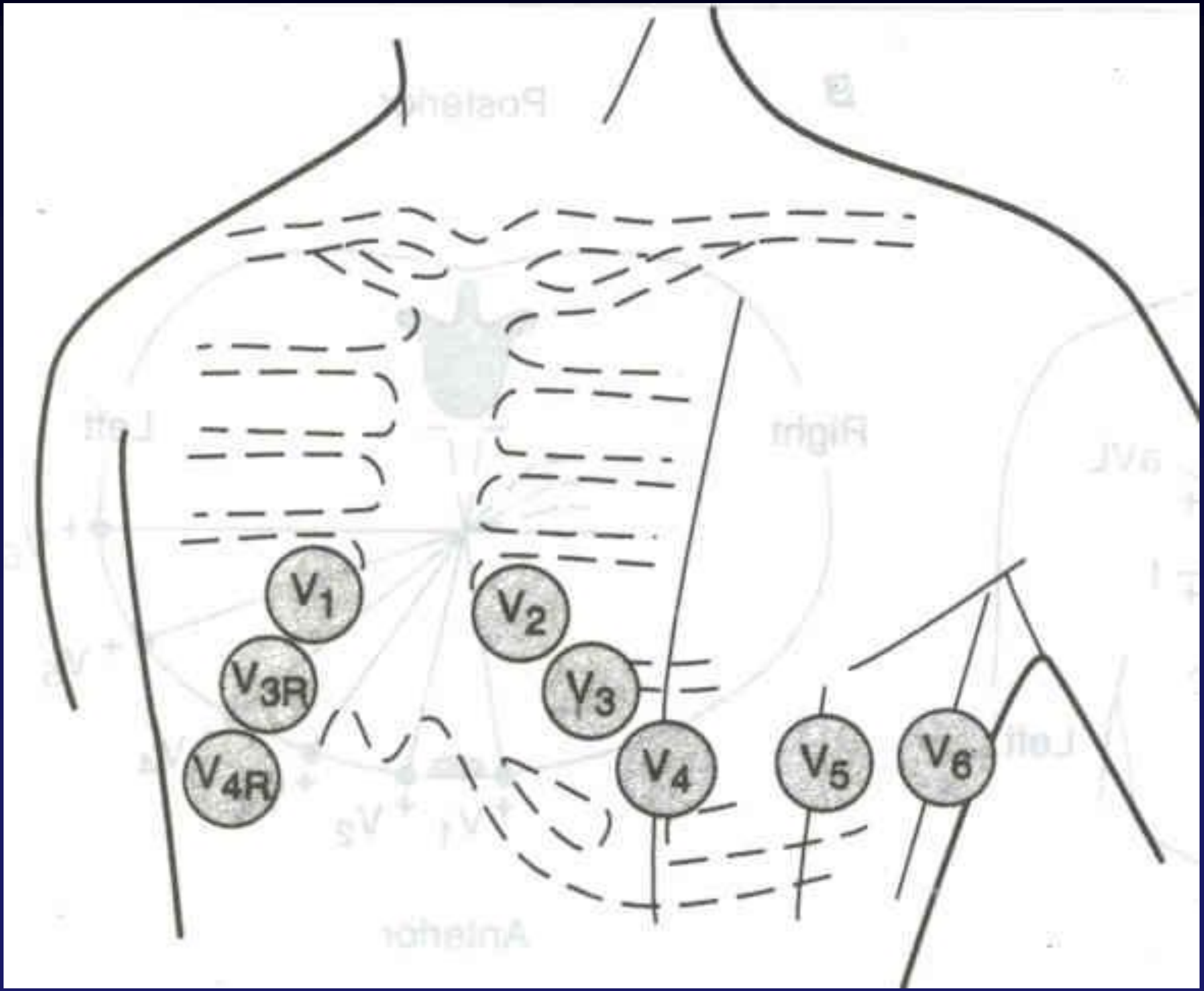
Precordial Leads



Position of Precordial Electrodes



Precordial Leads



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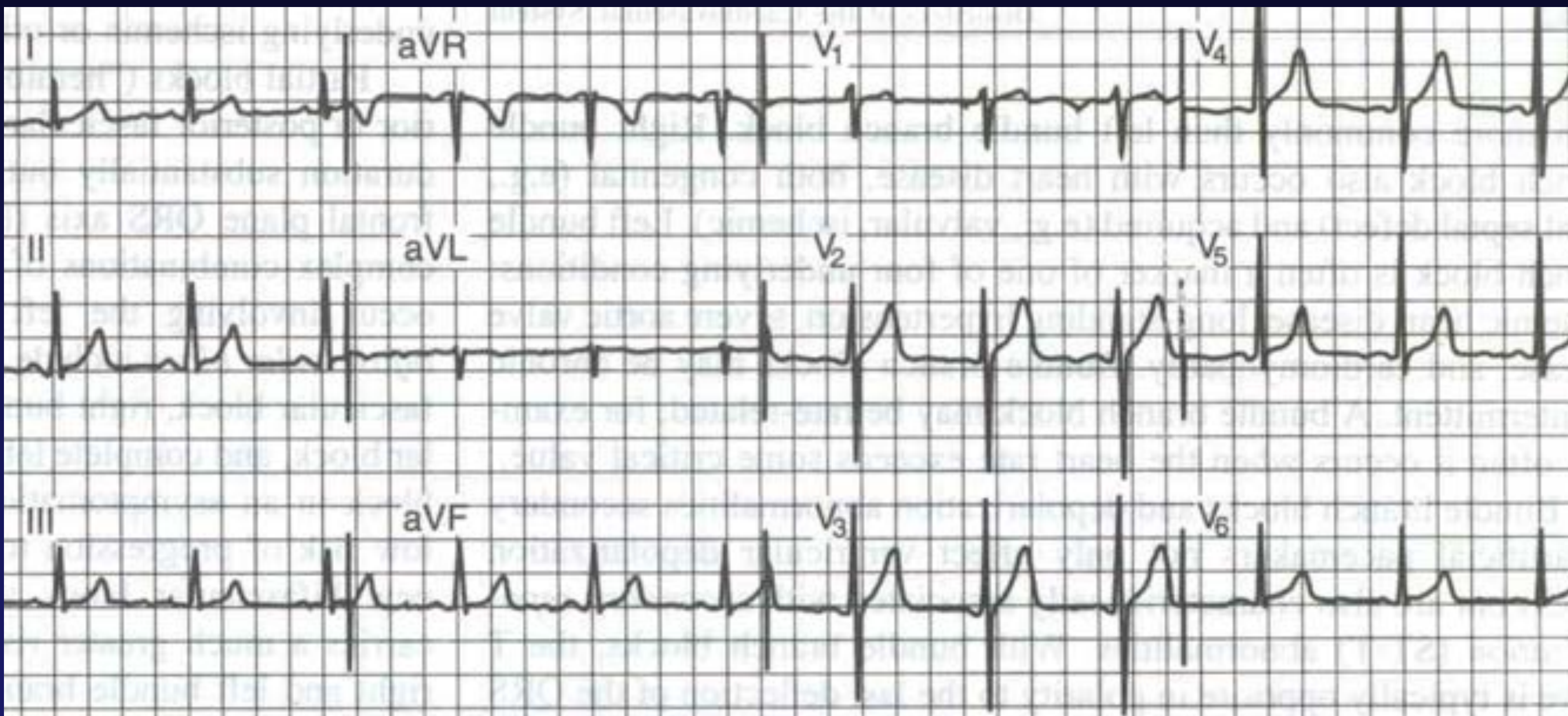
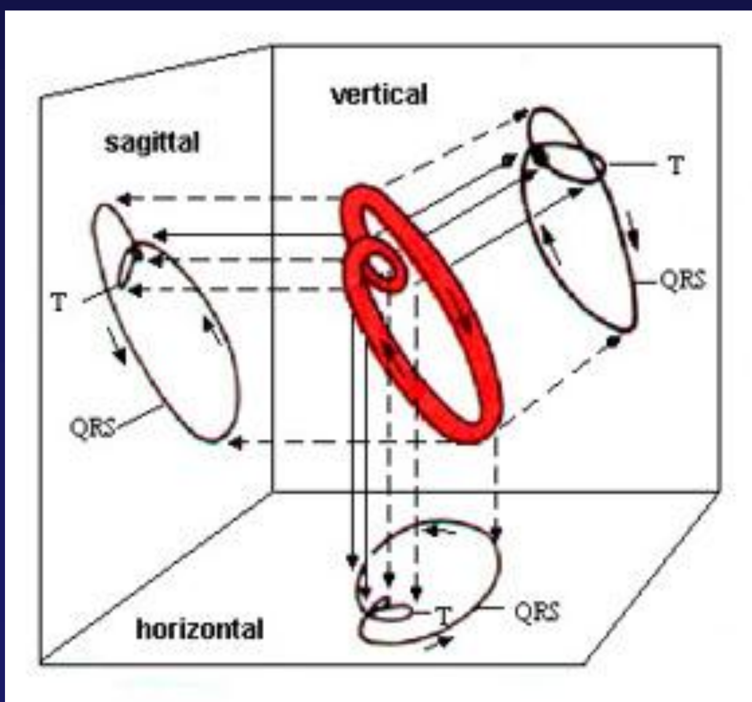
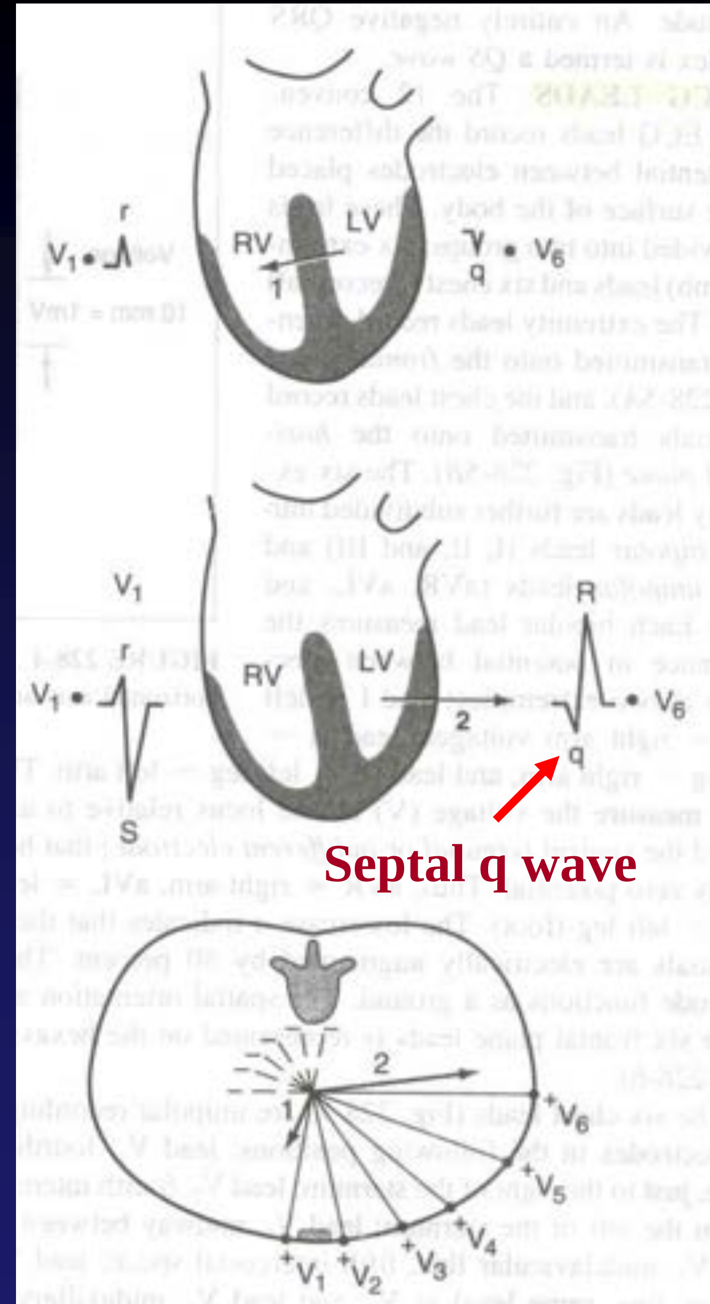
Normal Electrocardiogram

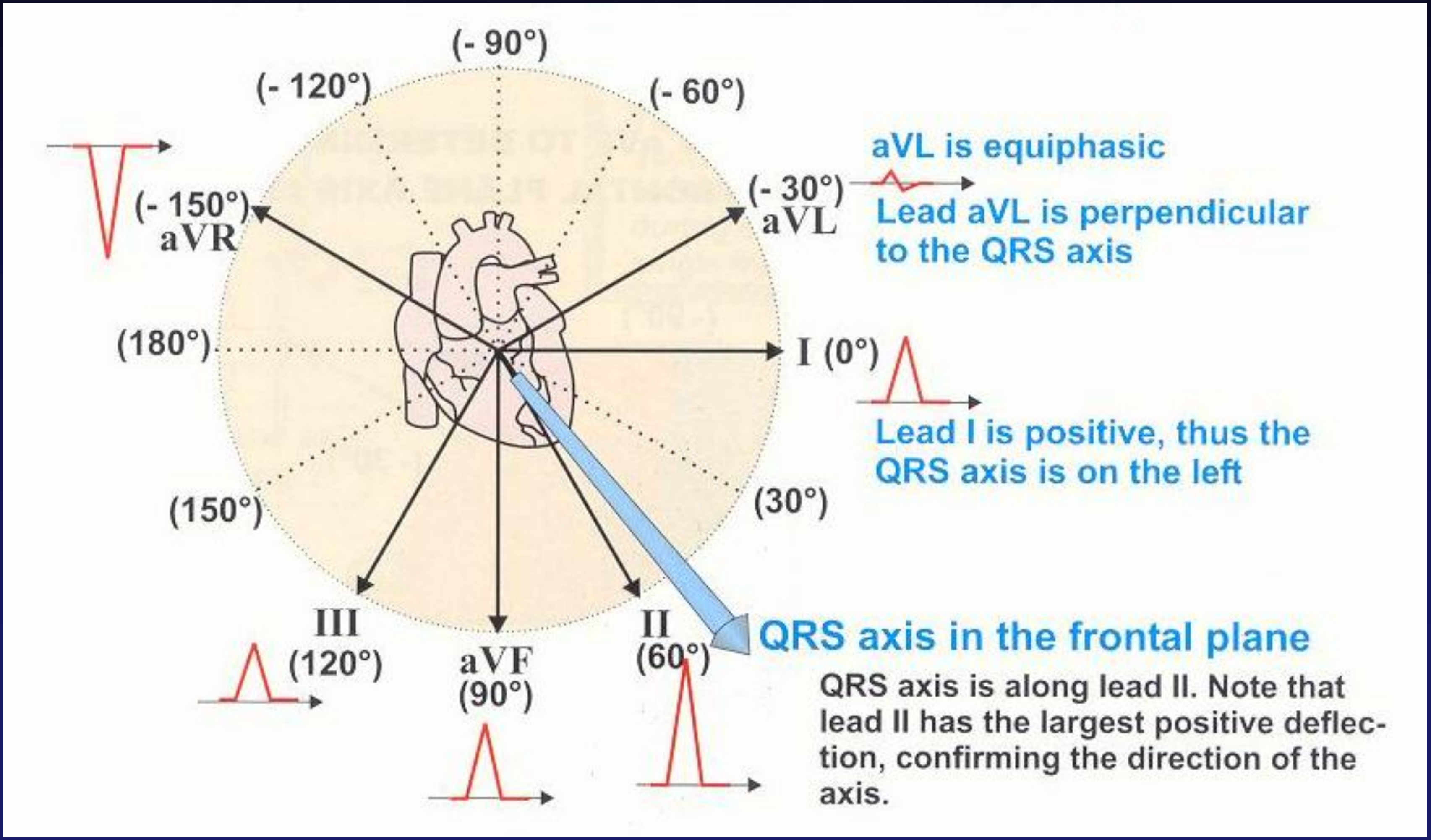


Ventricular Depolarization Axis

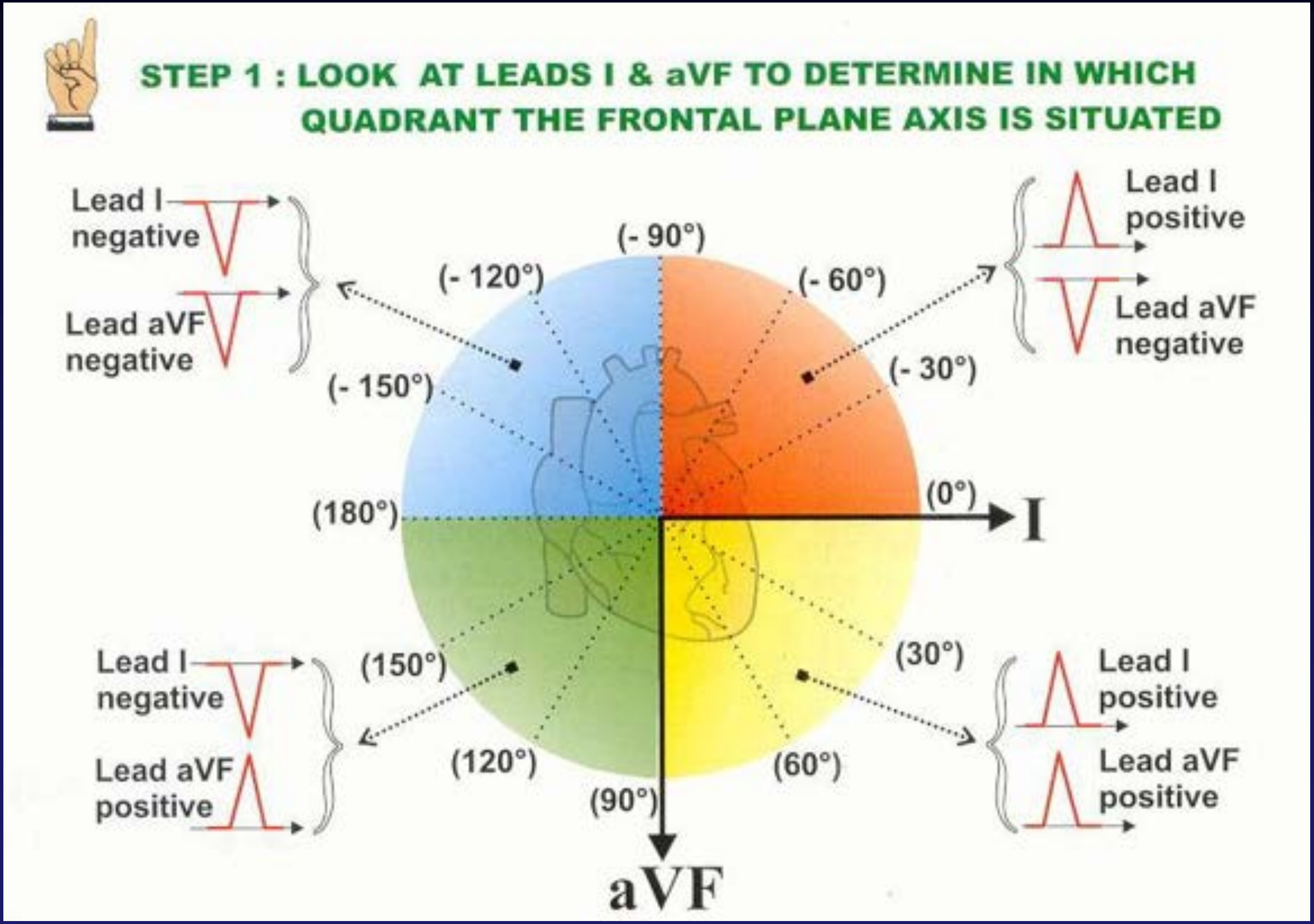




Mean Activation Vector



Determination of QRS Axis



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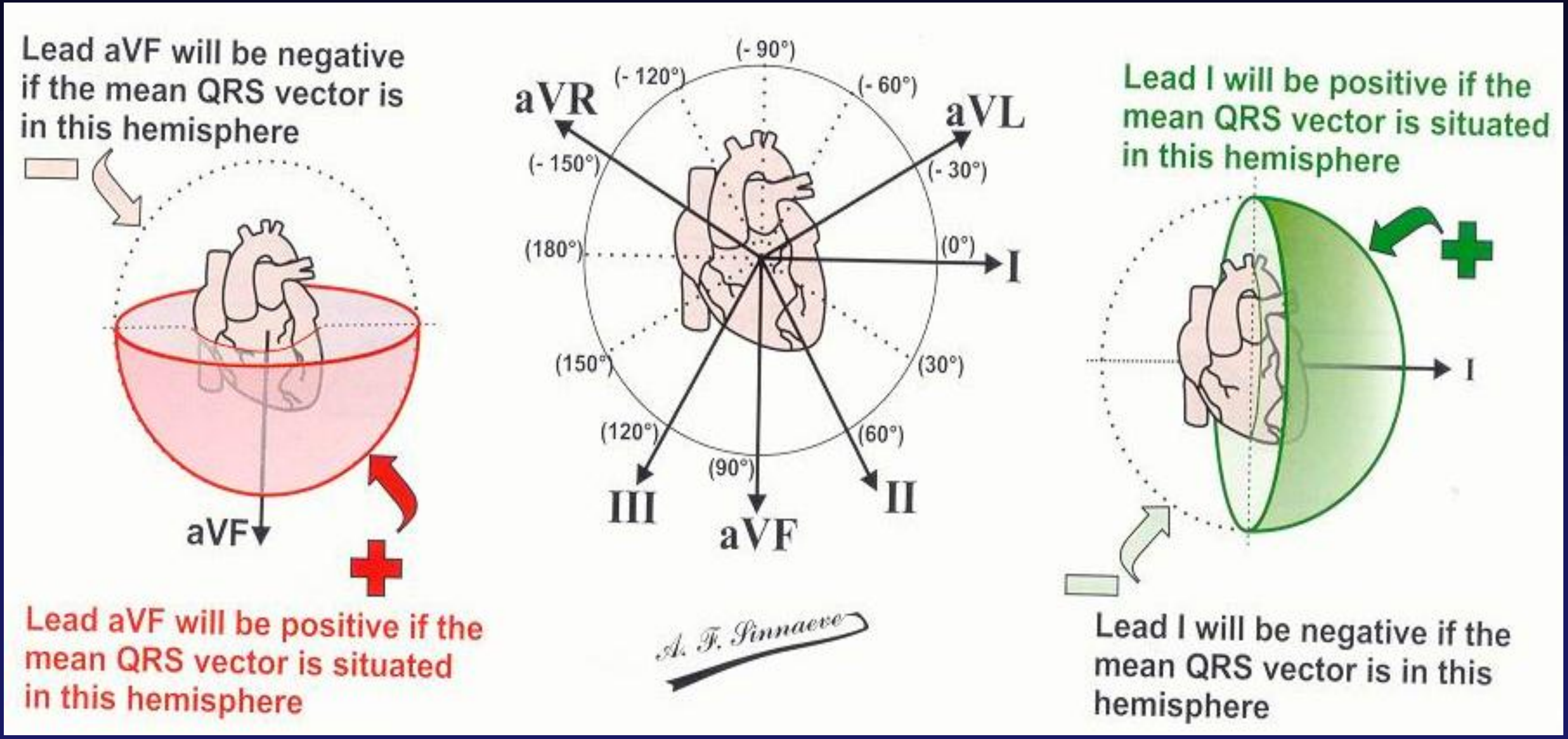
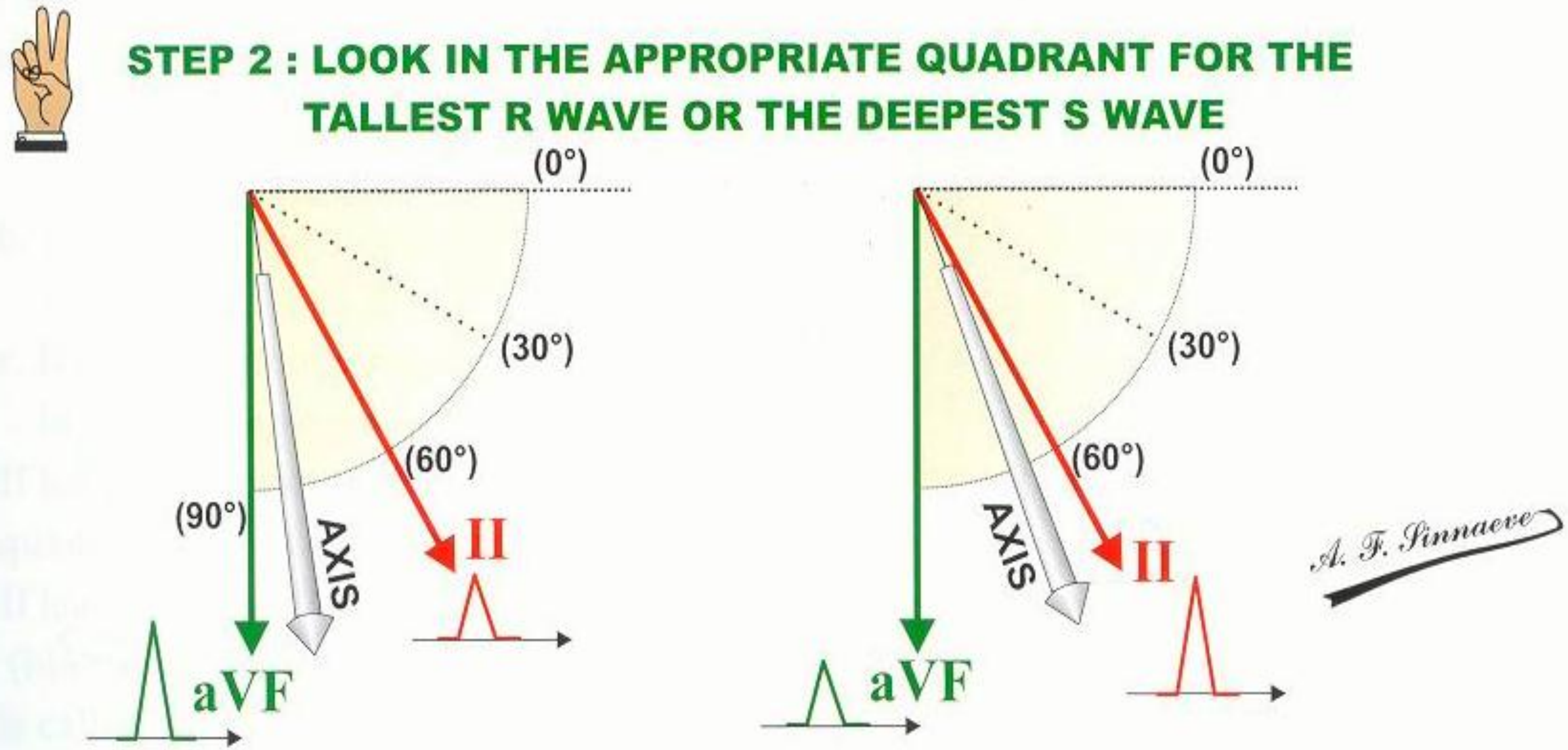
Direction of Propagation



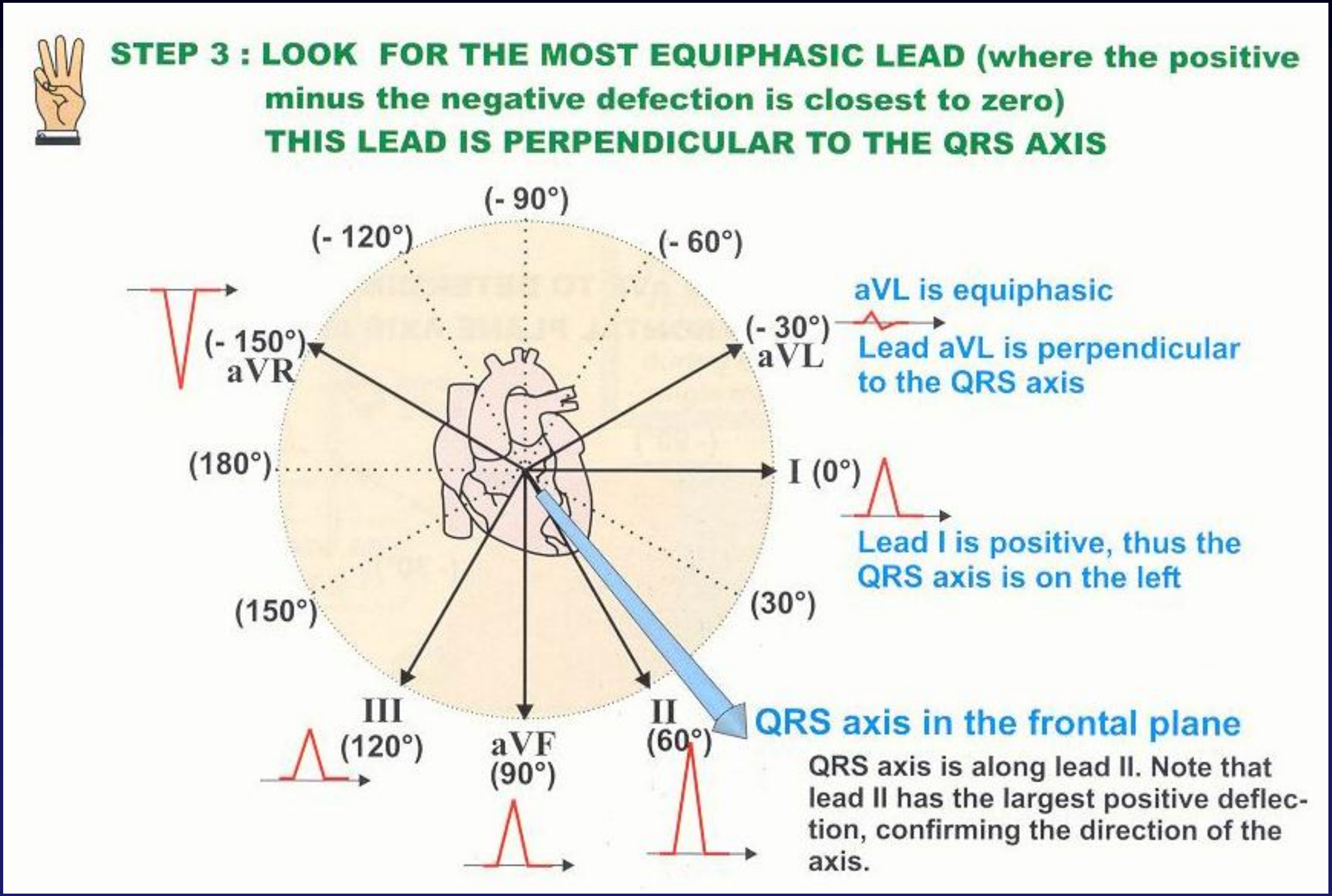
Determination of QRS Axis

STEP 2 : LOOK IN THE APPROPRIATE QUADRANT FOR THE TALLEST R WAVE OR THE DEEPEST S WAVE

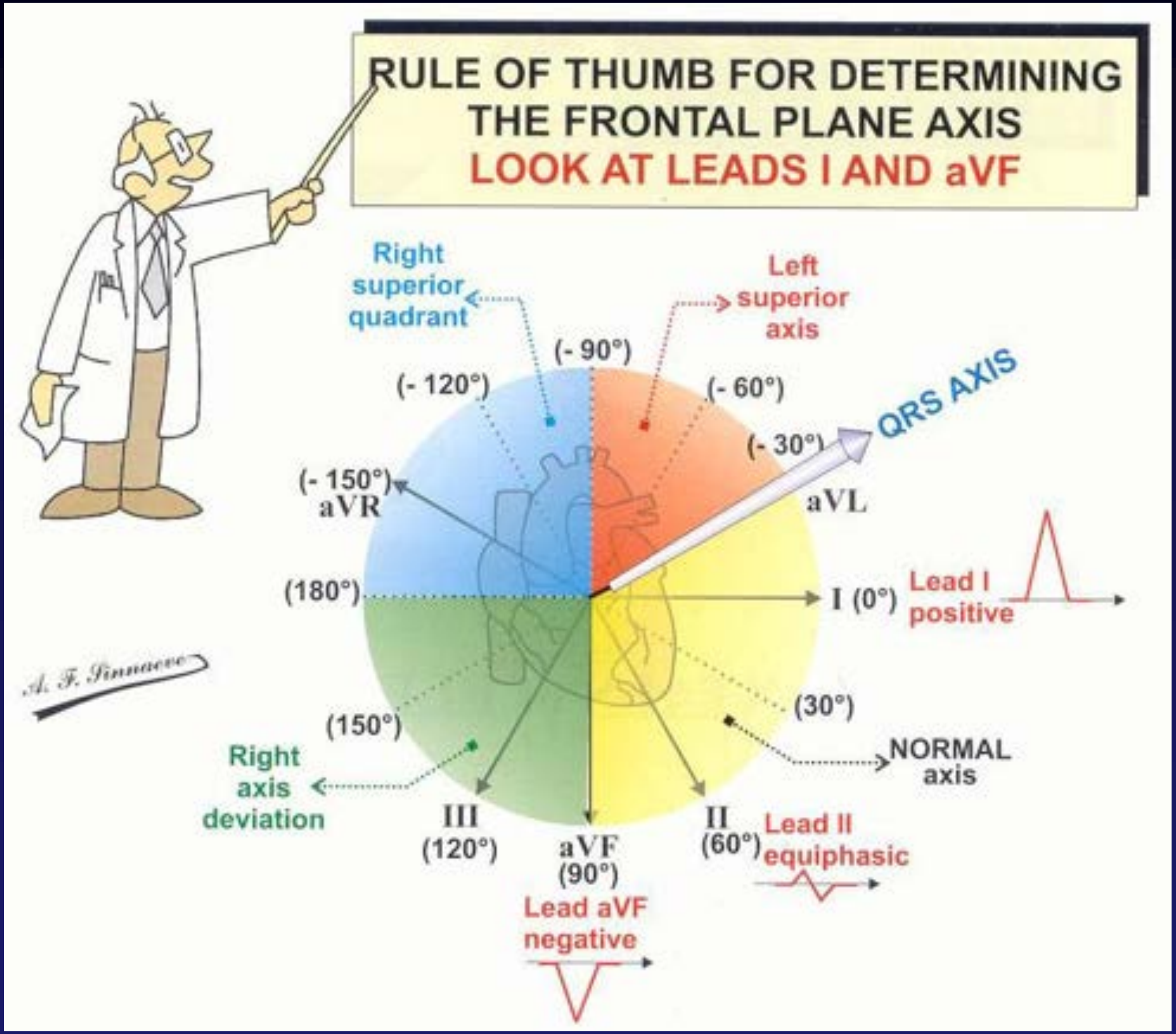


The lead nearest to (or parallel along) the QRS axis has the largest positive deflection. If two leads have equal positive deflections, the axis is exactly in the middle between these two leads.

Determination of QRS Axis

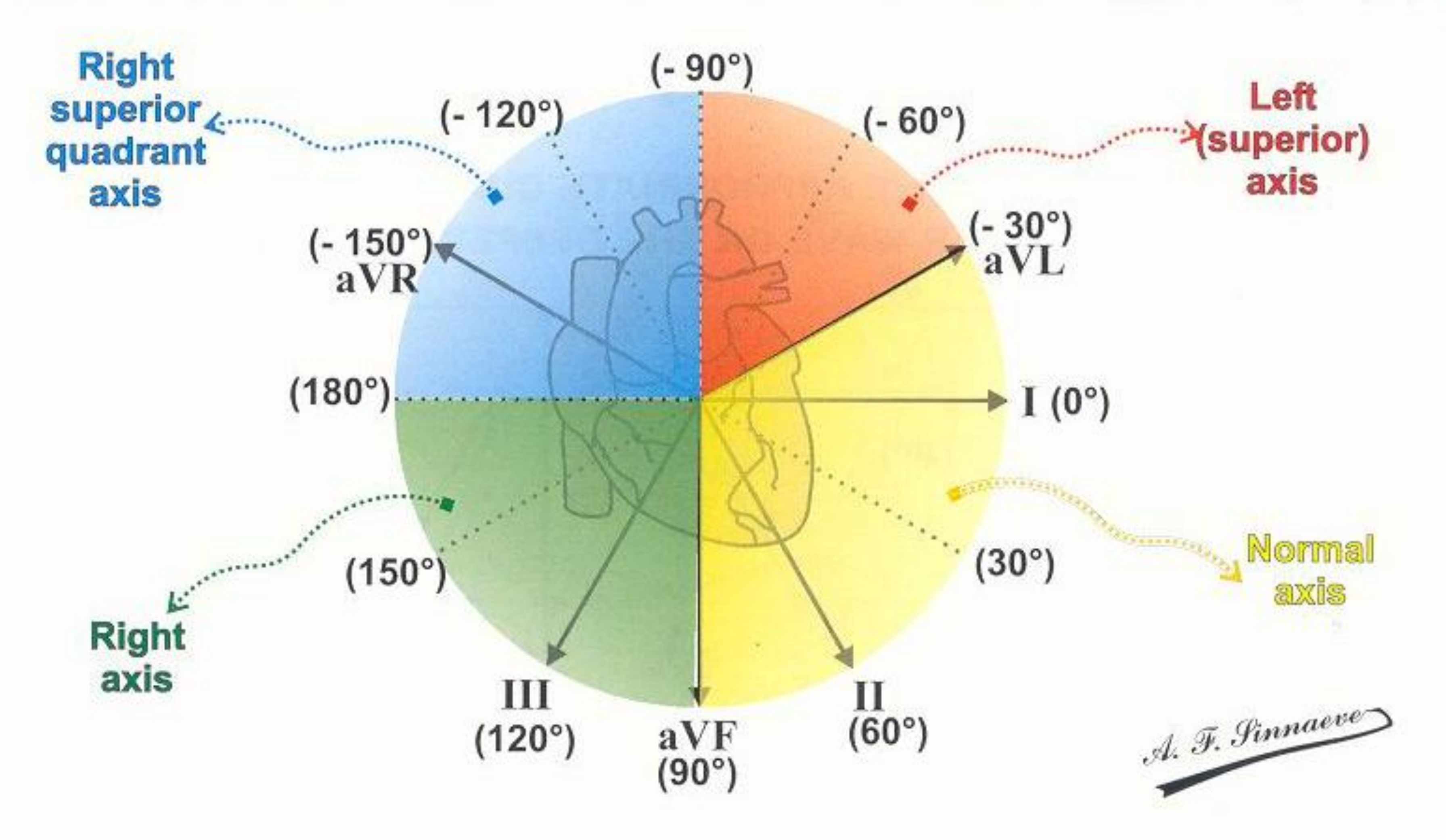


QRS Axis

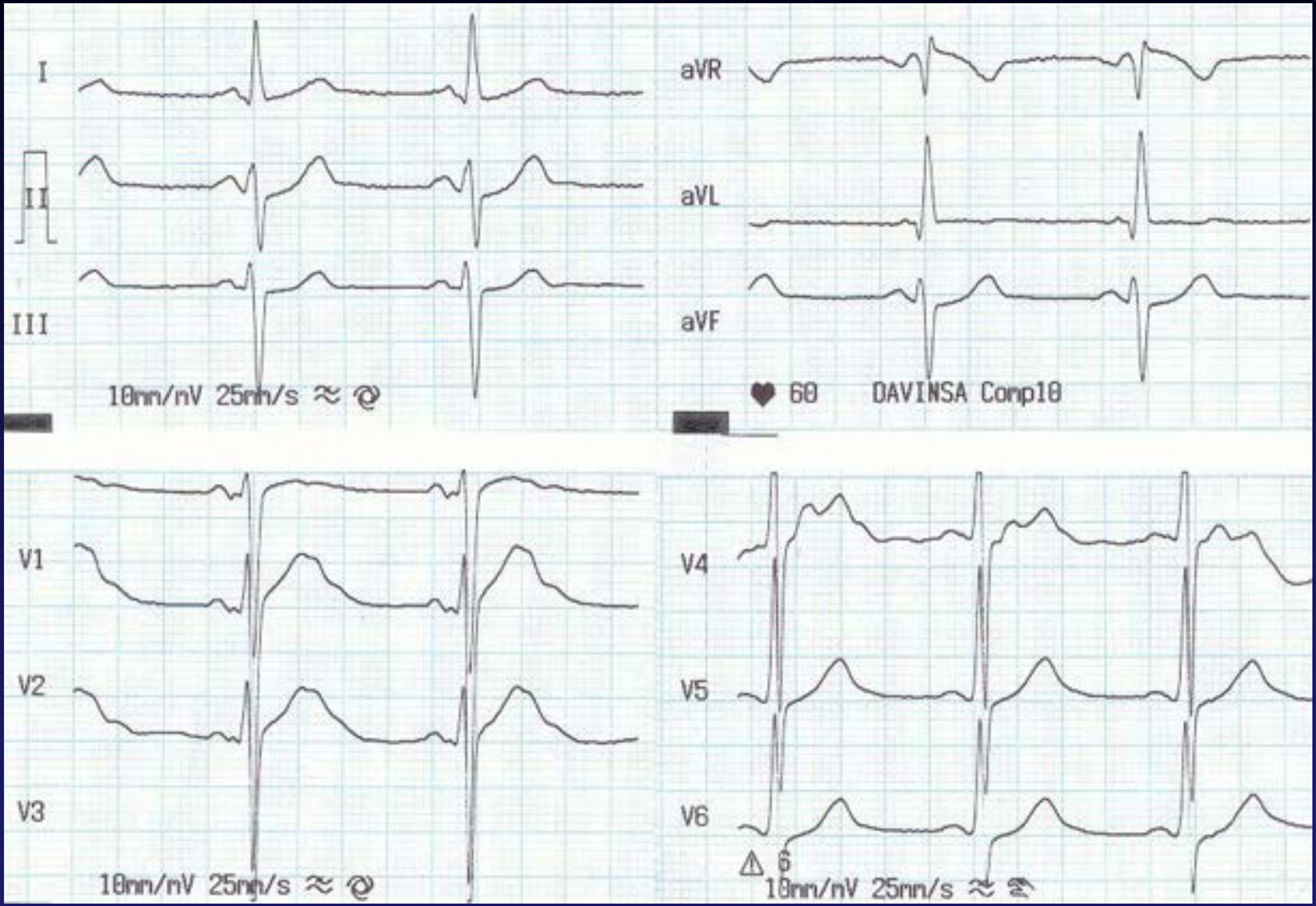


RULE OF THUMB FOR DETERMINING
THE FRONTAL PLANE AXIS
LOOK AT LEADS I AND aVF
Right
superior
quadrant
Left
superior
axis
(- 90°)
(- 120°)
(- 60°)
QRS AXIS
(- 30°)
(- 150°)
aVR
aVL
(180°)
I (0°)
Lead I
positive
A. F. Sinnaeve
(30°)
(150°)
NORMAL
axis
Right
axis
deviation
III
(120°)
aVF
(90°)
II
(60°)
Lead II
equiphasic
Lead aVF
negative

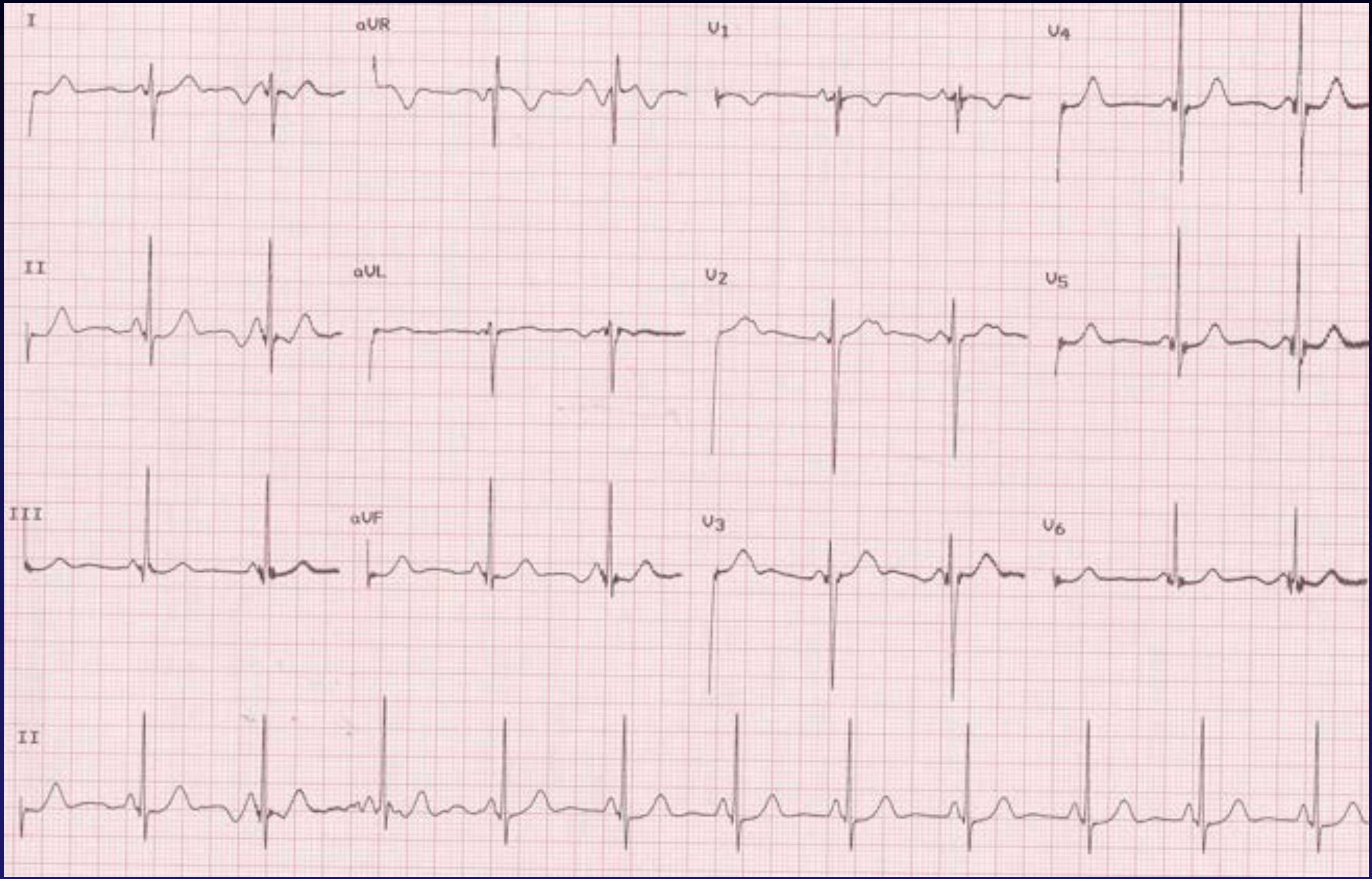
Normal QRS Axis



Left Axis Deviation



Right Axis Deviation



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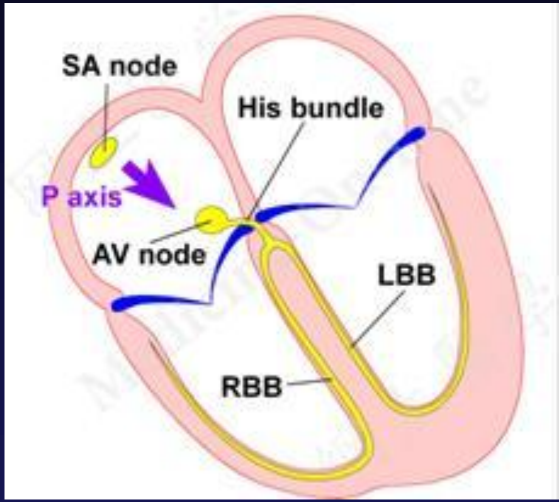
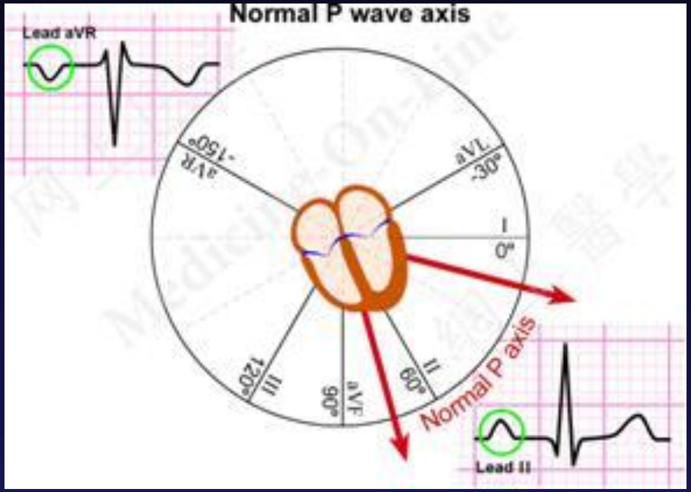
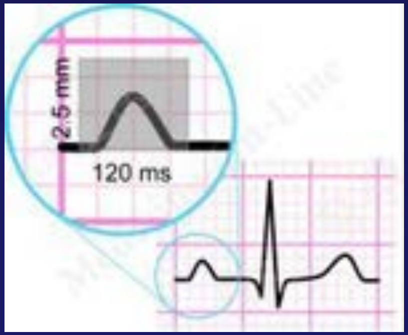
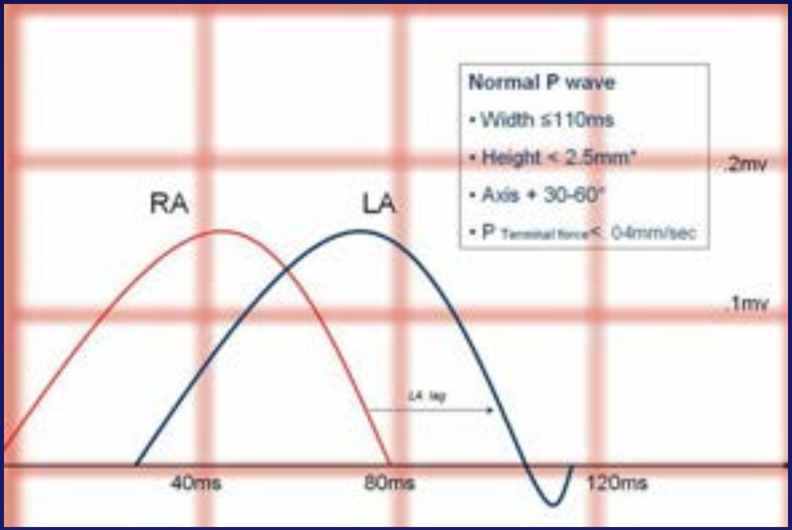
Sinus P Wave

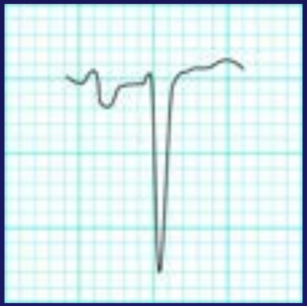






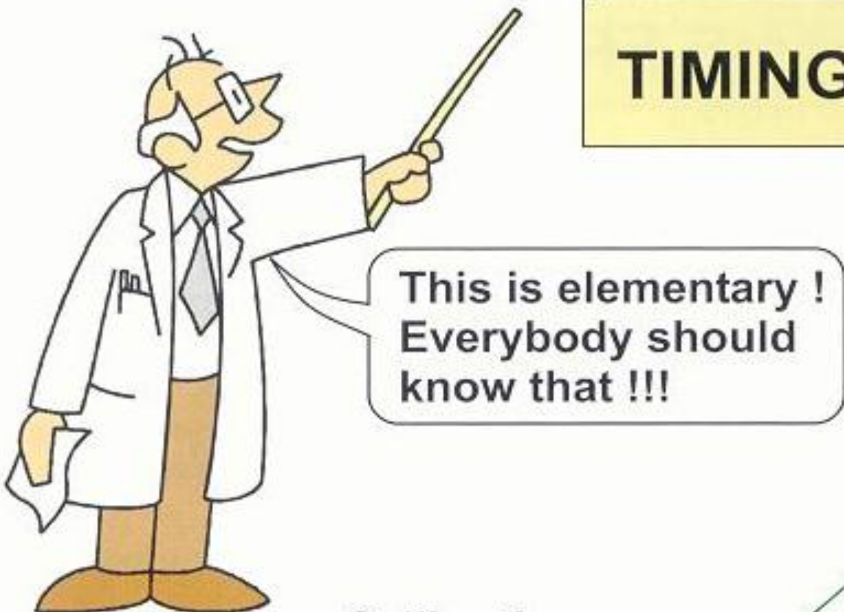
II

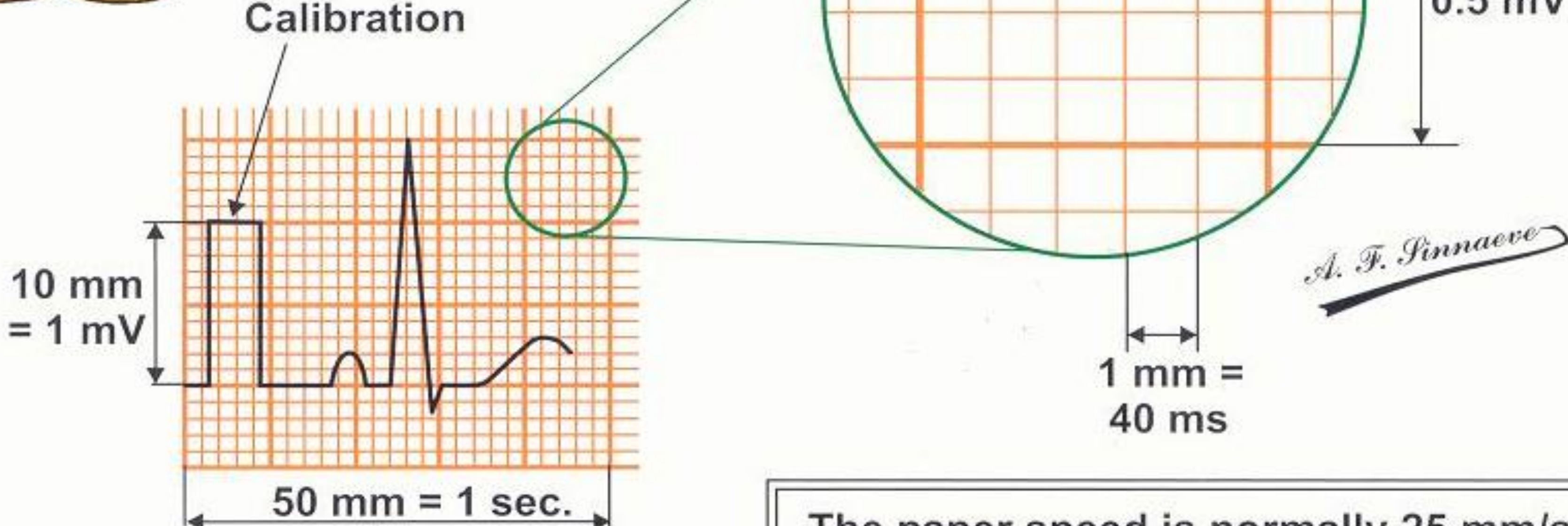




V1

TIMING INTERVALS VERSUS RATE

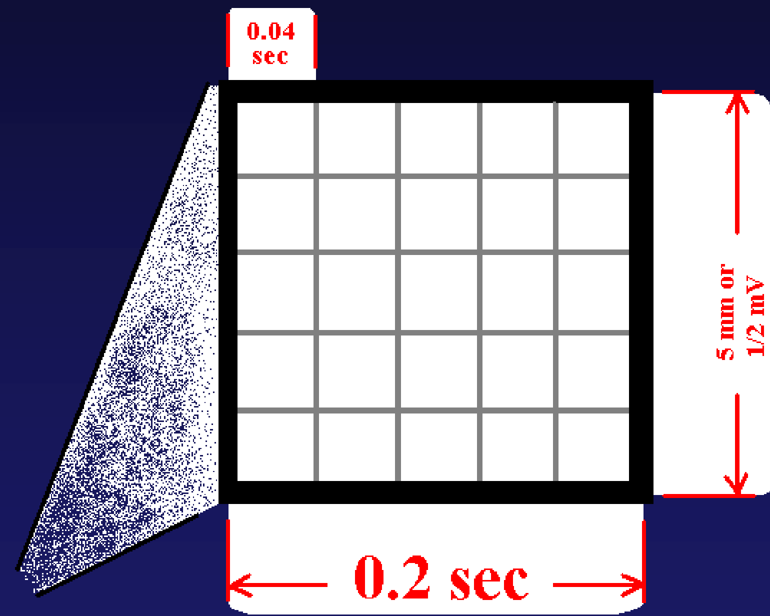




The paper speed is normally 25 mm/s, thus 1 mm on the paper corresponds with 1/25 s = 0.04 s = 40 ms

The ECG Paper

- Horizontally
  - One small box - 0.04 s
  - One large box - 0.20 s
- Vertically
  - One large box - 0.5 mV

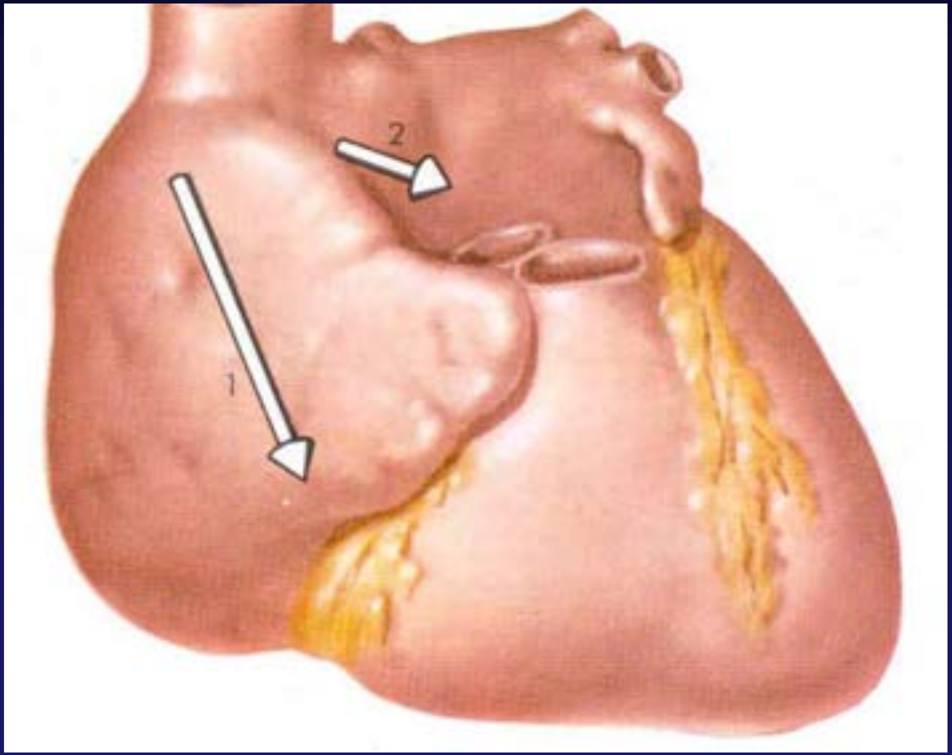


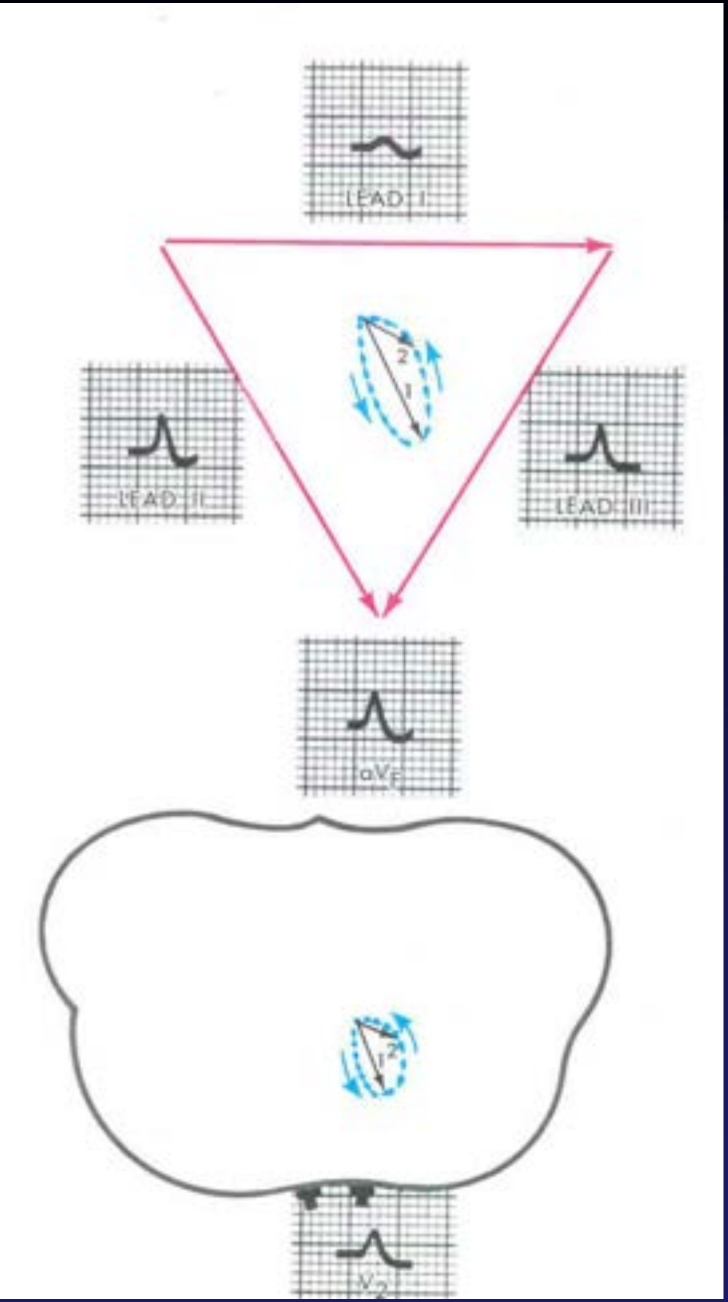
Timing in the ECG Paper

- Every 3 seconds (15 large boxes) is marked by a vertical line.
- This helps when calculating the heart rate.

Major ECG Abnormalities

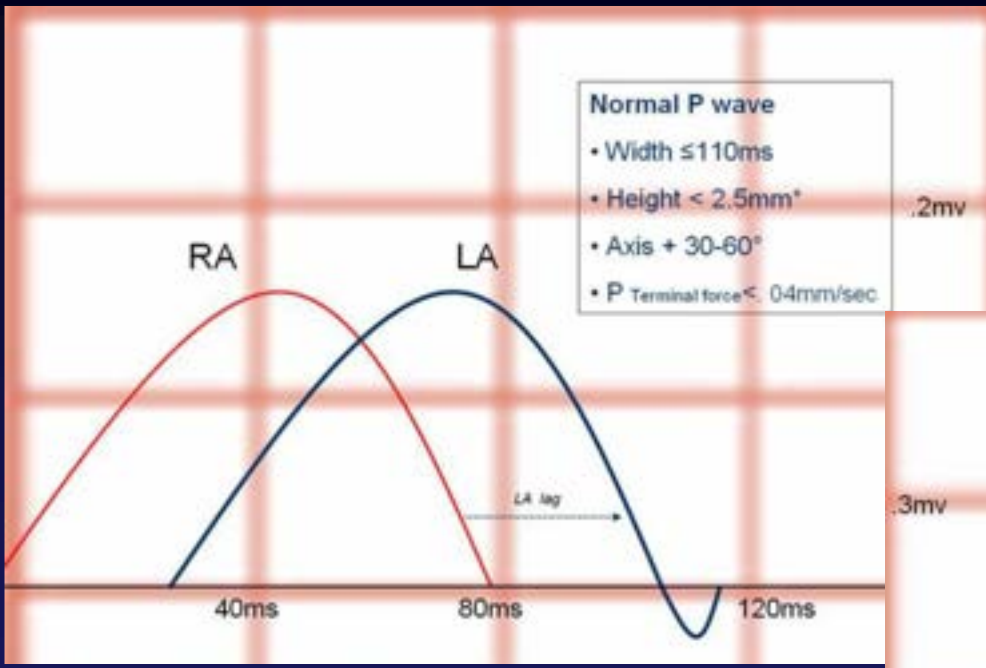
Right Atrial Enlargement

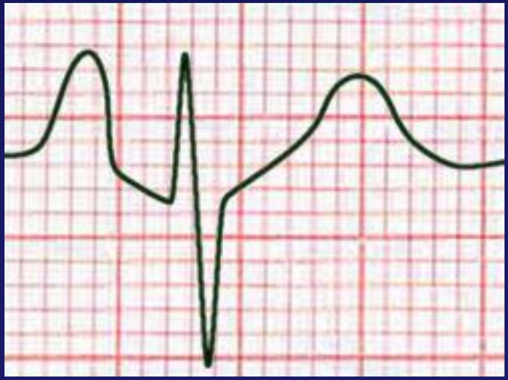


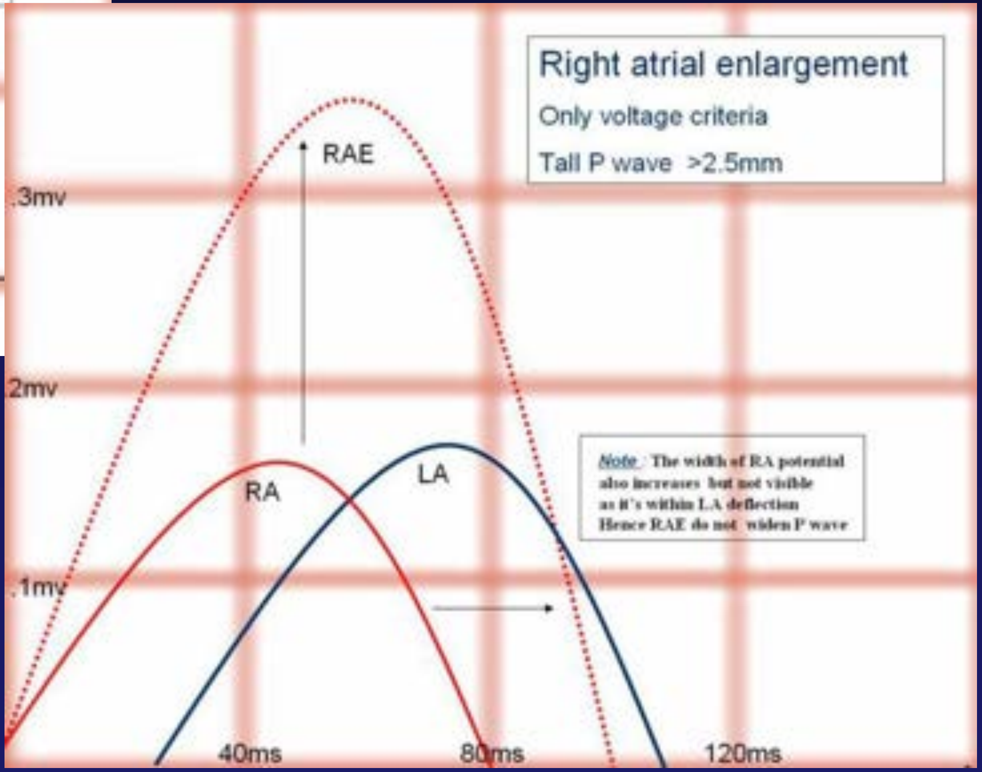


P Pulmonale, Amplitude ≥ 2.5 mm

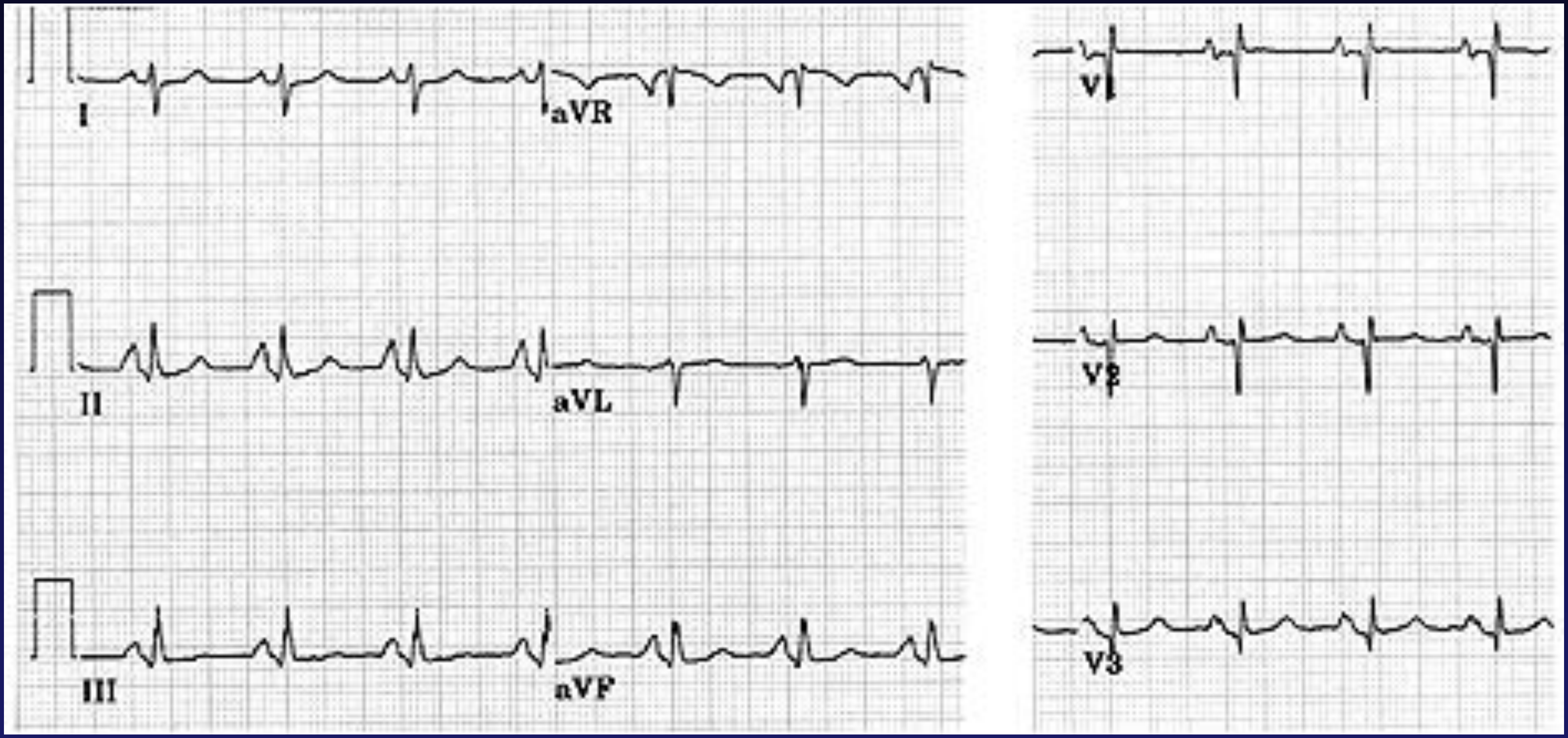
Atrial Activation







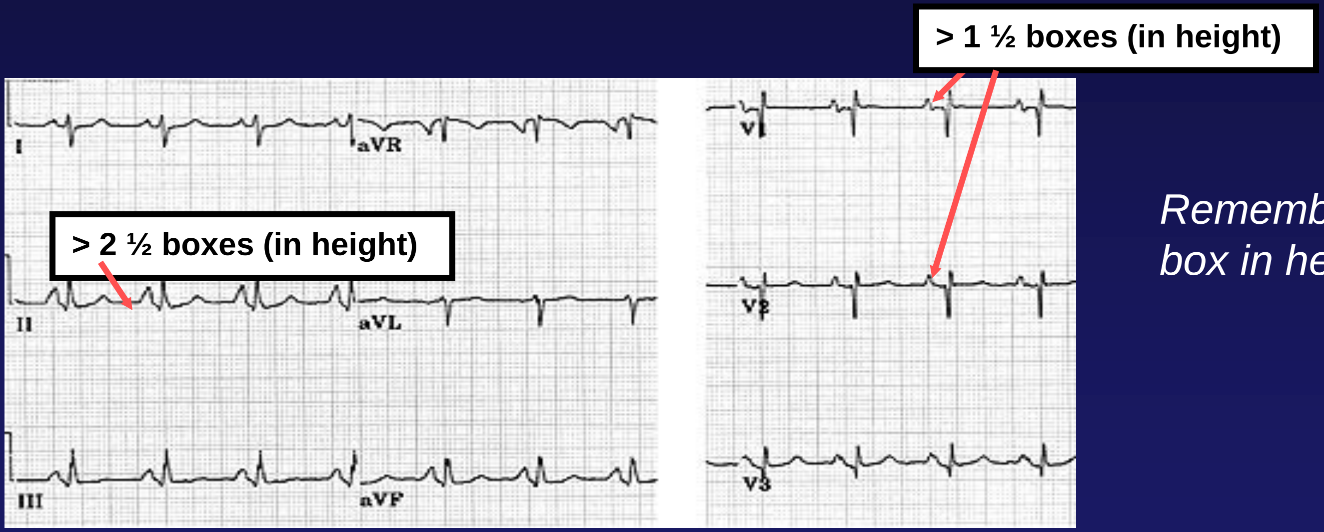
Right Atrial Enlargement



The P waves are tall, especially in leads II, III and avF.

Right Atrial Enlargement

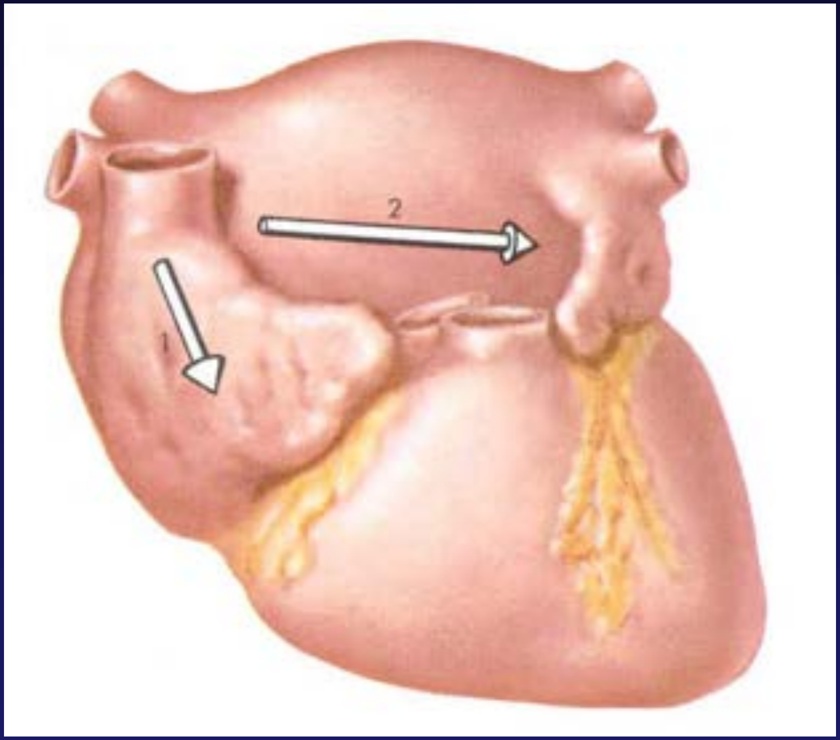
– To diagnose RAE you can use the following criteria:
  - II P > 2.5 mm, or
  - V1 or V2 P > 1.5 mm

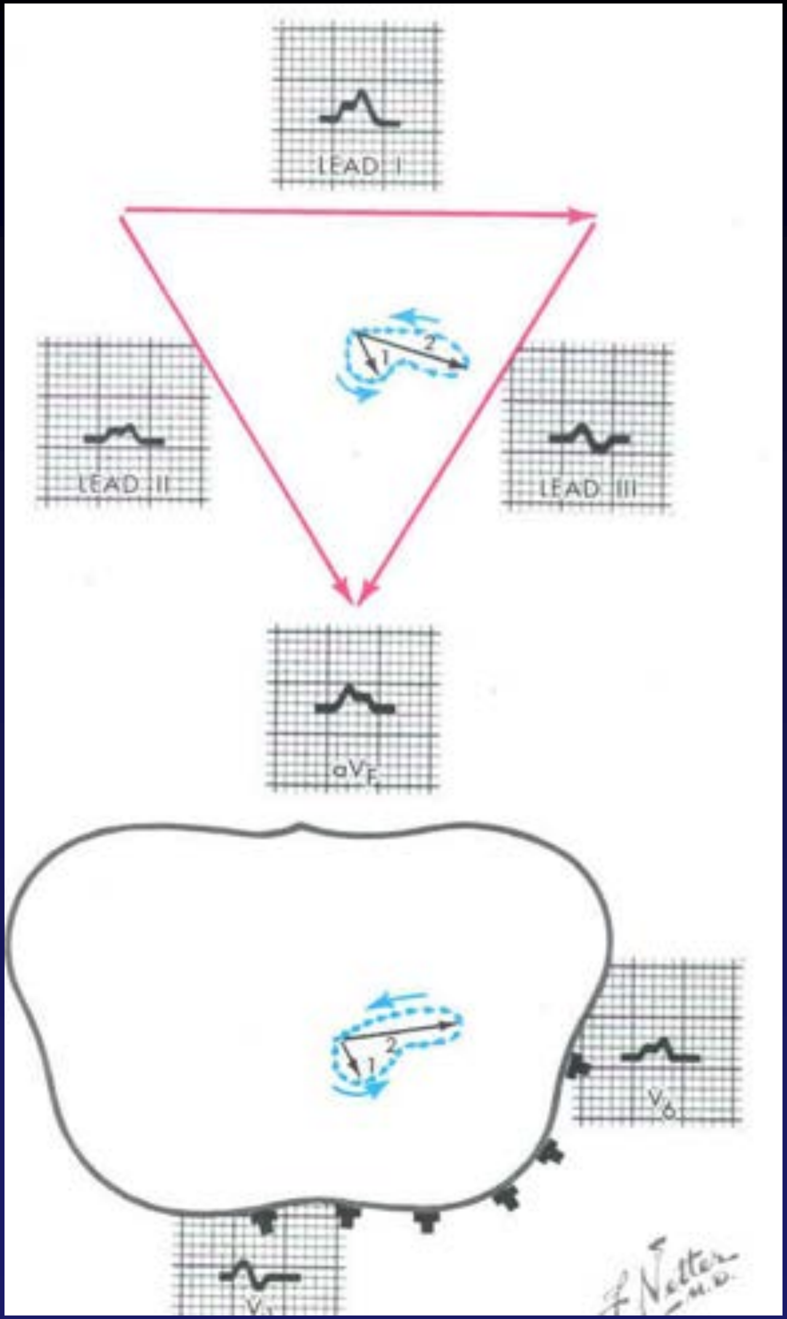


Remember 1 small box in height = 1 mm

A cause of RAE is RVH from pulmonary hypertension, hence P Pulmonale.

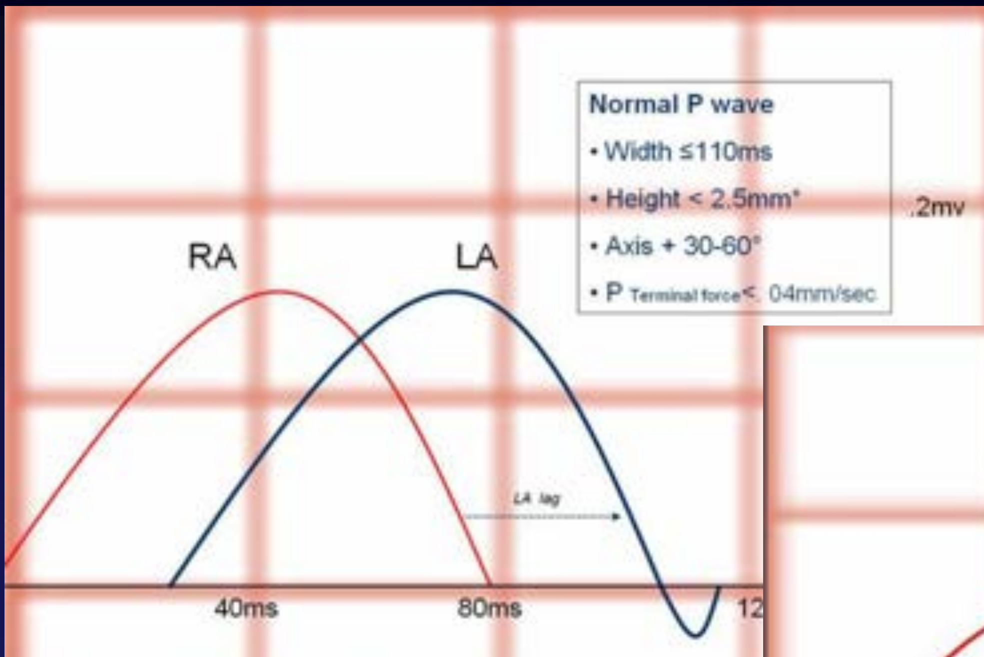
Left Atrial Enlargement

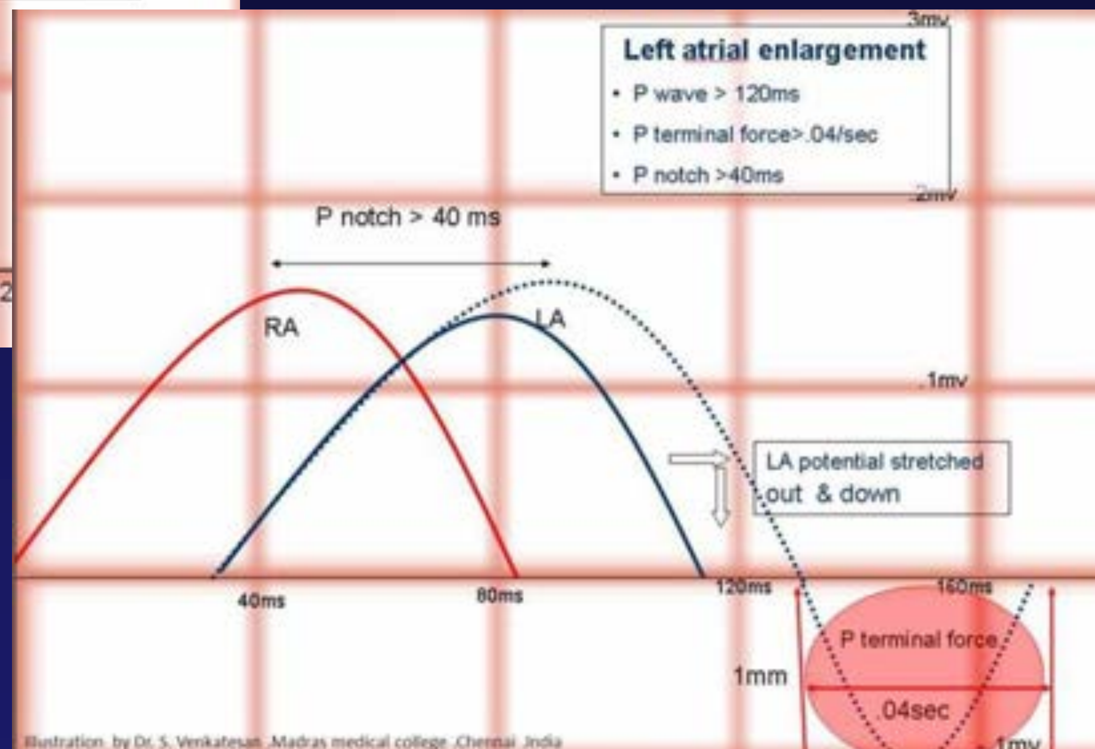


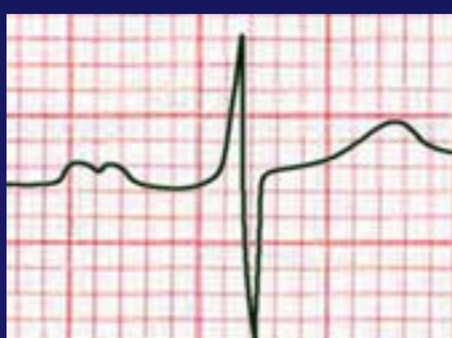


P Mitrale, Duration ≥ 120 ms

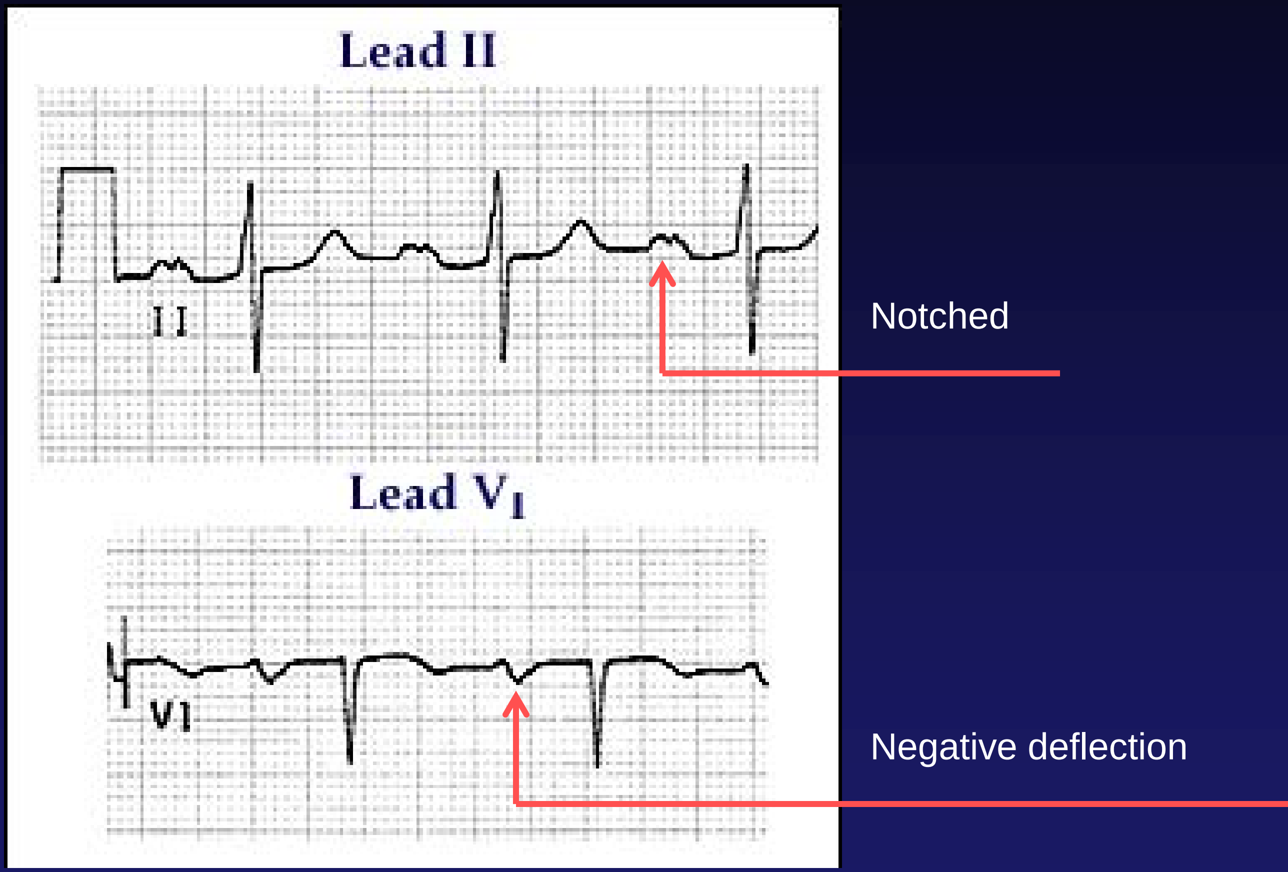
Atrial Activation







Left Atrial Enlargement

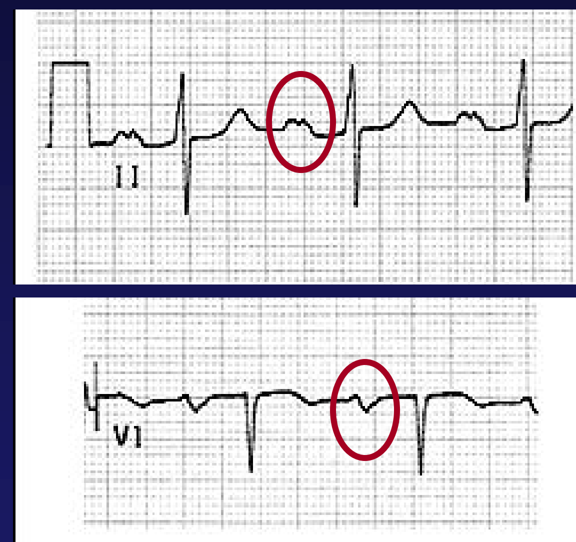


The P waves in lead II are notched and in lead V1 they have a deep and wide negative component.

Left Atrial Enlargement

– To diagnose LAE you can use the following criteria:
  - II > 0.04 s (1 box) between notched peaks, or
  - V1 Neg. deflection > 1 box wide x 1 box deep

Normal



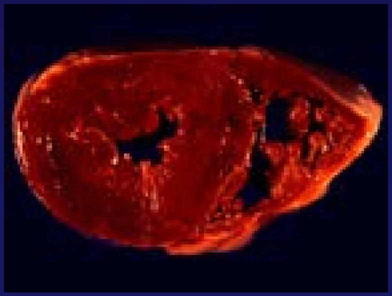
LAE

A common cause of LAE has been Mitral Stenosis, hence P Mitrale.

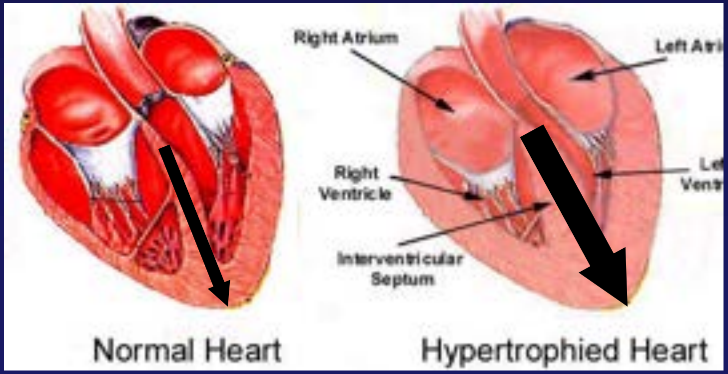
Left Ventricular Hypertrophy

Why is left ventricular hypertrophy characterized by tall QRS complexes?

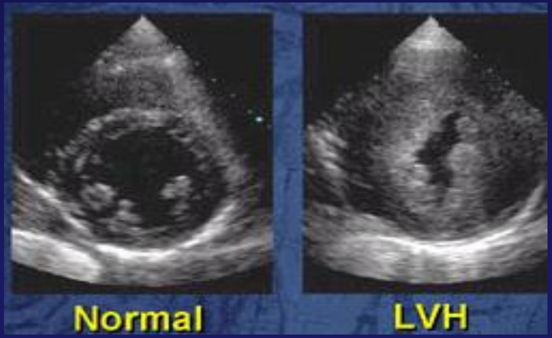
As the heart muscle wall thickens there is an increase in electrical forces moving through the myocardium resulting in increased QRS voltage.



LVH

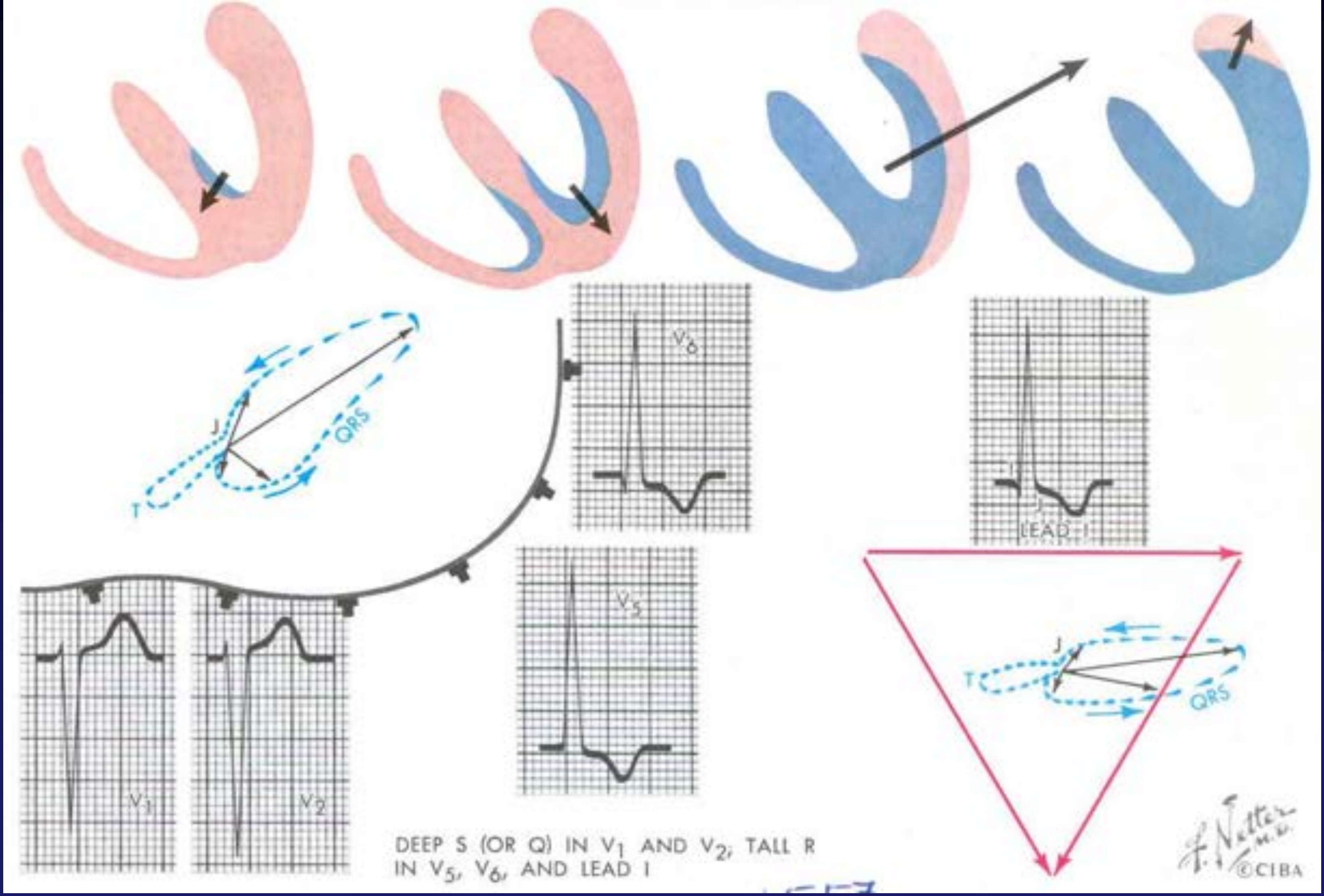


Increased QRS voltage



Echocardiogram

Left Ventricular Hypertrophy



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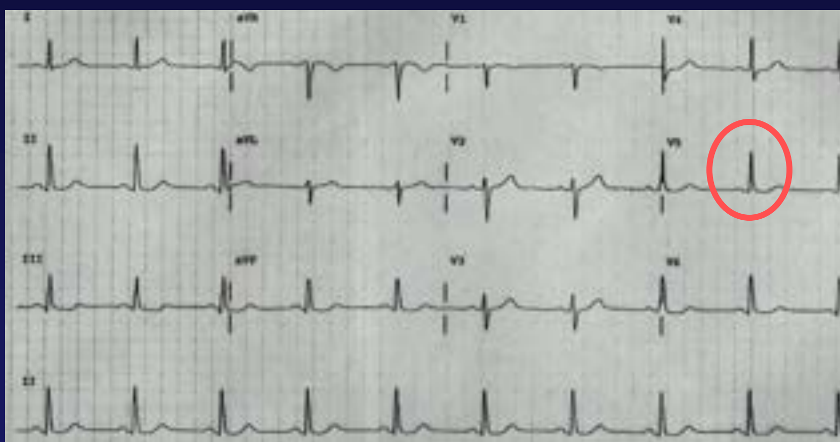
Left Ventricular Hypertrophy

Compare these two 12-lead ECGs. What stands out as different with the second one?



Normal

Left Ventricular Hypertrophy

Answer: The QRS complexes are very tall (increased voltage)

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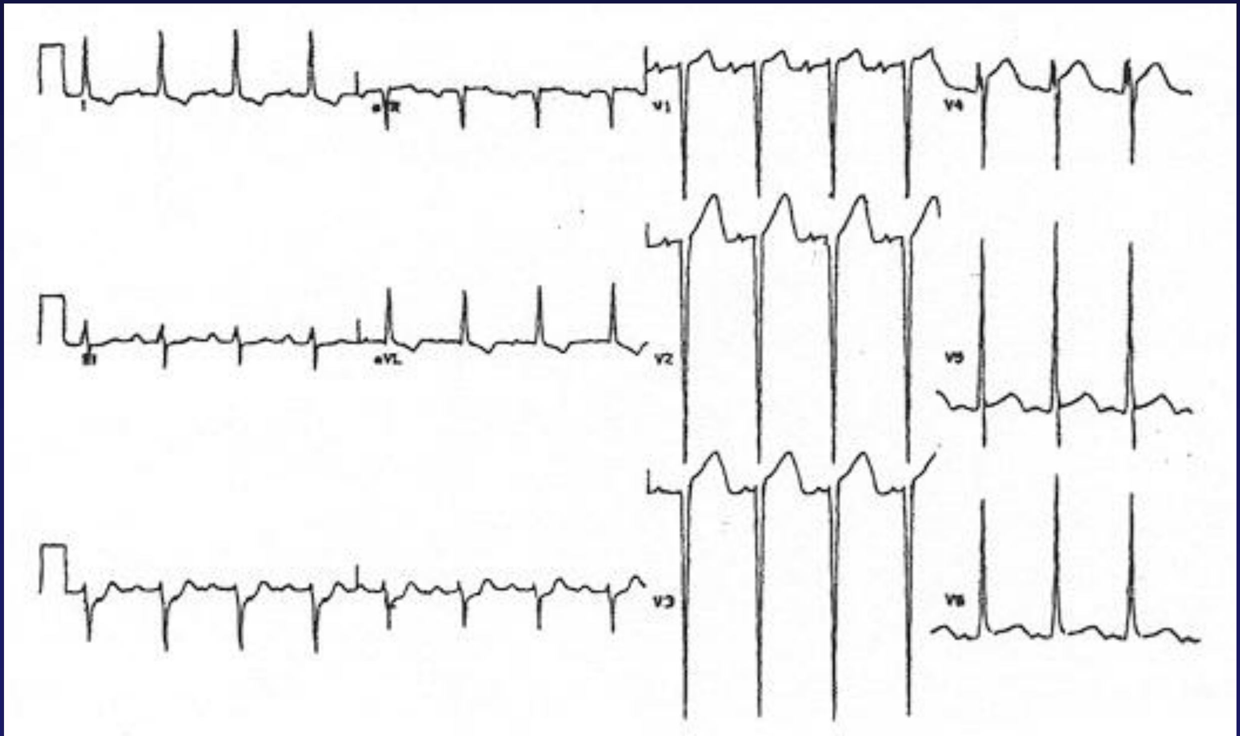
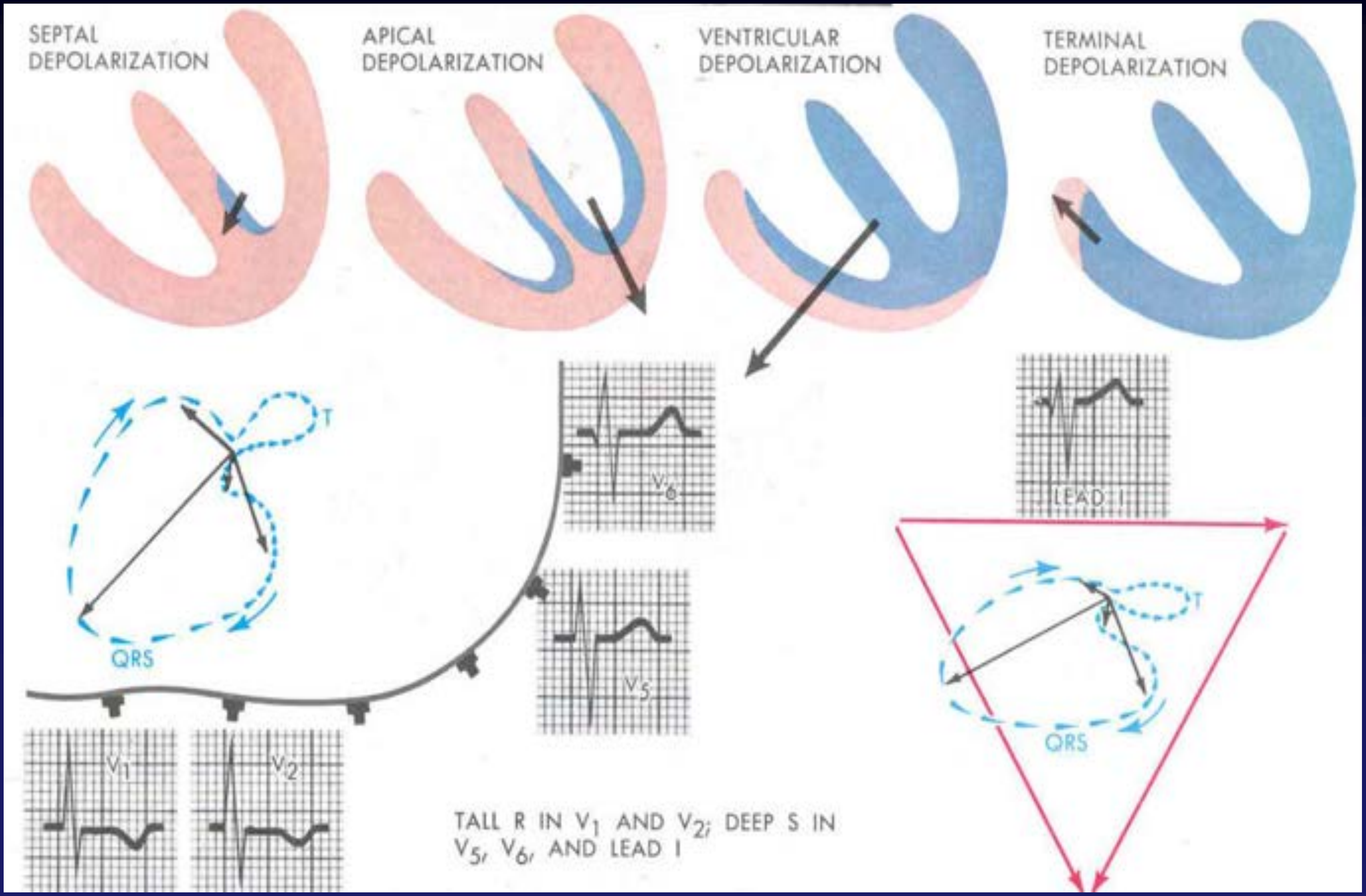
Left Ventricular Hypertrophy

- Criteria exists to diagnose LVH using a 12-lead ECG.
  - For example:
    - The R wave in V5 or V6 plus the S wave in V1 or V2 exceeds 35 mm.

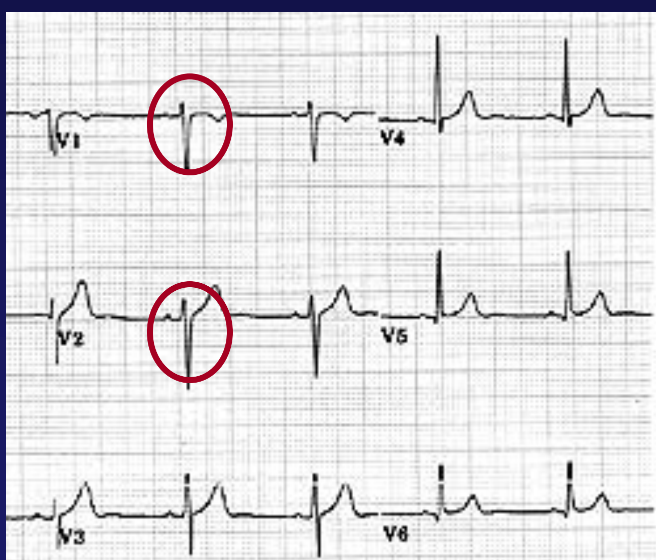


Right Ventricular Hypertrophy

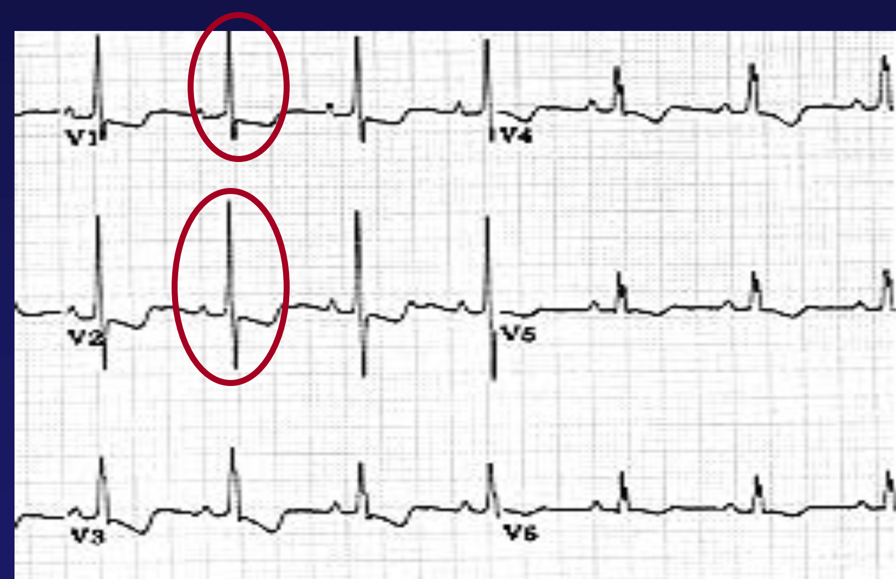


Right Ventricular Hypertrophy

- Compare the R waves in V1, V2 from a normal ECG and one from a person with RVH.
- Notice the R wave is normally small in V1, V2 because the right ventricle does not have a lot of muscle mass.
- But in the hypertrophied right ventricle the R wave is tall in V1, V2.



Normal



RVH

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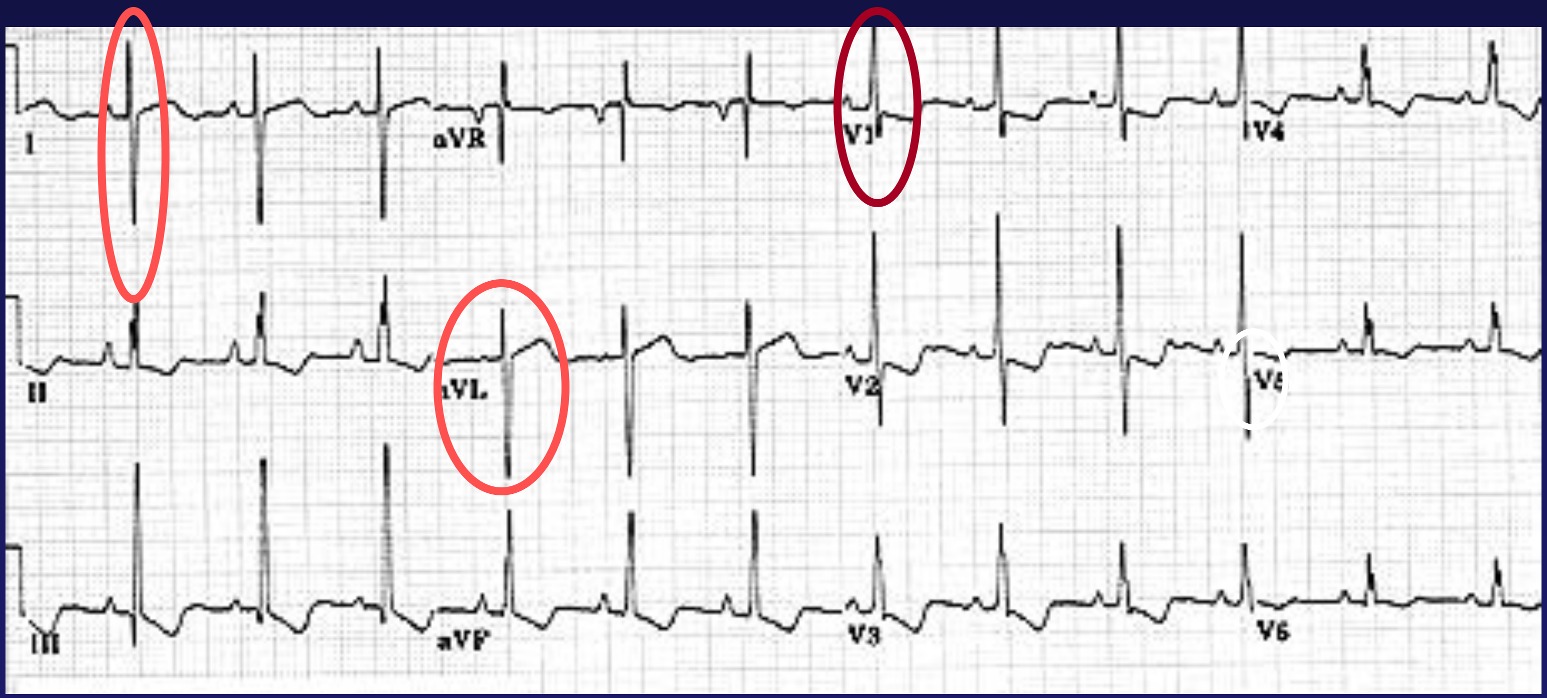
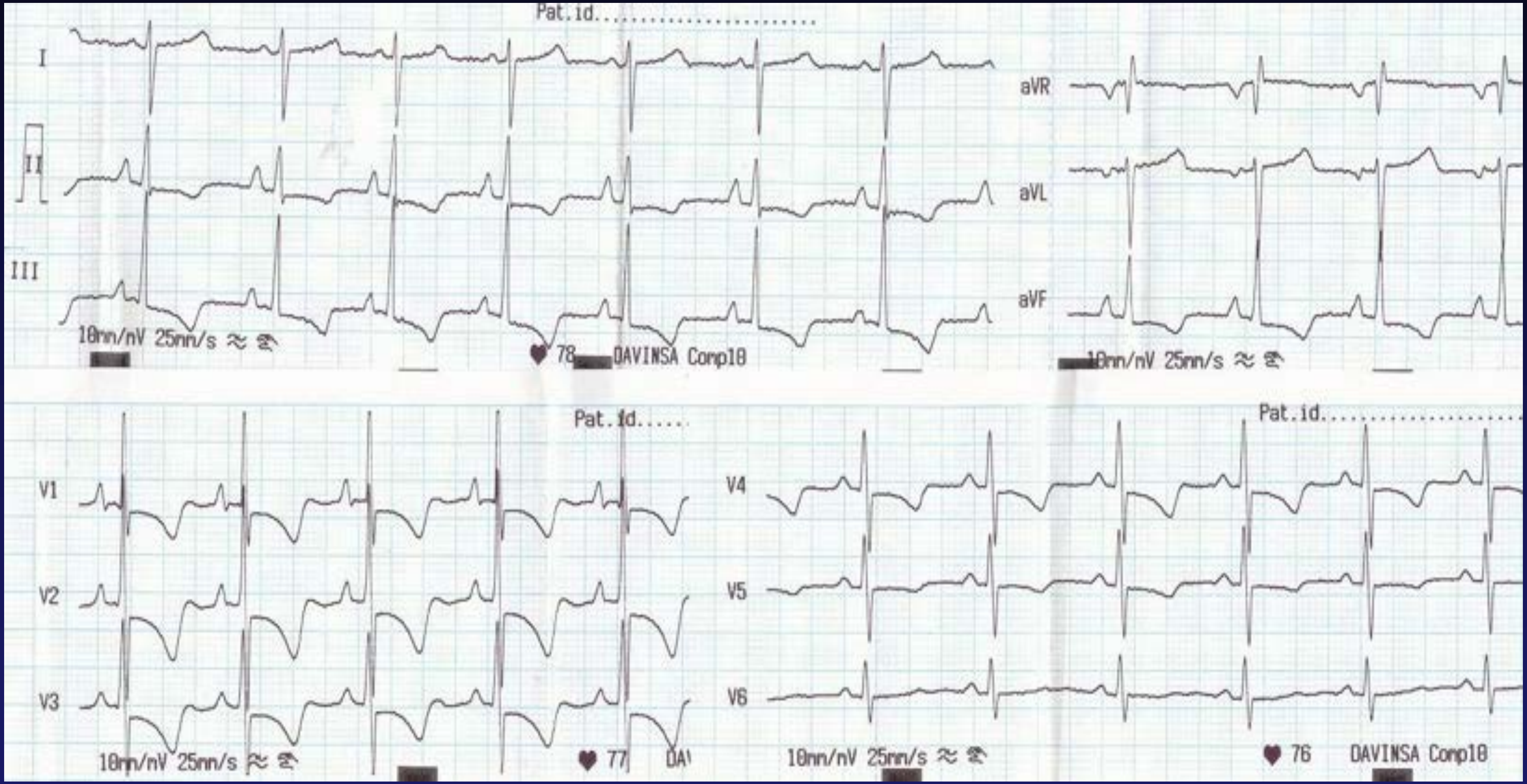
Right Ventricular Hypertrophy

To diagnose RVH you can use the following criteria:

- Right axis deviation, and
- V1 R wave > 7mm tall



RVH, RA enlargement



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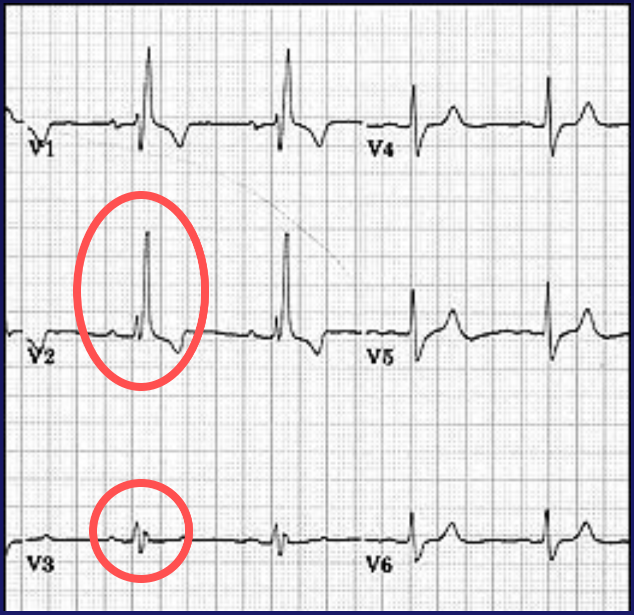
Bundle Branch Blocks

With Bundle Branch Blocks you will see two changes on the ECG.

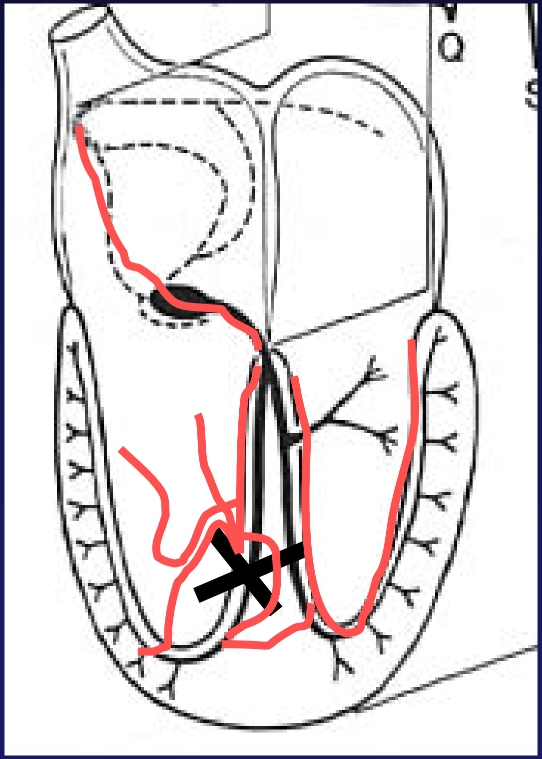
1. **QRS complex widens (> 0.12 sec).**
2. **QRS morphology changes (varies depending on ECG lead, and if it is a right vs. left bundle branch block).**



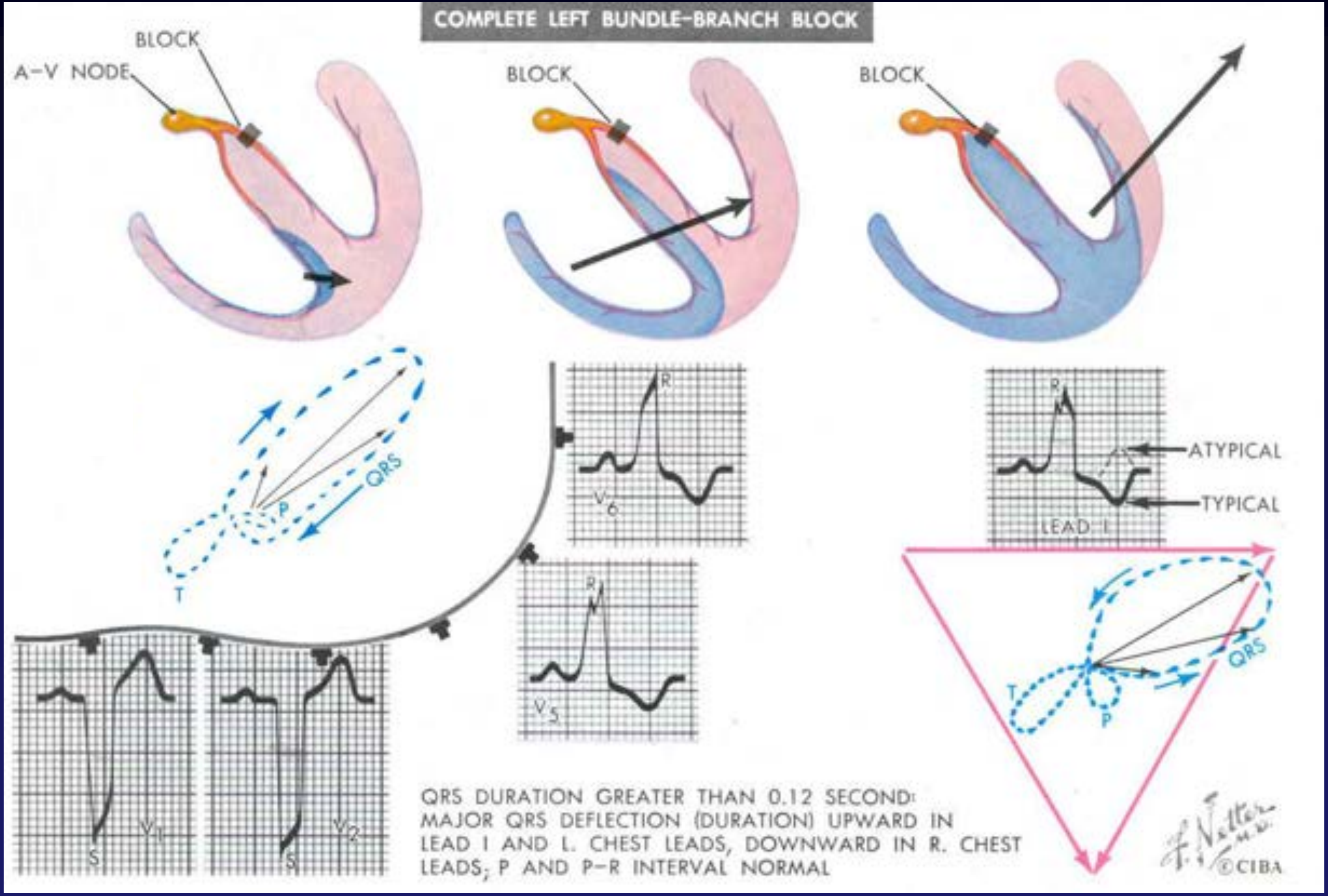
Bundle Branch Blocks

Why does the QQRS complex widen?

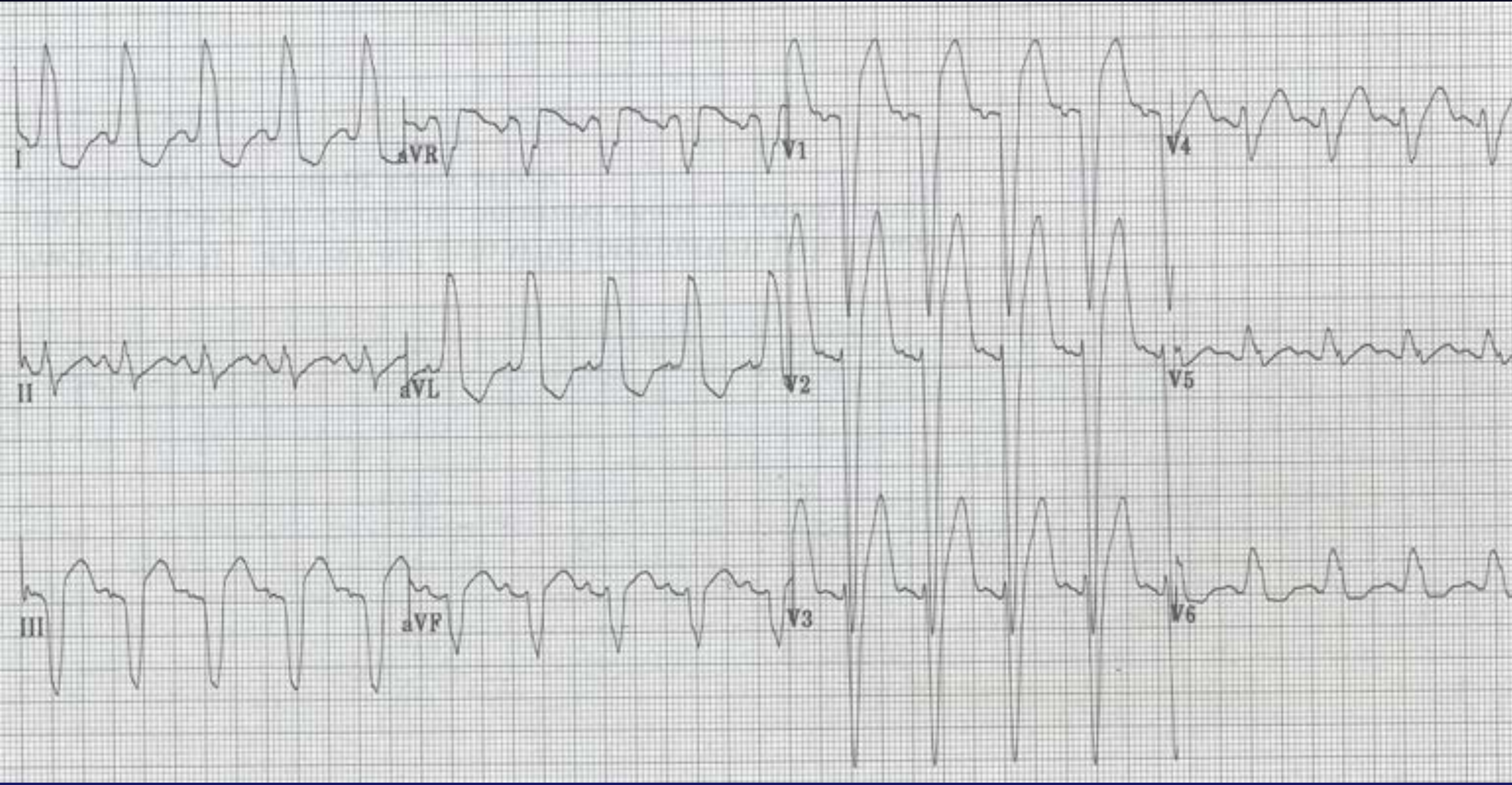
When the conduction pathway is blocked it will take longer for the electrical signal to pass throughout the ventricles.



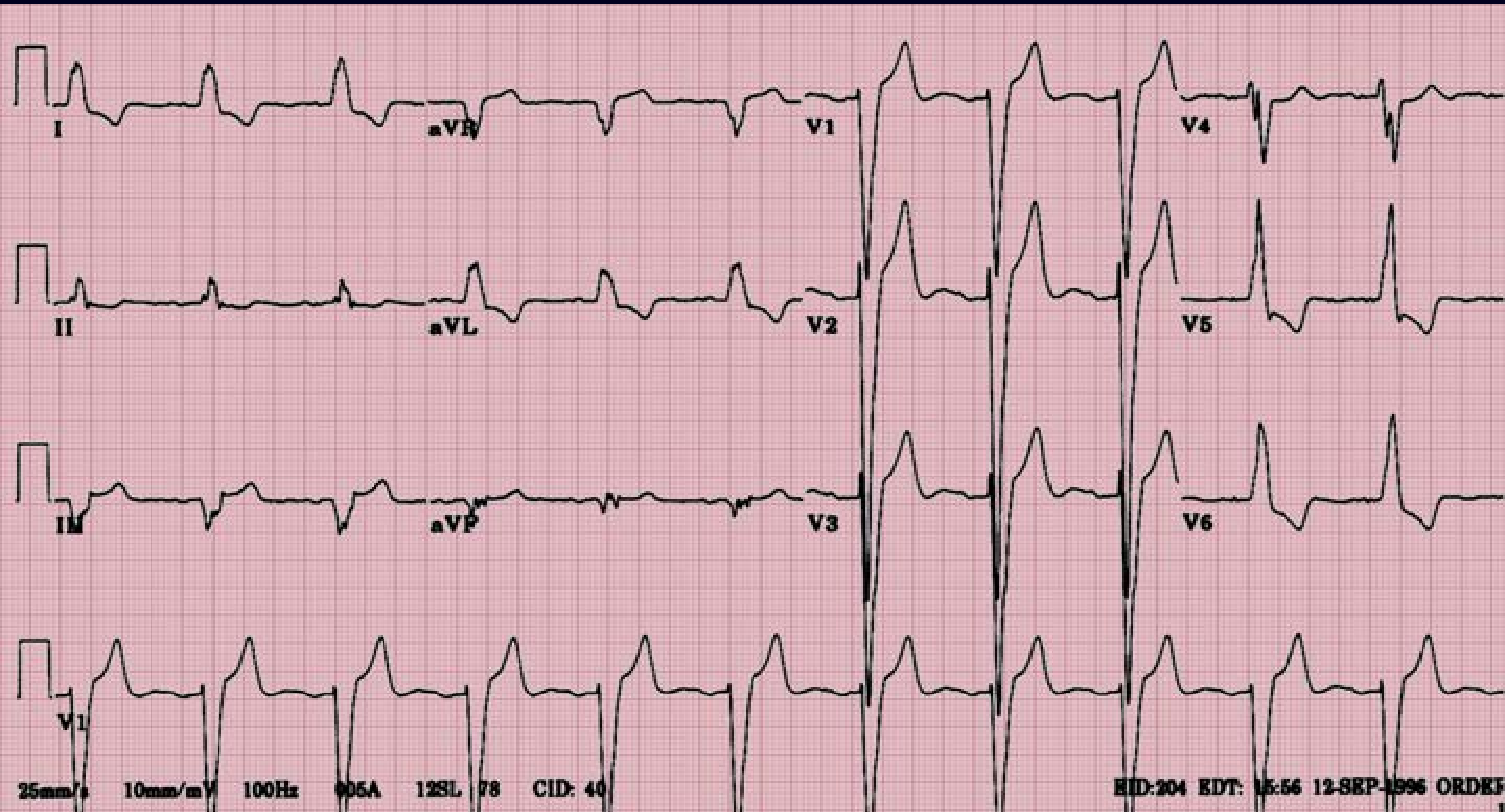
Left Bundle Branch Block



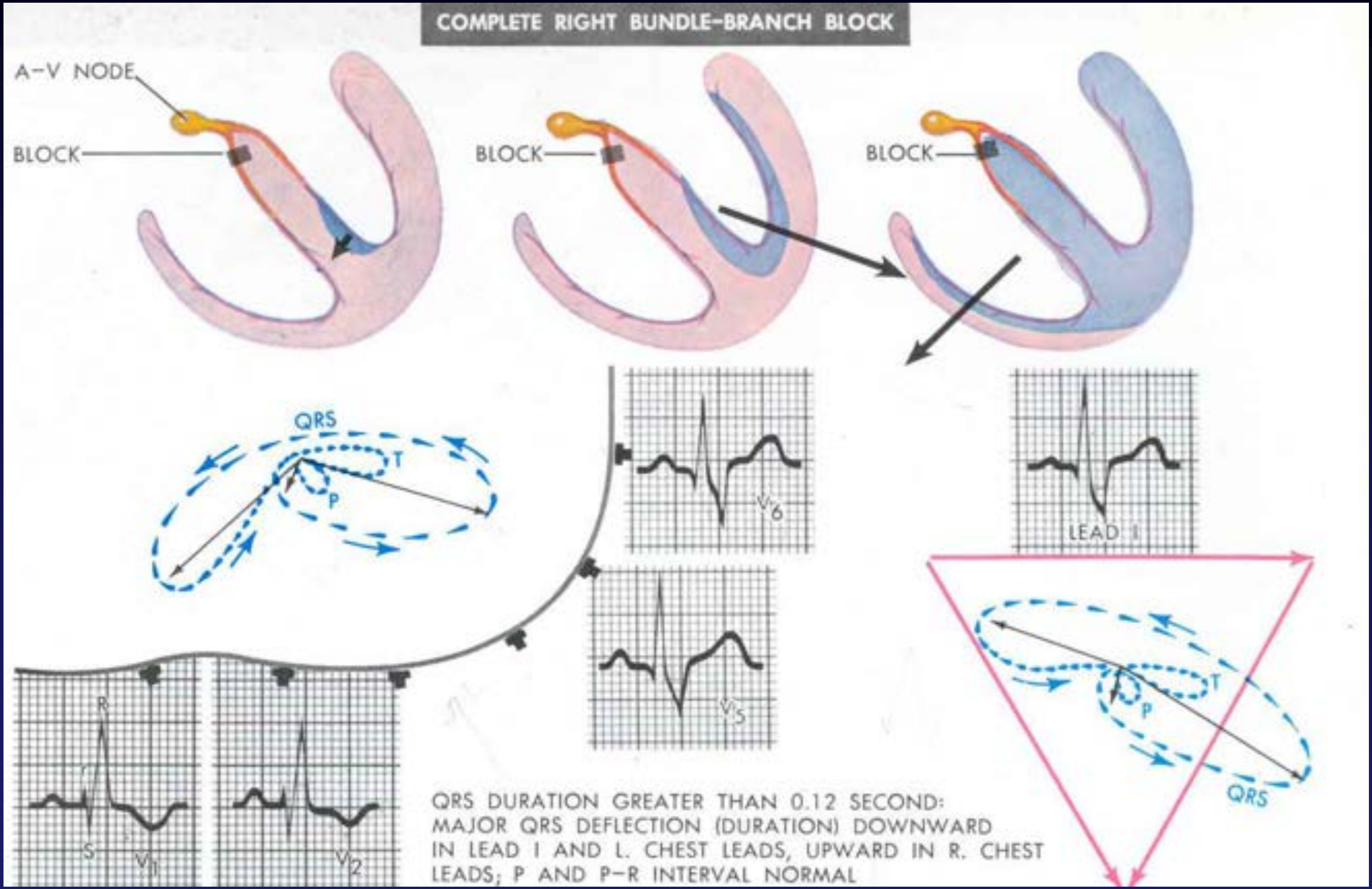
Left Bundle Branch Block



Left Bundle Branch Block



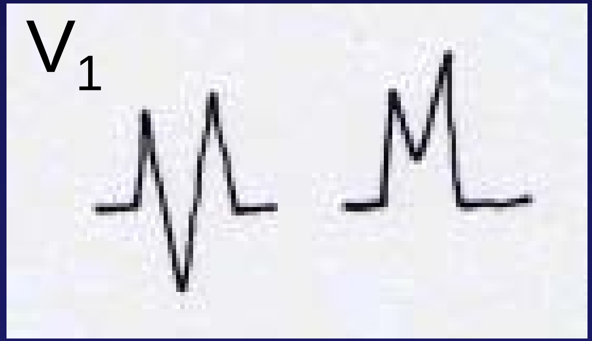
Right Bundle Branch Block



Right Bundle Branch Blocks

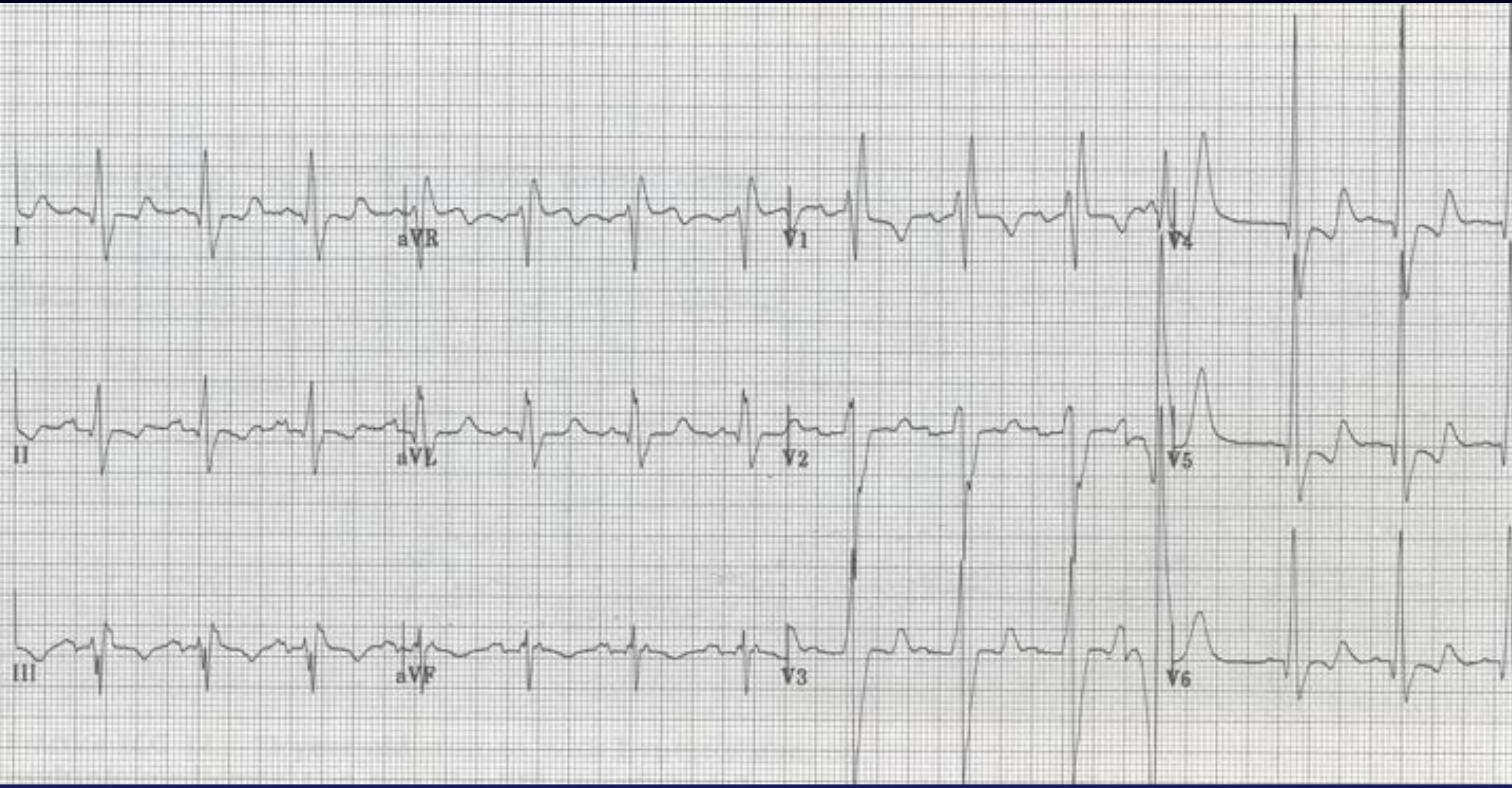
What QRS morphology is characteristic?

For RBBB the wide QRS complex assumes a unique, virtually diagnostic shape in those leads overlying the right ventricle (V_1 and V_2).

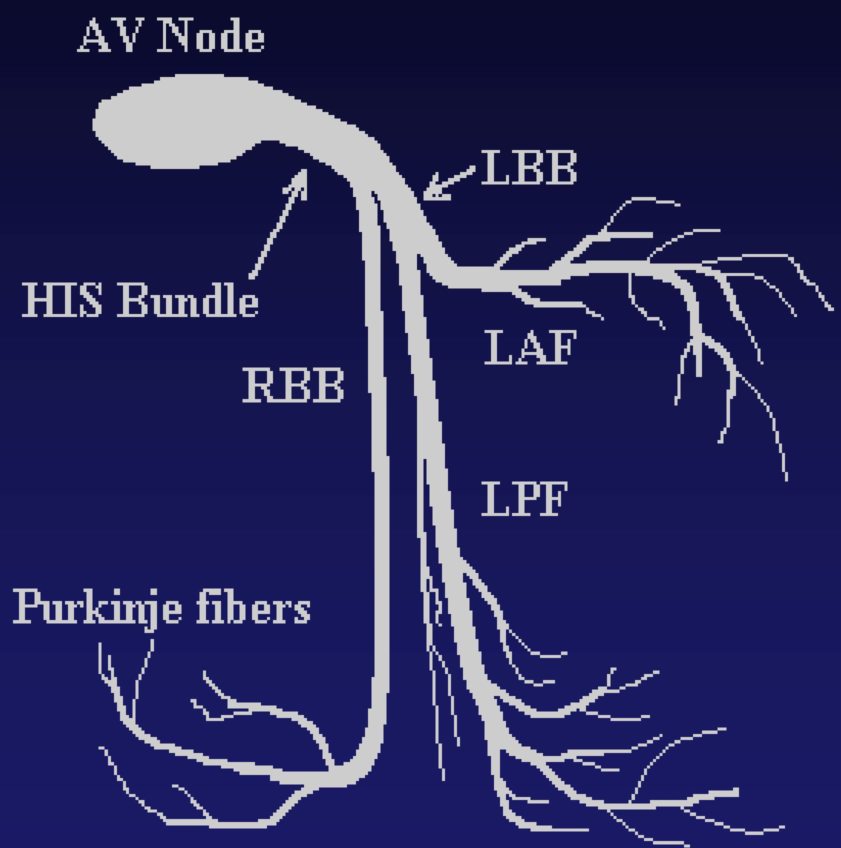


“Rabbit Ears”

RBBB

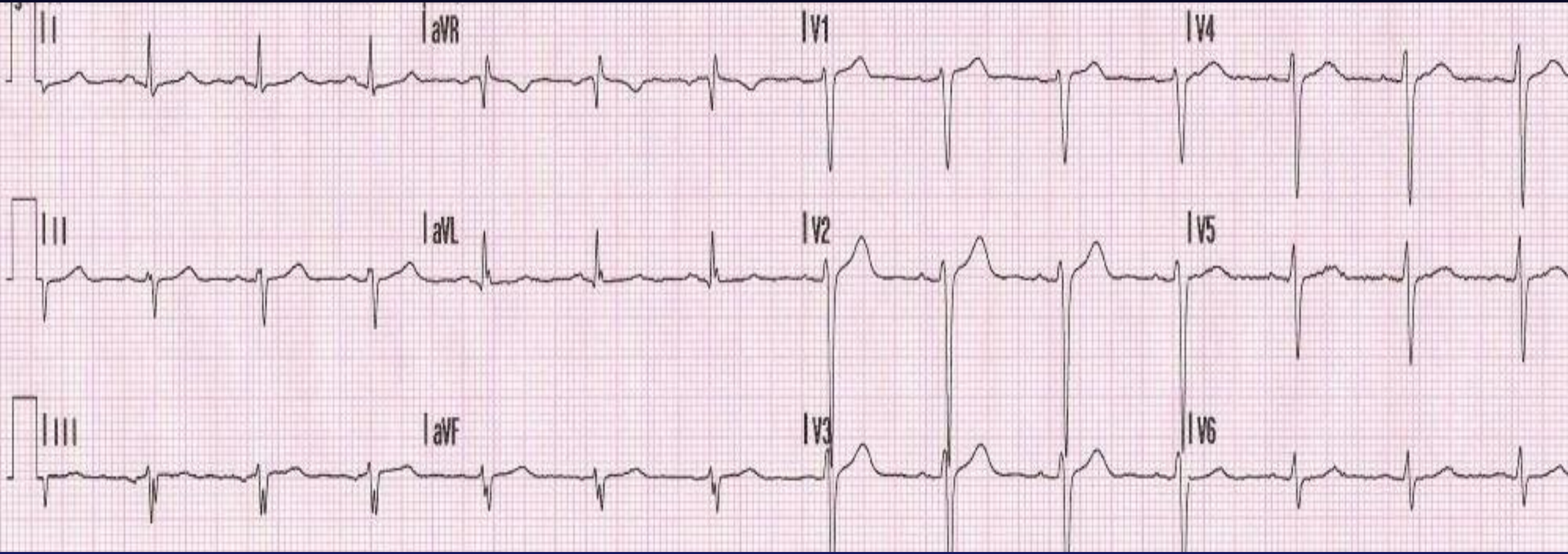


Left Bundle Branch Fascicles



Left Anterior Fascicular Block

Left Anterior Hemiblock



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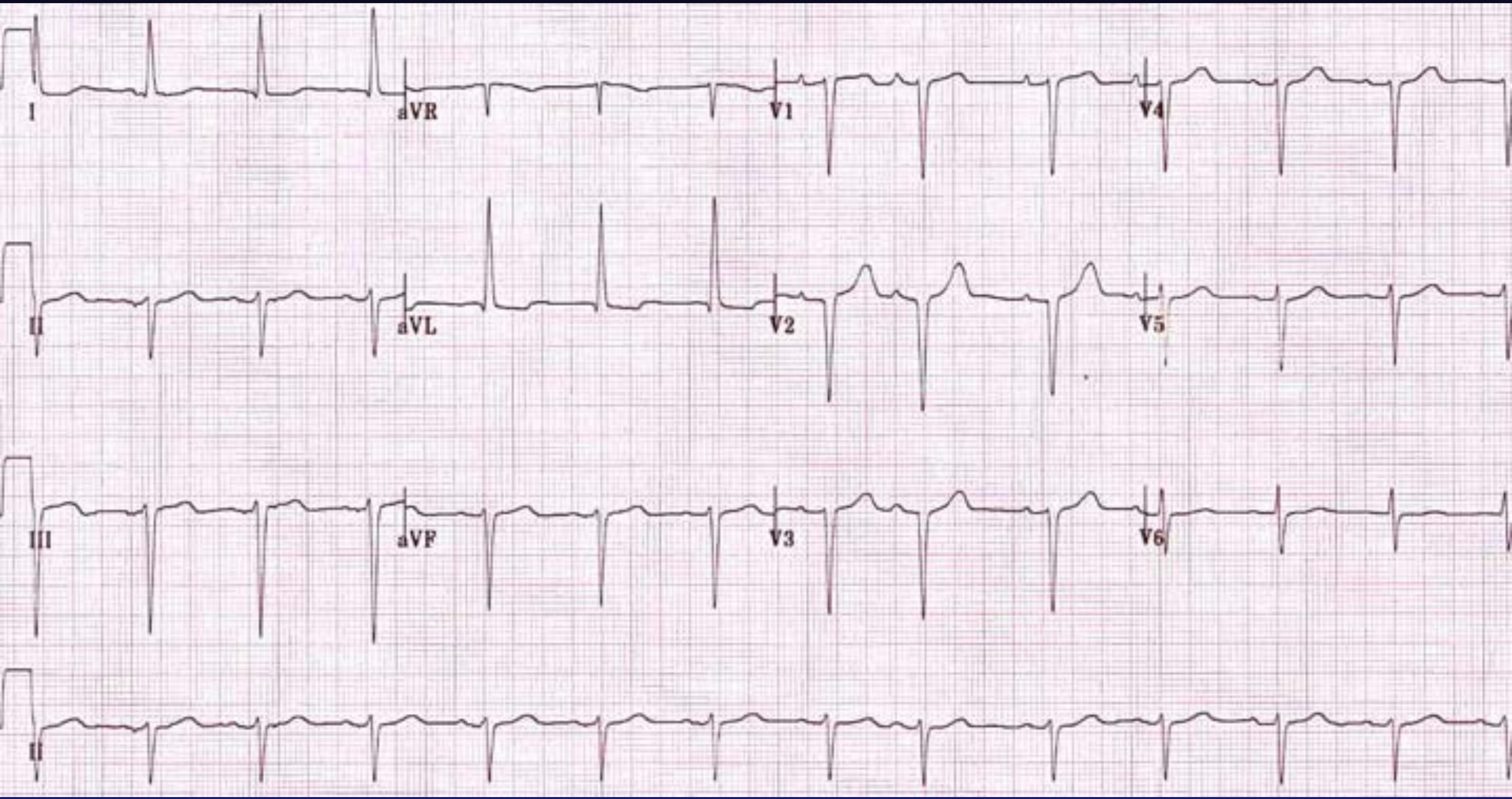
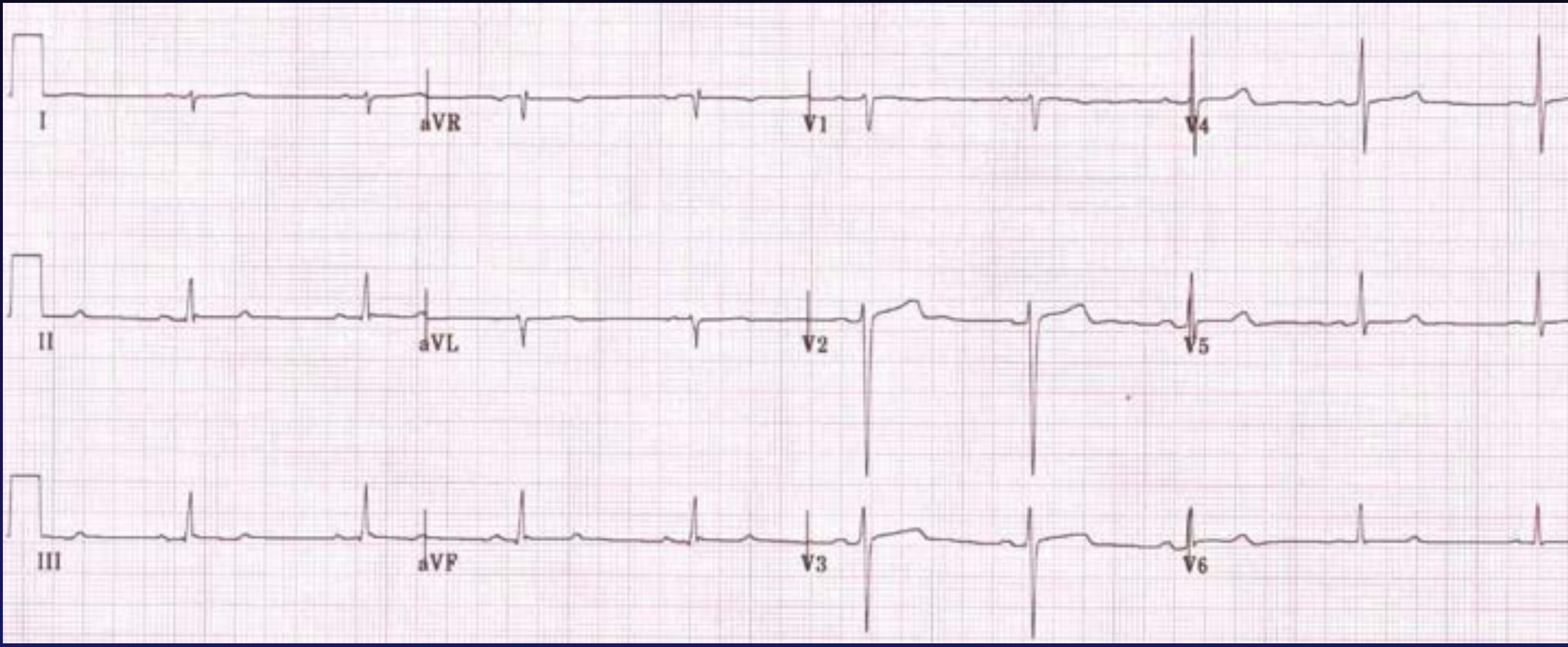
Left Anterior Fascicular Block

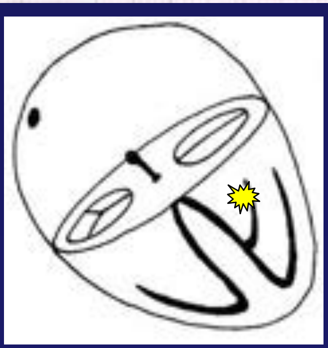
Left Anterior Hemiblock



Left Posterior Fascicular Block

Left Posterior Hemiblock





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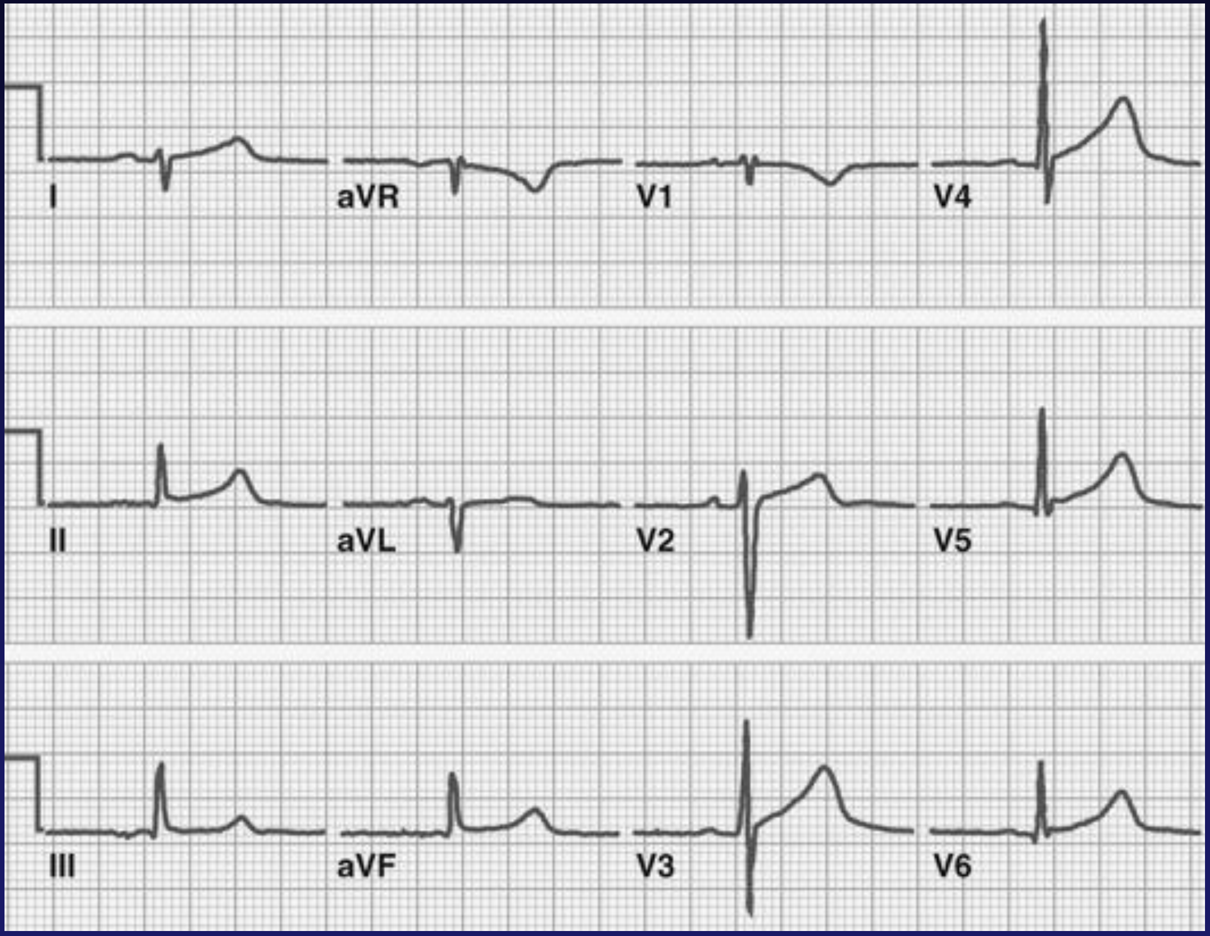
Left Posterior Fascicular Block

Left Posterior Hemiblock



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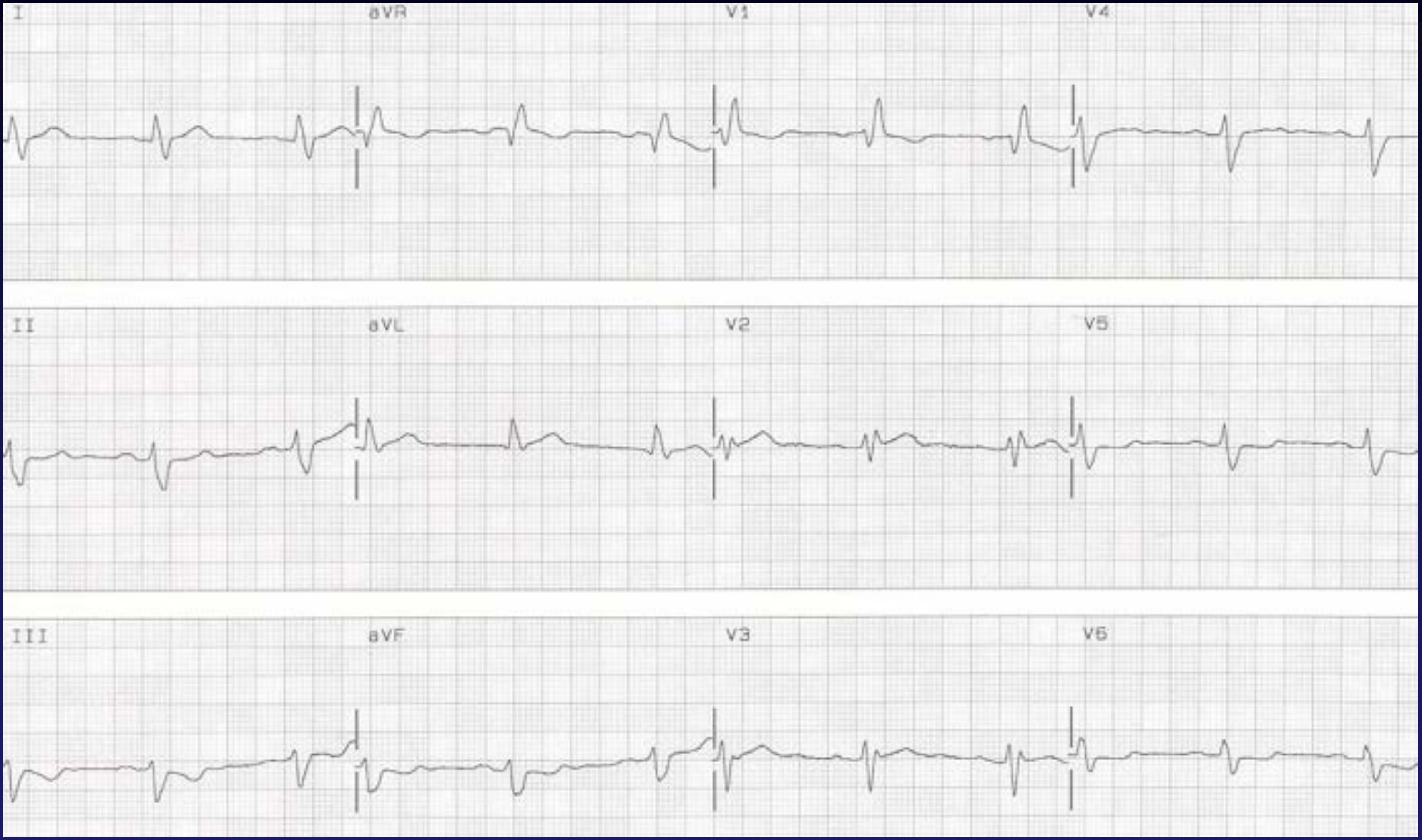
RBBB, LAH (Bifascicular Block)



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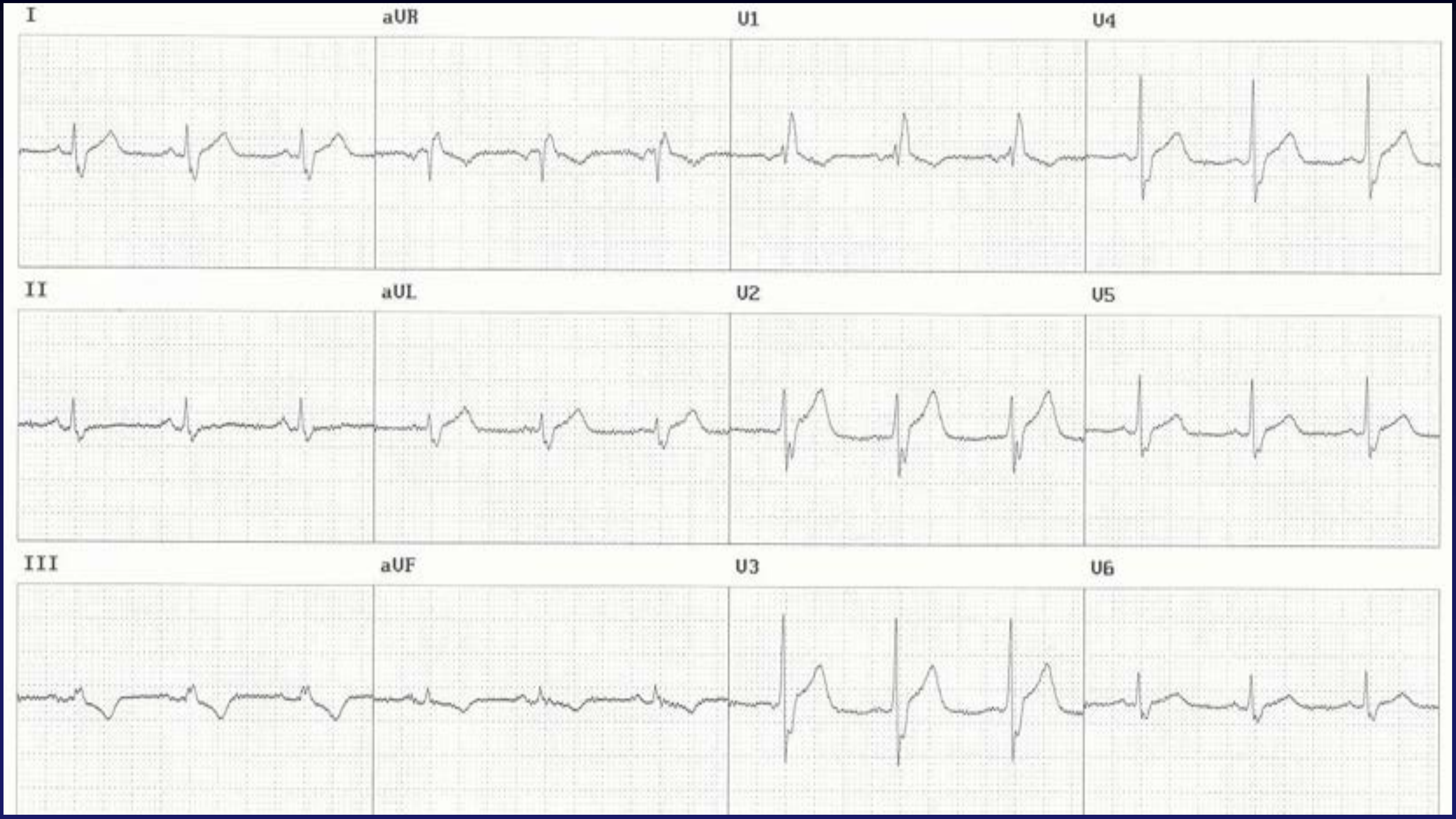
RBBB, LPH (Bifascicular Block)



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Myocardial Ischemia

- ECG is the cornerstone in the diagnosis of myocardial ischemia
- Findings depend on several factors:
  - Nature of the process, reversible vs. irreversible
  - Duration, acute vs. chronic
  - Extent, transmural vs. subendocardial
  - Localization, anterior vs. inferoposterior
  - Other underlying abnormalities

Evolution of a Myocardial Infarction

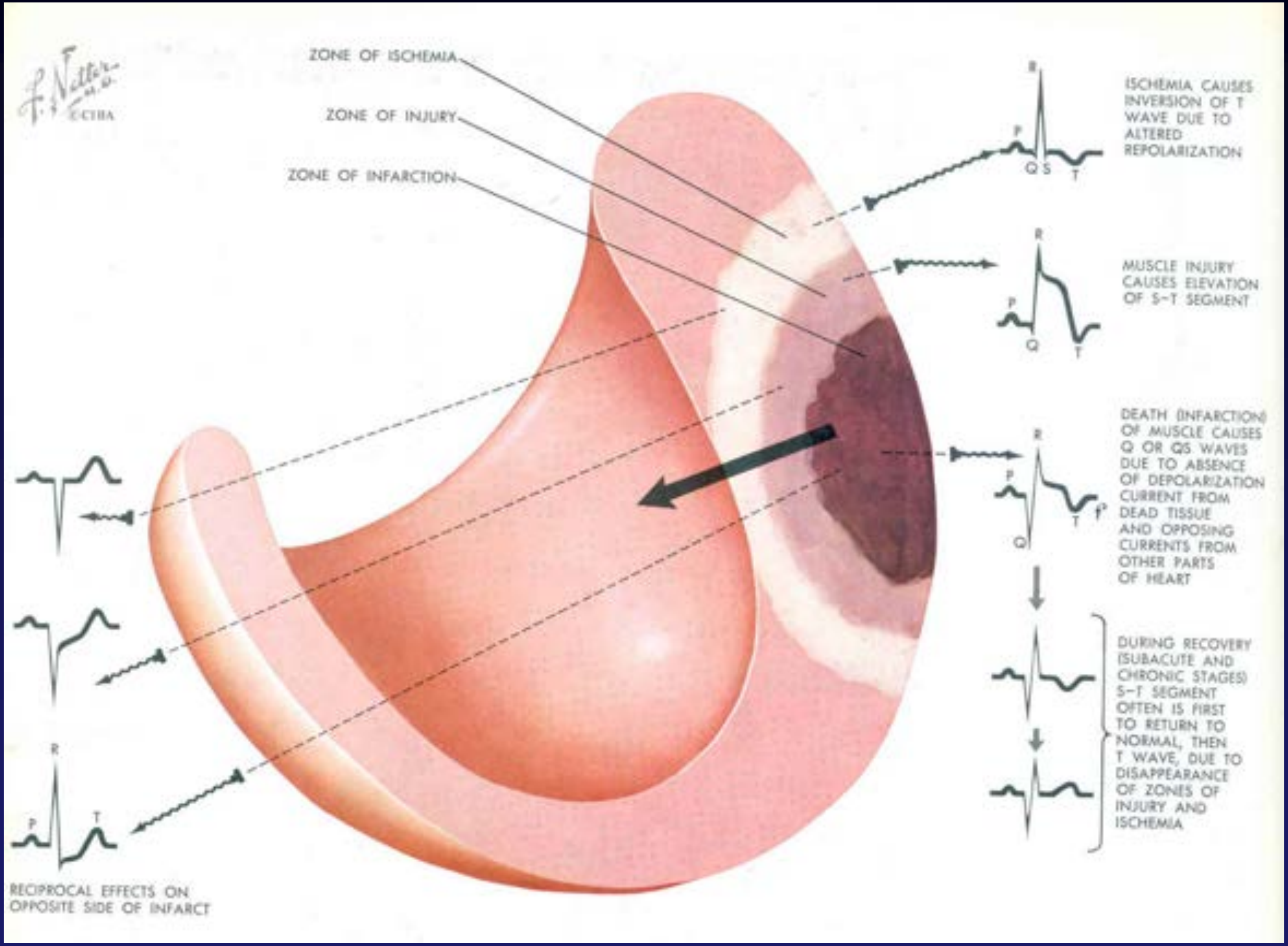
- When myocardial blood supply is abruptly reduced or cut off to a region of the heart, a sequence of injurious events occur beginning with ischemia (inadequate tissue perfusion), followed by necrosis (infarction), and eventual fibrosis (scarring) if the blood supply isn't restored in an appropriate period of time.
- The ECG changes over time with each of these events…

ST Elevation Infarction

The ECG changes seen with a ST elevation infarction are:

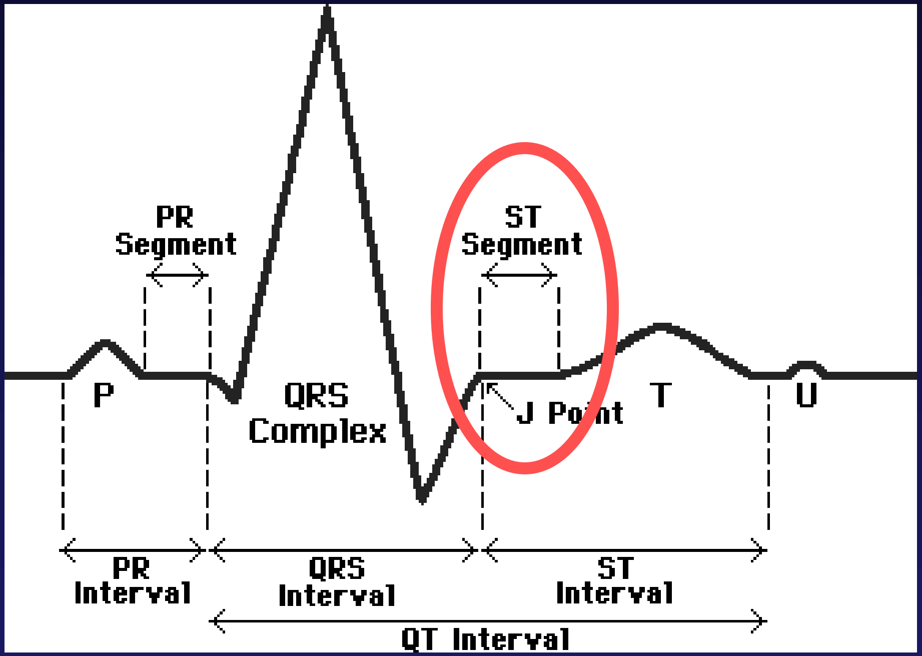
Before injury ↓	**Normal ECG**
Ischemia ↓	**Peaked T-waves, then T-wave inversion, ST depression,**
Infarction ↓	**ST elevation & appearance of Q-waves**
Fibrosis	**ST segments and T-waves return to normal, but Q-waves persist**

Acute Ischemia



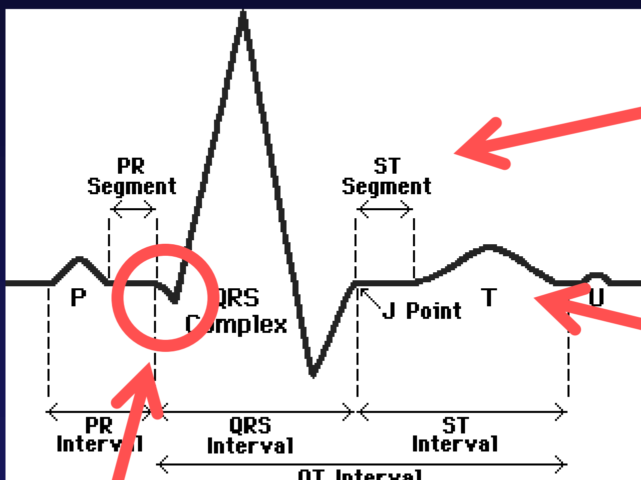
ST Elevation

A great way to diagnose an acute MI is to look for elevation of the ST segment.



ECG Changes

Ways the ECG can change include:



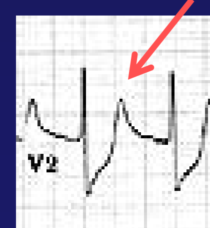
ST elevation & depression

T-waves

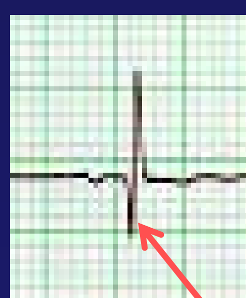
peaked

flattened

inverted



Appearance of pathologic Q-waves



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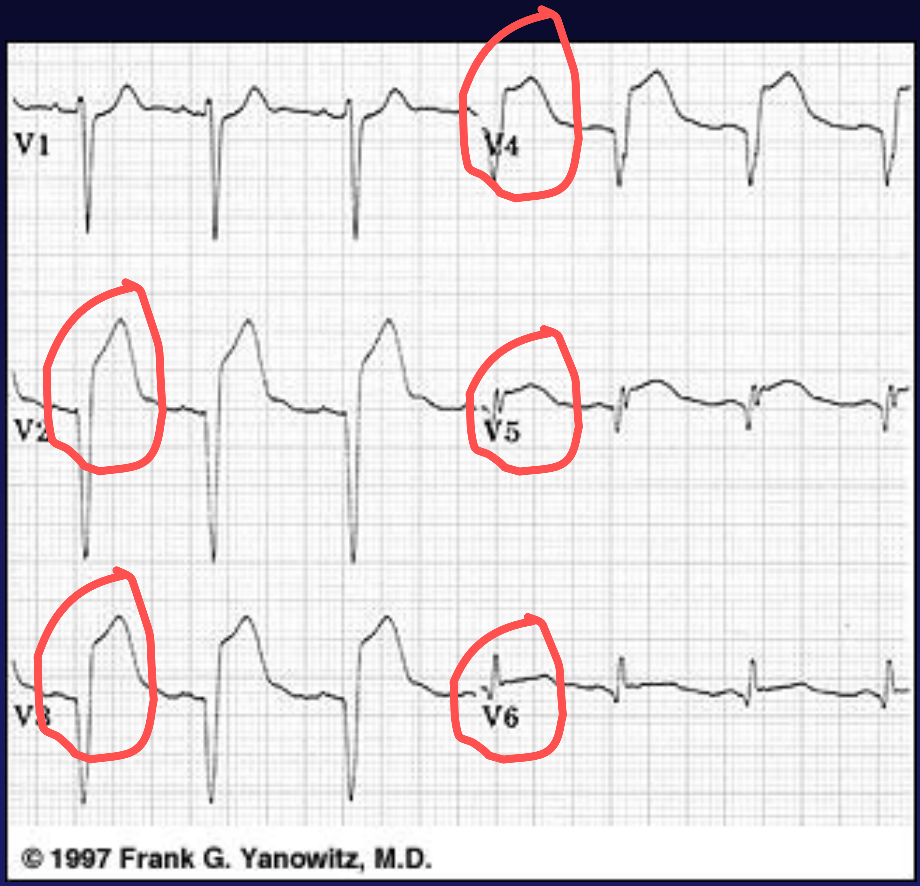
ST Elevation

Elevation of the ST segment (greater than 1 small box) in 2 leads is consistent with a myocardial infarction.



ST Elevation Infarction

Evolving infarction:

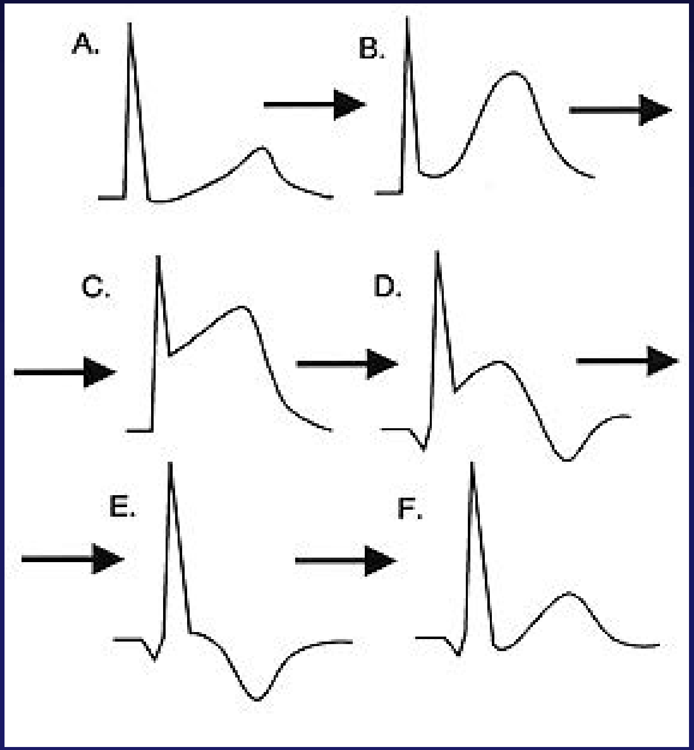
A. Normal ECG prior to MI

B. Ischemia from coronary artery occlusion results in ST depression (not shown) and peaked T-waves

C. Infarction from ongoing ischemia results in marked ST elevation

D/E. Ongoing infarction with appearance of pathologic Q-waves and T-wave inversion

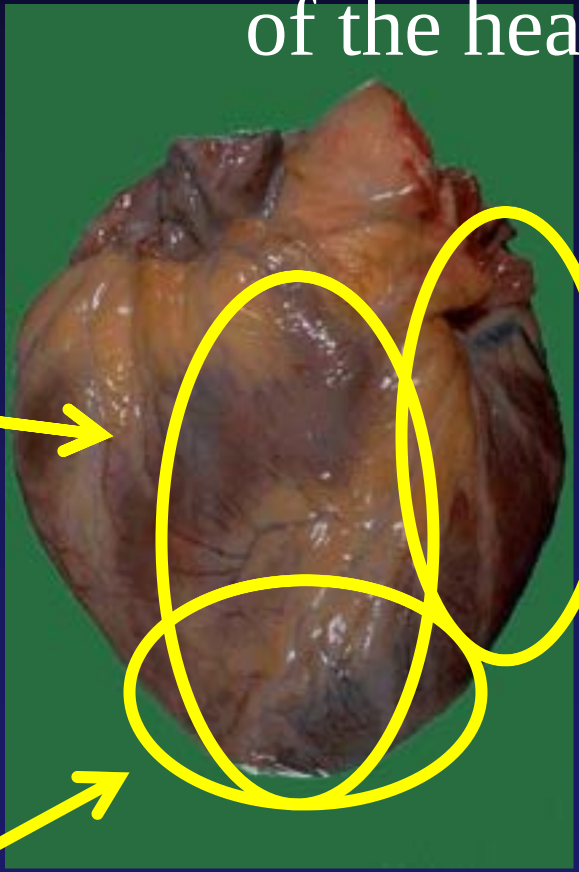
F. Fibrosis (months later) with persistent Q- waves, but normal ST segment and T- waves



Views of the Heart

Some leads get a good view of the:

Lateral portion of the heart



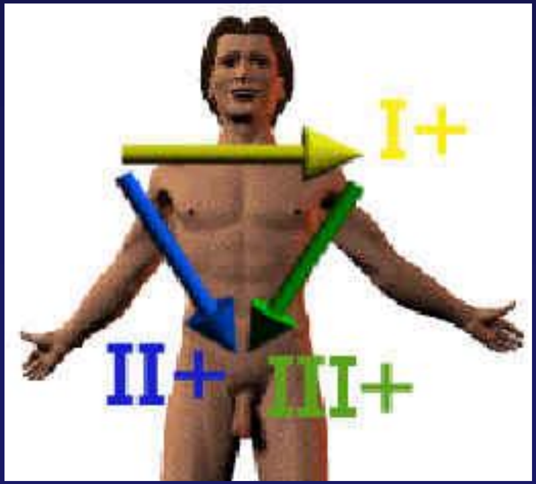
Anterior portion of the heart

Inferior portion of the heart

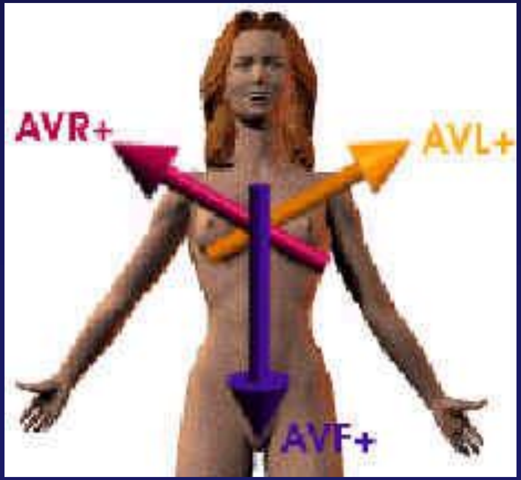
Anterior MI

Remember the anterior portion of the heart is best viewed using leads V_1- V_4.

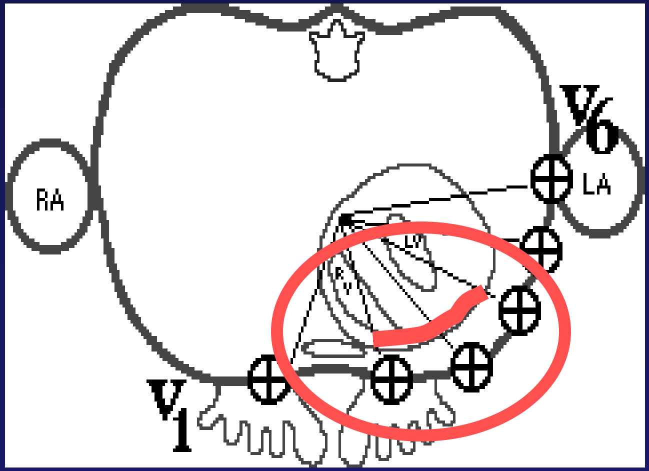
Limb Leads



Augmented Leads



Precordial Leads

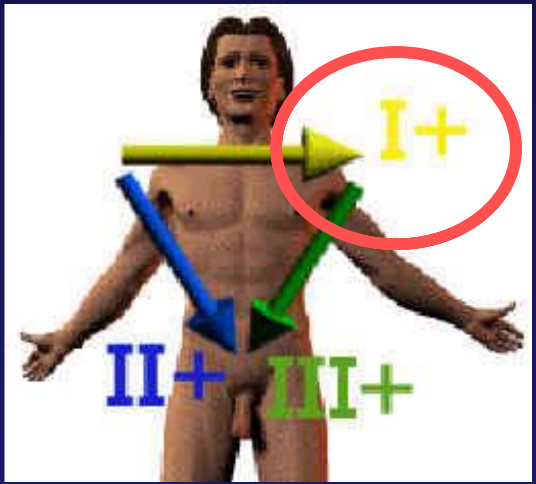


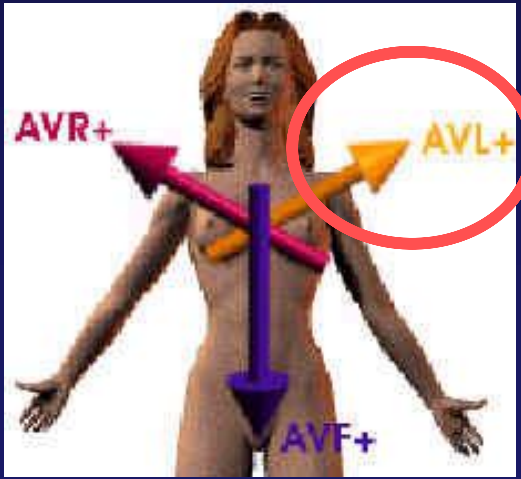
Lateral MI

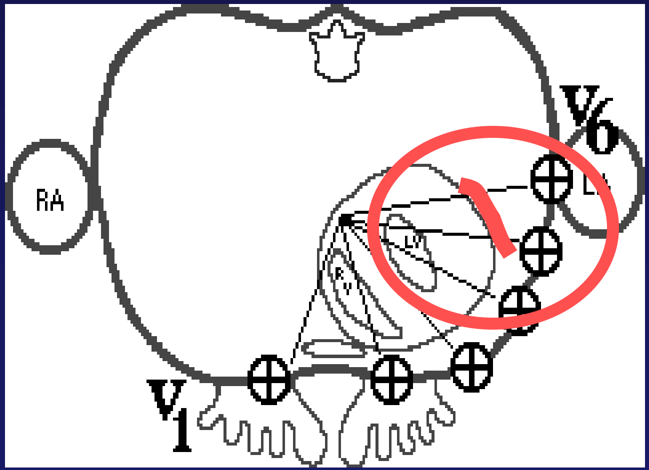
The lateral portion of the heart is best viewed by:

Leads I, aVL, and V_5- V_6

Limb Leads **Augmented Leads** **Precordial Leads**







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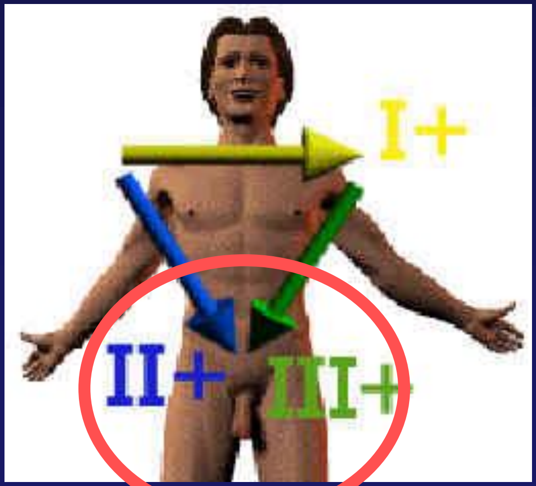
Inferior MI

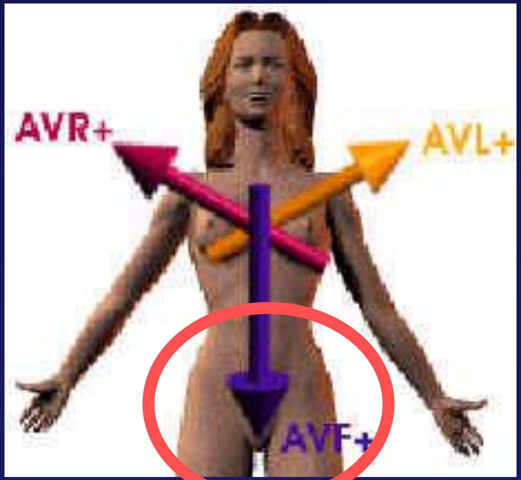
The inferior portion of the heart by:

Leads II, III and aVF

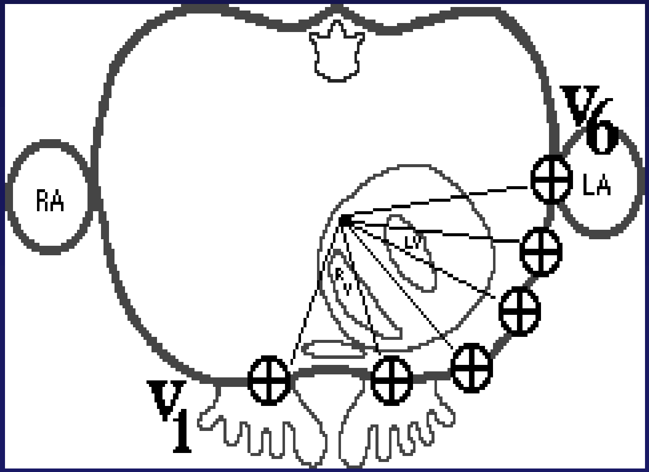
Limb Leads



Augmented Leads



Precordial Leads



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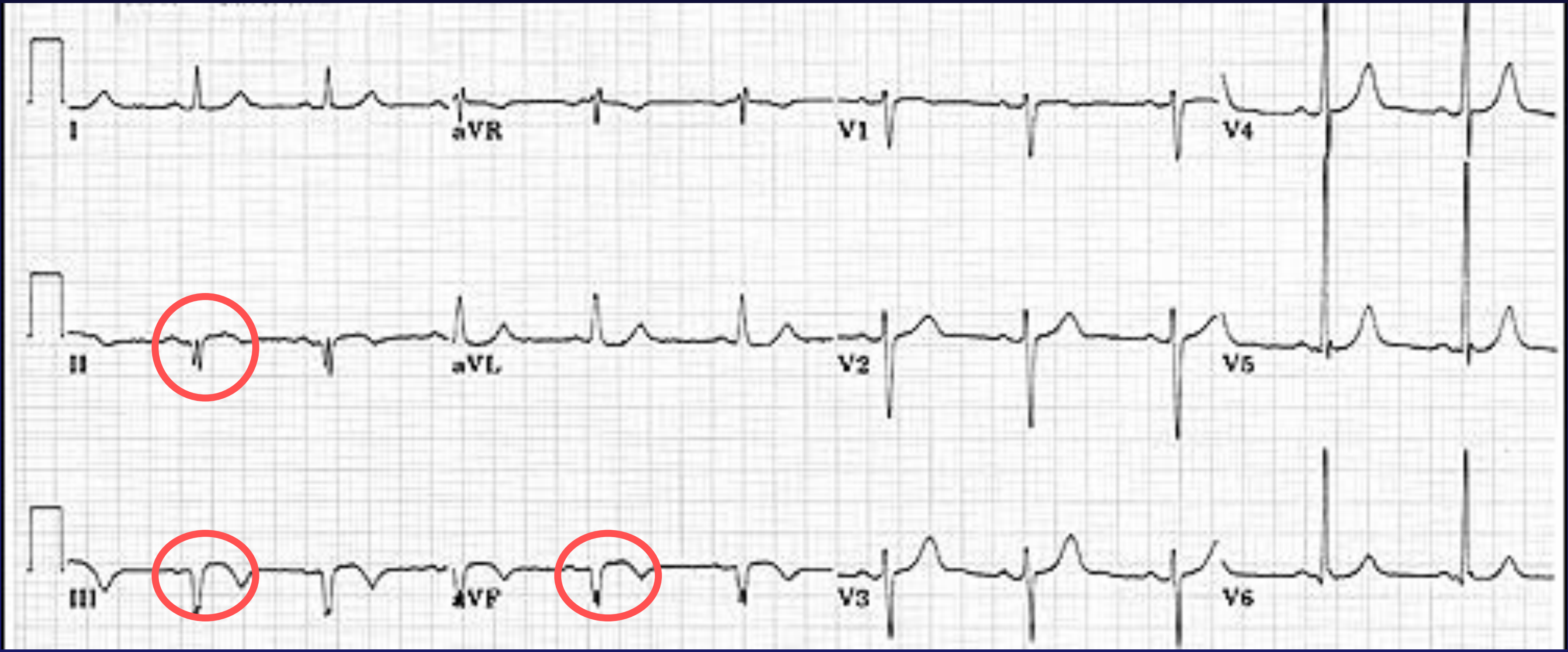
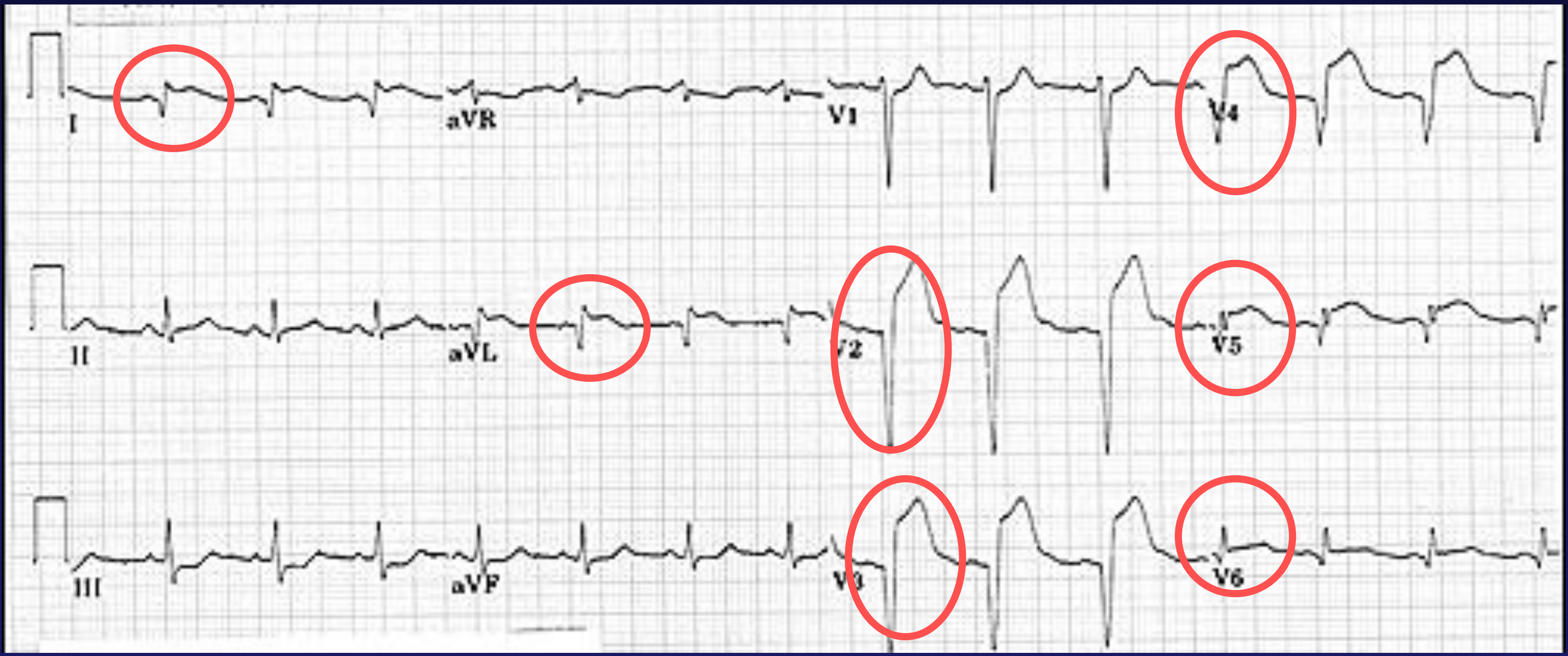
Inferior Wall MI

Note the ST elevation in leads II, III and aVF.

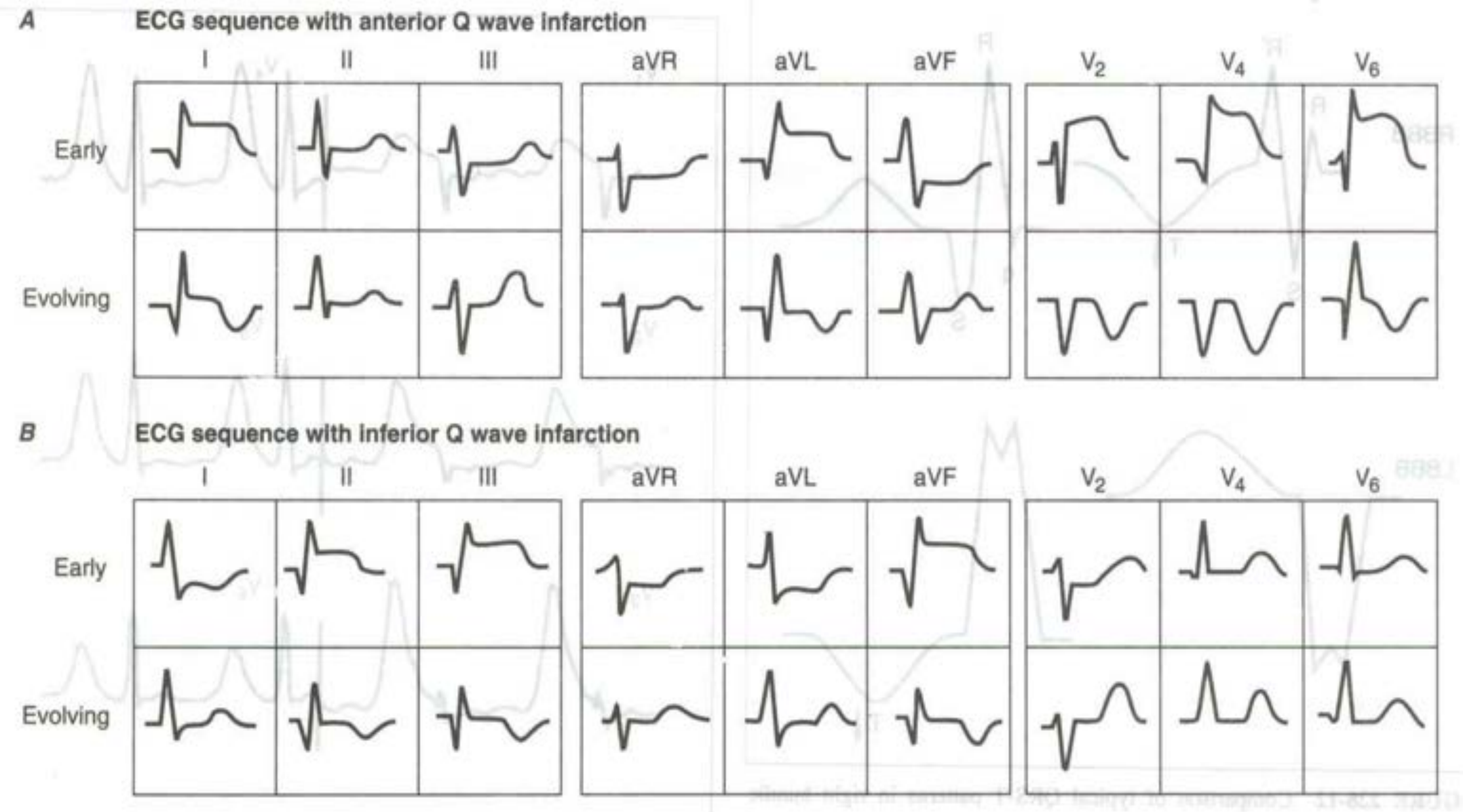


Anterolateral MI

This person's MI involves both the anterior wall (V_2-V_4) and the lateral wall (V_5-V_6, I, and aVL)!

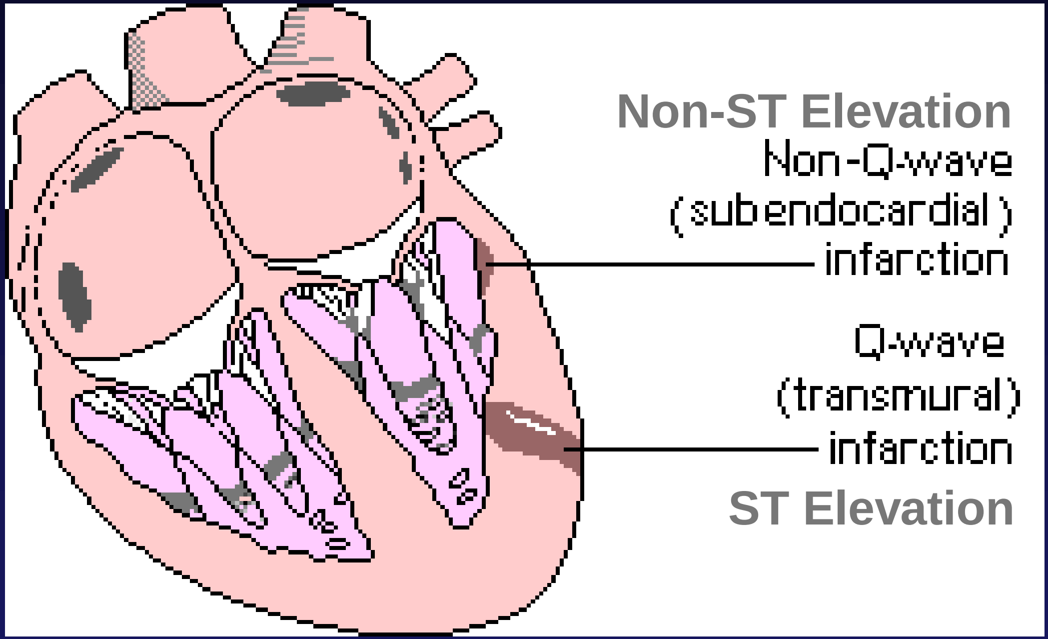


Myocardial Infarction



Non-ST Elevation MI

There are two distinct patterns of ECG change depending if the infarction is:

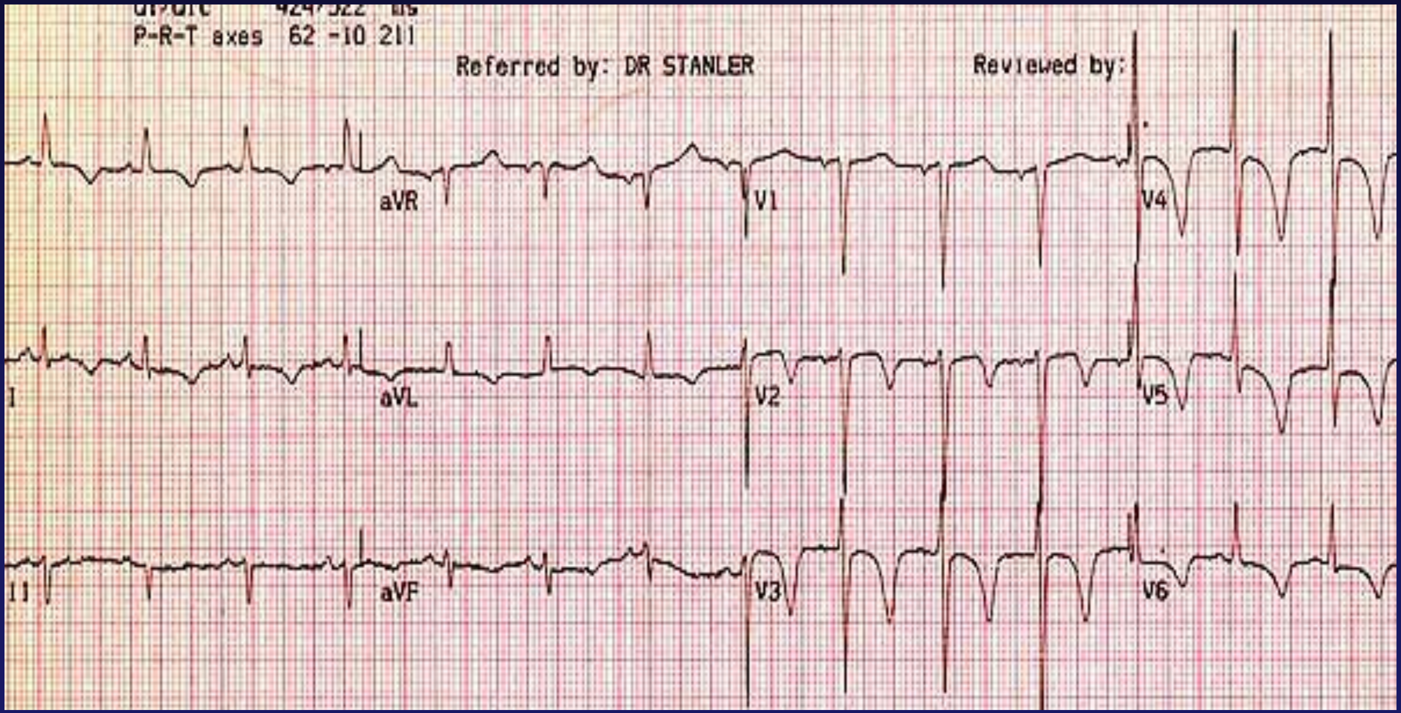


- ST Elevation (Transmural or Q-wave), or
- Non-ST Elevation (Subendocardial or non-Q-wave)

Non-ST Elevation Infarction

ECG of an evolving non-ST elevation MI:

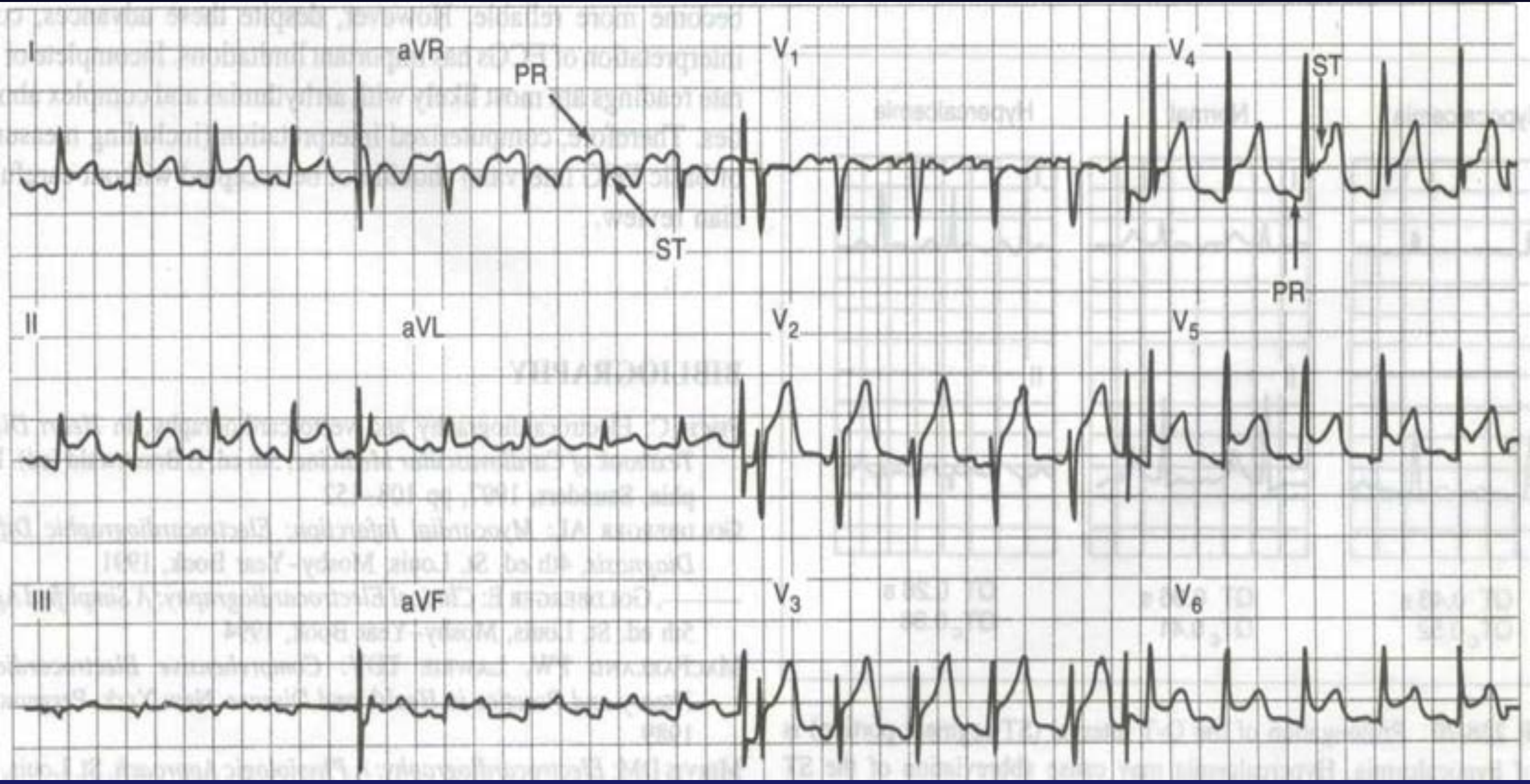
Note the ST depression and T-wave inversion in leads V_2-V_6.



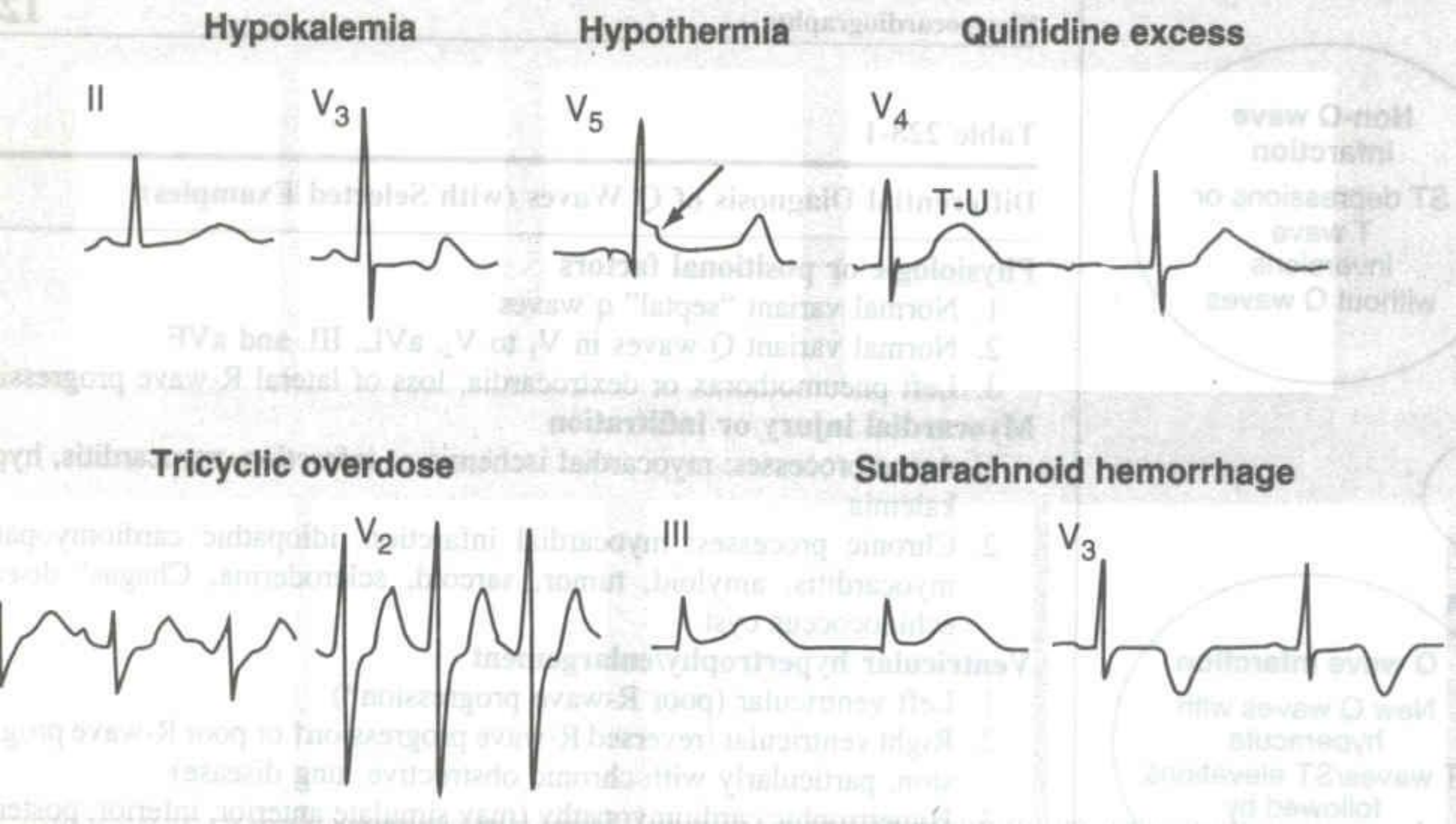
Question:
What area of the heart is infarcting?

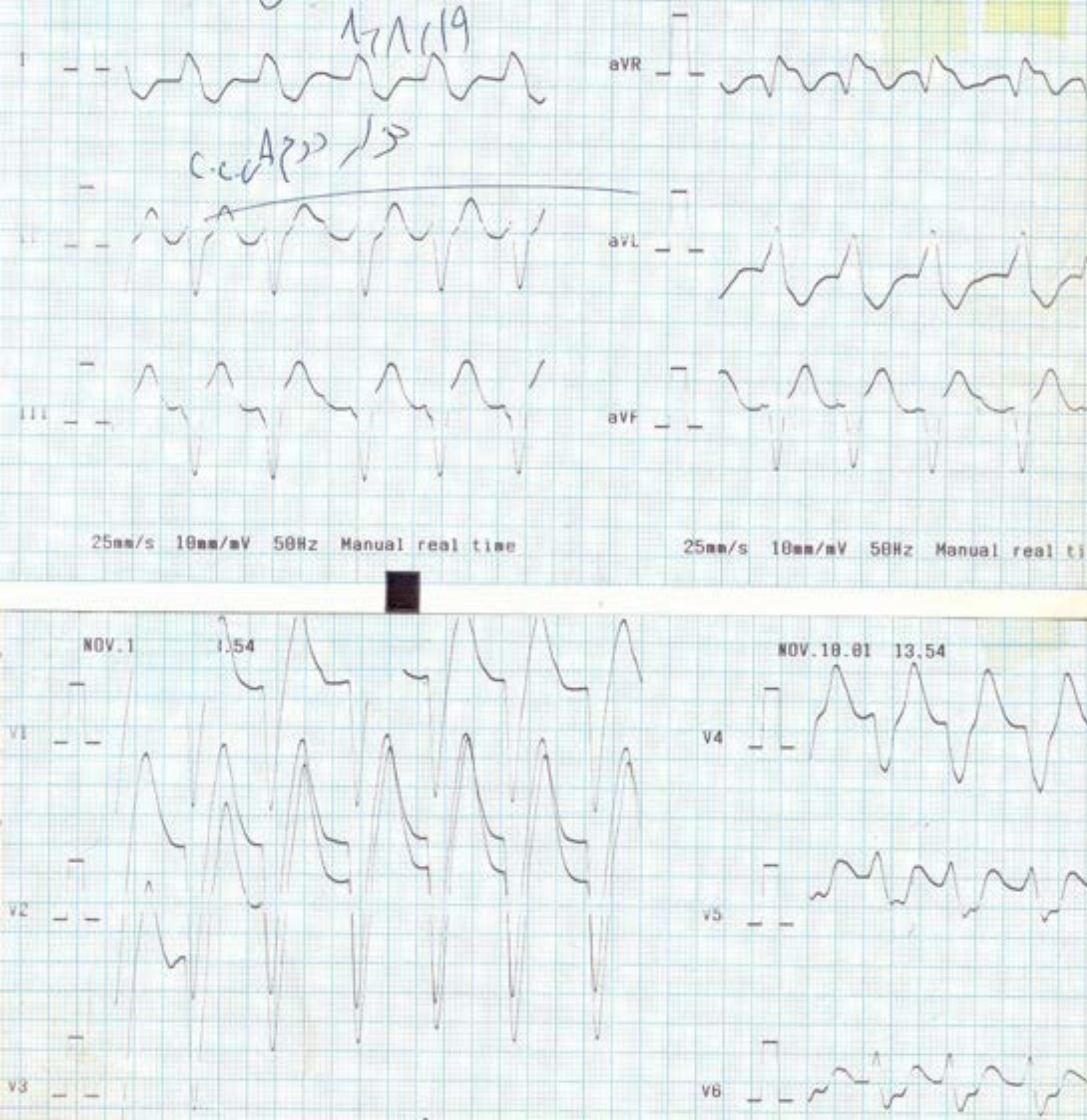
Cannot say!

Acute Pericarditis



Metabolic Abnormalities





Hyper-kalemia K 6.9

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Same patient

K 3.9

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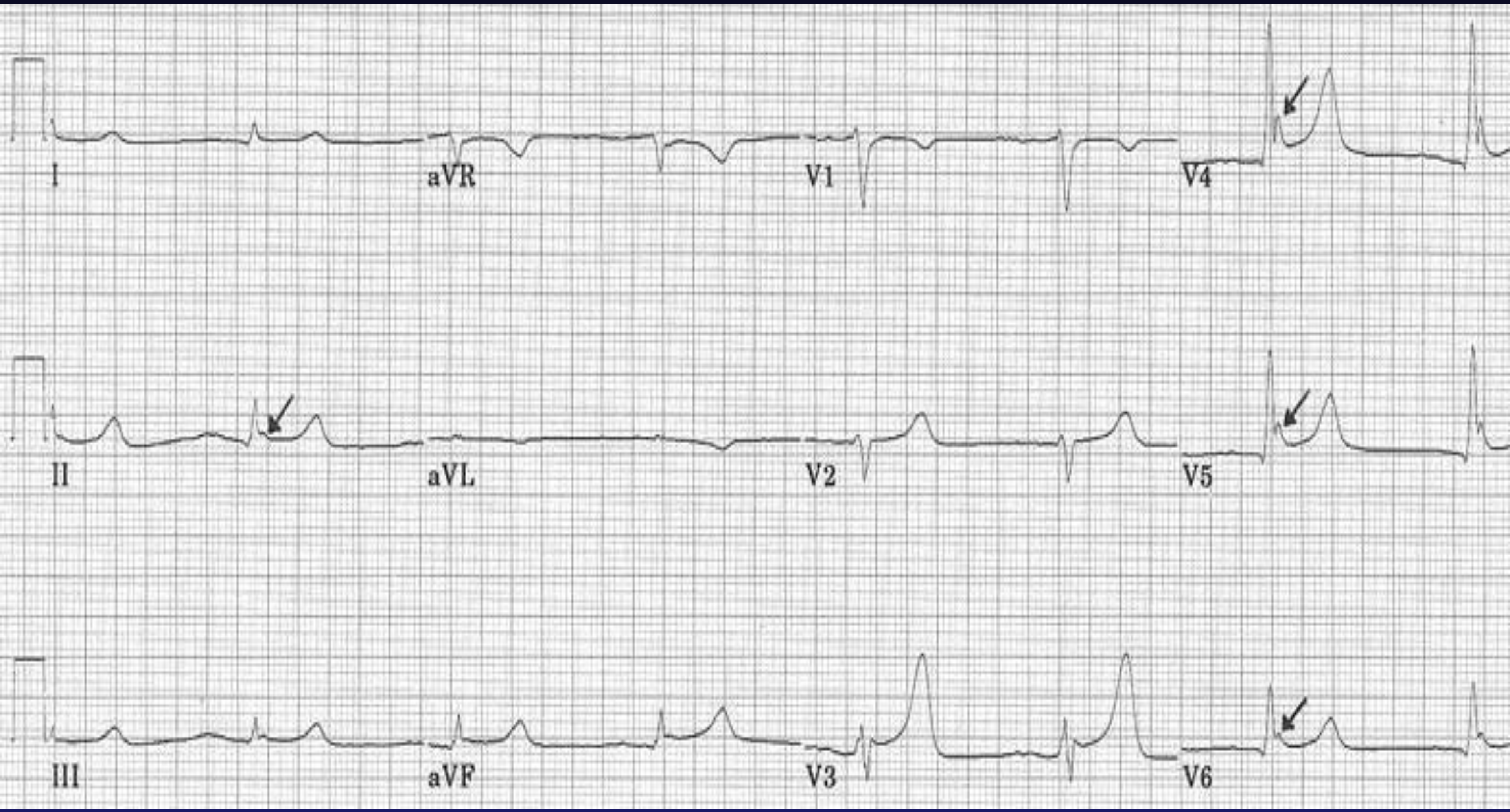
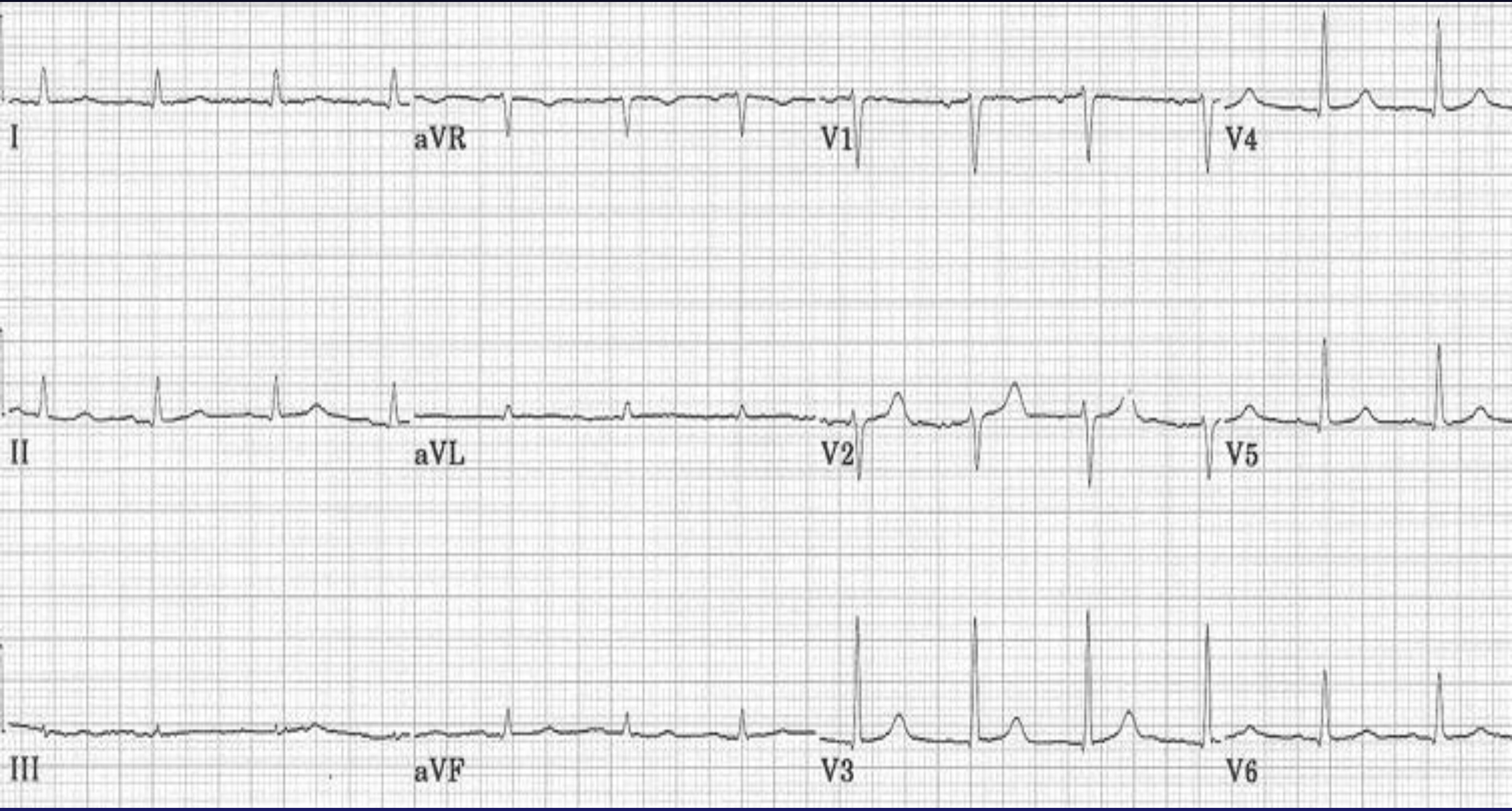
Hypothermia, Osborn Wave



Hypothermia, Corrected

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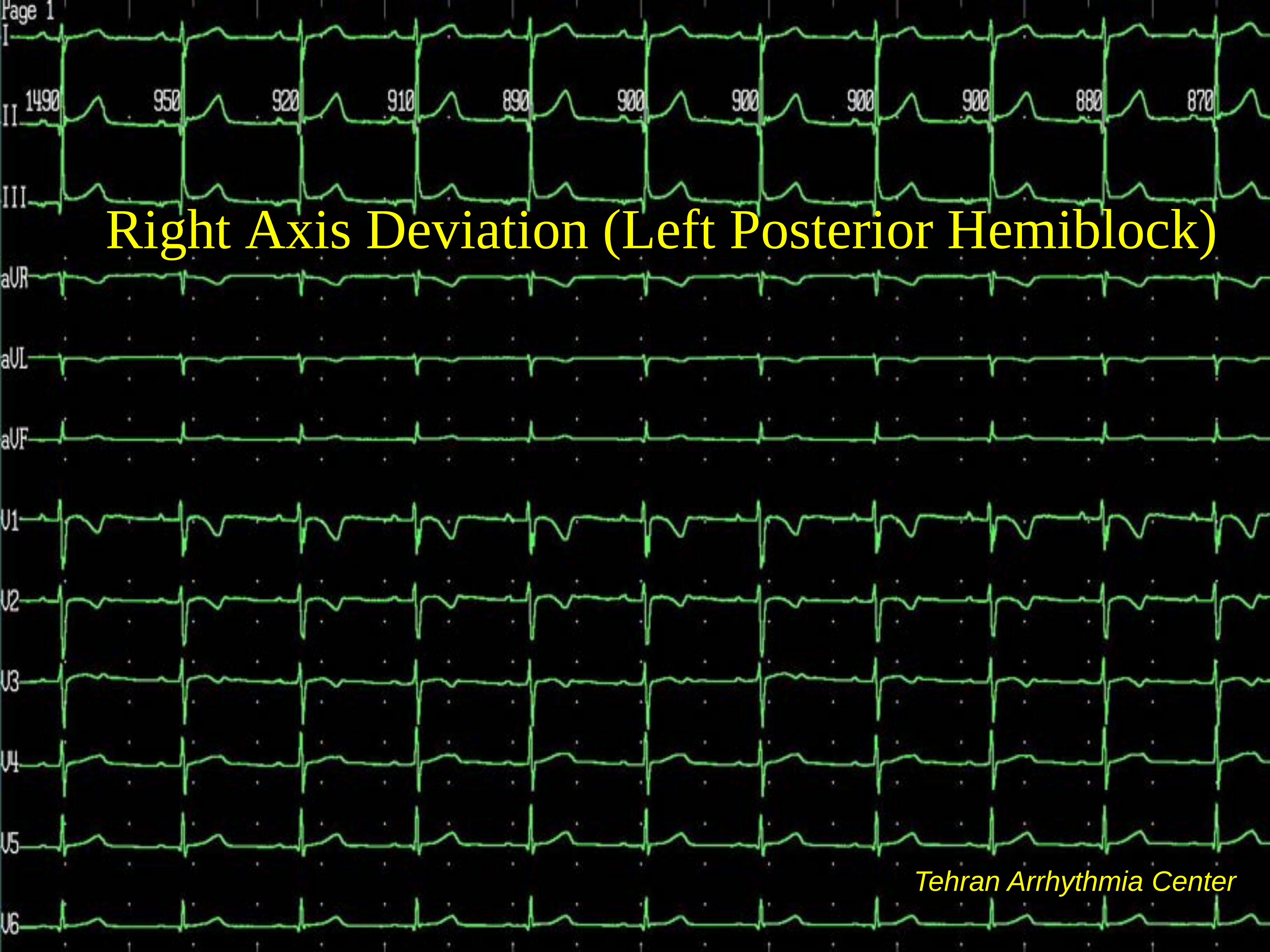
Right Axis Deviation (Left Posterior Hemiblock)



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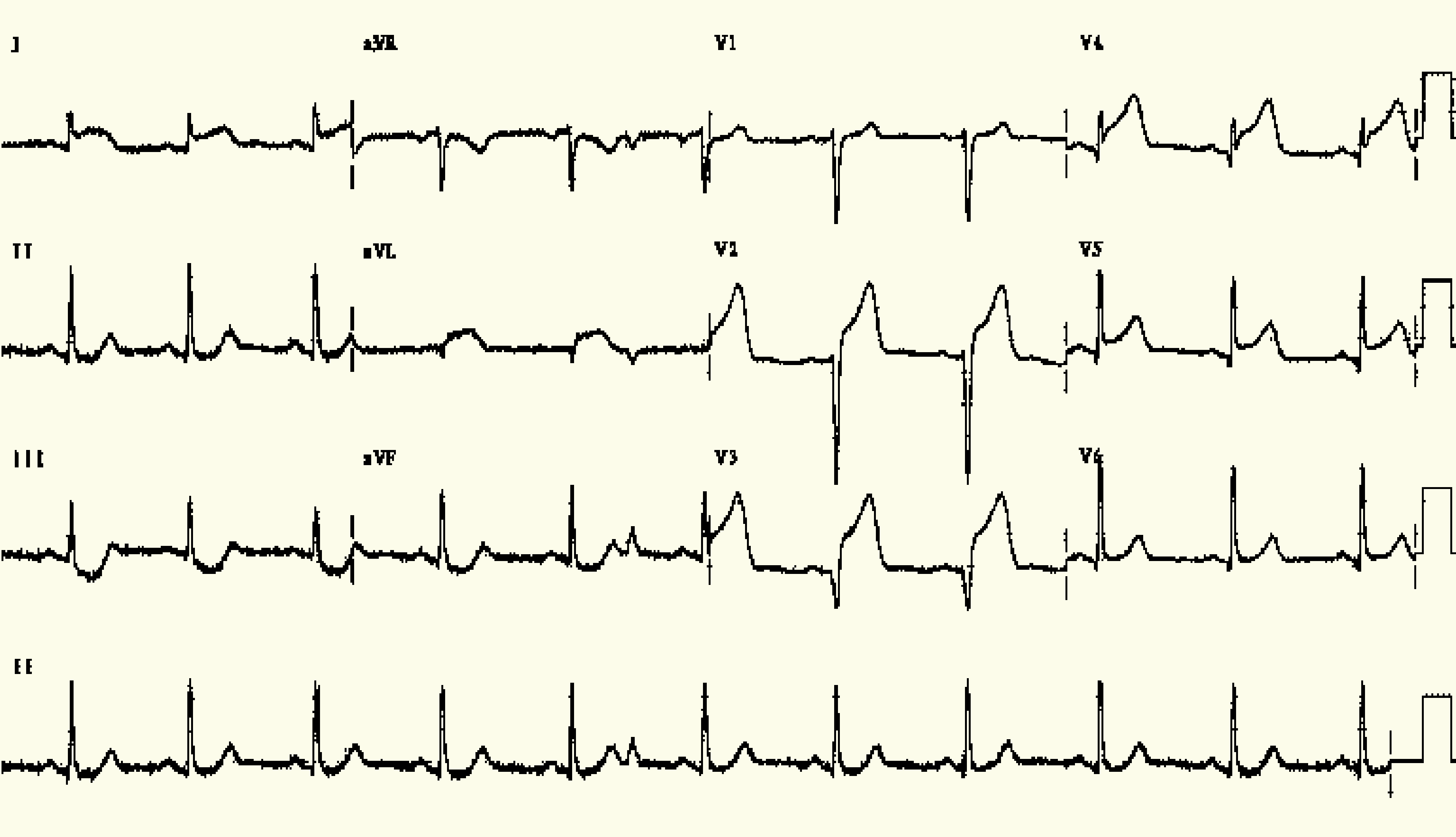
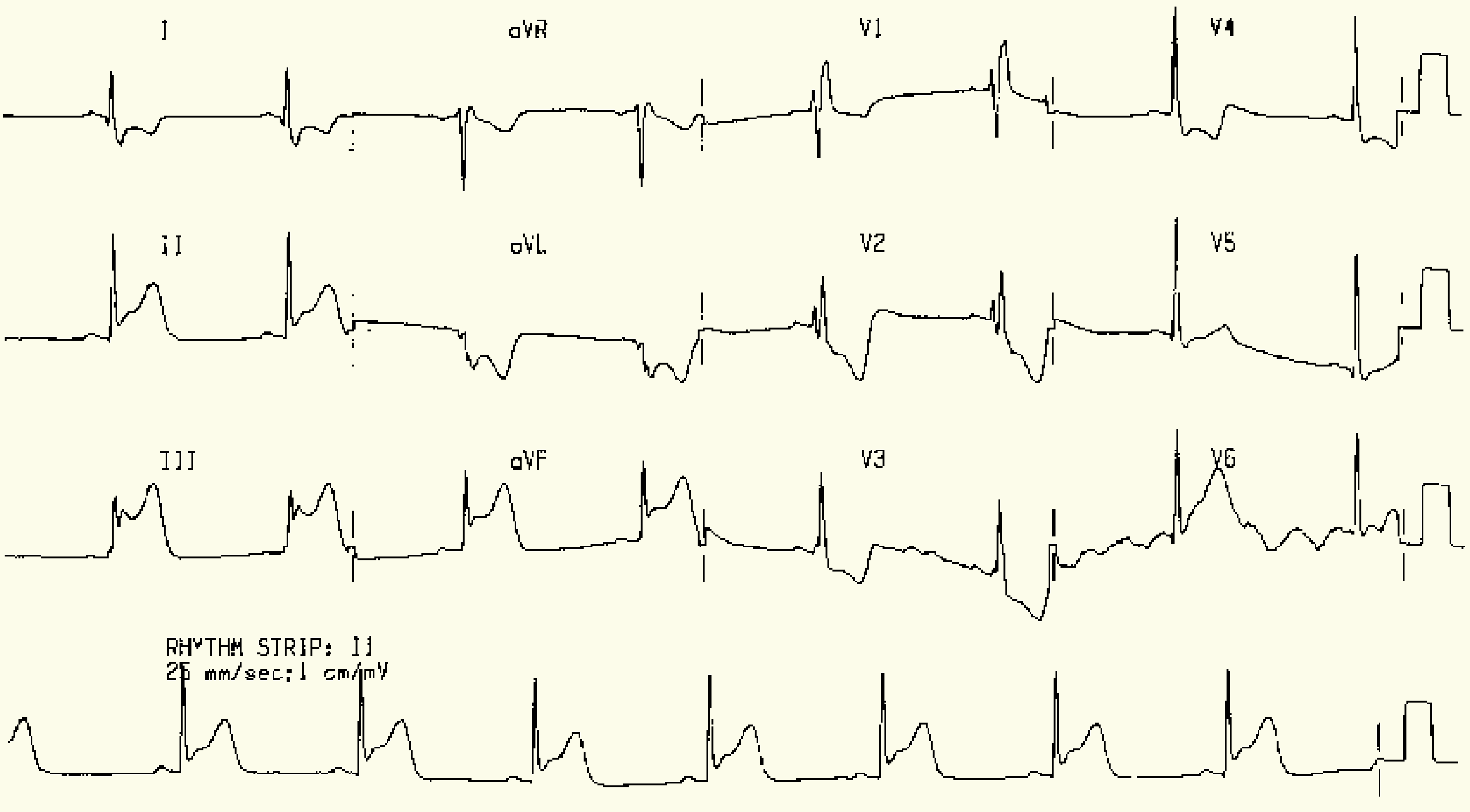
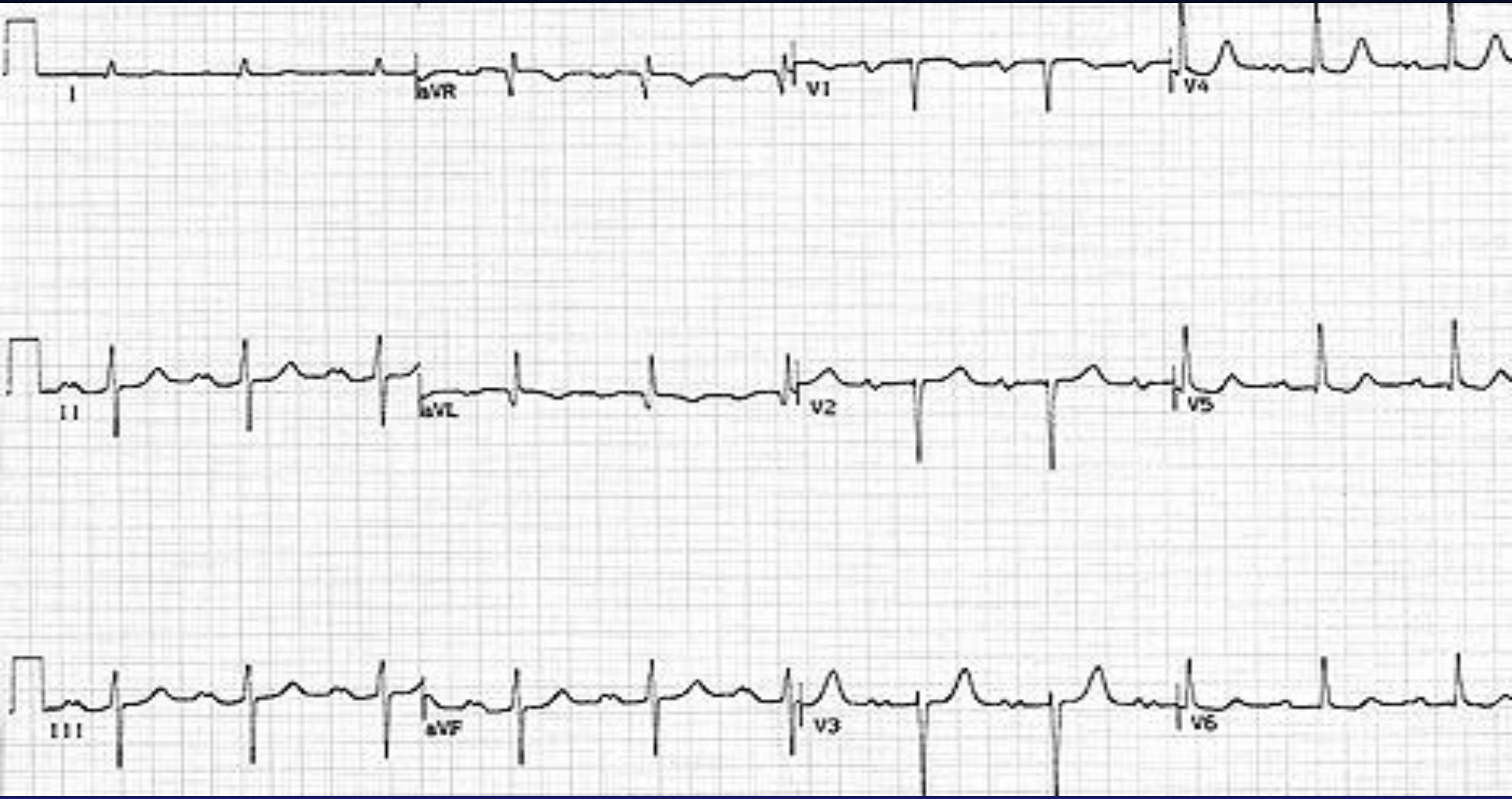
Anterior MI



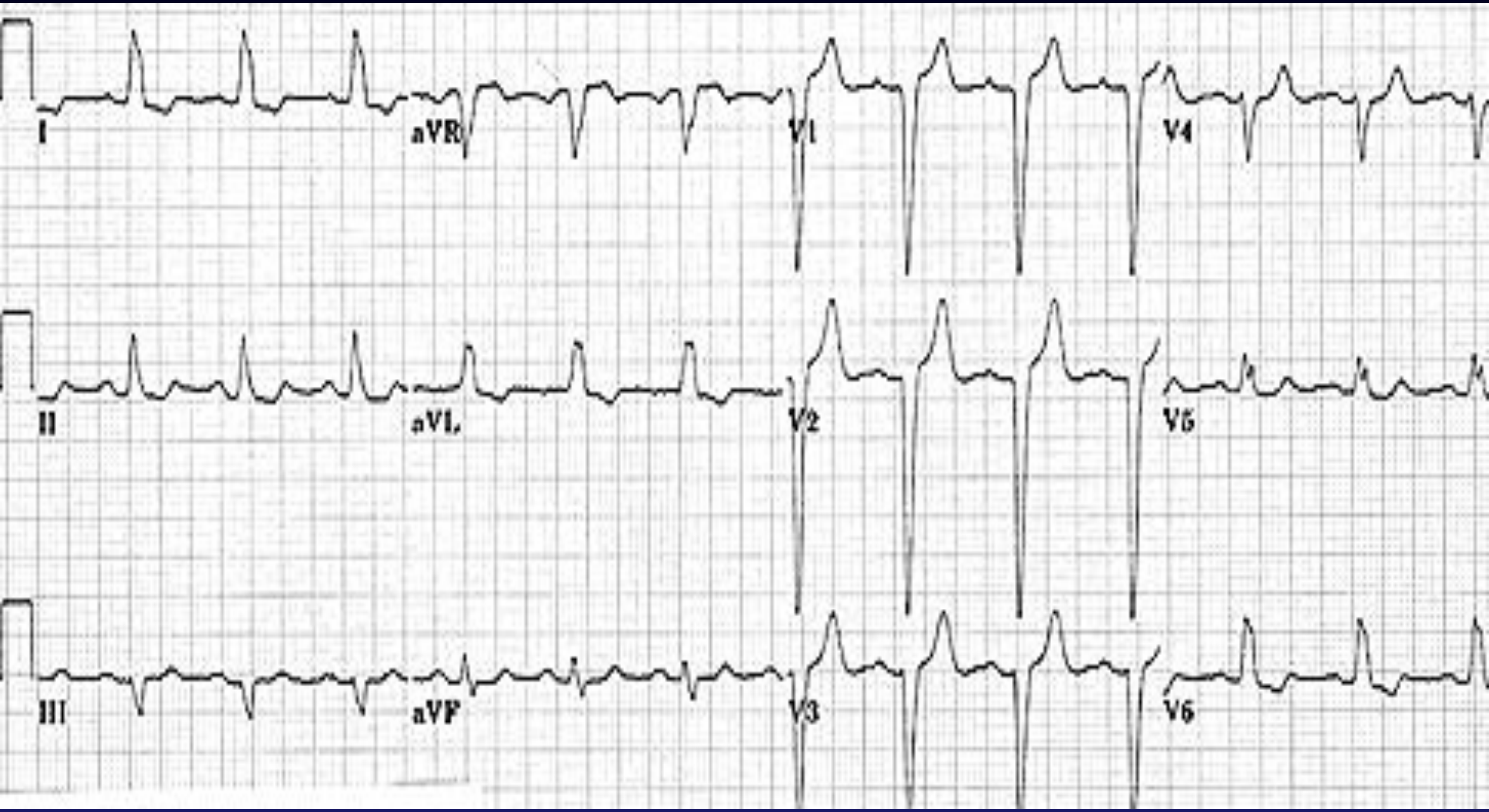
RBBB and Inferior MI



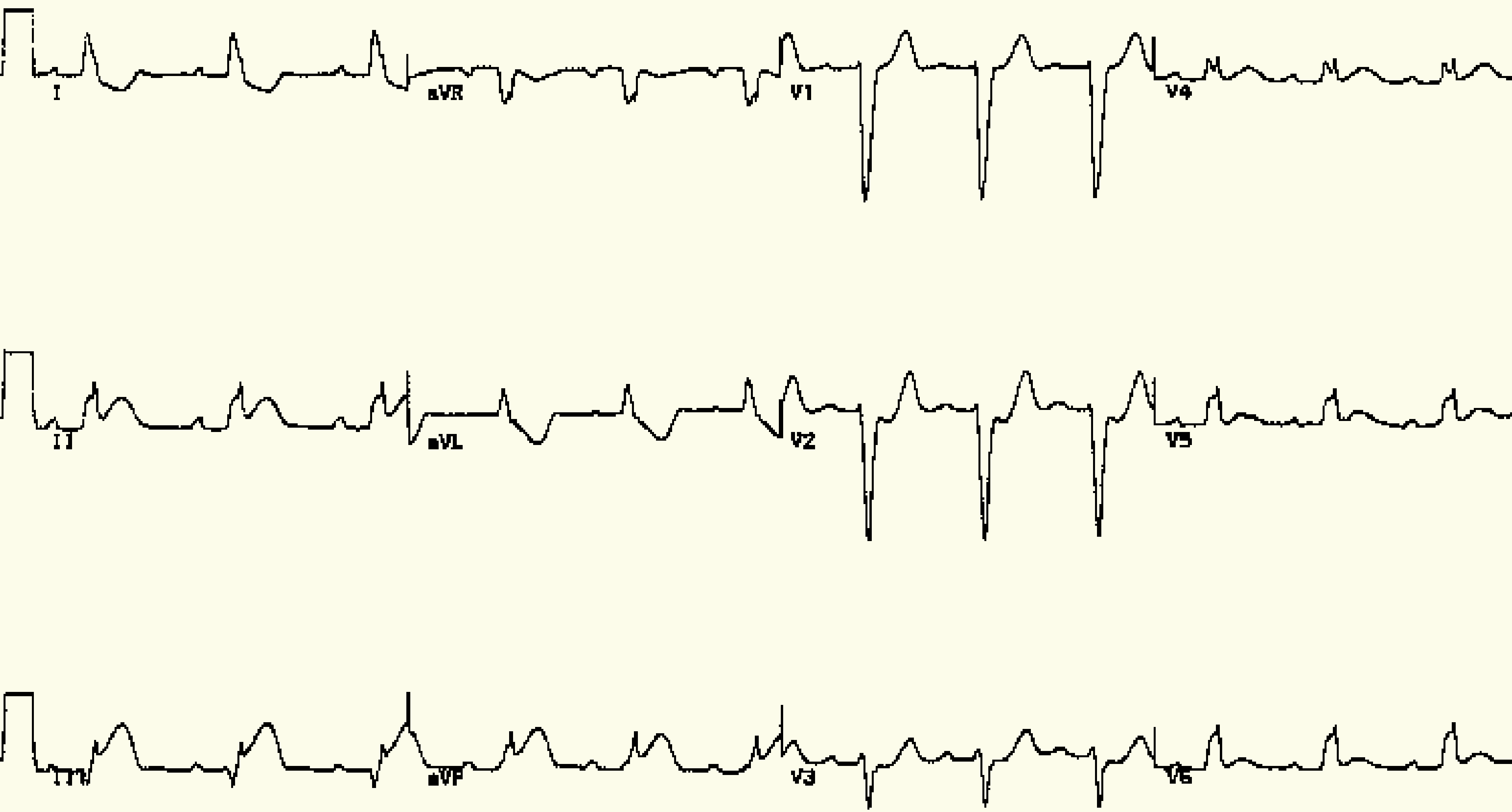
LA Enlargement and Prolonged PR Interval



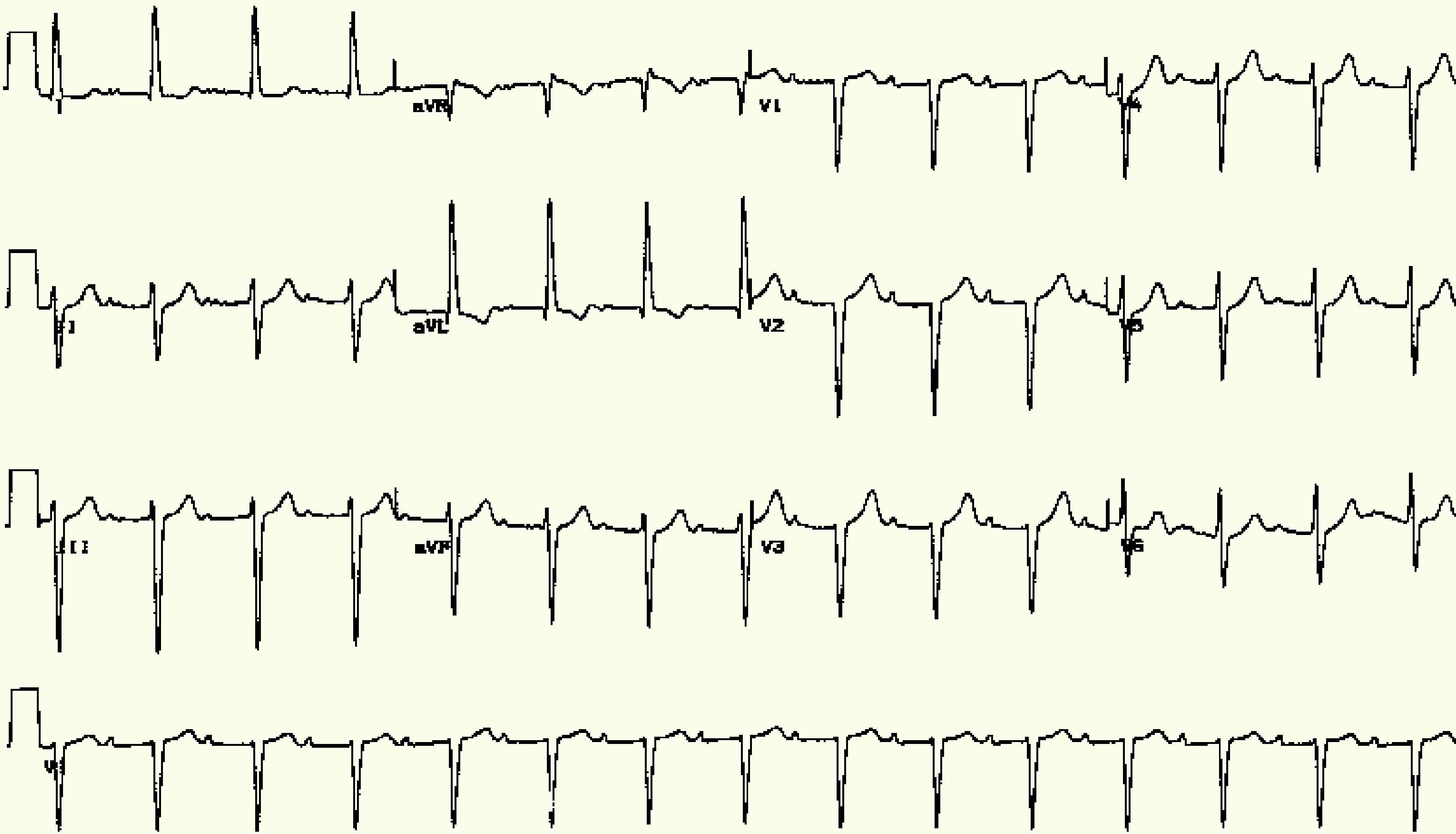
LBBB



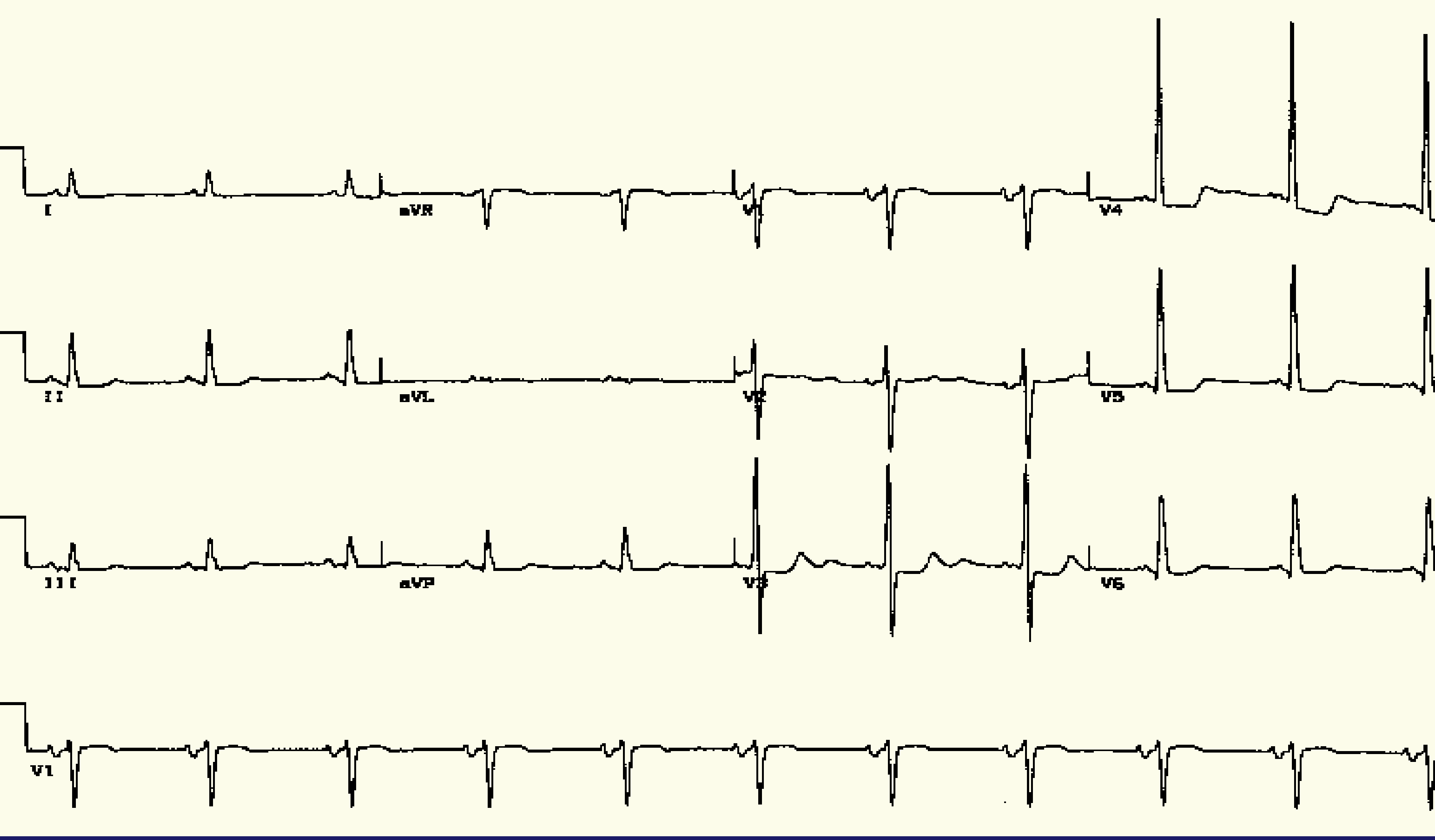
Acute Inferior MI



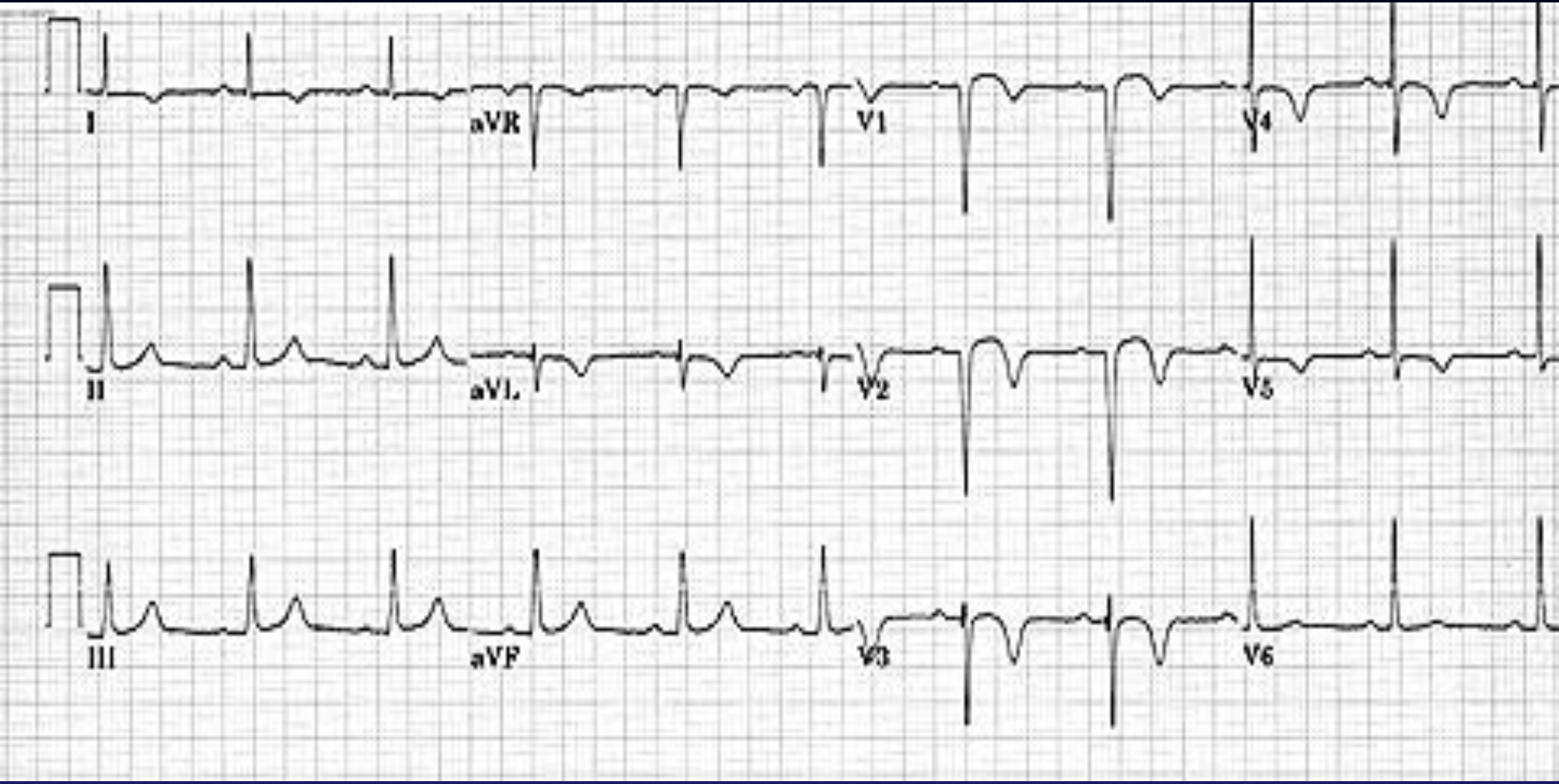
Left Anterior Hemiblock, Prolonged PR interval



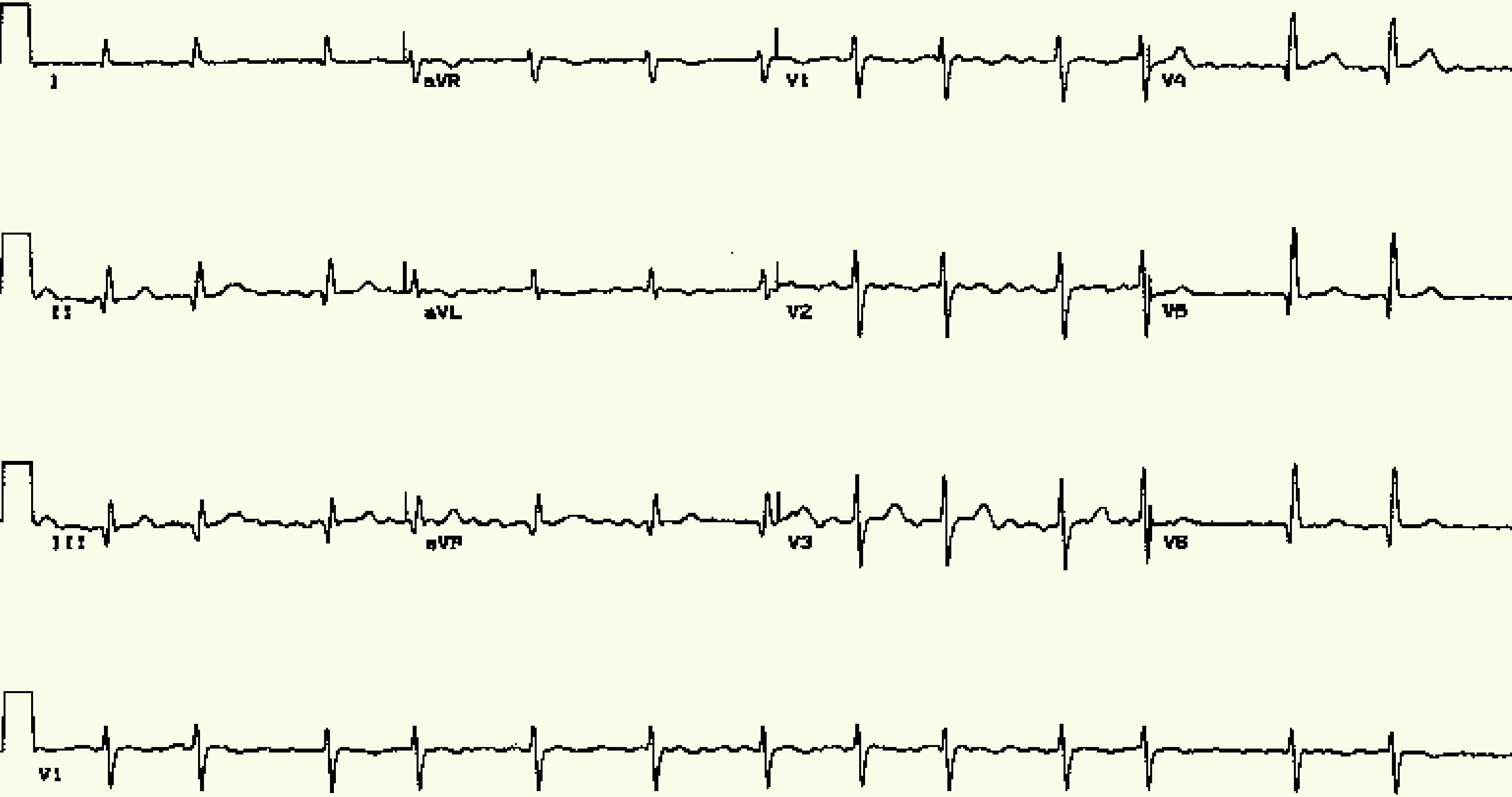
LVH and LA Enlargement



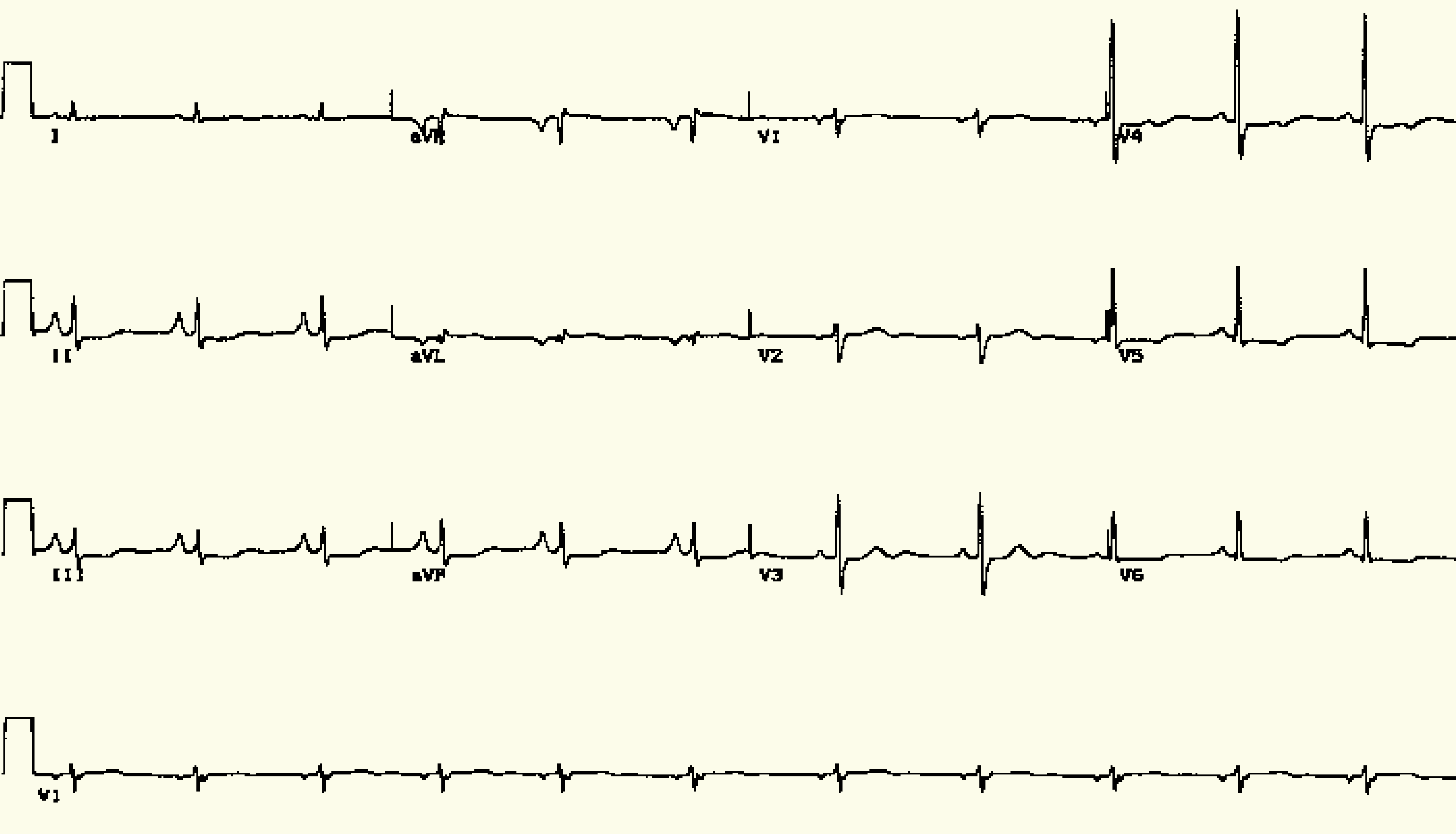
Anterior MI



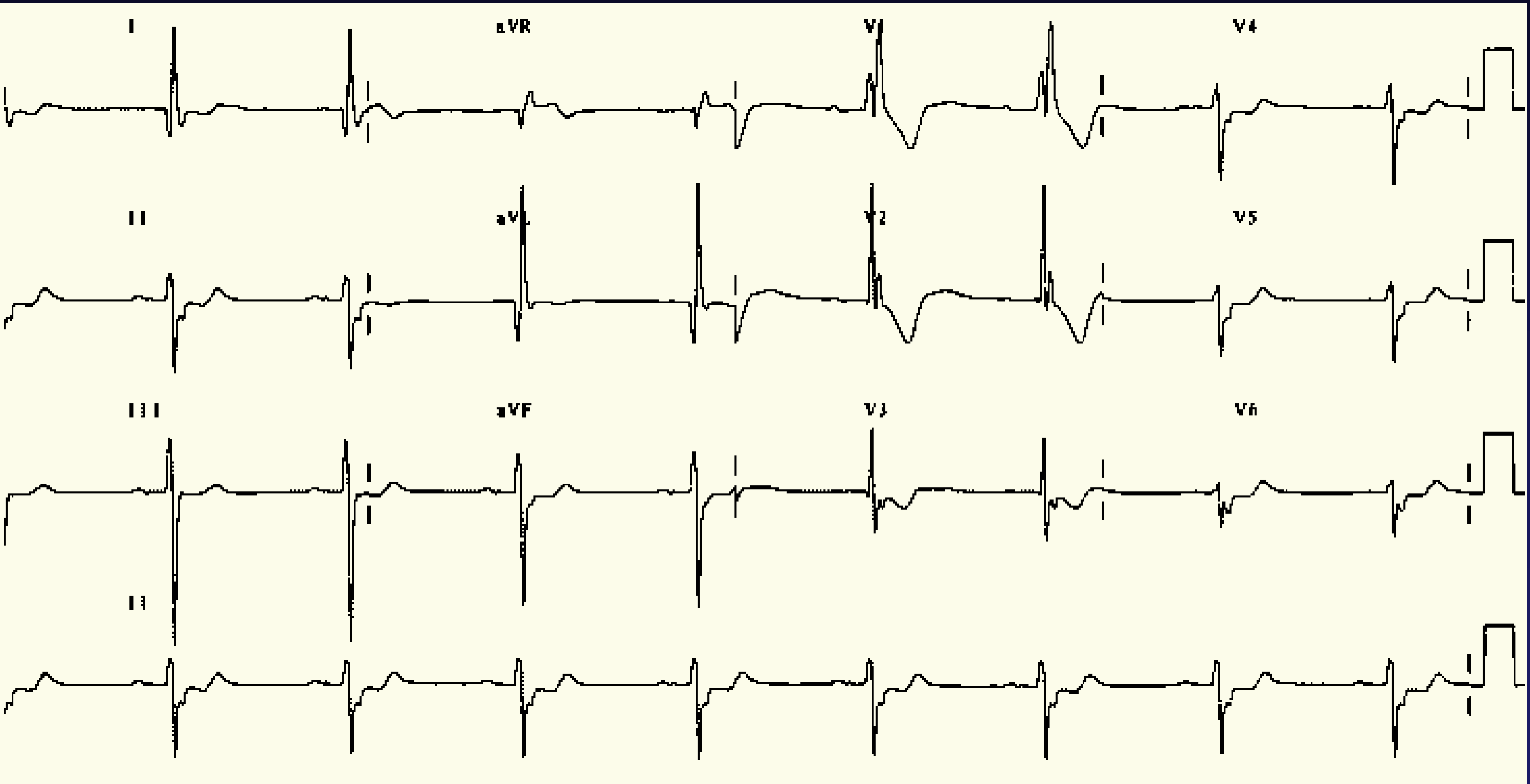
Old Inferior MI and Atrial Fibrillation



RA Enlargement



RBBB, LAH, Prolonged PR
(Trifascicular Block)



Tehran Arrhythmia Center

Tehran Arrhythmia Center

www.TehranEP.center

info@TehranEP.center