HOW TO READ AN ECG

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Electrocardiography (ECG)

❖What is an ECG?

- (ECG): is a test that measures the electrical activity of the heart.
- With each beat, an electrical impulse ("wave") travels through the heart. This wave causes the muscle to squeeze and pump blood from the heart.
- Although the heart has four chambers, from the electrical point of view it can be thought of as having only two, because the two atria contract together ('depolarization'), and then the two ventricles contract together.
- The contraction of any muscle (Skeletal or cardiac) is associated with electrical changes called 'depolarization', and these changes can be detected by electrodes attached to the surface of the body.

Cont.

- Since all muscular contraction will be detected, the electrical changes associated with contraction of the heart muscle will only be clear if the patient is fully relaxed and no skeletal muscles are contracting. Therefore,

The electrodes detect the small electrical changes that are a consequence of cardiac muscle depolarization followed by repolarization during each cardiac cycle (heartbeat).

- ECG records the heart's rhythm and activity on a moving strip of paper.

Automaticity of the heart

- **Automaticity** is defined as the ability of heart cells (myocytes) to **spontaneously** depolarize and generate an action potential controlled by pacemaker cells.

- **Independent** of CNS stimulus.

- The CNS **influences** the heart by sympathetic and parasympathetic regulation.

Pacemakers of the heart

- SA node is the dominant pacemaker of the heart.
- Other pacemakers are present, but they are slower.
- If the SA node is no longer functioning, other pacemakers take over.

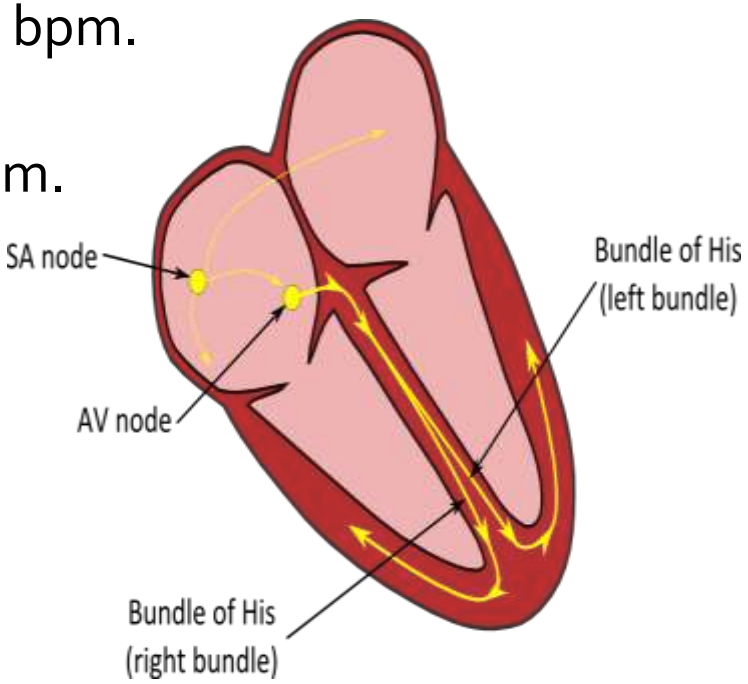
✓ SA node: <u>Dominant</u> pacemaker with an intrinsic rate of 60 - 100 bpm.

✓ AV node: Back-up pacemaker with an intrinsic rate of 40 - 60 bpm.

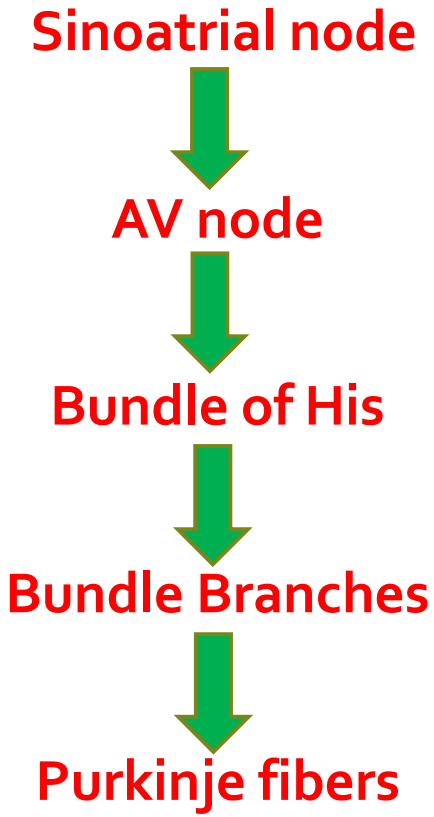
✓ Bundle of HIS (25-40 bpm)

✓ Bundle branches (25-40 bpm)

✓ Purkinje fibers (25–40 bpm)

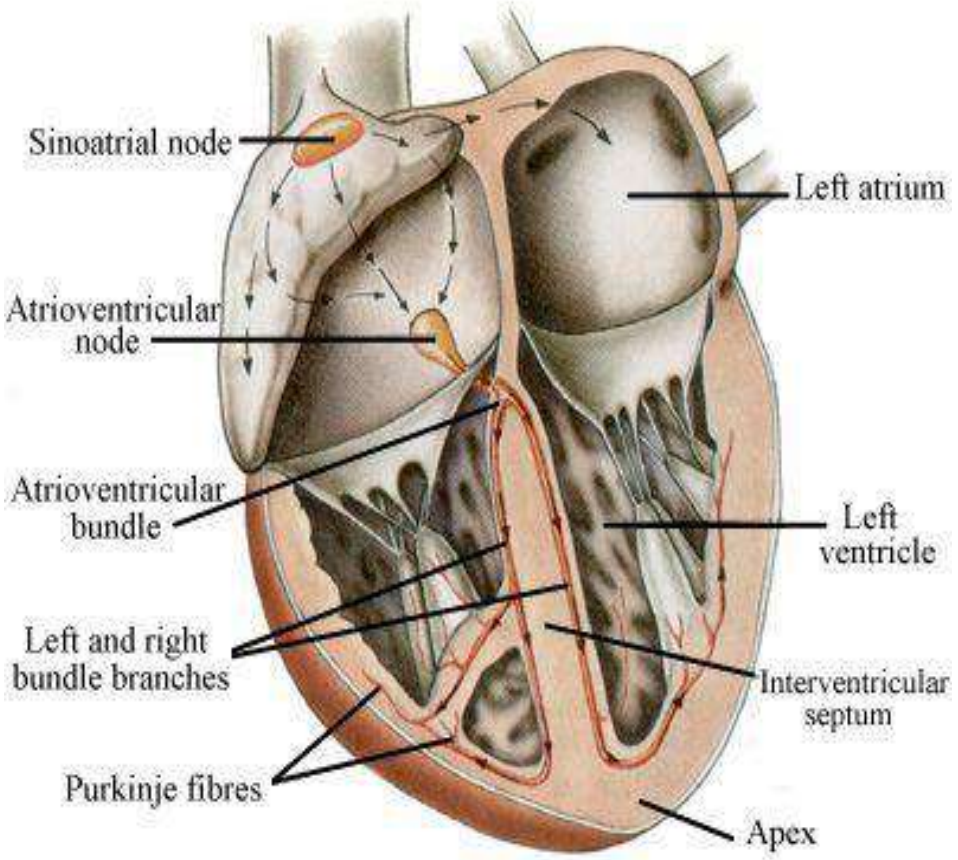


Pulse Conduction



Conduction Velocities

- Once depolarization waves are conducted from SA node to AV node, delaying occurs in AV node.
- SLOWEST conduction is through AV node(there is a delay)>>**The electrical signal is delayed in the AV node for approximately 0.20 seconds when the atria contract.**
- This delay is very important, **as it gives enough time for ventricles to refill.** (that's why the atria contract separately from ventricles)
- **Purkinje fibers → fastest conduction (QRS complex is narrow in normal ECG = short duration of ventricular contraction)**

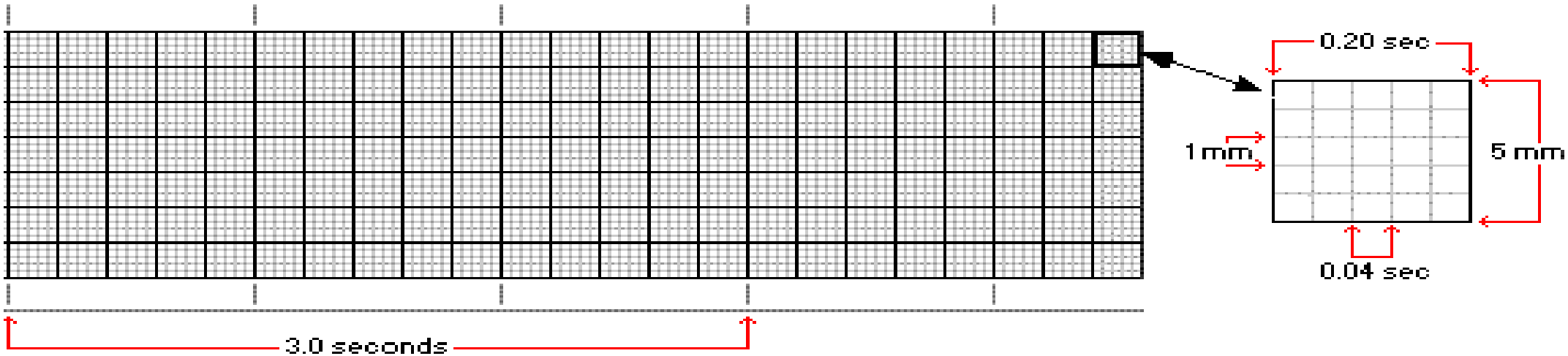


ECG Paper

- Light lines are small squares- 1 X 1 mm
- Bold lines are large squares 5 X 5 mm
- **Horizontal axis = Time**

  *Distance across small square=0.04 sec. *Distance across large square=0.2 sec
- **Vertical axis=voltage**

  *Distance across small square=0.1 mV *Distance across large square=0.5 mV



ECG LEADS

Electrodes

- An **ECG electrode** is a **conductive pad** which is attached to the skin to **record electrical activity**.
- The standard ECG has 12 leads: **3 Standard Limb Leads** (L I, II, III), **3 Augmented Limb Leads** (aVL, aVF, aVR), **6 Precordial Leads** (V1-V6).

❖Precordial (Chest) leads:

V1: 4th intercostal space at the right sternal edge.

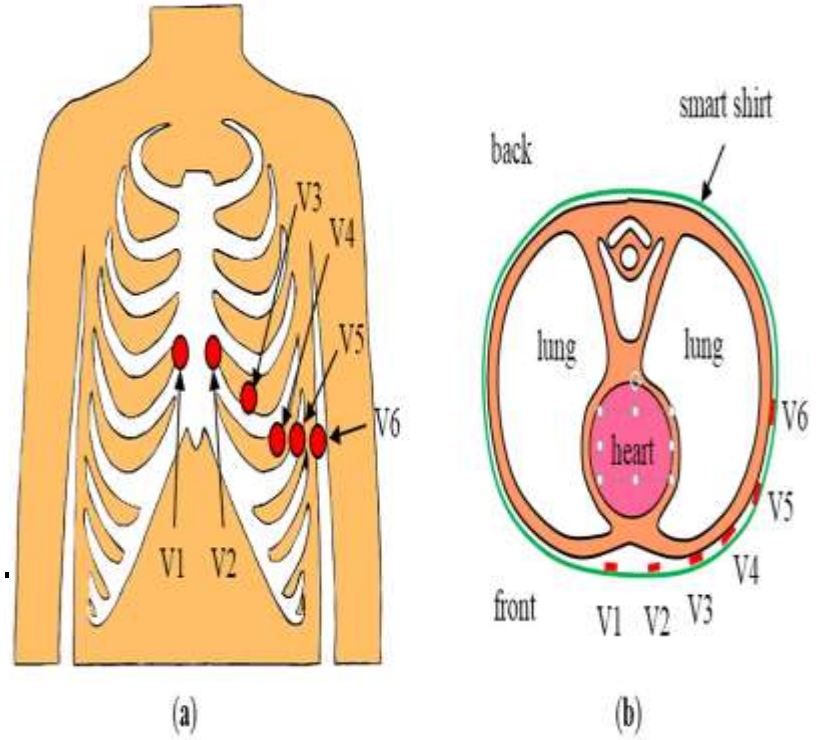
V2: 4th intercostal space at the left sternal edge.

V3: midway between the V2 and V4 electrodes.

V4: 5th intercostal space in the midclavicular line.

V5: left anterior axillary line at the same horizontal level as V4.

V6: left mid-axillary line at the same horizontal level as V4 and V5.



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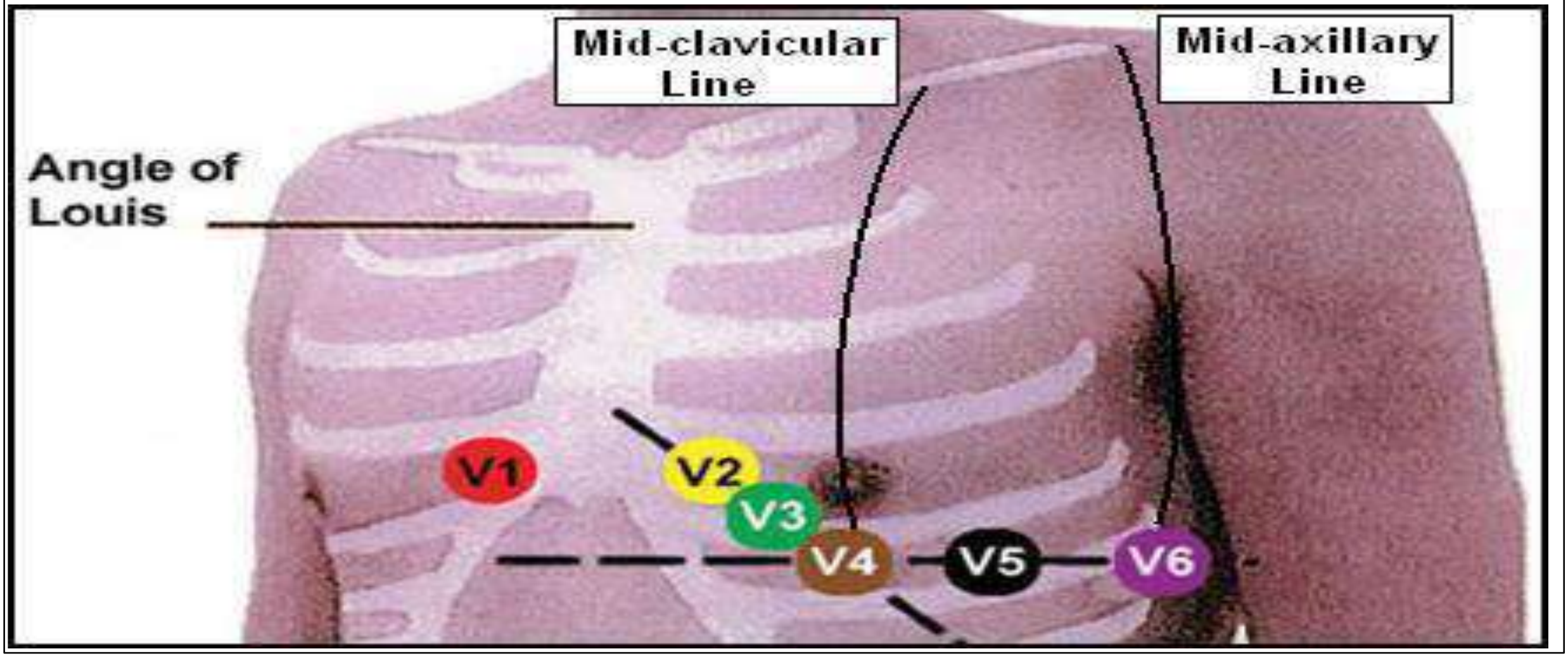

Mid-clavicular Line
Mid-axillary Line
Angle of Louis
V1
V2
V3
V4
V5
V6

Cont.

❖Limb electrodes:

The six limb leads (Lead I, II, III, aVF, aVL, aVR) look at the heart in **vertical plane** and are obtained from three electrodes (RA, LA, LL).

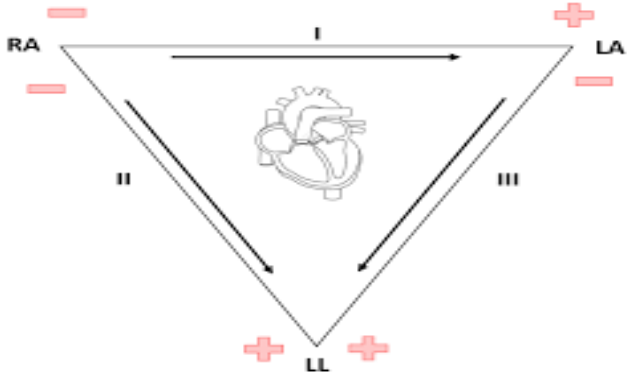
*Note: **electrode** is the conductive pad that is attached to the patient's body, while **lead** is description of the electrical activity and is recorded from the electrodes.

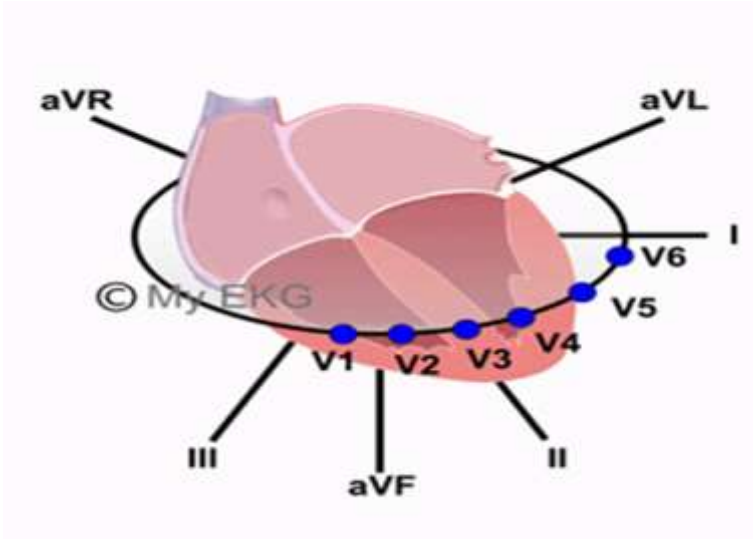
- **Red (RA):** on the ulnar styloid process of the right arm.
- **Yellow (LA):** on the ulnar styloid process of the left arm.
- **Green (LL):** on the medial or lateral malleolus of the left leg.

$$aVL: \quad \frac{Lead\ I - Lead\ III}{2}$$

$$-aVR: \quad \frac{Lead\ I + Lead\ II}{2}$$

$$aVF: \quad \frac{Lead\ II + Lead\ III}{2}$$

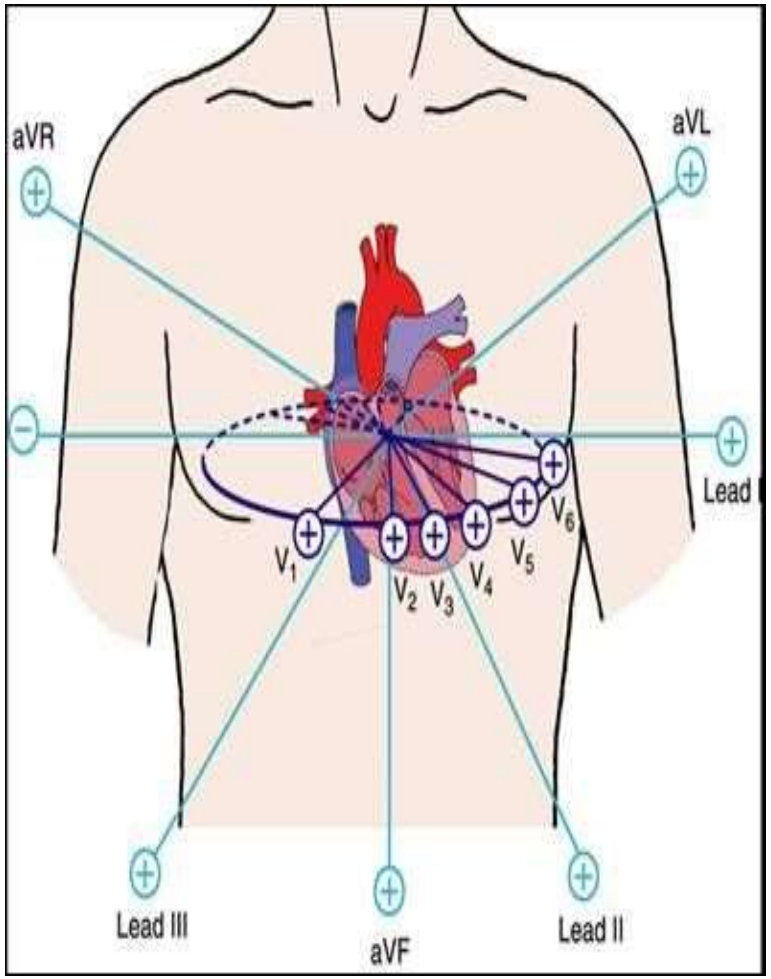




Anatomic groups

Anatomical relations of leads in a standard 12 lead electrocardiogram:

- **II, III, and aVF**: inferior surface of the heart.
- **V1 to V4**: anterior surface and septum.
- **I, aVL, V5, and V6**: lateral surface.
- **aVR**: right atrium and cavity of left ventricle.



Anatomic groups

I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

Blood supply of the heart

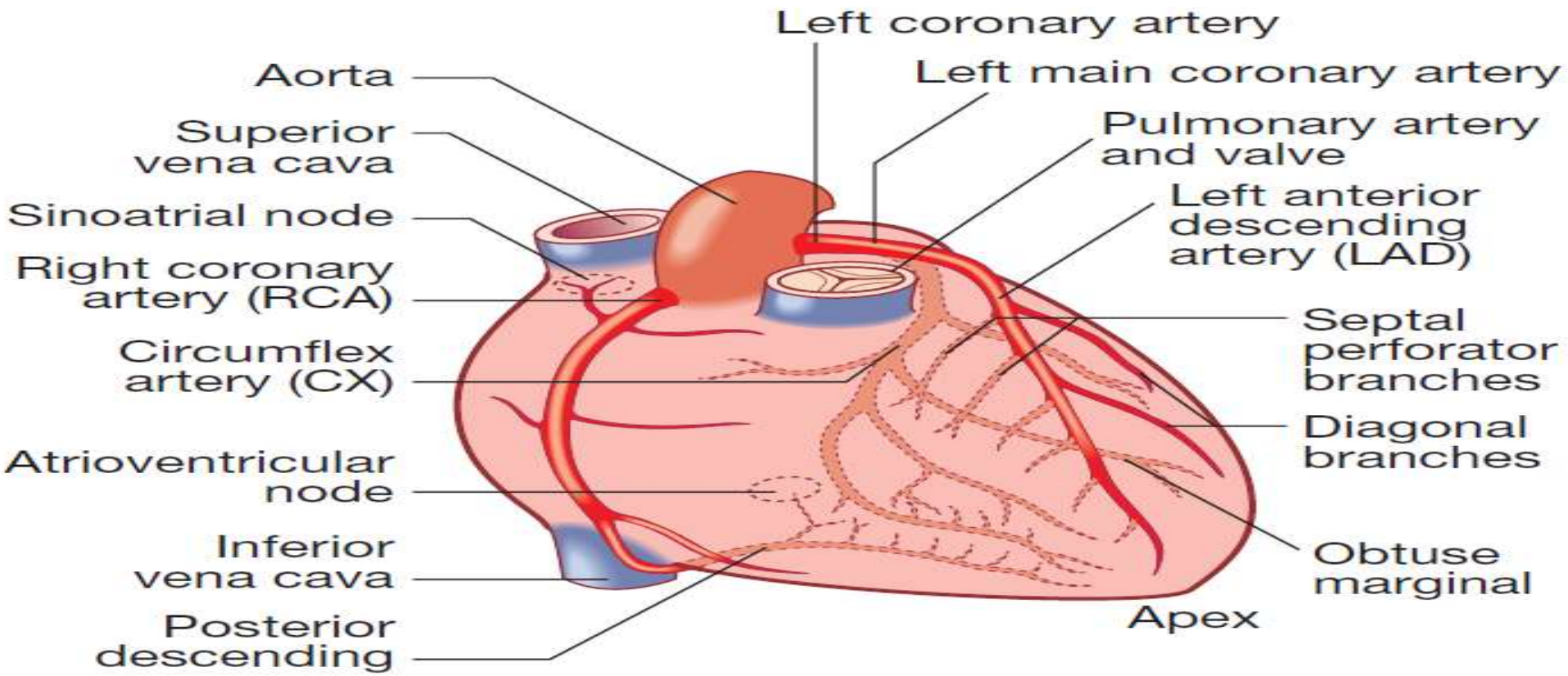
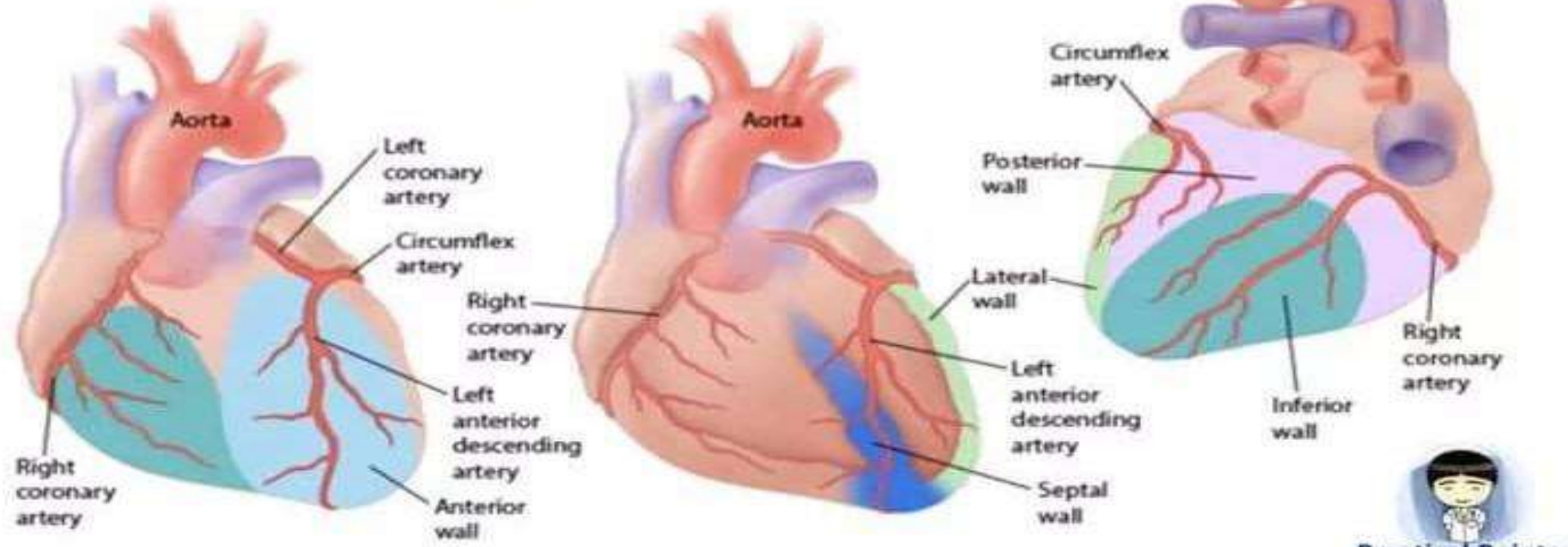


Fig. 18.3 The coronary arteries. Diagram of the anterior view.

I	aVR	V_1	V_4
II	aVL	V_2	V_5
III	aVF	V_3	V_6

Inferior: II, III, aVF
Septal: V_1, V_2
Anterior: V_3, V_4
Lateral: I, aVL, V_5, V_6



Practical Points For Extern

Wall Affected	Leads Showing ST Elevation	Leads Showing Reciprocal ST Depression	Suspected Artery
Septal	V1, V2	None	Left Anterior Descending - LAD
Anterior	V3, V4	None	Left Anterior Descending - LAD
Anteroseptal	V1, V2, V3, V4	None	Left Anterior Descending - LAD
Anterolateral	V3, V4,V5,V6,I,aVL	II, III, aVF	Left Anterior Descending – LAD, Circumflex – LCX
Extensive Anterior (Can be called Anteroseptal w/Lateral Extension)	V1, V2, V3, V4,V5,V6,I,aVL	II, III, aVF	Left Main Coronary Artery – LCA
Inferior	II,III,aVF	I, aVL	Right Coronary Artery –RCA, or Circumflex - LCX
Lateral	I,aVL,V5,V6	II, III, aVF	Circumflex - LCX
Posterior (Often associated w/Inferior or Lateral but also can be isolated)	V7,V8,V9	V1, V2, V3, V4	Posterior Descending – PDA, (branch of RCA or Circumflex – LCX)
Right Ventricular (Usually associated w/Inferior)	II,III,aVF,V1,V4R	I, aVL	Right Coronary Artery - RCA

Normal ECG

Normal ECG

P waves:

P waves represent **atrial depolarisation**.

In healthy individuals, there should be a **P wave** preceding each **QRS** complex.

PR interval:

The **PR interval** begins at the **start of the P wave** and ends at **the beginning** of the **Q wave**.

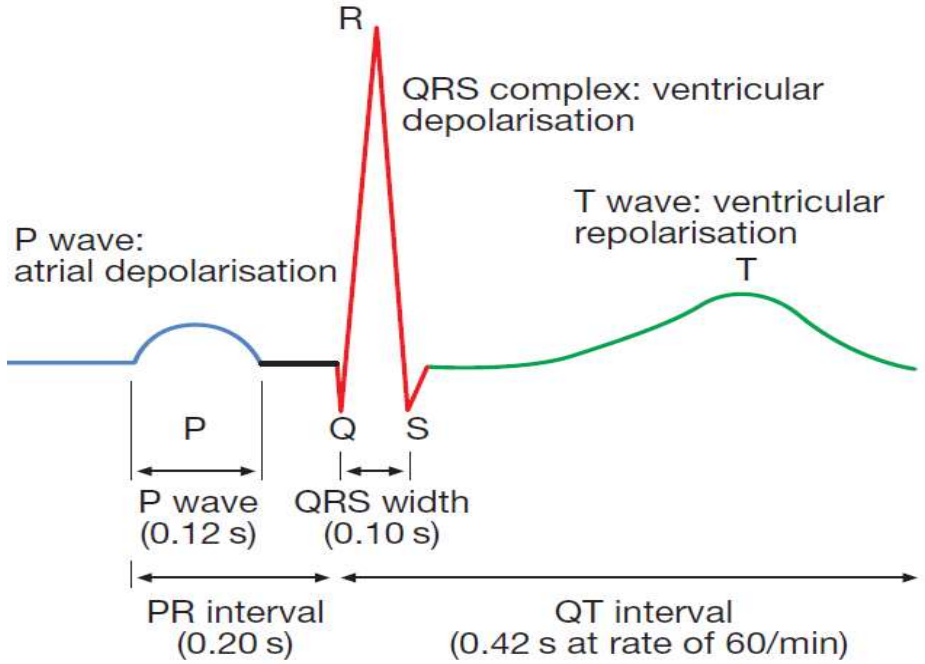
It **represents** the **time taken** for electrical activity to move **between the atria and the ventricles**.

The Normal PR interval is 0.12-0.20s.

QRS complex

The **QRS complex** represents **depolarisation of the ventricles**.

The normal QRS duration is <=0.1sec



Cont.

ST segment

The **ST segment starts** at the **end** of the **S wave** and **ends** at the **beginning** of the **T wave**.
It represents the
time **between depolarisation** and **repolarisation** of
the **ventricles** (i.e. ventricular contraction).

T wave

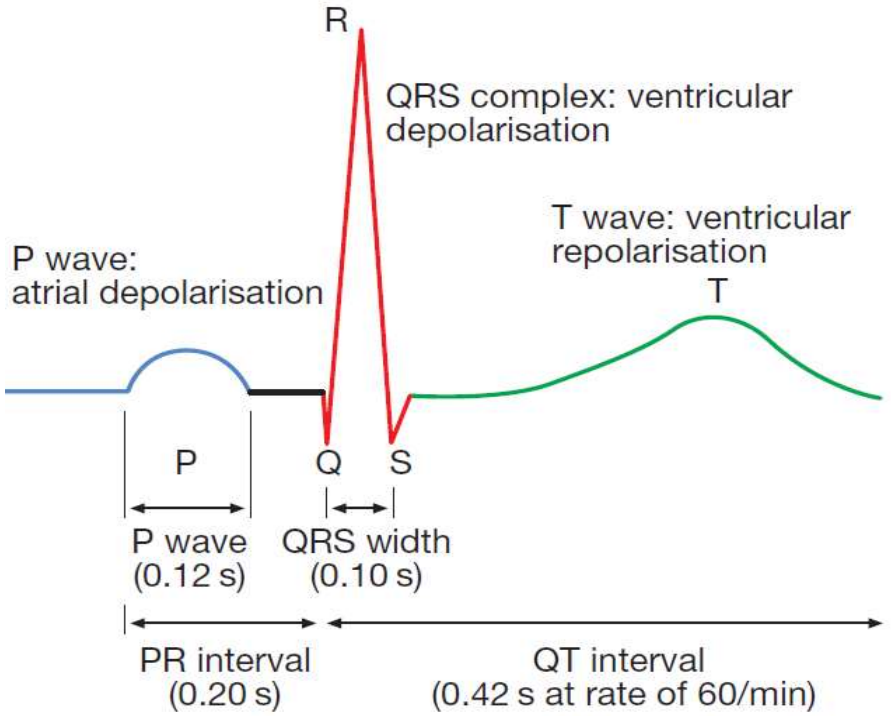
The T wave represents ventricular repolarisation.

RR interval

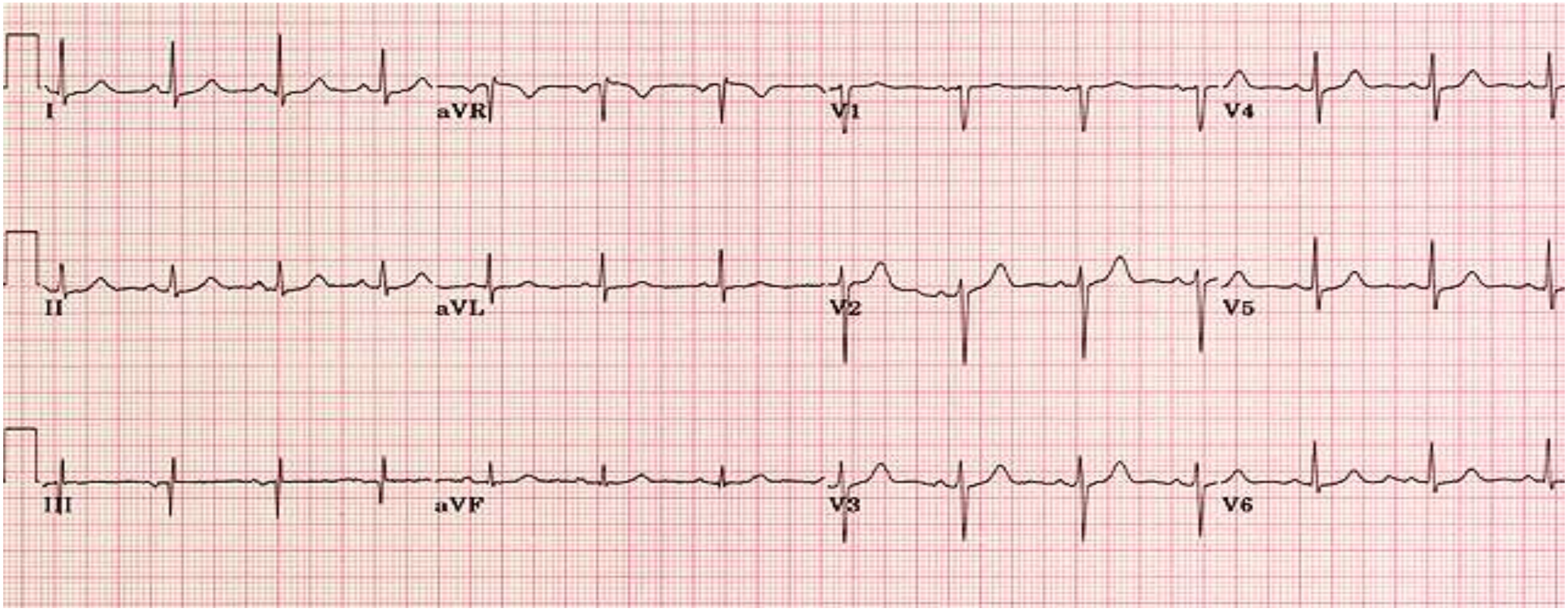
The RR interval begins at the peak of one R wave and ends at the peak of the next R wave.

QT interval

The QT interval begins at the start of the QRS complex and finishes at the end of the T wave.
It represents the time taken for
the ventricles to depolarise and then repolarise.



Normal ECG

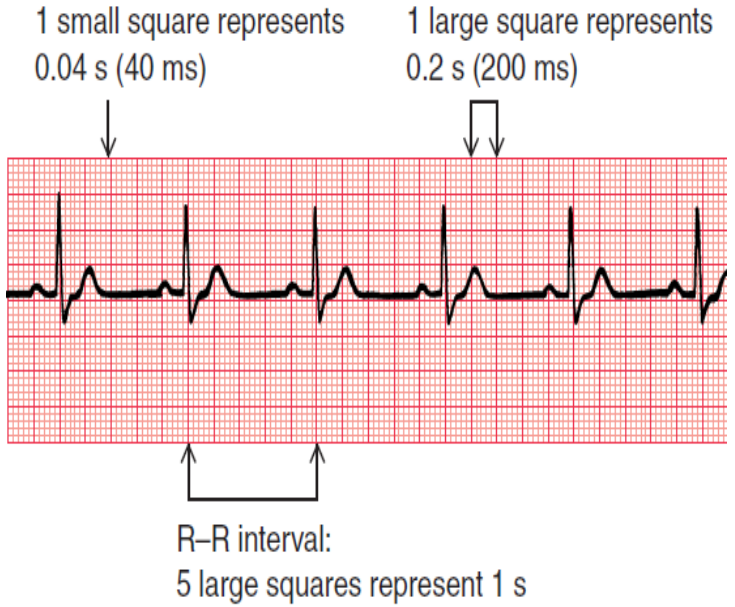


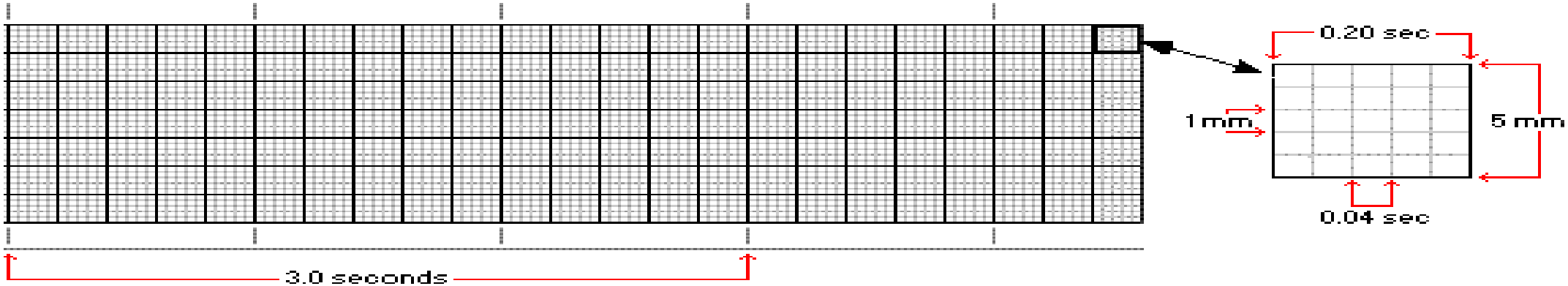
Remember:

ECG machines run at a standard **rate** of 25mm/sec and use **papers** of standard sized squares

- Each **small square** represents **0.04 seconds**
- Each **large square** represents **0.2 seconds**
- **5 large squares = 1 second**
- **300 large squares = 1 minute**

Vertically, the **ECG** graph measures the height (amplitude) of a given wave or deflection. The **standard calibration** is 10 mm (10 small boxes), equal to 1 mV





Abnormalities in ECG

Abnormalities in ECG can be due to:

- Cardiac Abnormalities,

such as **atrial fibrillation** and **ventricular tachycardia**.

- Inadequate coronary artery blood flow,

such as **myocardial ischemia** and **myocardial infarction**.

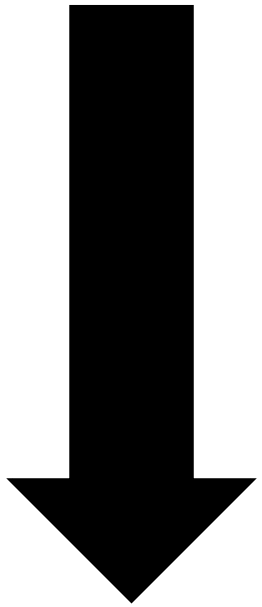
- Electrolyte disturbances,

such as **hypokalemia** and **hyperkalemia**.

How to interpret an ECG?

How to interpret an ECG?

The best way to interpret an ECG is to do it step-by-step



Rhythm

Rate

Cardiac Axis

P – wave

PR - interval

QRS Complex

ST Segment

QT interval (Include T and U wave)

Other ECG signs

Heart Rhythm

- Is there a P wave in front of every QRS complex ?
- Is every P wave followed by a QRS complex?
- Do the P wave all look the same ?
- Is the rhythm Regular, Regularly Irregular ,Irregularly irregular

By paper test by measuring the space between two successive QRS (R to R) or (S to S)

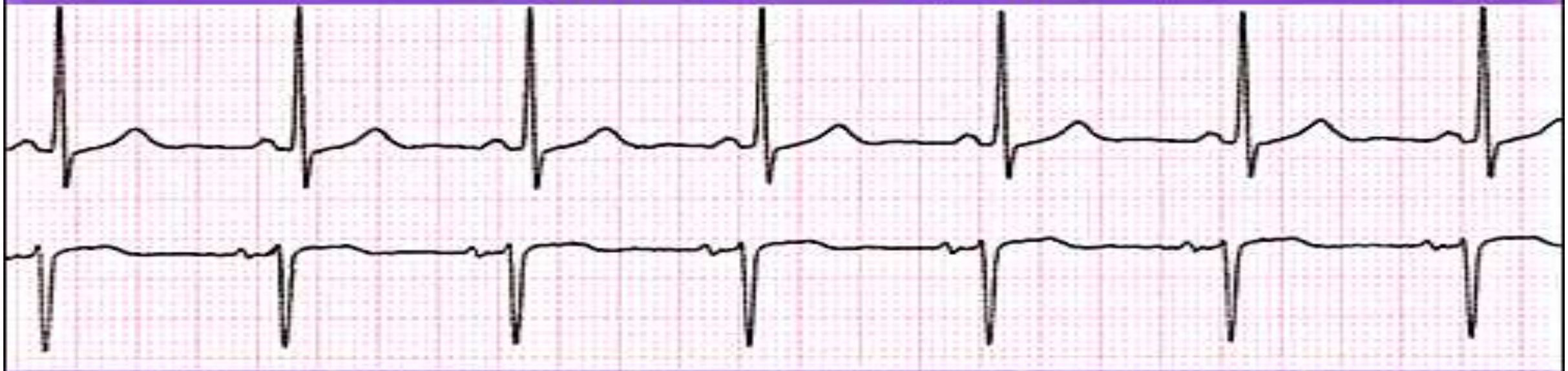
- Are the QRS complex: Narrow

  Wide

  Mixture of the two Rhythm

Normal/Regular Rhythm

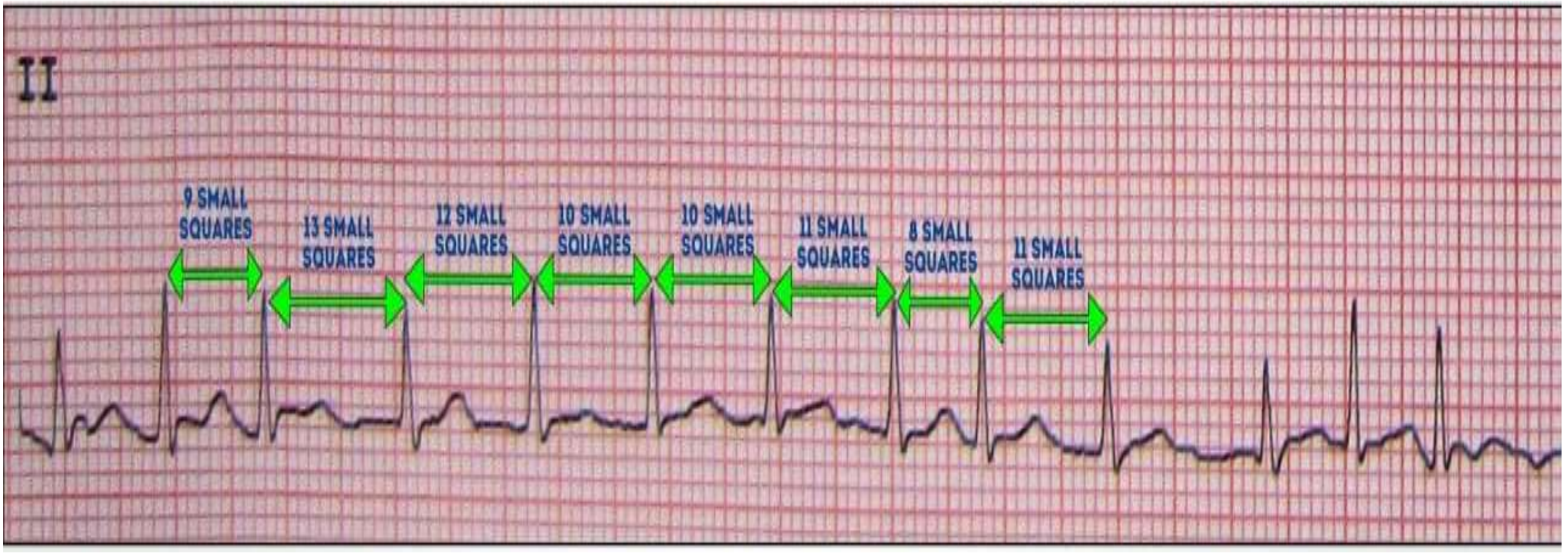
Normal Sinus Rhythm



Heart Rate	Rhythm	P Wave	PR interval (in seconds)	QRS (in seconds)
60-100 bpm	Regular	Before each QRS, identical	.12 to .20	<.12

Regularly Irregular

Irregularly Irregular



Heart Rate

- For **REGULAR** heart :

Count the number of ***large squares*** between two consecutive R waves

300 / # of large squares = !! Bpm

- For **IRREGULAR** heart :

Count the number of **R waves** in 2 seconds (10 LS) multiplied by 30, **OR**

Count the number of **R waves** in 4 seconds (20LS) multiplied by 15, **OR**

Count the number of ***R waves*** in 6 sec (30 LS) multiplied by 10.

(10 or 20 or 30) x # of R waves = !! bpm

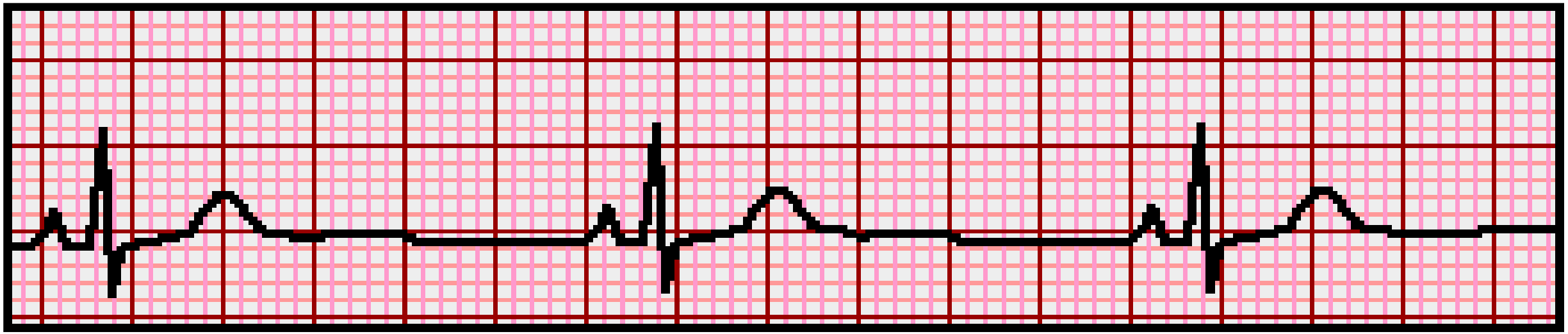
Heart Rate

Normal = 60 – 100 bpm

Tachycardia > 100 bpm

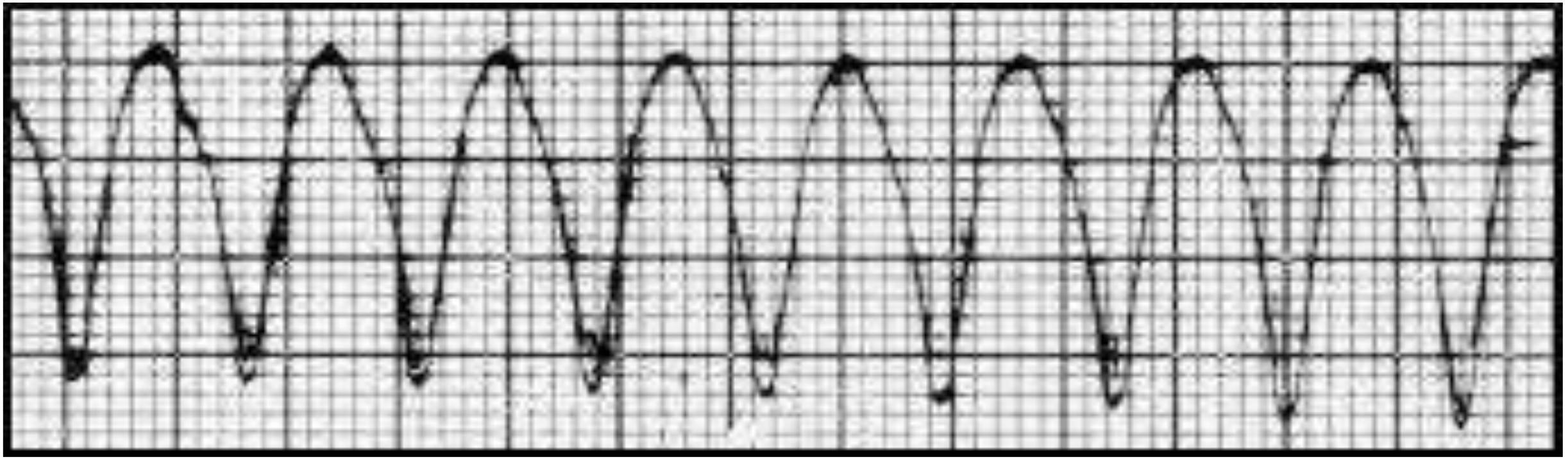
Bradycardia < 60 bpm

Calculate the heart rate



HR= (300 / 6) = 50 bpm

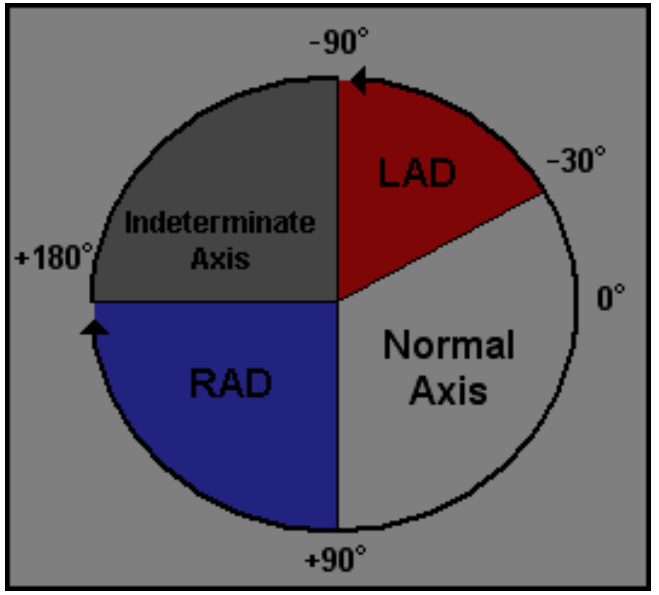
Calculate the heart rate



HR= (300 / 1.5) = 200 bpm

The QRS axis

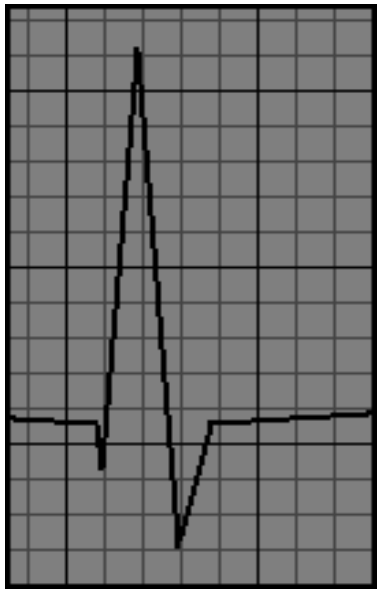
- represents overall direction of the heart's electrical
- activity.
- Abnormalities hint at:
  - Ventricular enlargement
  - Conduction blocks (i.e. hemiblocks)

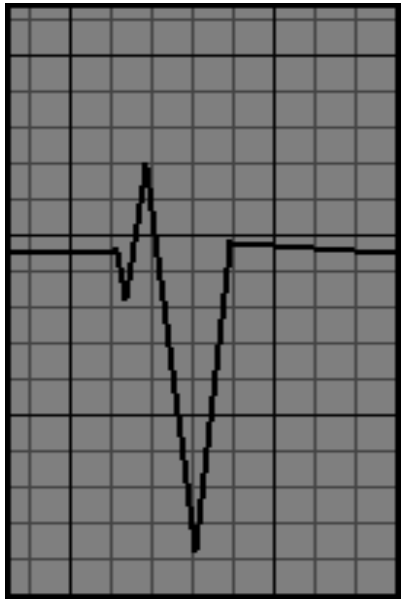


- Normal QRS axis from -30° to +90°.
- -30° to -90° is referred to as a left axis deviation (LAD)
- +90° to +180° is referred to as a right axis deviation (RAD)

- Normal QRS axis from -30° to +90°.
- determine if they are predominantly positive or negative.
- The combination should place the axis into one of the 4 quadrants below.
- When LAD is present :
- If the QRS in II is positive, the LAD is non-pathologic or the axis is normal
- If negative, it is pathologic.

		Lead aVF	
		Positive	Negative
Lead I	Positive	Normal Axis	LAD
	Negative	RAD	Indeterminate Axis

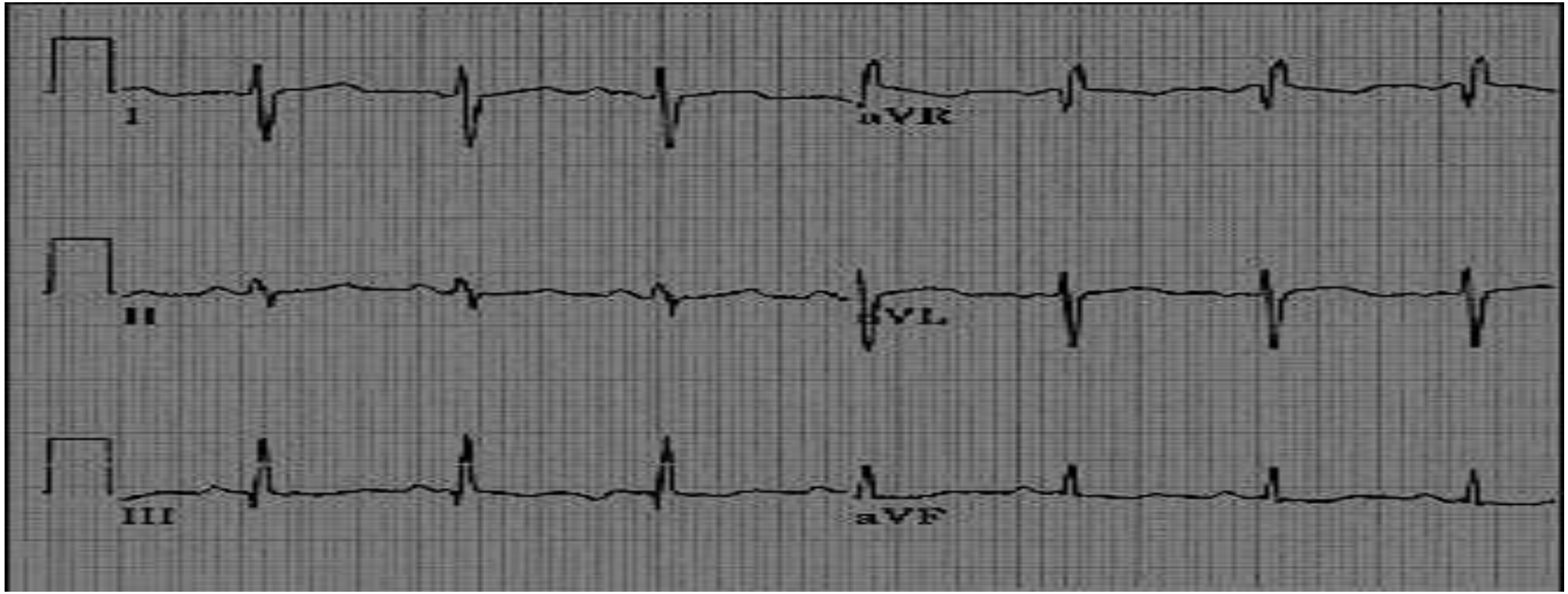




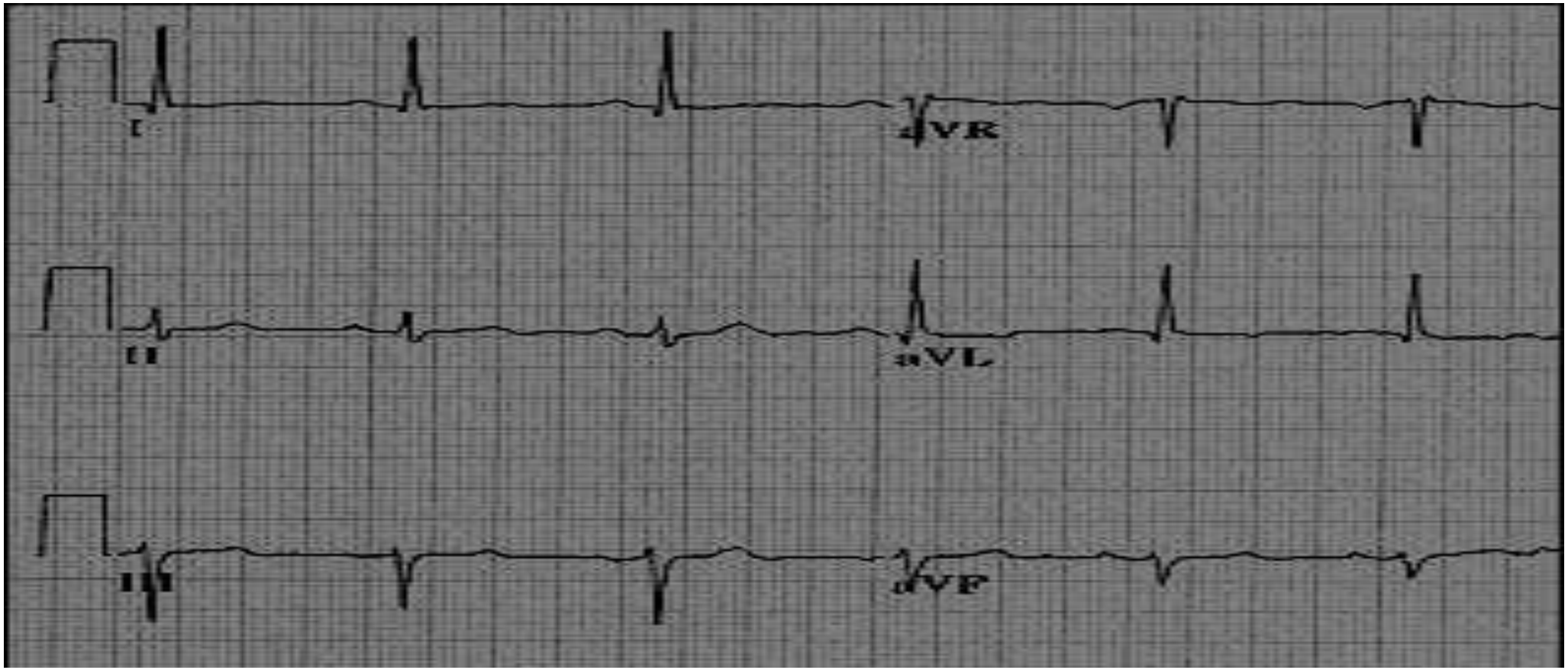
- Predominantly Positive

Predominantly Negative

Equiphasic

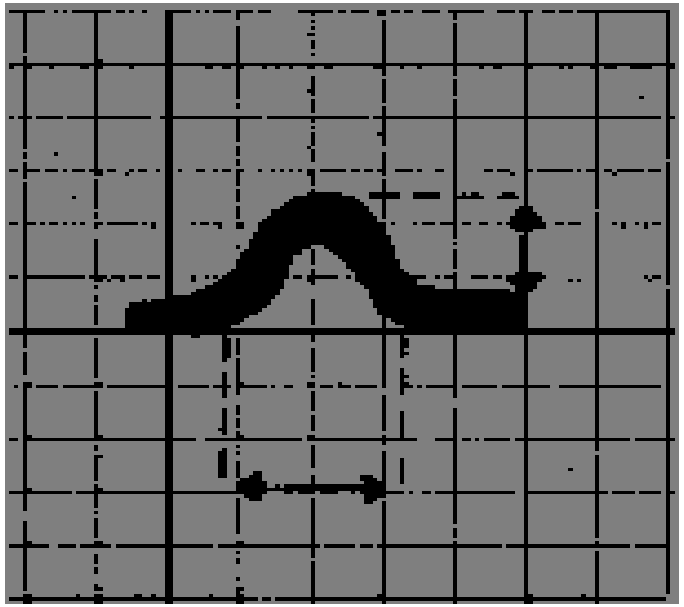


- Negative in I, positive in aVF ==> RAD



- Positive in I, negative in aVF, Predominantly positive in II ==> Normal Axis (non-pathologic LAD)

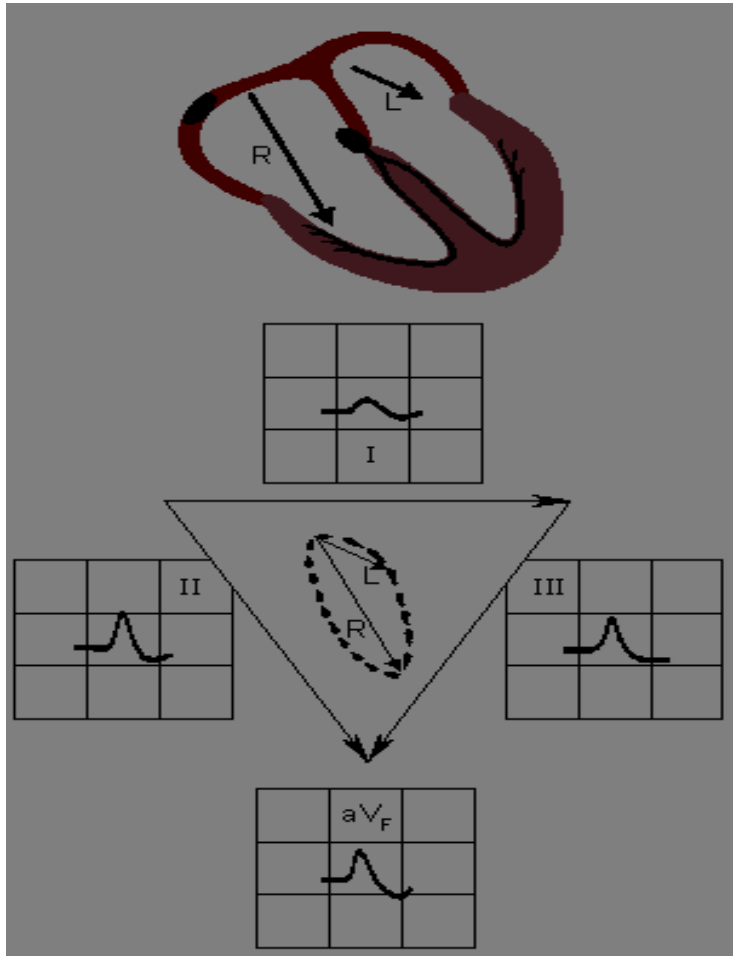
- **P wave**
- It is important to remember that the P wave represents the sequential activation of the right and left atria.
- Always positive in lead I and II
- Always negative in lead aVR
- < 3 small squares in duration
- < 2.5 small squares in amplitude
- Commonly biphasic in lead V1
- Best seen in leads II



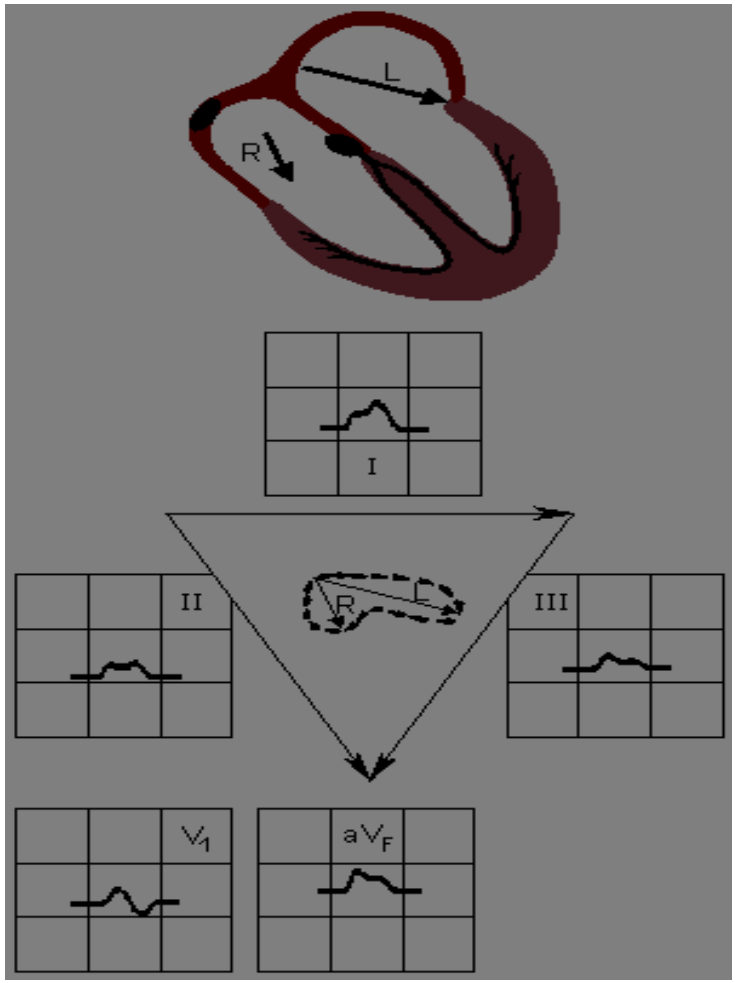
- **P wave = present, 1 per QRS, shape, duration, voltage.**

  - Absent p wave , the base line shows fibrillatory “f” waves (instead of p waves)

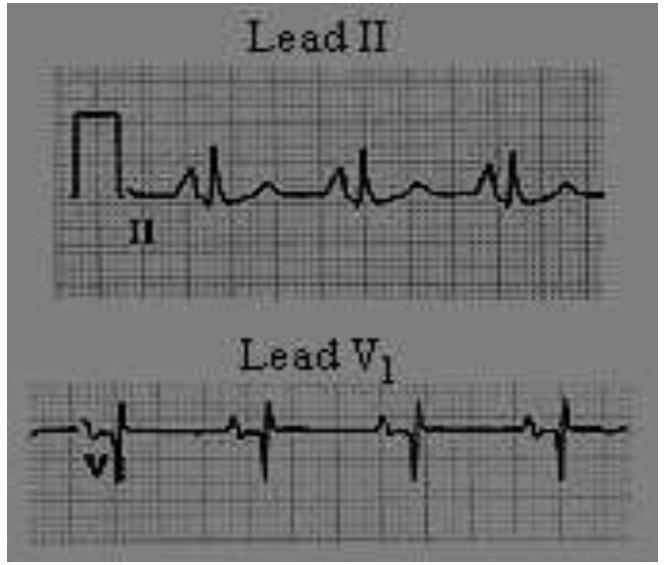
- Atrial Enlargement
- RAE



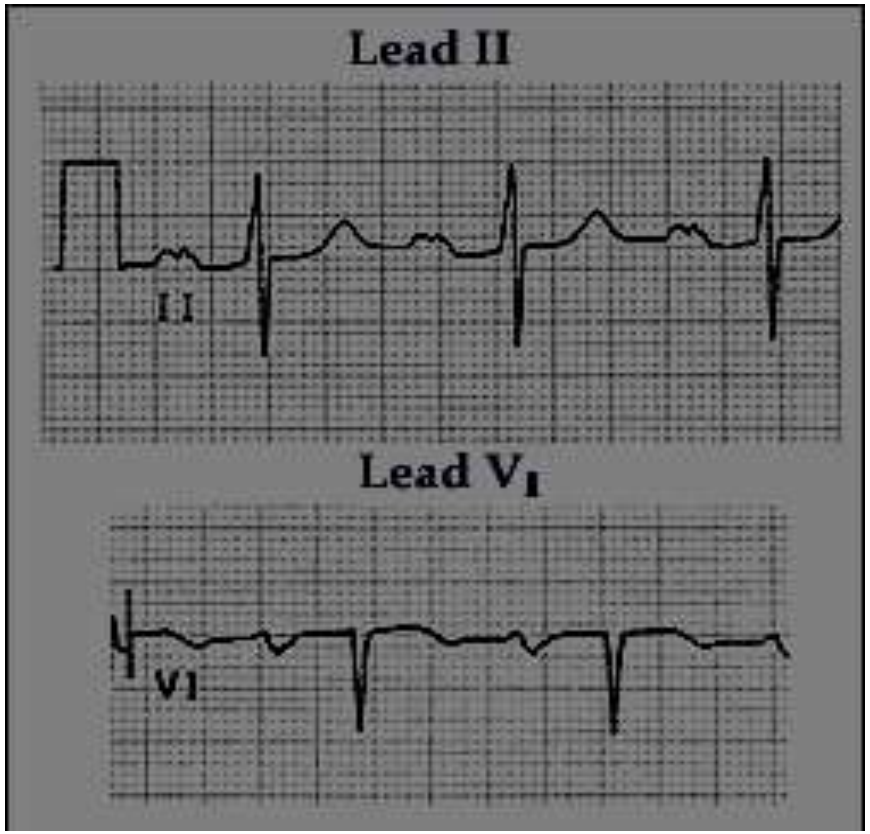
LAE



- Right Atrial Enlargement
- Criteria :
- P wave height in II ≥ 2.4mm
- pointed P waves (P Pulmonale)



- Left Atrial Enlargement
- Criteria :
- P wave duration in II ≥120ms
- (‘M’ shaped) P wave (P ‘mitrale’)



- P Pulmonale P Mitrale

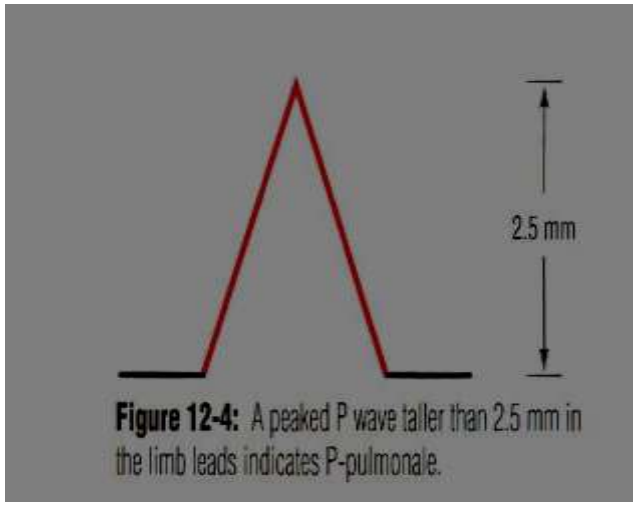
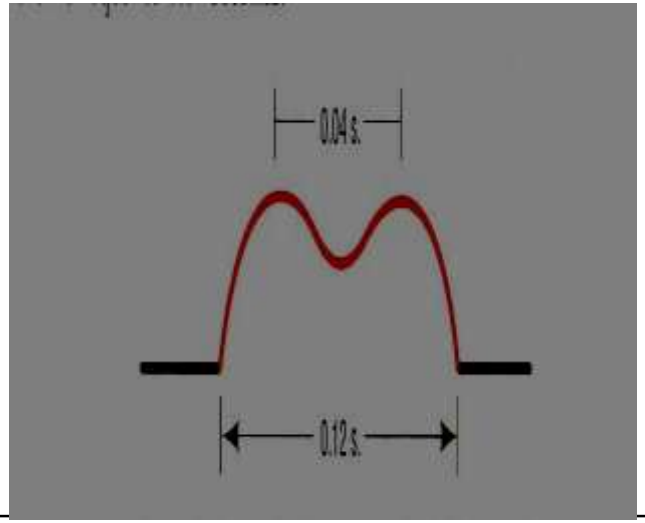


Figure 12-4: A peaked P wave taller than 2.5 mm in the limb leads indicates P-pulmonale.



- **PR Interval**

- P-R interval = length (0.12 - 0.2 sec = <1 big square), isoelectric.
- measured from beginning of P to beginning of QRS
- 0.12-0.20 s (3-5 small squares).
- Best seen in lead II .

- Indication of atrioventricular conduction time.

- **Prolonged PR interval (>0.2 seconds)**

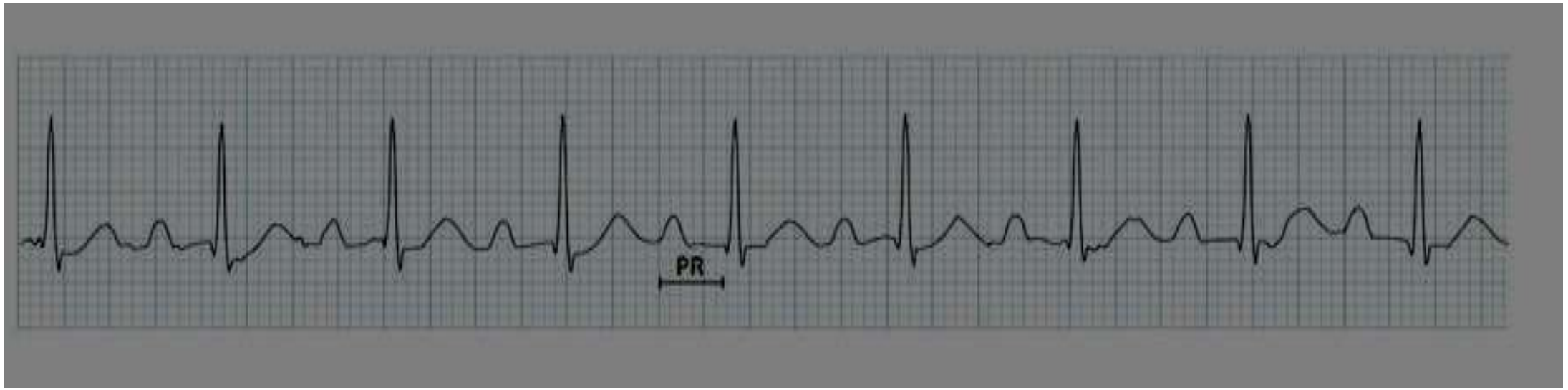
1-First degree AV block

2-Second degree AV block

3-AV dissociation

First degree heart block :

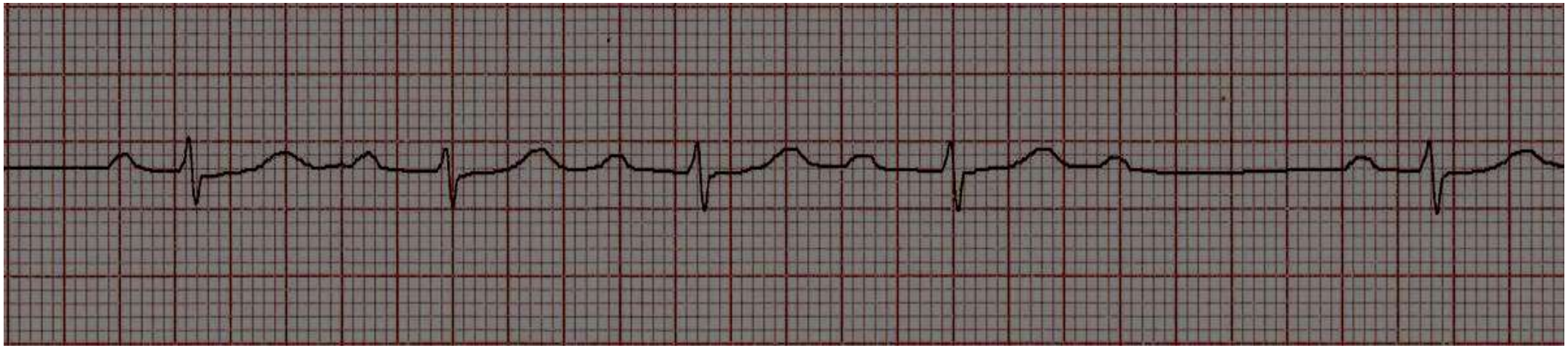
- Rate : usually within normal range , but depends on the underlying rhythm
- PR interval : prolonged more than 0.20 sec (more than 5 small squares) but **constant.**



Second degree heart block

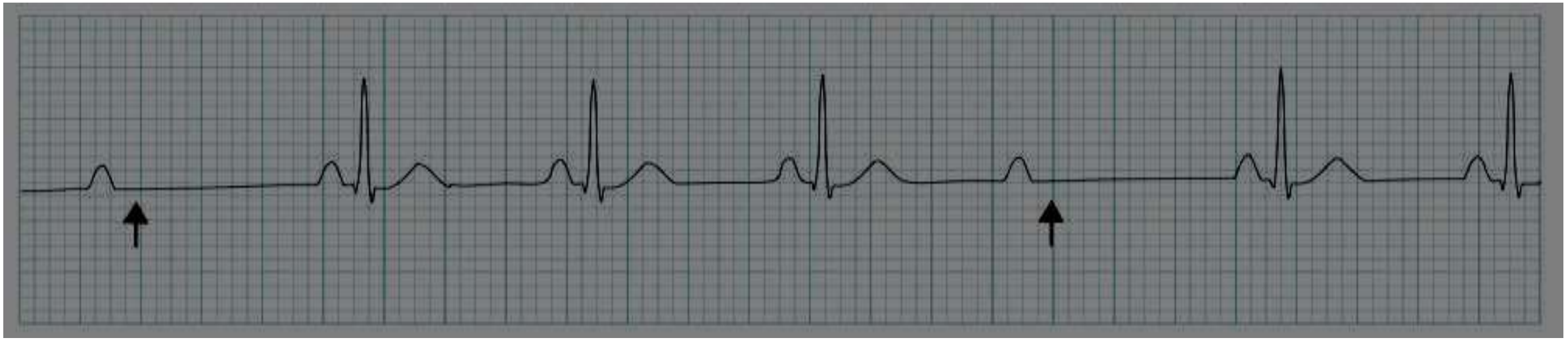
1- type 1 (Wenckebach , Mobitz type 1)

• There is a progressive increase in PR interval , until a P wave appears without a QRS complex, then the cycle is repeated.



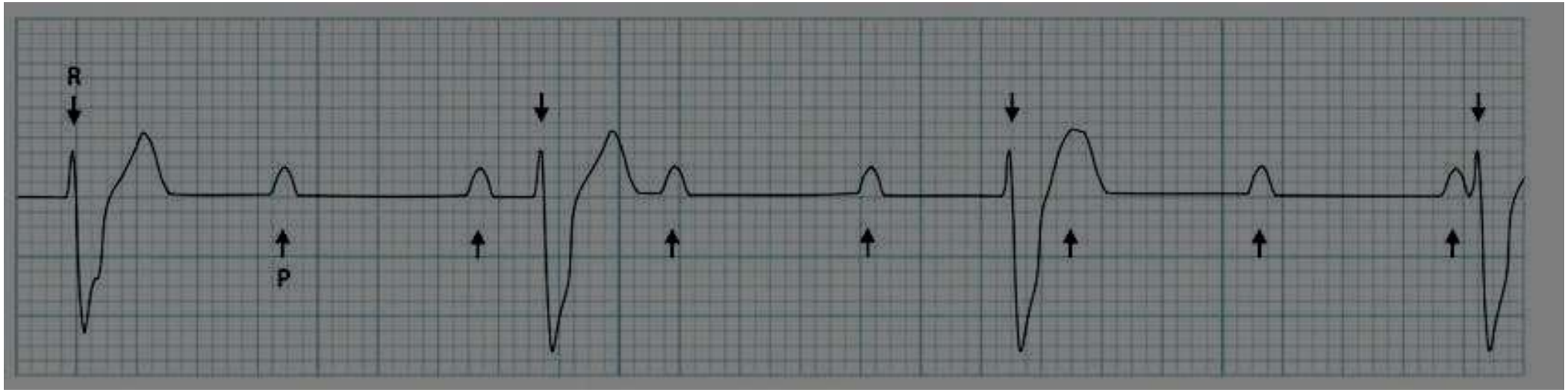
2- Mobitz type 2

• The PR interval of the conducted impulses remain constant but some P waves not followed by QRS complexes



Third degree heart block (complete)

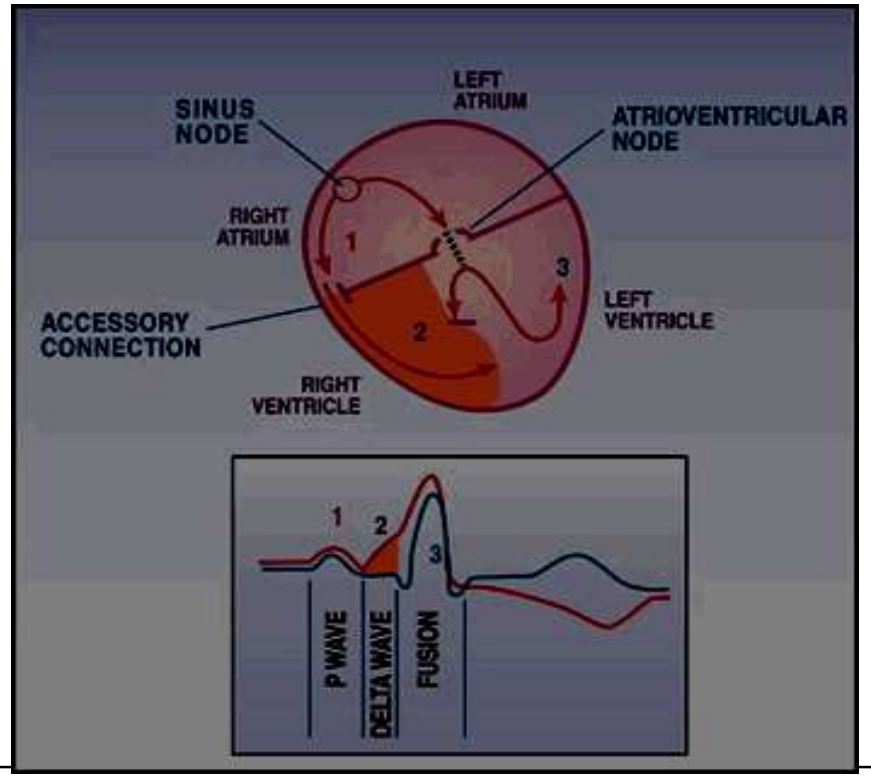
- AV dissociation (the atria and ventricles beat independently)
- The Rate is slow (25-50 /min).

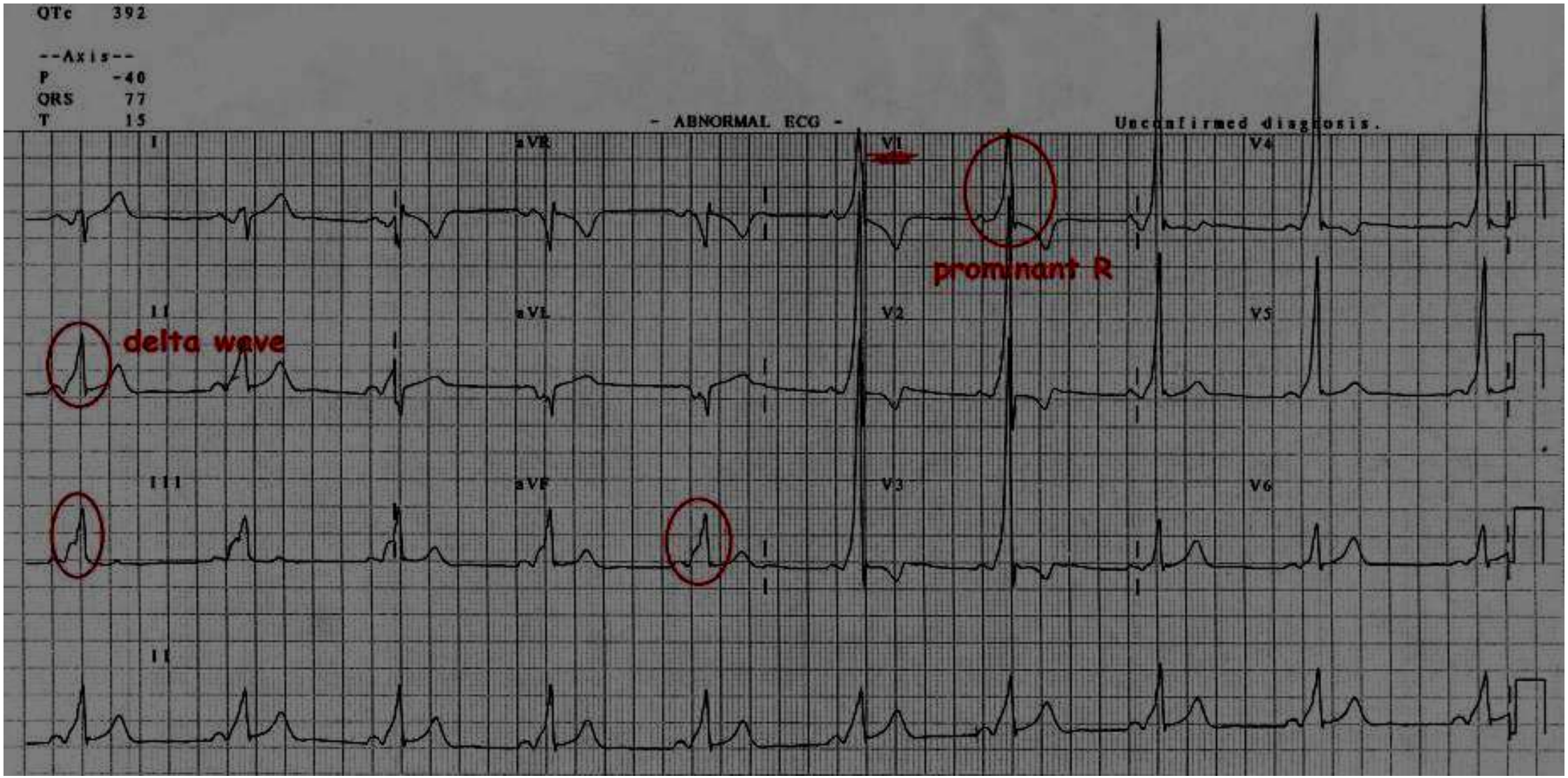


Short PR interval < 0.12s

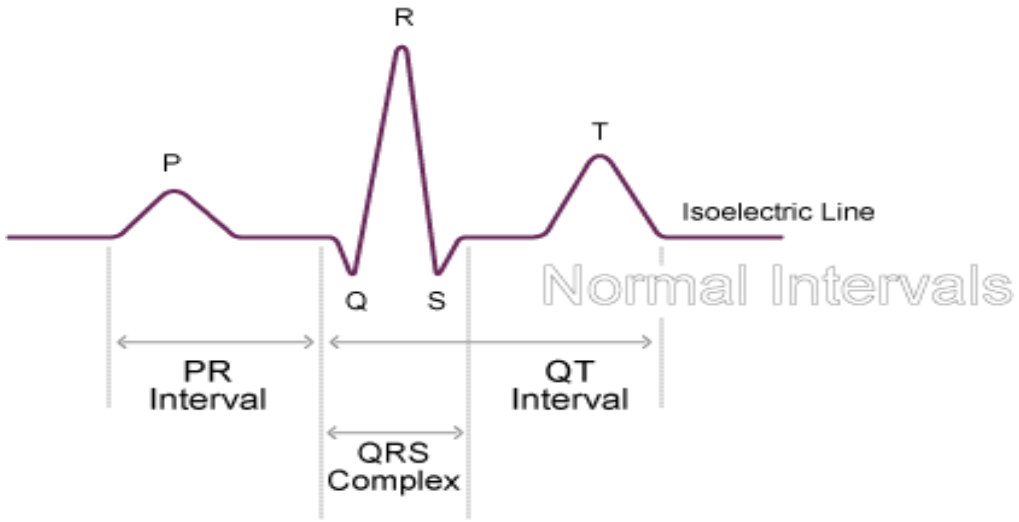
1-Preexcitation syndromes:

- WPW (Wolff-Parkinson-White) Syndrome: An accessory pathway connects the right atrium to the right ventricle or the left atrium to the left ventricle, and this permits early activation of the ventricles (delta wave) and a short PR interval.



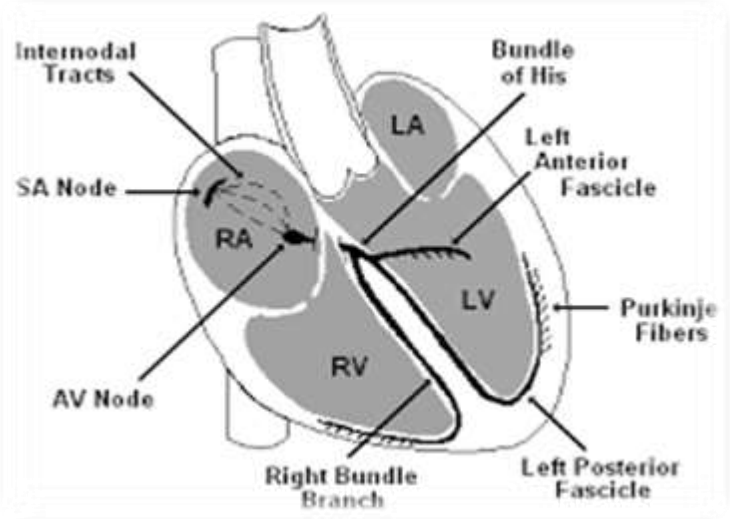

QTc 392
--Axis--
P -40
QRS 77
T 15
- ABNORMAL ECG -
Unconfirmed diagnosis.
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
delta wave
prominant R

QRS COMPLEX

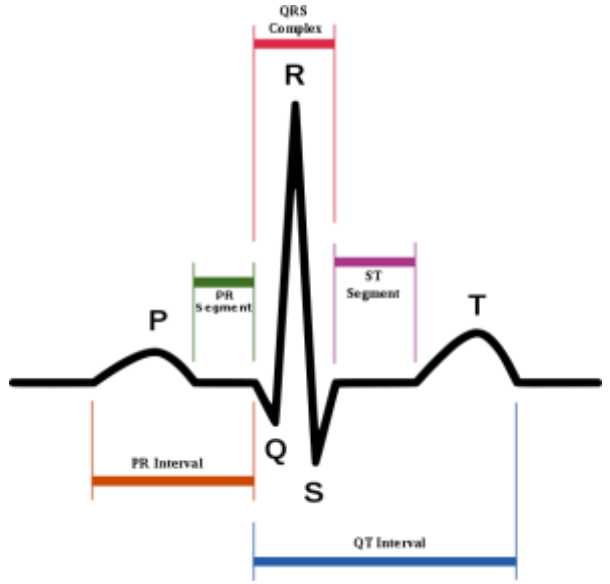


- The QRS complex is the combination of three of the graphical deflections seen on a typical electrocardiogram (ECG).
- It is usually the central and most visually obvious part of the tracing. It corresponds to the depolarization of the right and left ventricles of the heart and contraction of the large ventricular muscles.

Cont.

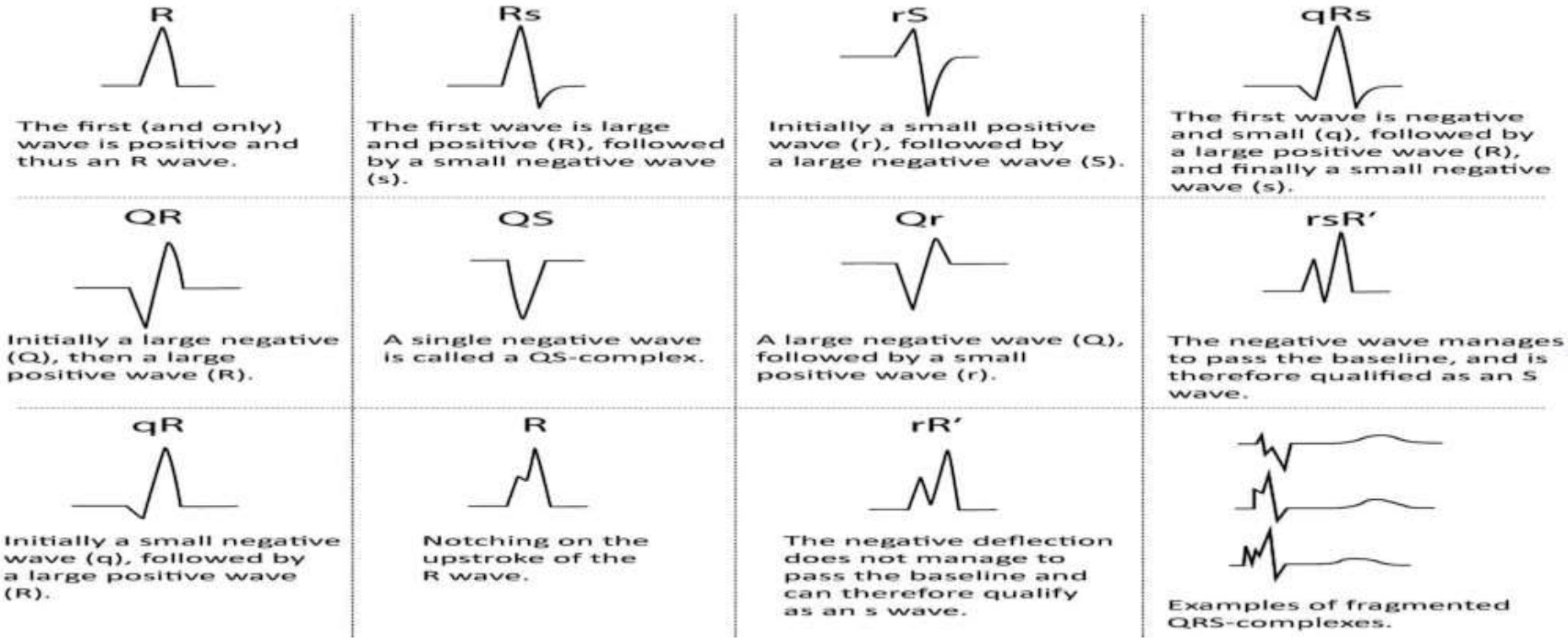


- remember that QRS complex represents ventricular depolarization, not contraction.
- Contraction proceeds during the ST segment
- The duration (width) of the QRS complex should not exceed 0.10 s, less than 3 small squares



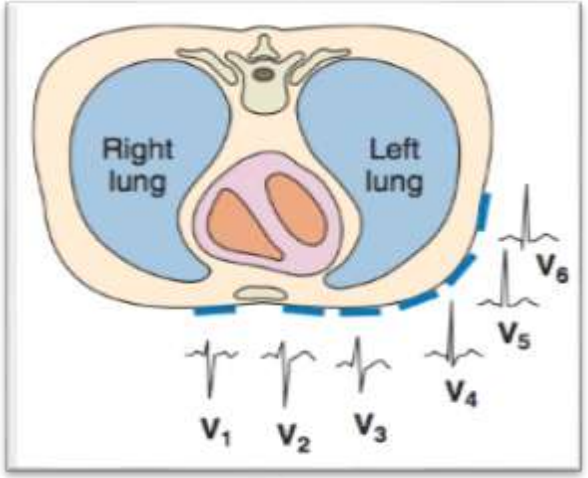
Characteristics of QRS Complex

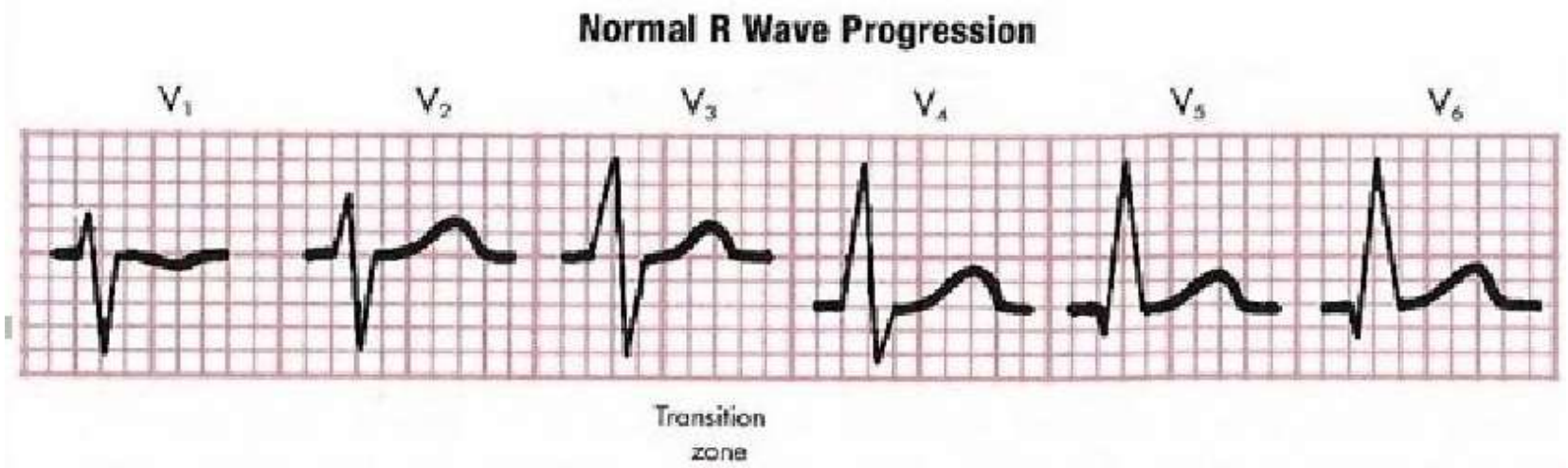
- Q : the first (- ve) wave after p wave not preceded by any other deflection.
- R: the first (+ ve) deflection after the Q wave.
- S: the first (- ve) deflection following a positive one.



Cont.

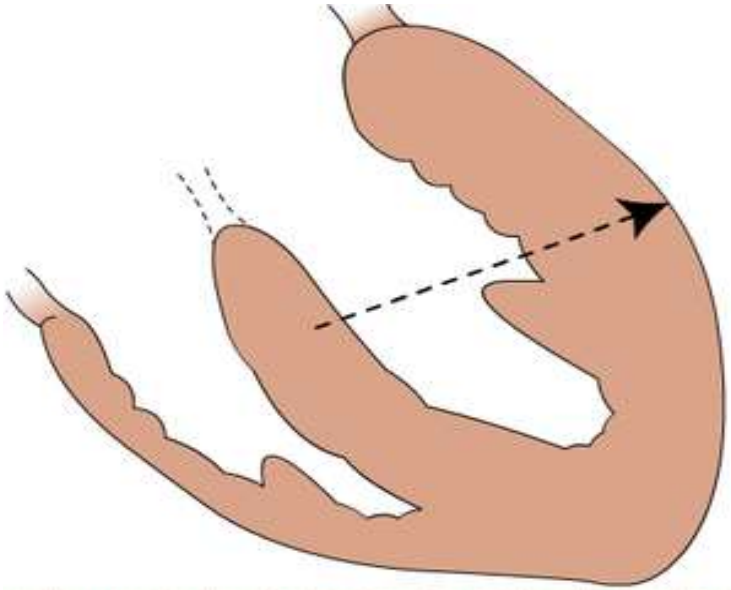
- Voltage amplitude increase normally from V1 to V6
- V1 predominant (negative) and become predominant positive in left chest leads





left ventricular hypertrophy:

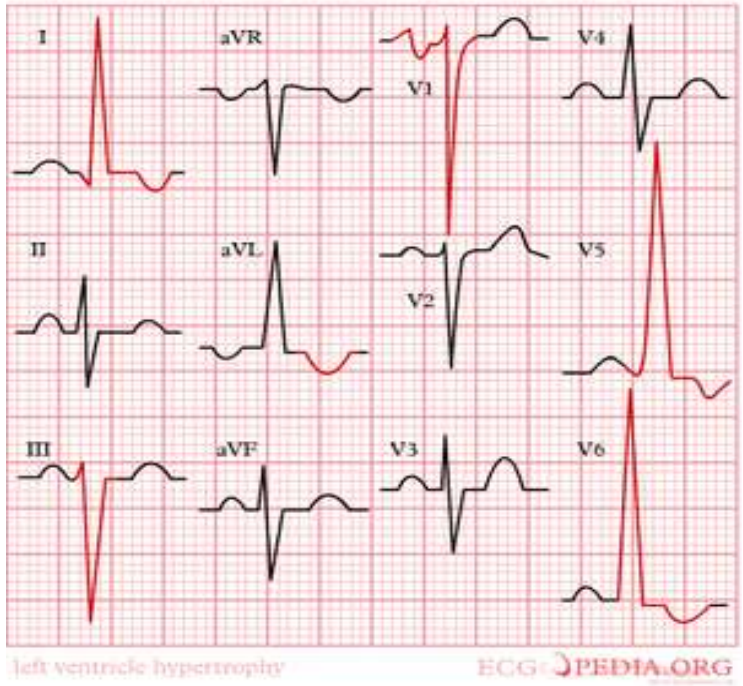
- Left ventricular hypertrophy (LVH) is a pathologic increase in muscle mass of the left ventricle in response to pressure overload



ECG FEATURES :

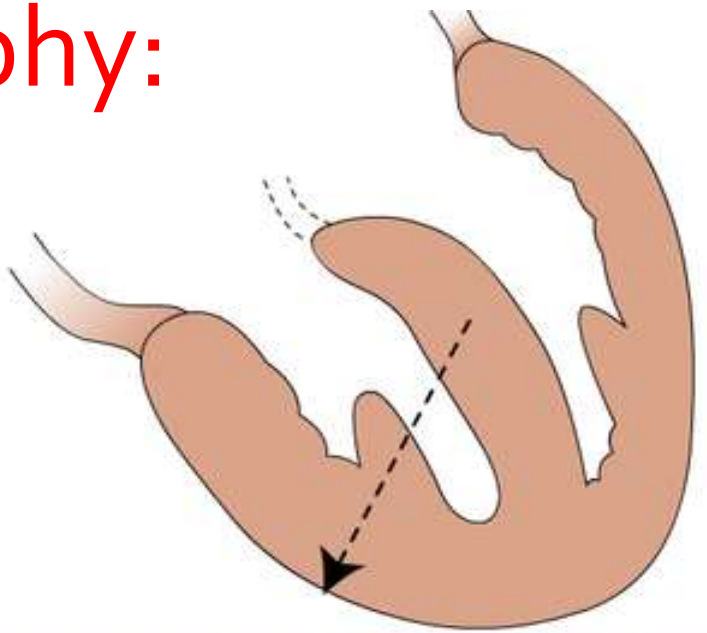
- same direction for chest leads

- The (-ve) s in V1 plus the (+ve) V5 or V6 is greater than 35 small squares (7 big squares)



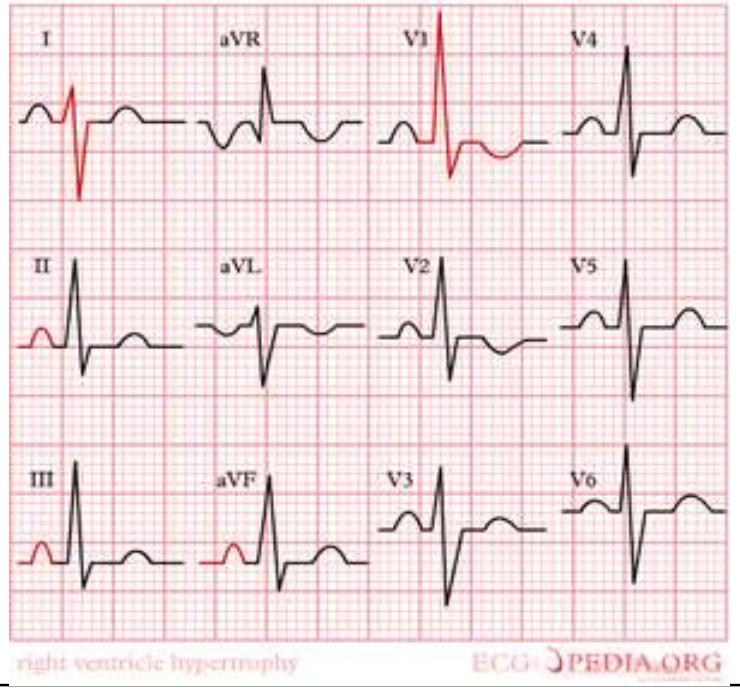
Right ventricular hypertrophy:

- Right ventricular hypertrophy (RVH) is a pathologic increase in muscle mass of the right ventricle in response to pressure overload



- ECG FEATURES :
- V1 is positive and V6 is more negative in S wave
- (+ve) R in V1 plus deep (-ve) S in

left chest leads (V5-V6)

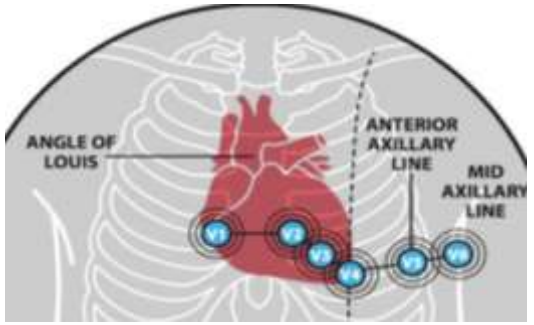


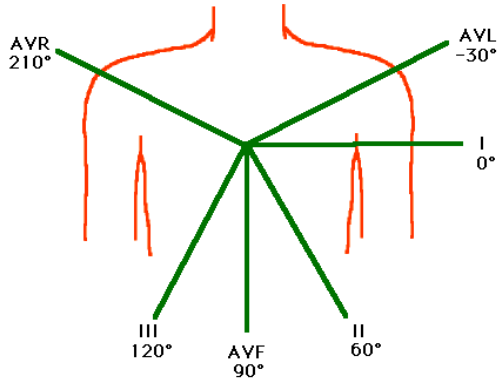
Low voltage ECG

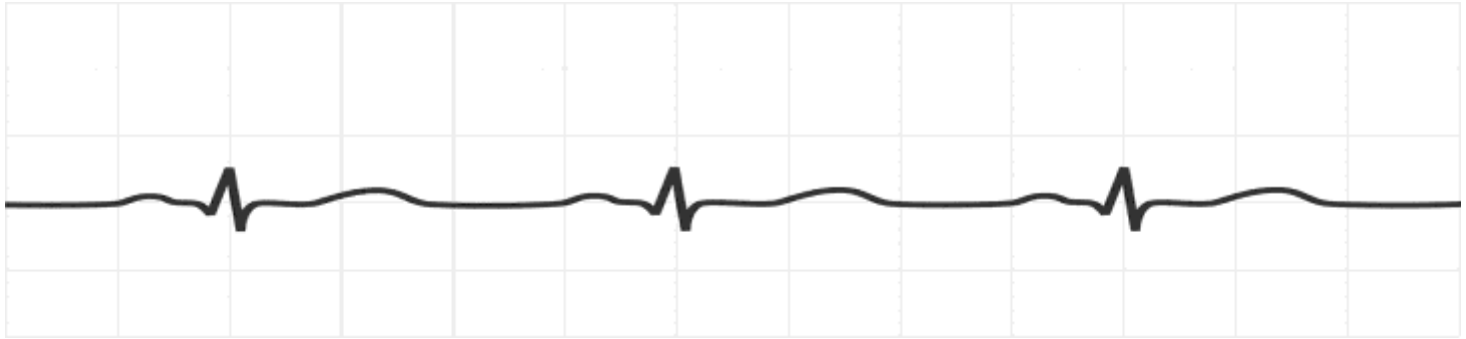
1- QRS voltage amplitude is less than 10 small squares in all chest leads

OR

2- QRS voltage amplitude is less than 5 small squares in all limb leads







Causes of low voltage ECG

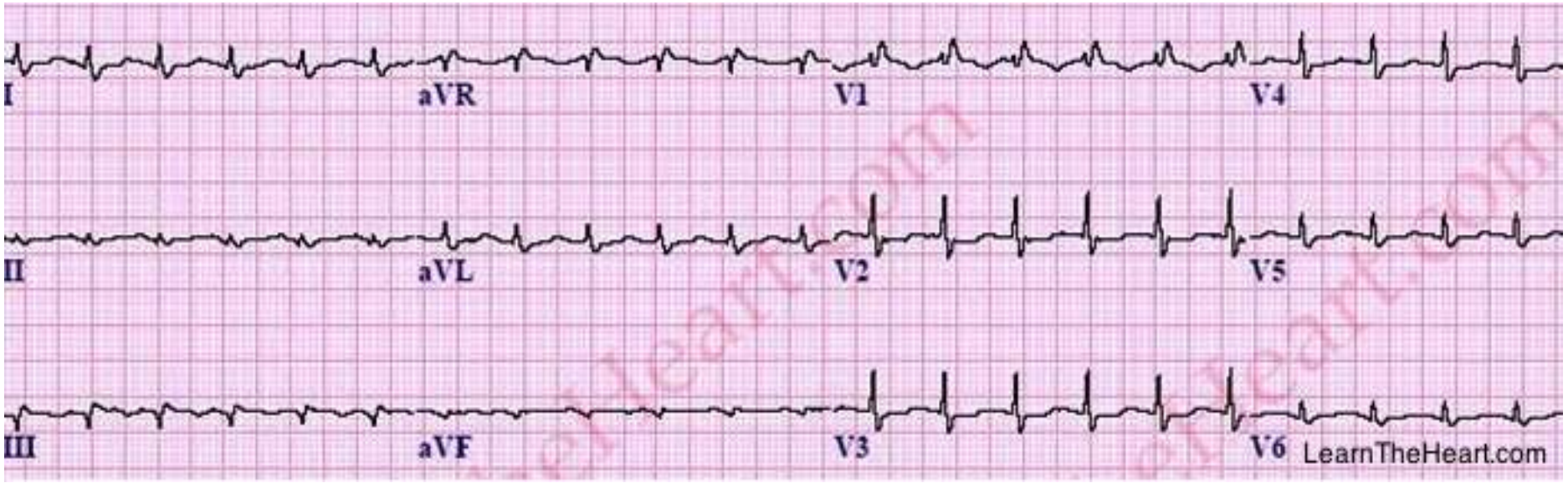
1- Severe obesity

2- Large left pneumothorax

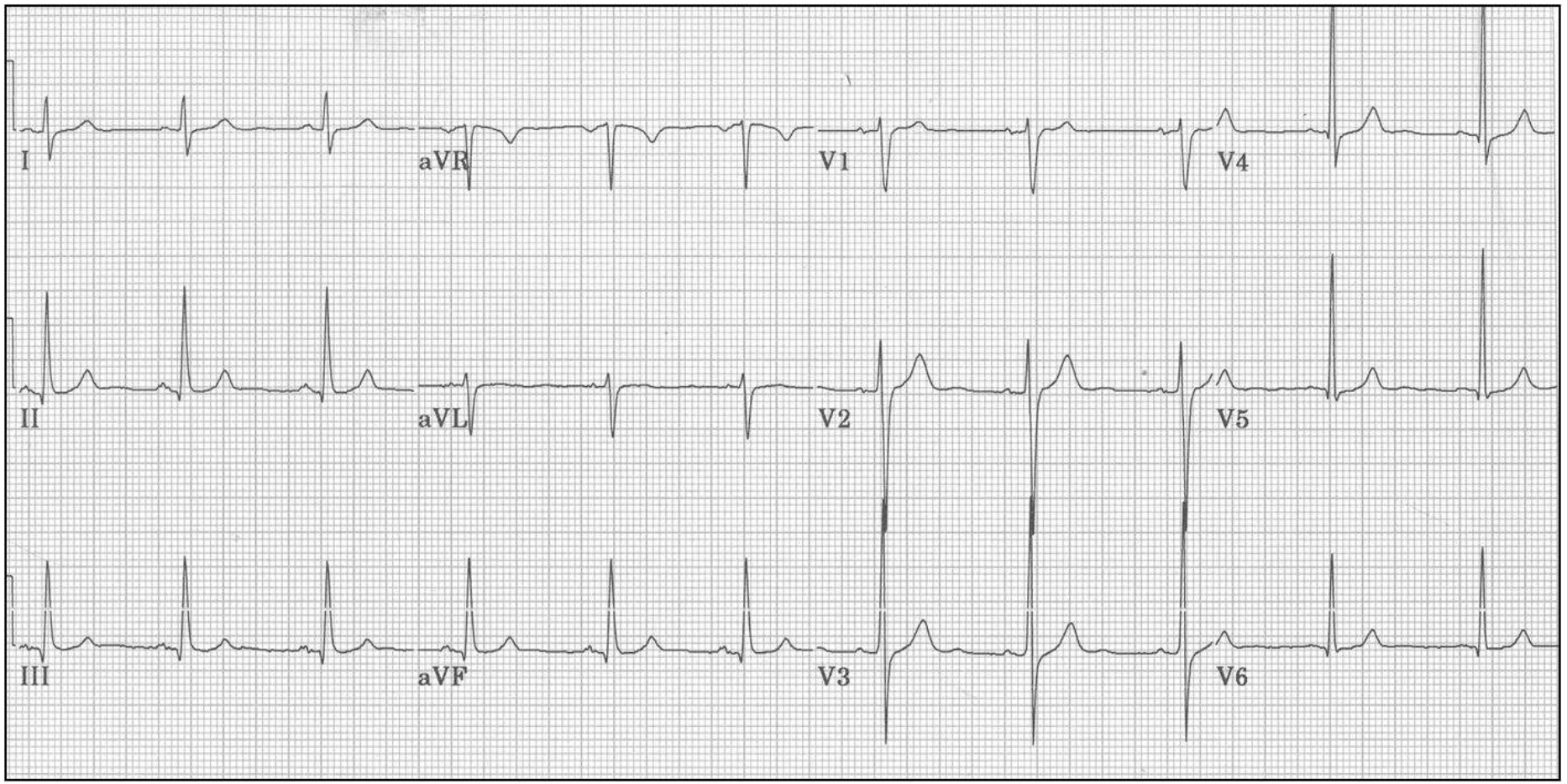
3- Emphysema

4- Pericardial effusion

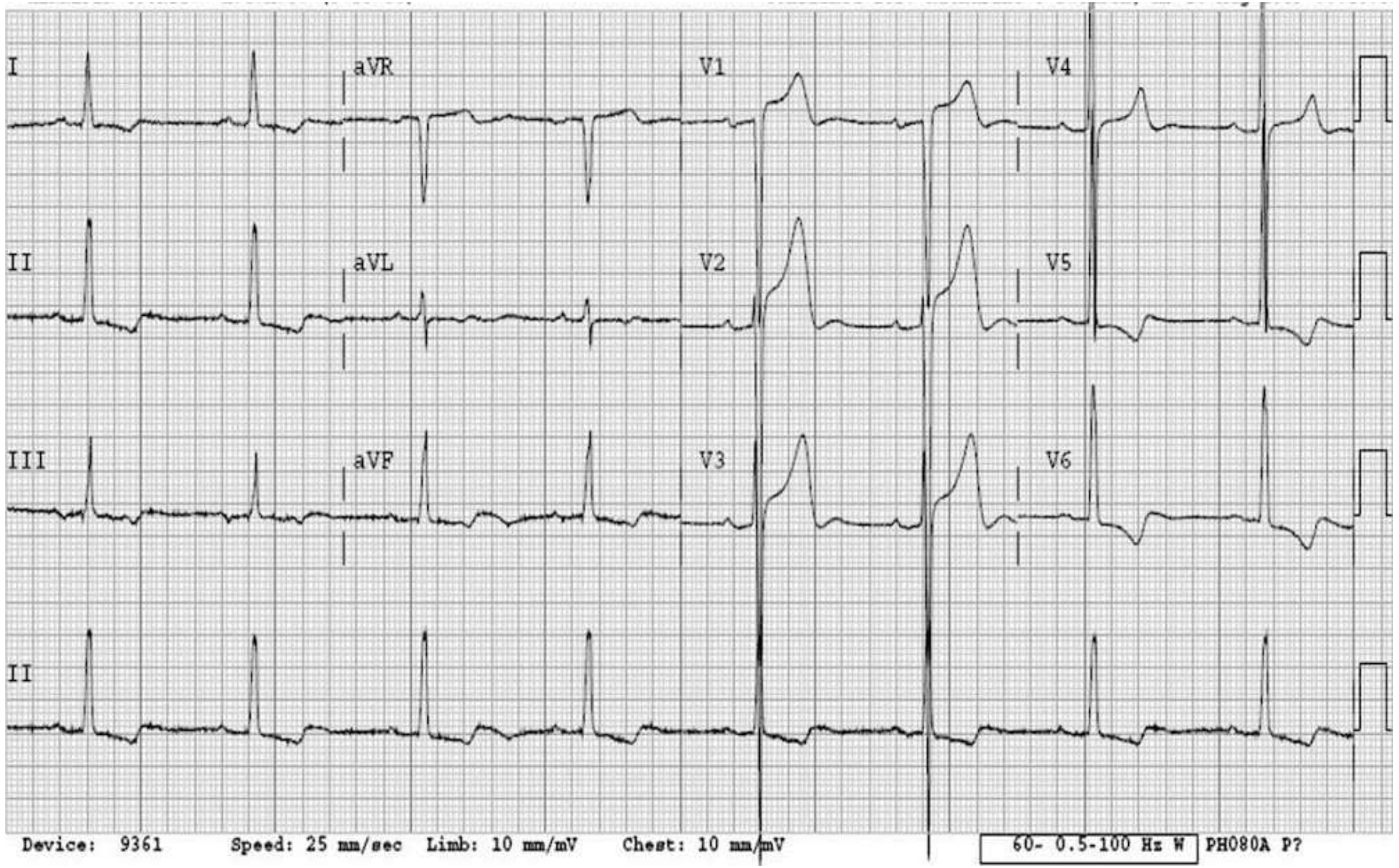
5 -AMI



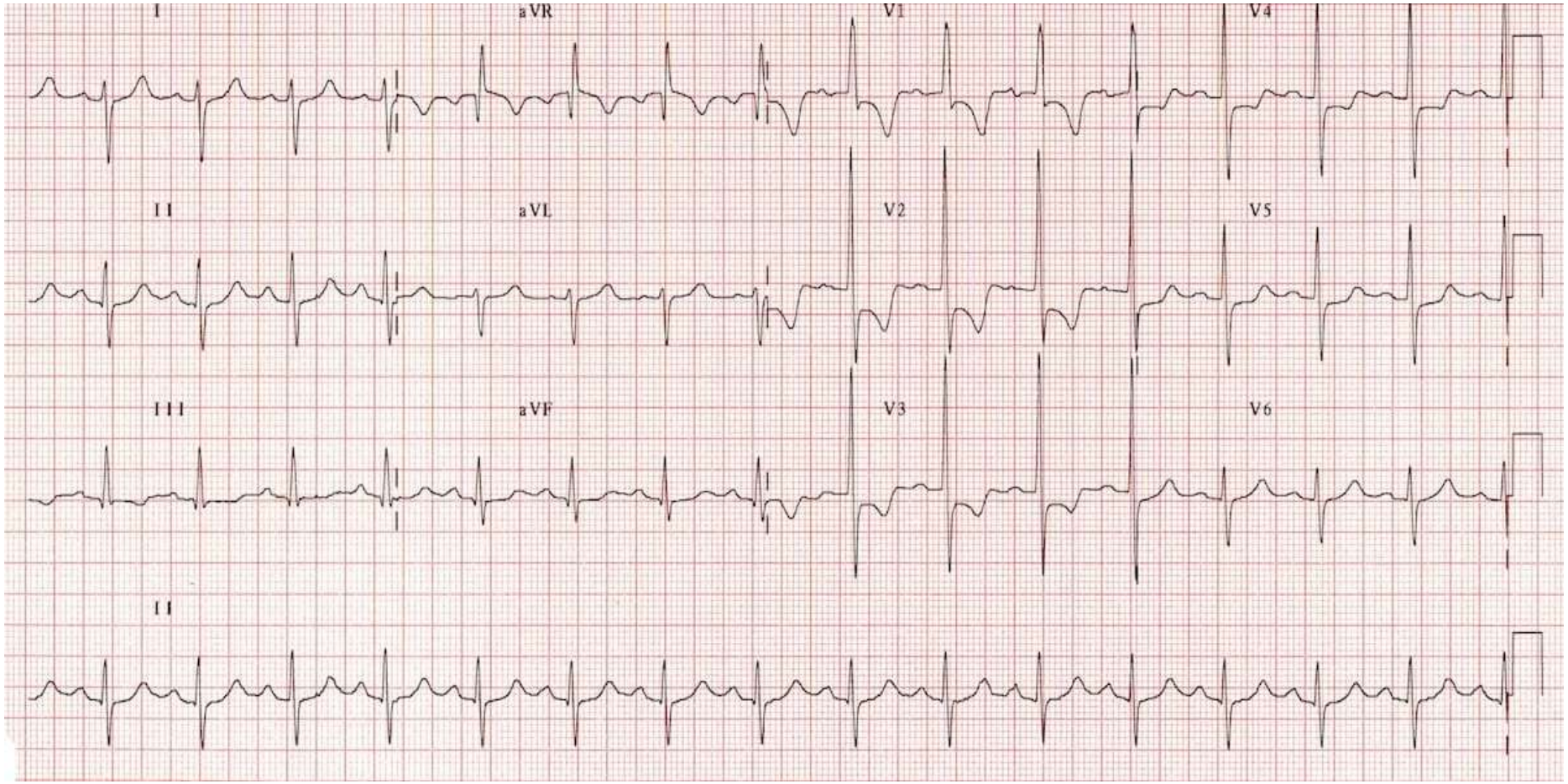
Normal ECG



LVH

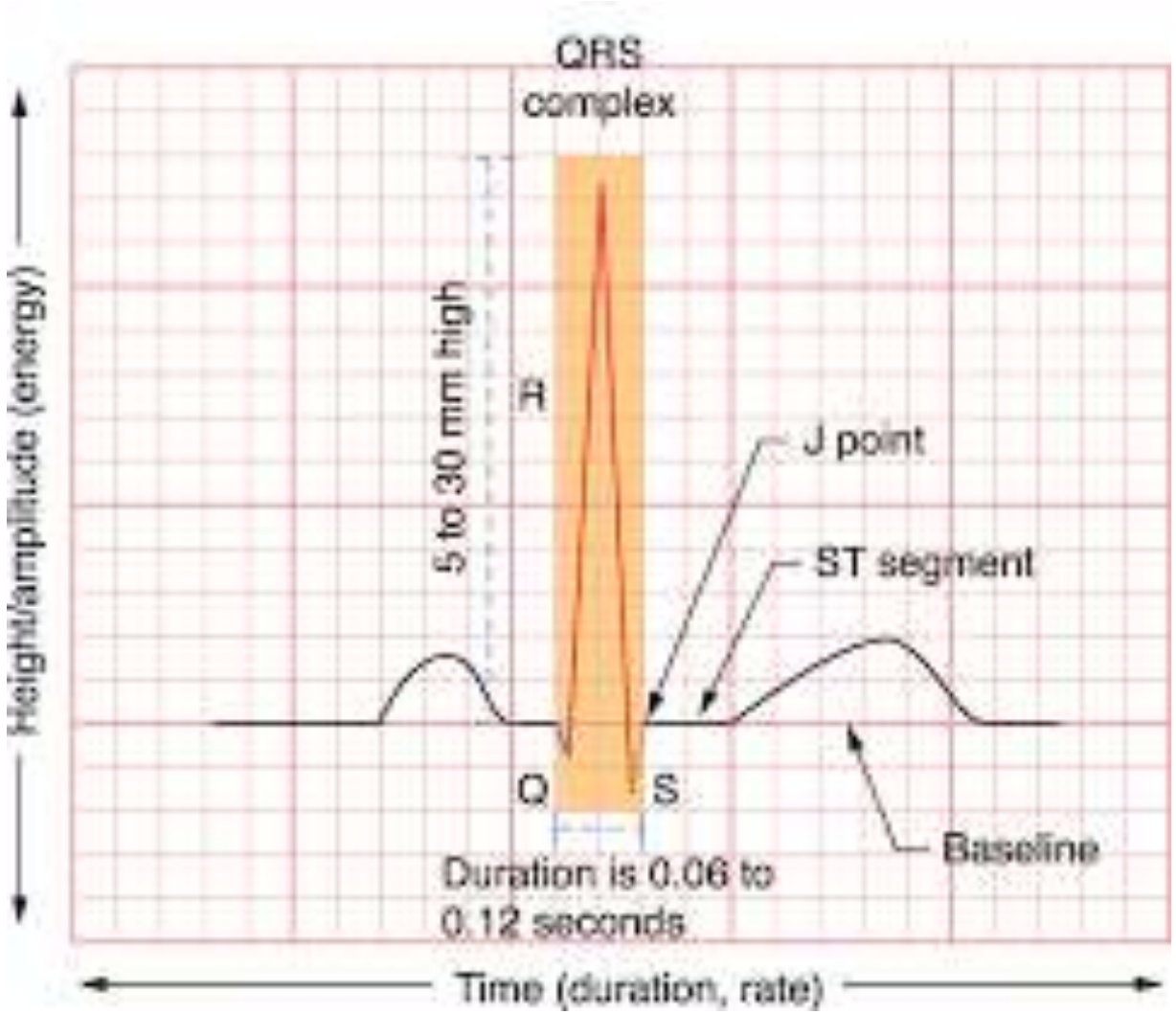

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
Device: 9361
Speed: 25 mm/sec
Limb: 10 mm/mV
Chest: 10 mm/mV
60- 0.5-100 Hz W
PH080A P?

RVH



The QRS duration:

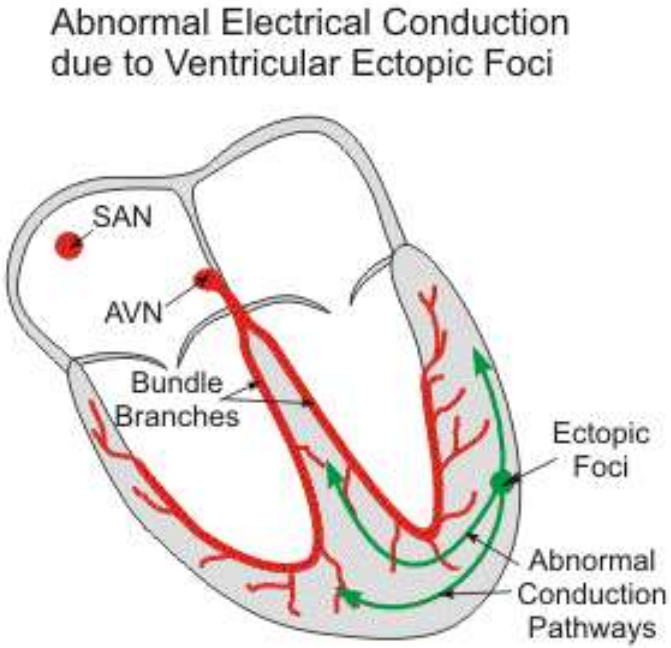
- Normal : Less than 3 small squares



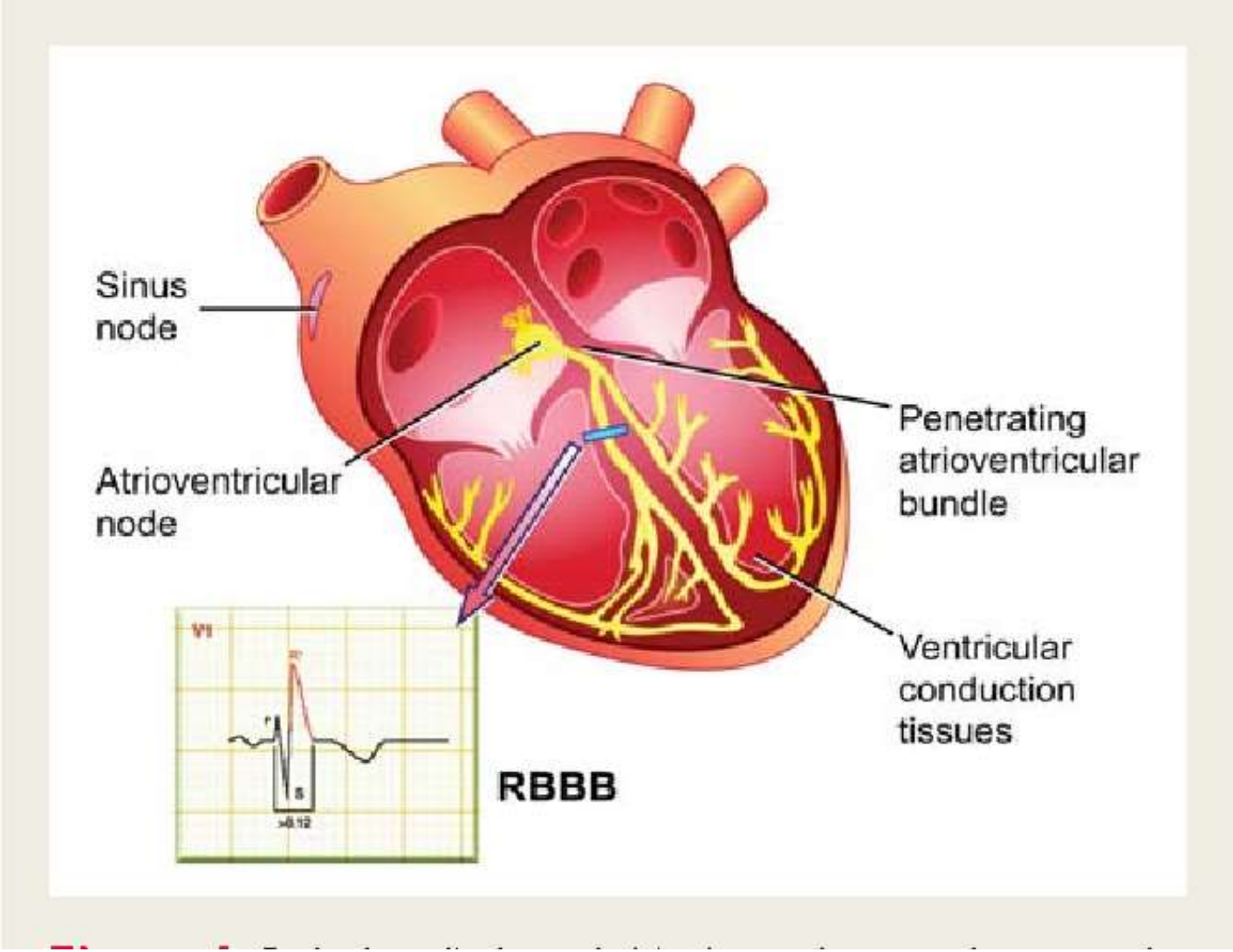
Causes of wide QRS complex

1- Ectopic focus in the ventricle

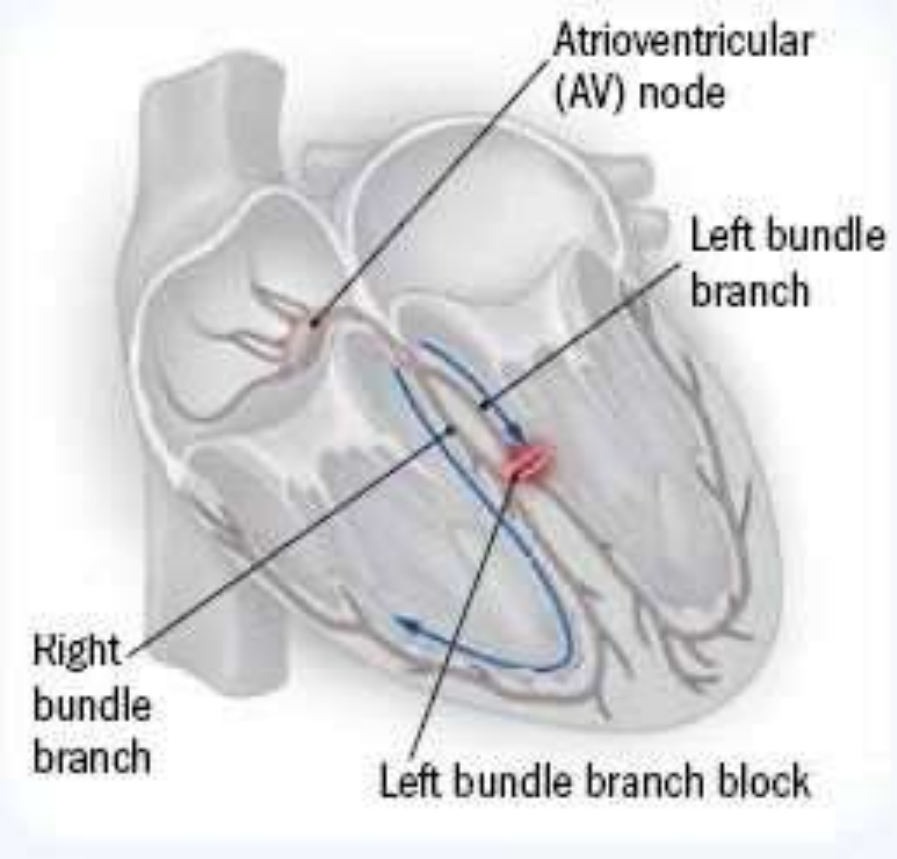
- Ventricular premature contractions (VPCS)
- Idioventricular Rhythm (IVR)
- Ventricular Tachycardia (VT)

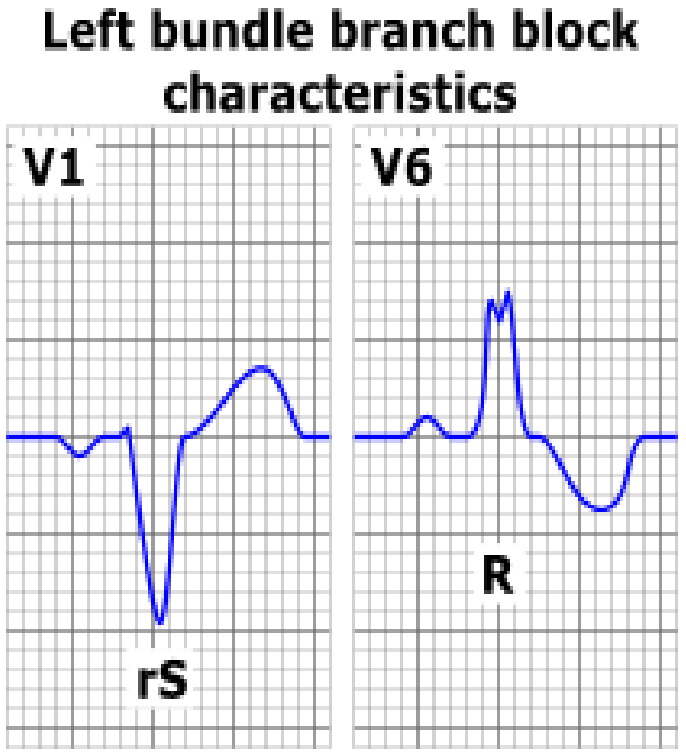


2- right bundle branch block (RBBB)



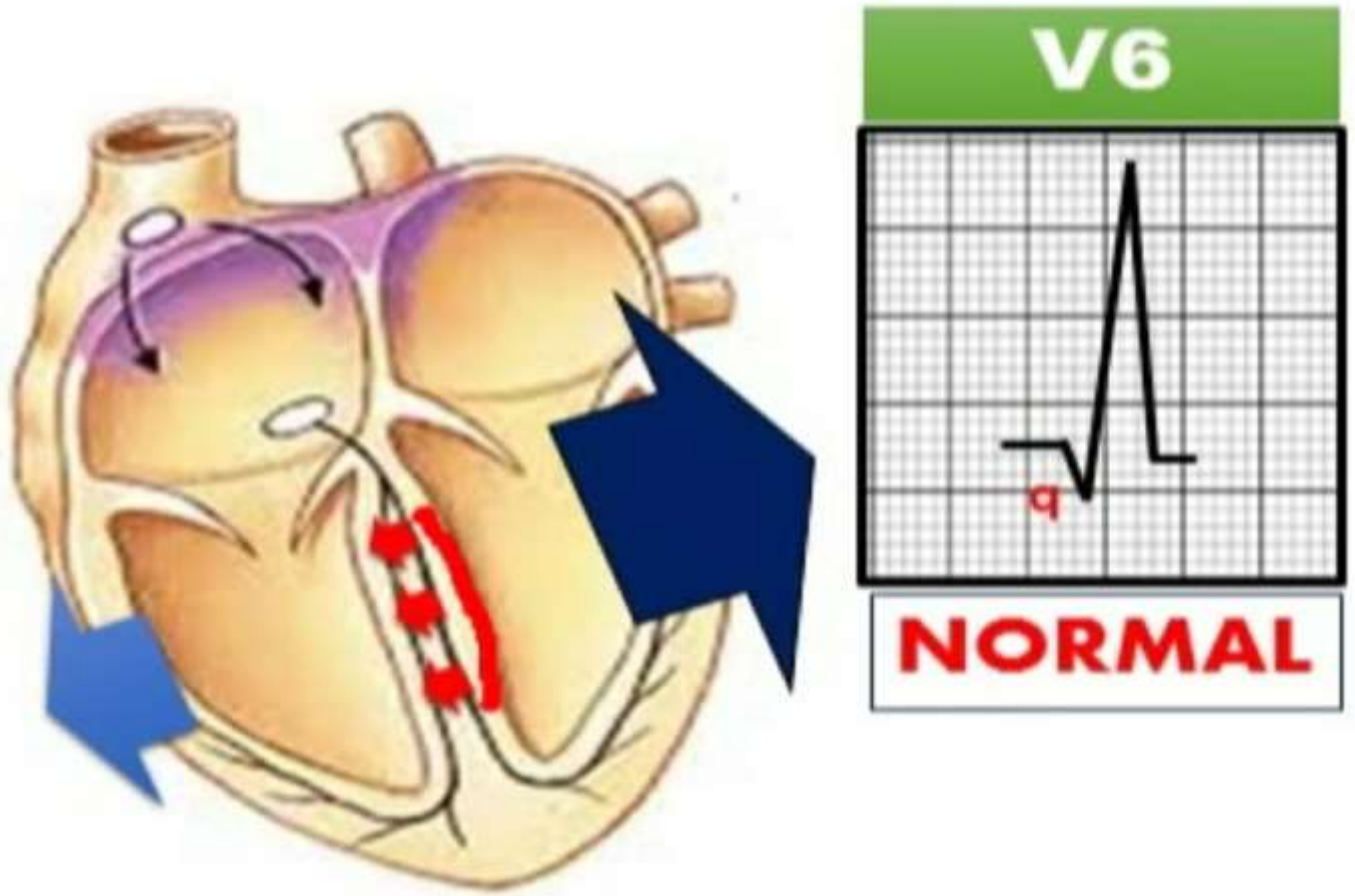
3- left bundle branch block (LBBB)



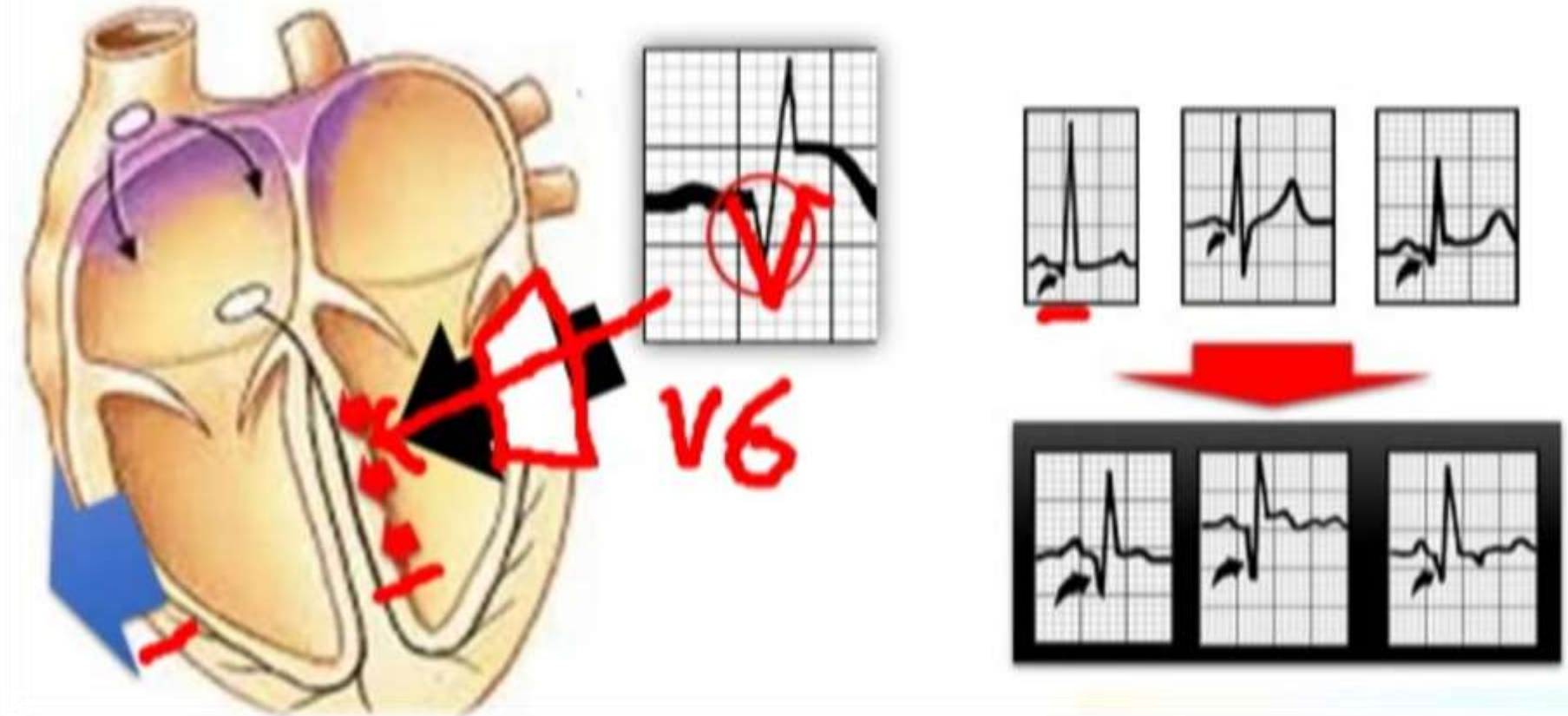



RBBB
V1
V6
rSR'
qRs
Anterior
Lateral
LBBB
V1
V6
rS
R
Anterior
Lateral
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

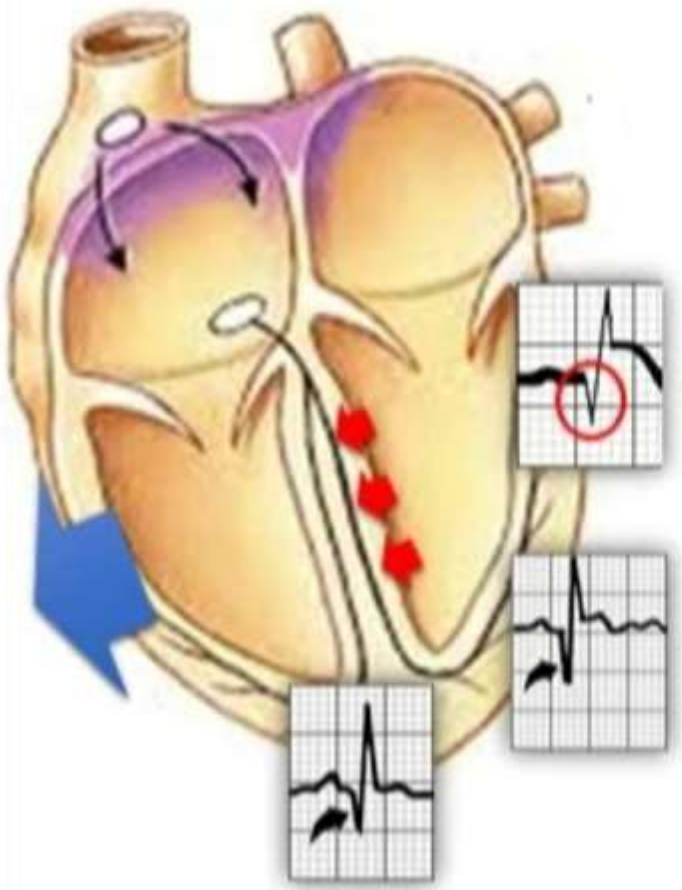
Q Wave



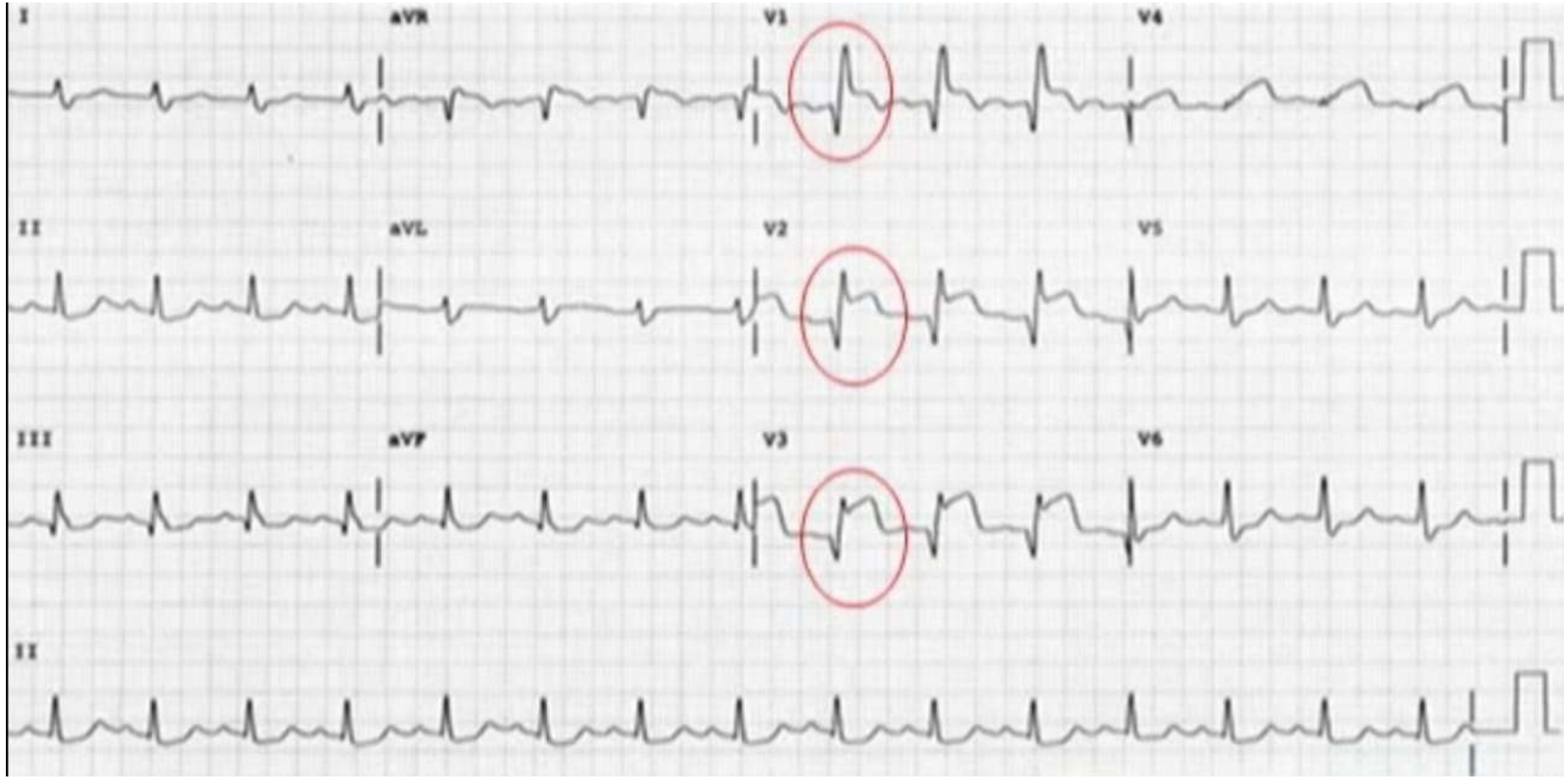
The formation of Q waves



The Criteria of Q waves



1. More than 1 small square in width
2. Amplitude is at least 25% of the following R
3. Appears in multiple leads corresponding to a certain cardiac segment (rather than a single lead)
4. Appears in leads where q waves are typically absent (Normally you can see q wave in V6, aVL, and LI)
5. Appearance of new q waves in the ECG record of the same patient


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

T wave

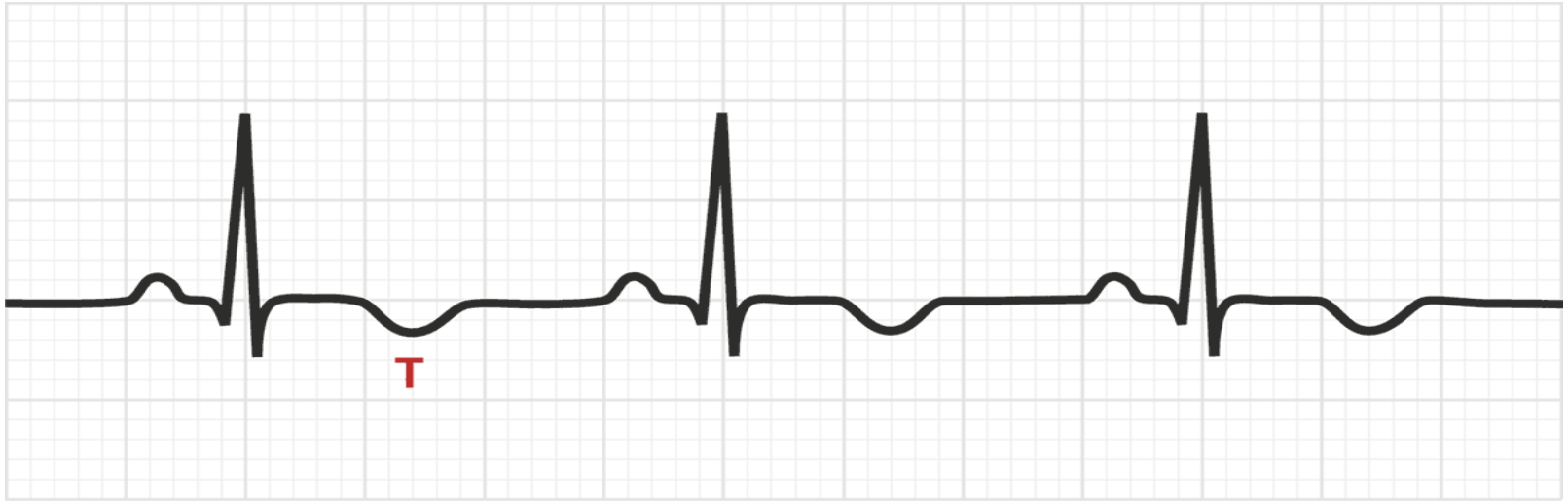
- T wave: produced by ventricular repolarization

NORMAL

T wave follow the direction of the QRS complex (+ve in most leads , -ve in aVR)

Its height is usually not more than 5 small squares in limb leads (L1,L2,L3 and aVR,aVL,aVF) and 10 small squares in chest leads (V1,V2,V3,V4,V5,V6)

Causes of T wave inverion

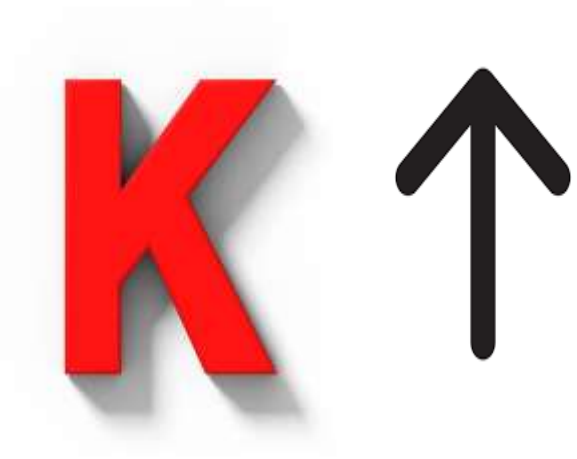


1) ventricular ischemia (the most dangers when finding T wave inversion)
2) Ventricular strain

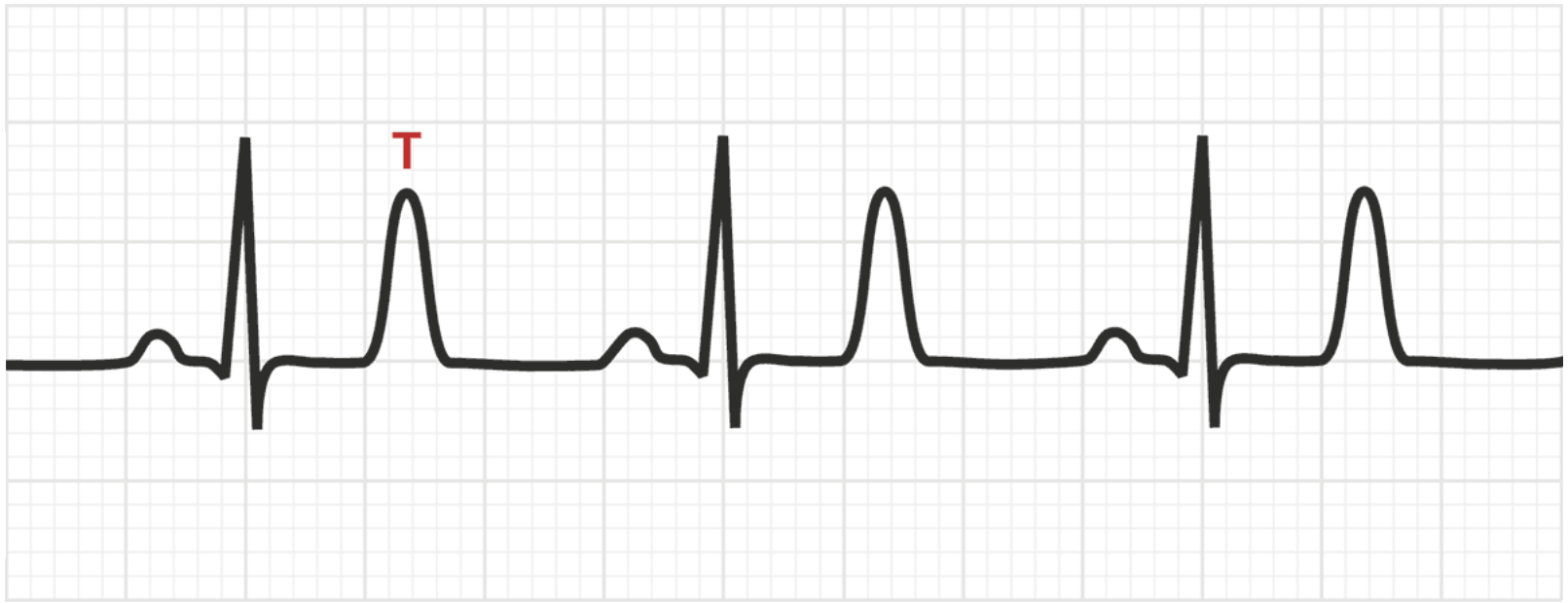
(pulmonary hypertension,systemic hypertension,pulmonary embolism)

3) Pericarditis
4) Digitalis effcct
5) Intracranial hemorrhage (deep ,wide inverted t wave)
6) Asociated with BBB (bondle branch block)

Tall peak T wave



Tented t wave



Hyperkalemia

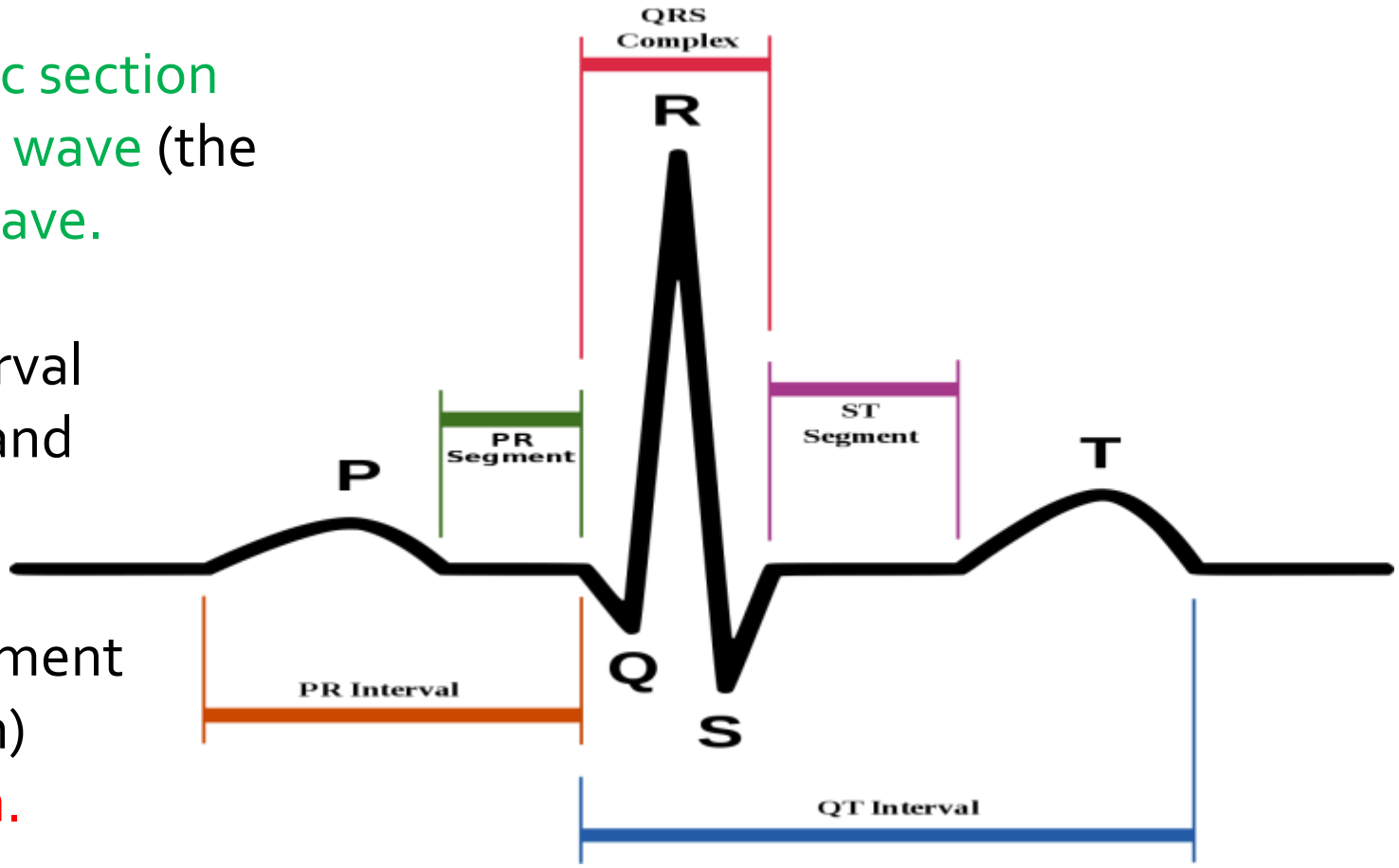
ST Segment

S-T Segment

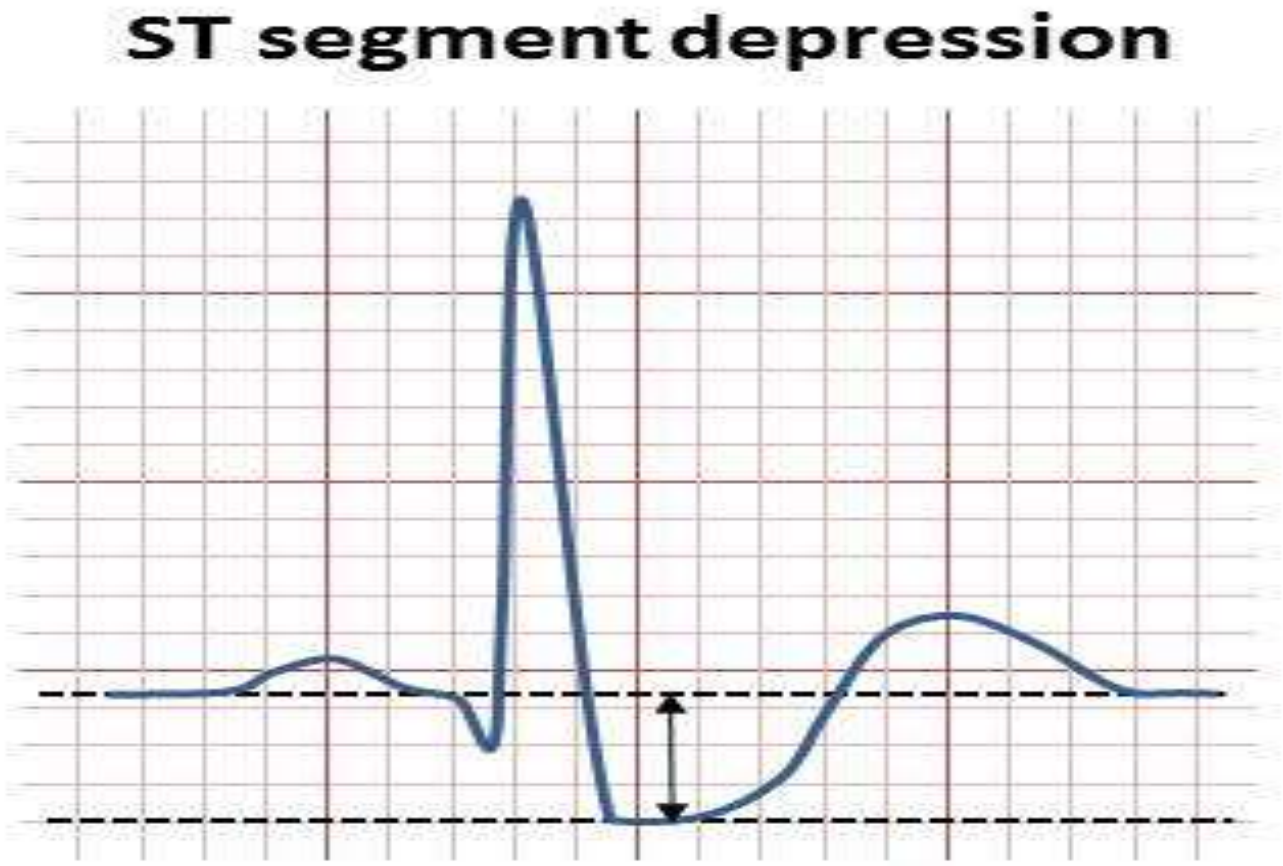
The ST segment is the flat, isoelectric section of the ECG between the end of the S wave (the J point) and the beginning of the T wave.

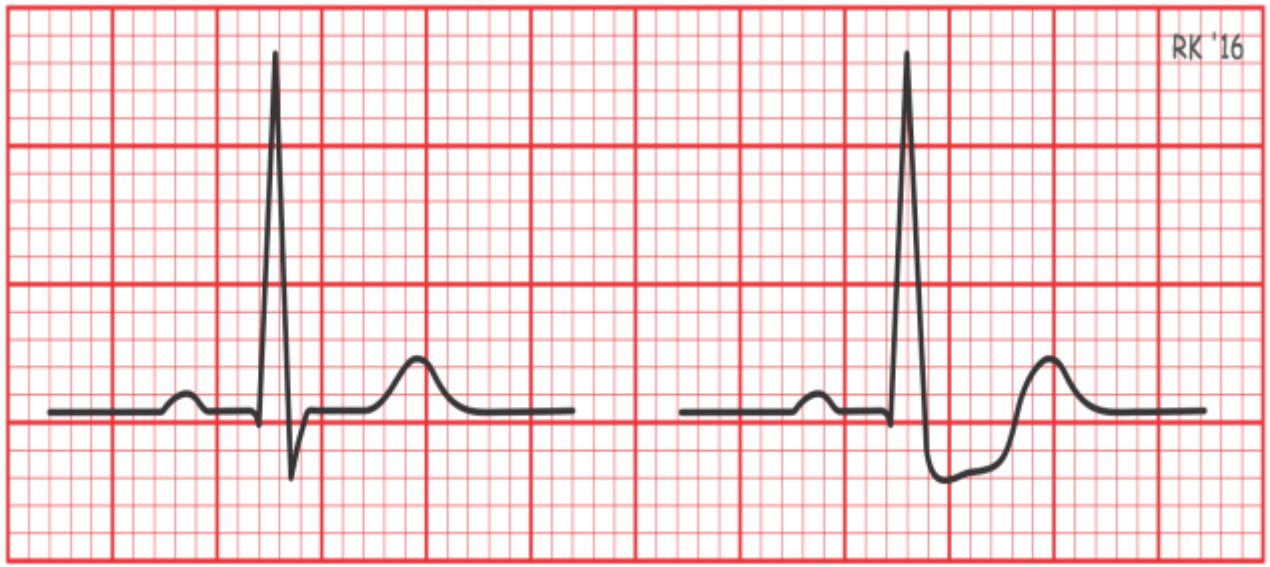
The ST Segment represents the interval between ventricular depolarization and repolarization.

The most important cause of ST segment abnormality (elevation or depression) is myocardial ischaemia or infarction.



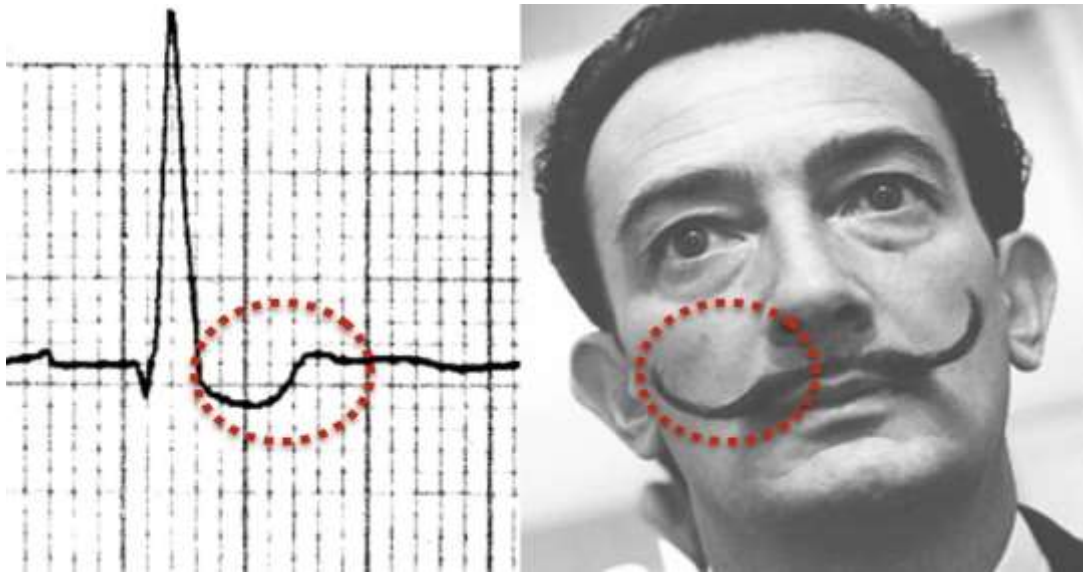
Subendocardial injuries





ischemia

Digitalis effect

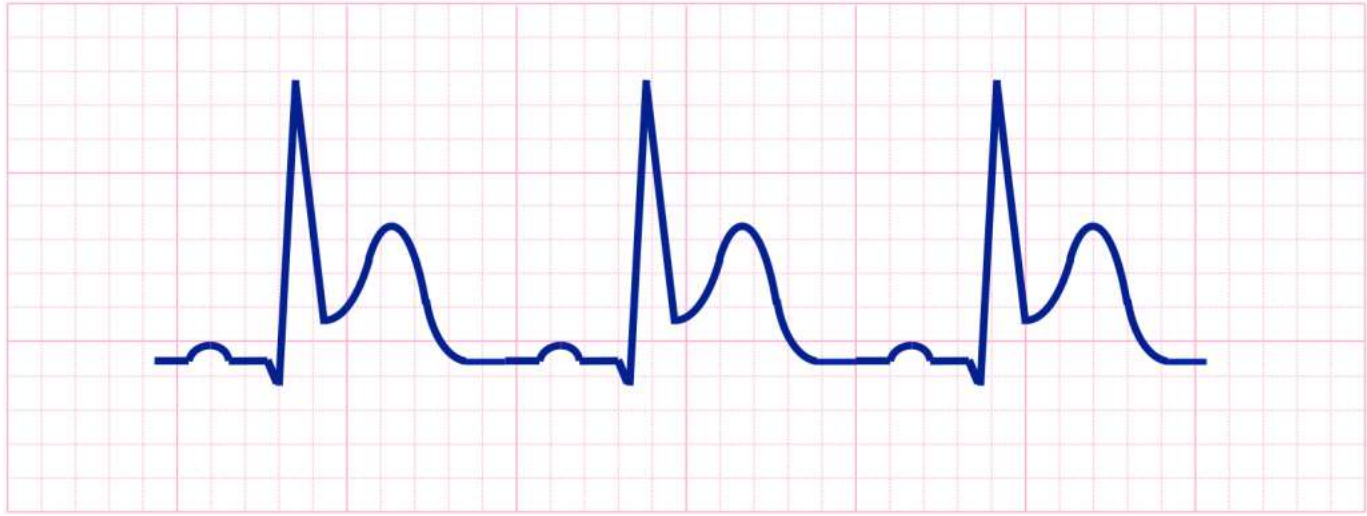


Scooping of the ST segment
(reverse tick sign , Salvador Dali's moustache)

ST segment elevation

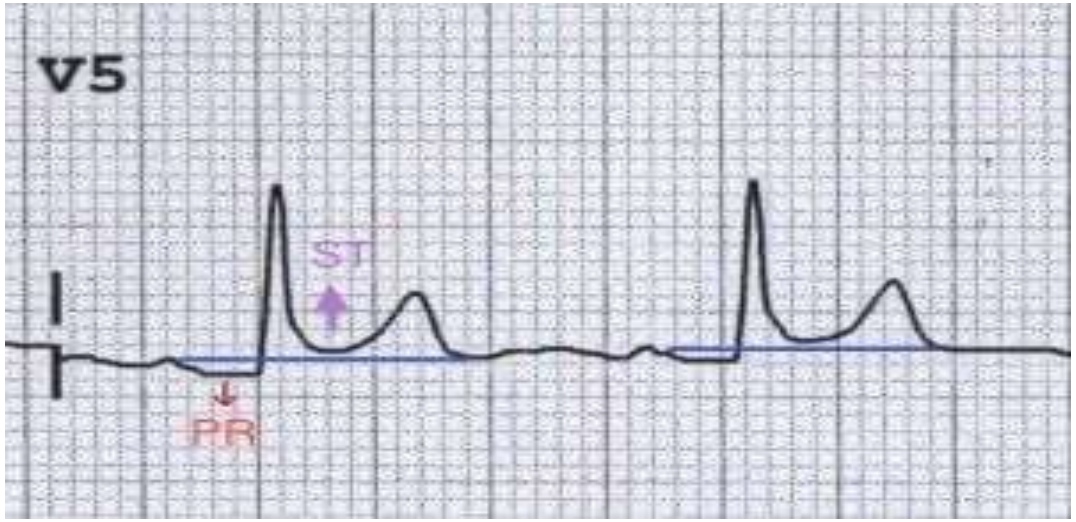
STEMI
- usually the STE is localized

Convex upward



elevated

In acute pericarditis
- Diffuse st elevation (concave upward) in most leads except in avr
- The most specific ecg changes in pericarditis is PR depression

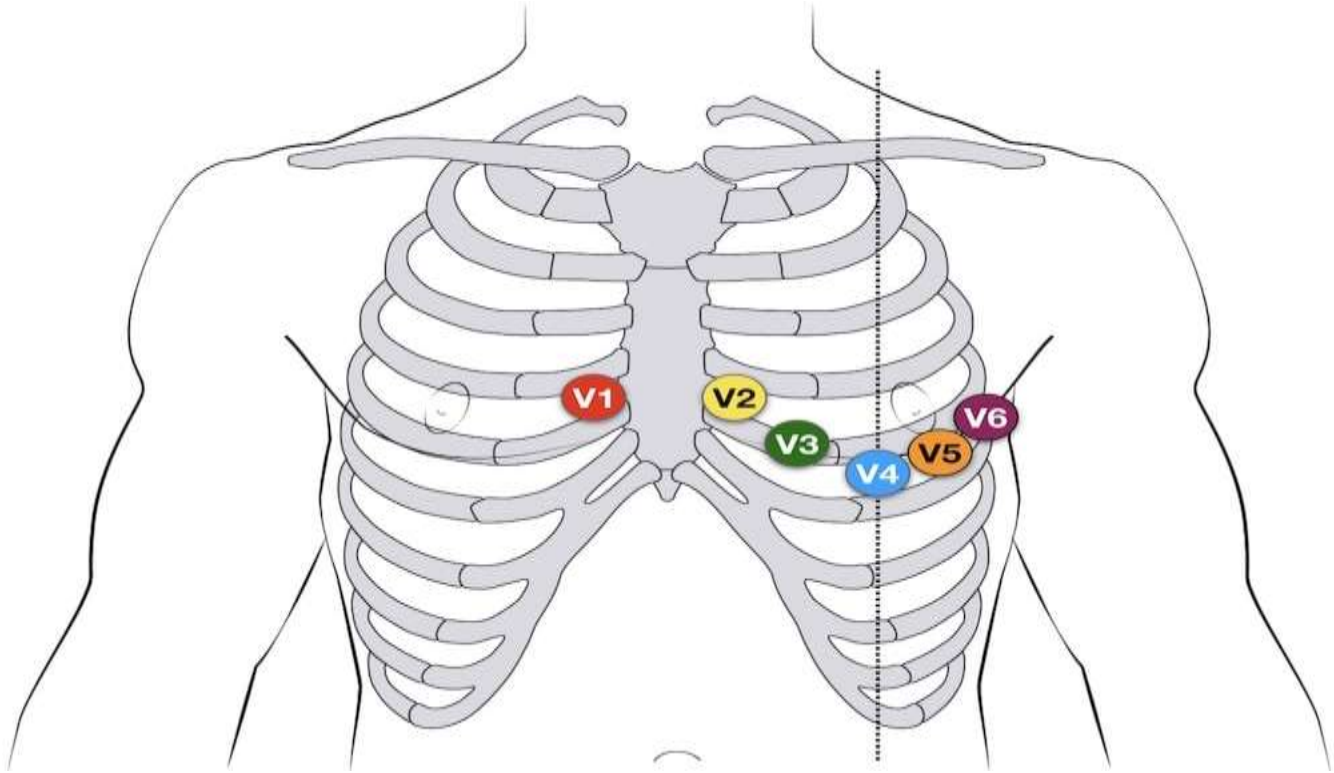


Concave upward

AMI: acute myocardial infarction

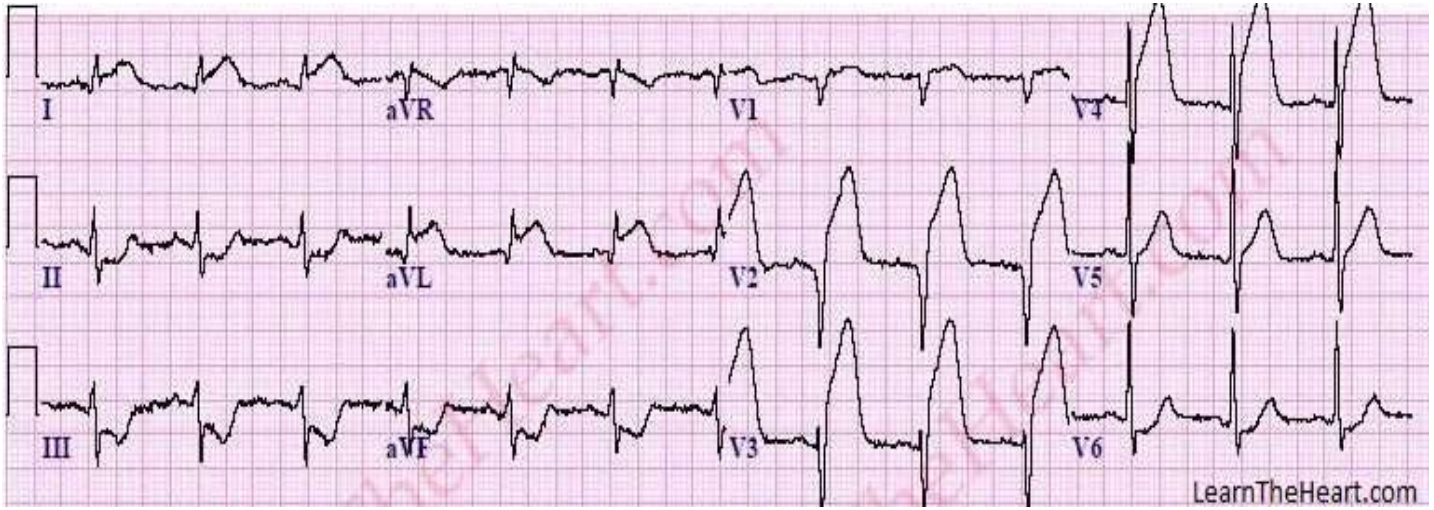
The 3 cardinal features of AMI are:

Deep: Q
Eelvated: ST segment
Depressed: Twave

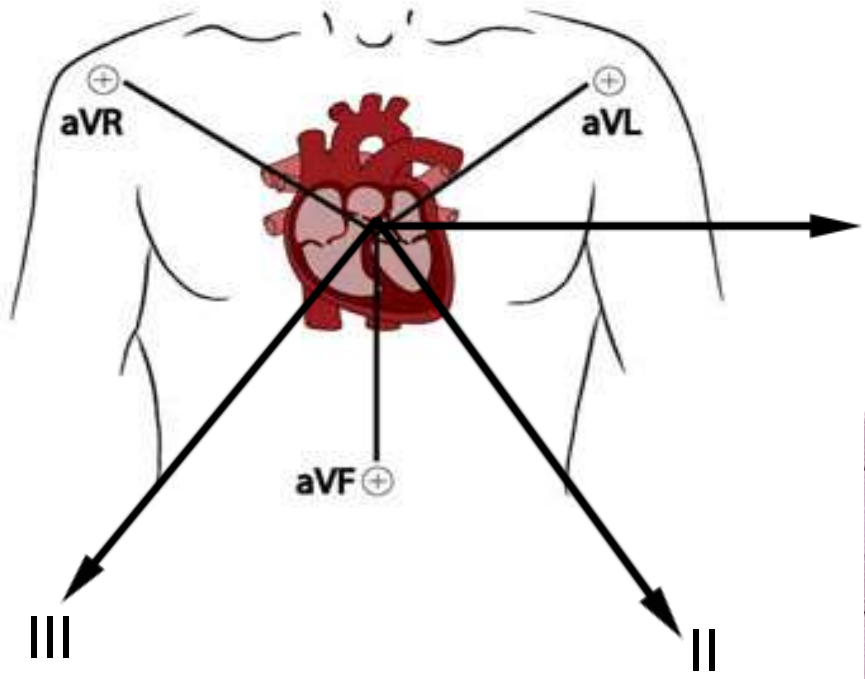


1) Anterior wall myocardial infarction

V1+V2: septal
V3+V4: anterior wall
V1+V2+V3+V4: anteroseptal
V5+V6: lateral wall
V3+V4+V5+V6: anterolateral
ALL: extensive anterior wall myocardial infarction

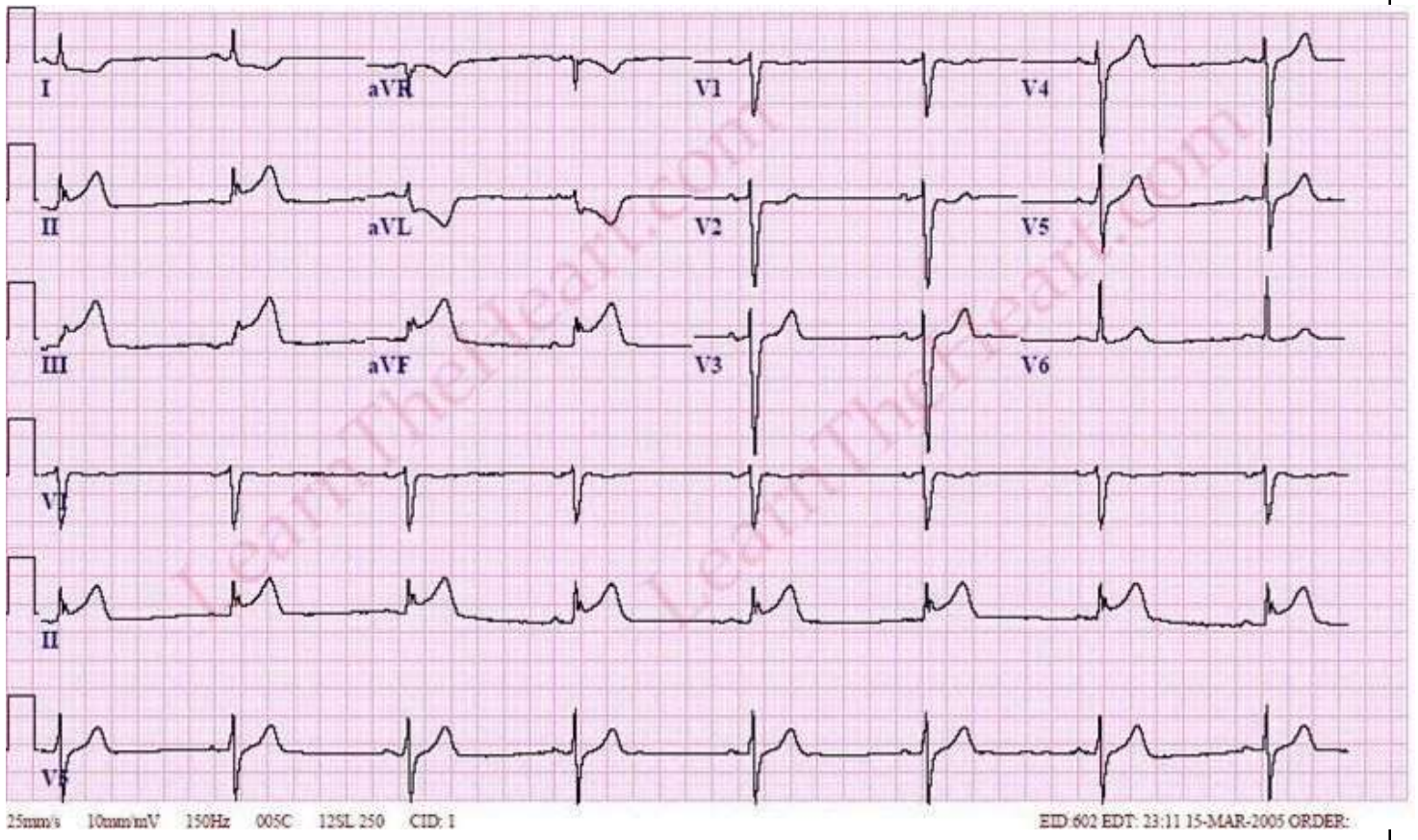


2)Inferior wall myocardial infrction



II,III AND AVF = INFERIOR MI

RIGHT CORONARY ARTERY



ETT: exercise treadmill test

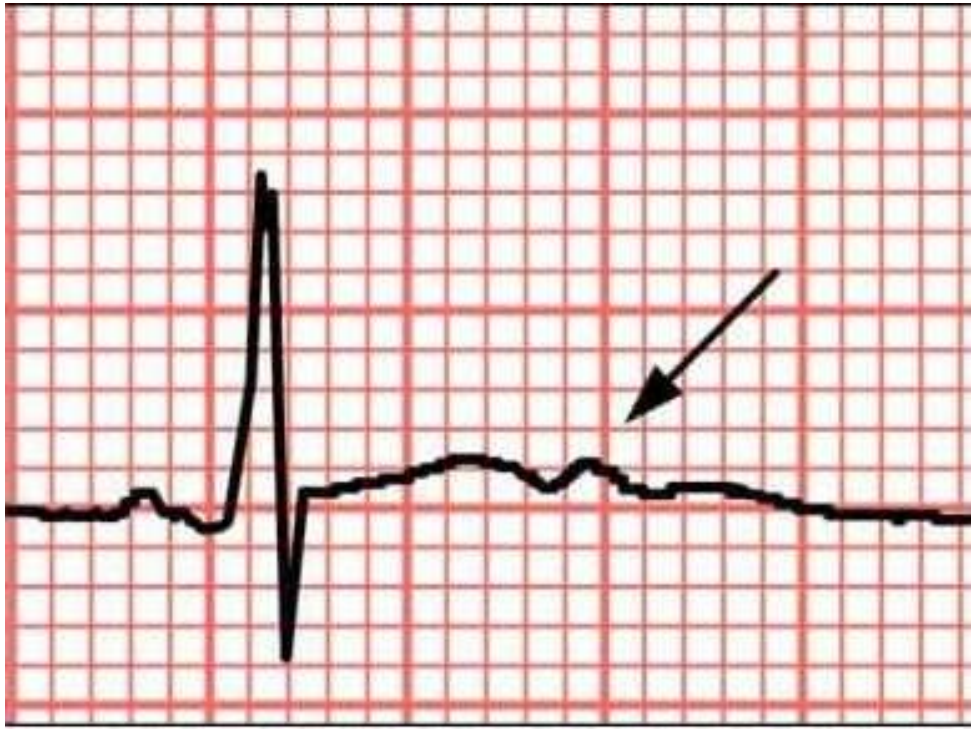
An exercise stress test is **used to determine how well your heart responds during times when** it's working its hardest. During the test, you'll be asked to exercise — typically on a treadmill — while you're hooked up to an electrocardiogram (EKG) machine. This allows your doctor to monitor your heart rate.

Depression of the ST segment more than 2 small squares
Is significant

Patients with a positive stress test should undergo cardiac catheterization

U wave

- Not a common finding.
- The U wave is a >0.5mm deflection after the T wave best seen in V2 or V3.
- These become larger the slower the bradycardia – classically U waves are seen in various **electrolyte imbalances** or **hypothermia**, or **antiarrhythmic therapy** (such as digoxin, procainamide or amiodarone).



Chamber enlargement

- Tricuspid stenosis or Pulmonary HTN (peaked P)
- Mitral stenosis (broad bifid P)

Fig. 4.1

Right atrial hypertrophy

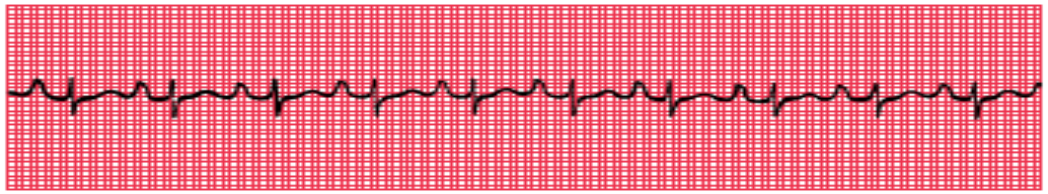
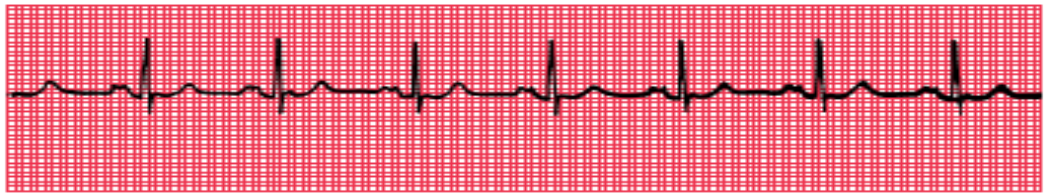


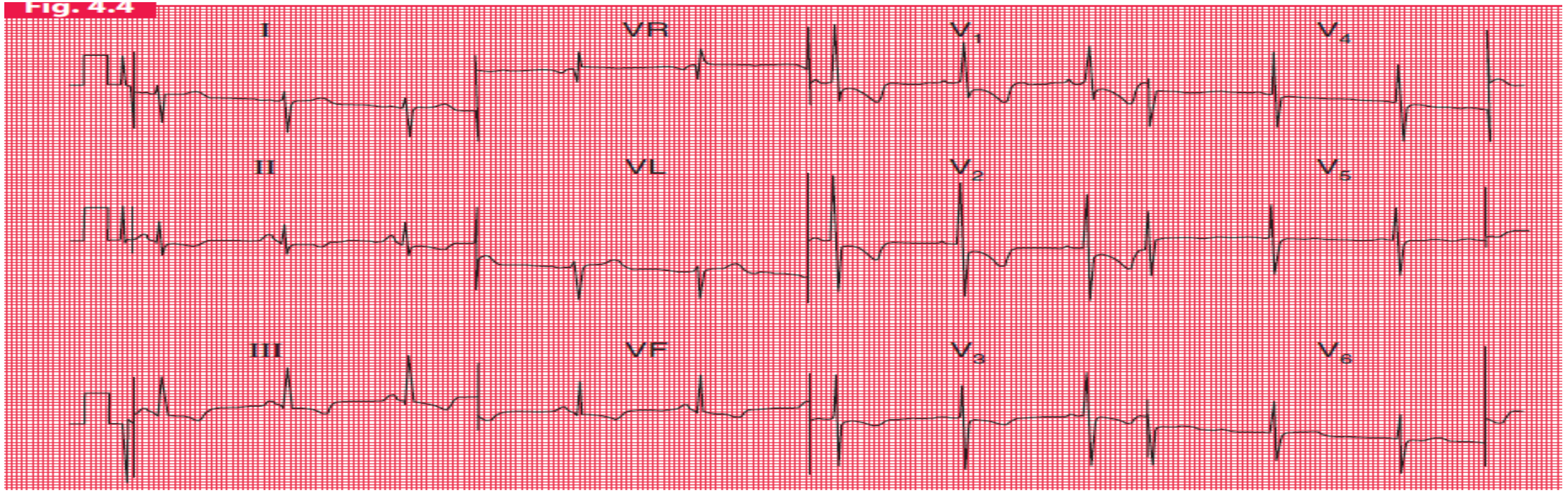
Fig. 4.2

Left atrial hypertrophy



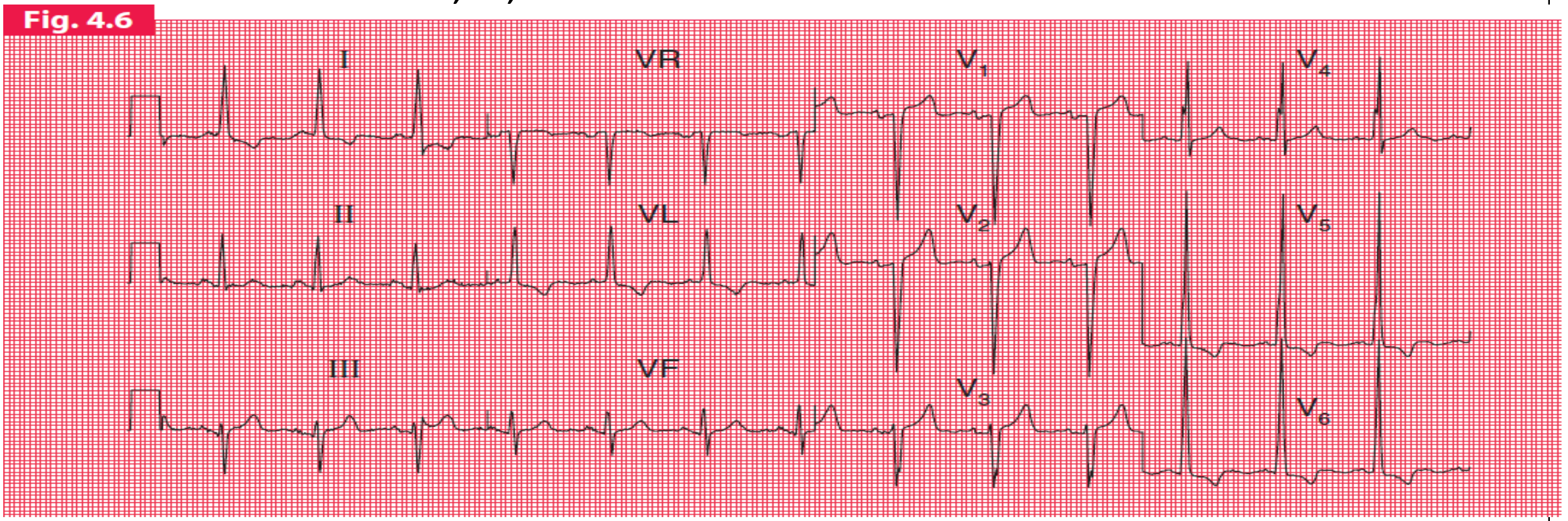
Severe Right ventricular Hypertrophy

- Dominant R waves in lead V1
- Deep S waves in lead V1-3
- Inverted T in II,III,VF, V1-3
- Flat T in V4-5



Left ventricular Hypertrophy

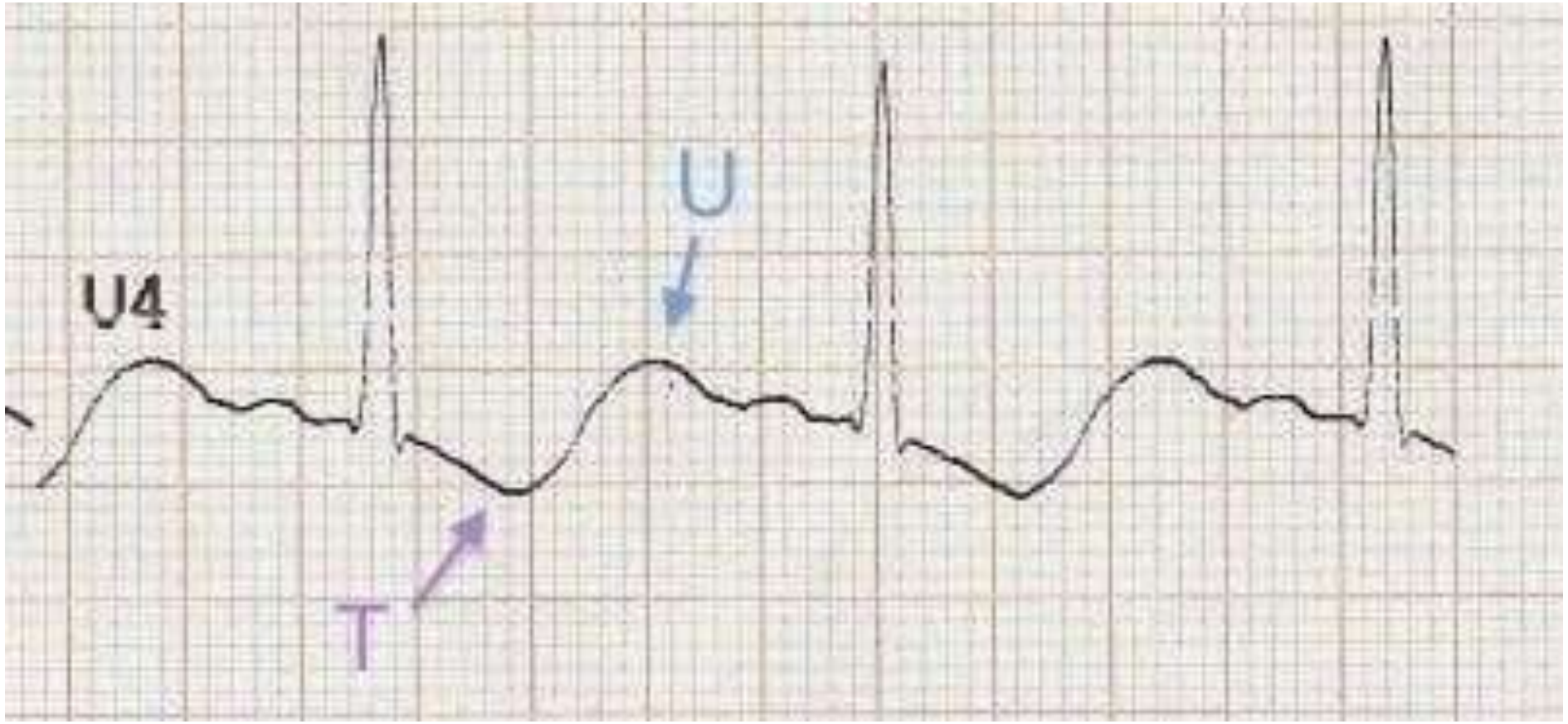
- Tall R in V5-6 and Deep S in V1-2
- Inverted T in lead I ,VL, V5-6



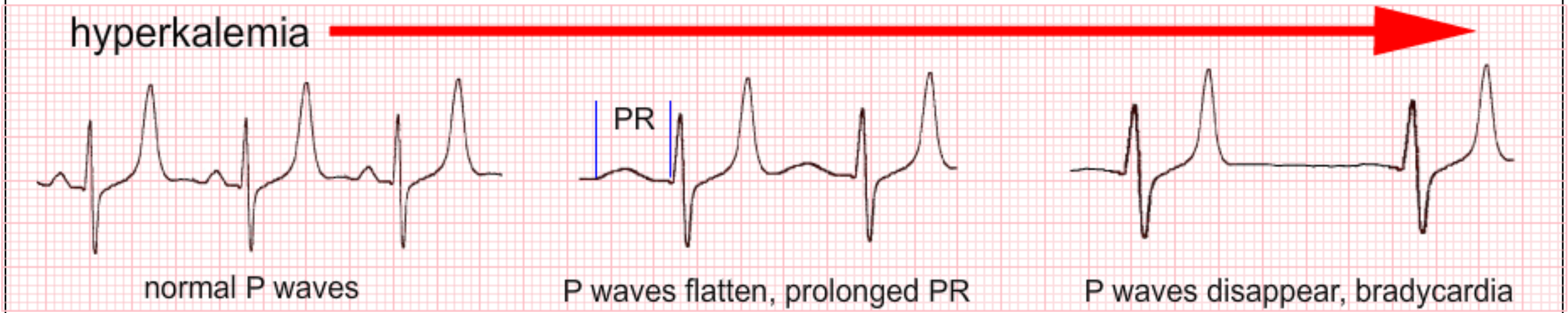
Electrolytes Disturbance

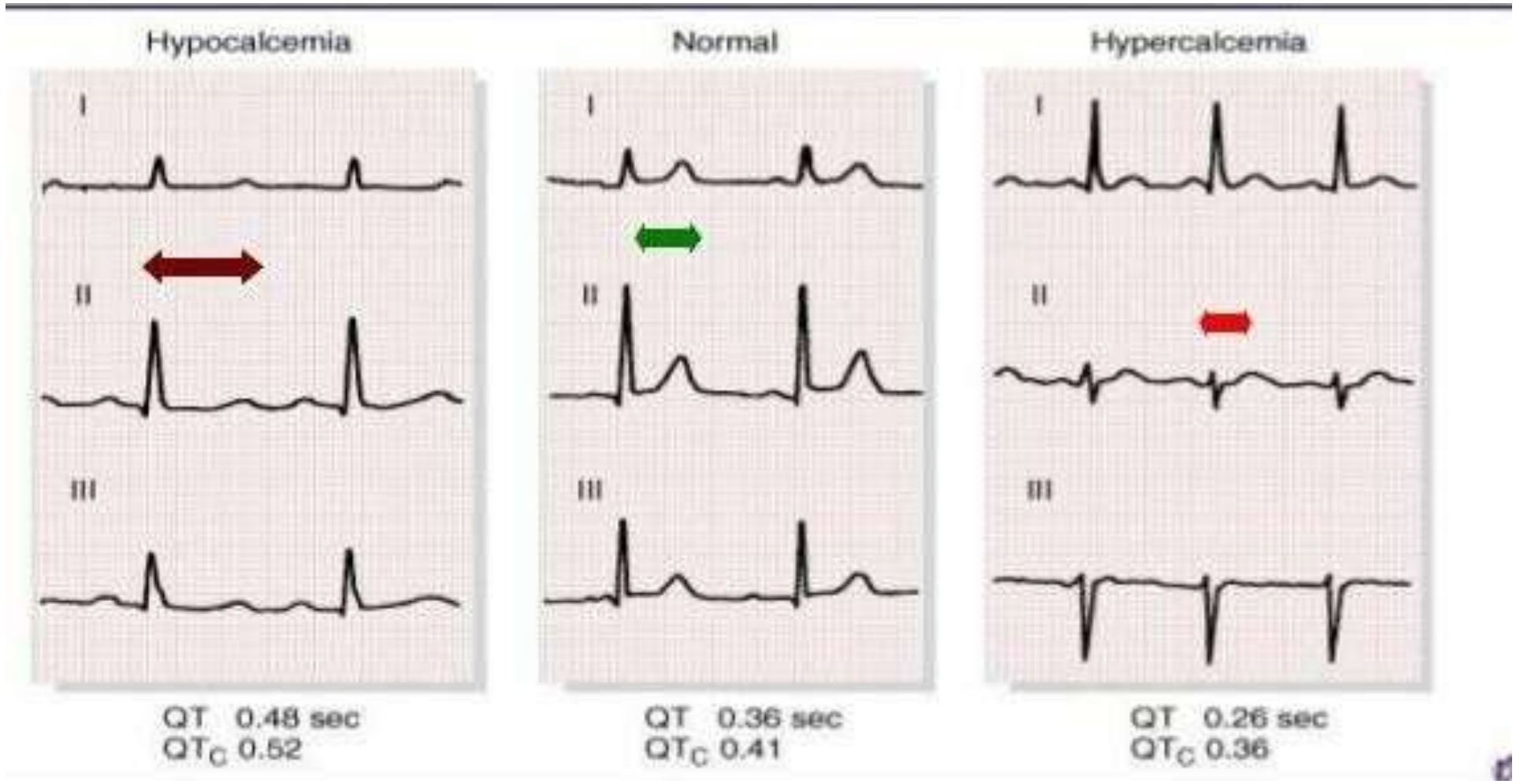
- A low K+ level : T wave flattening, U wave
- A high K+ level : peaked T waves ,disappearance of the ST segment. The effects of abnormal magnesium levels are similar.
- A low plasma Ca+2 level causes prolongation of the QT interval, and a high plasma calcium level shortens it.

Hypokalemia



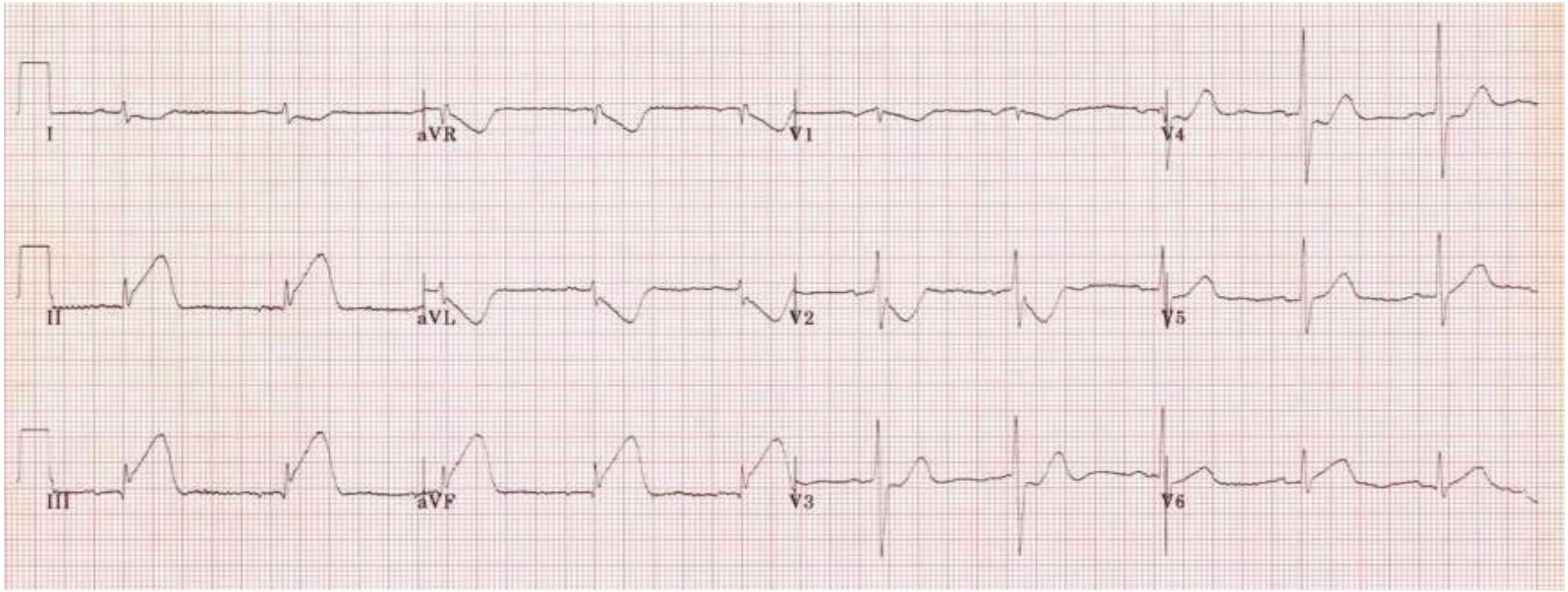
Hyperkalemia




Hypocalcemia
Normal
Hypercalcemia
I
II
III
QT 0.48 sec
QTC 0.52
QT 0.36 sec
QTC 0.41
QT 0.26 sec
QTC 0.36

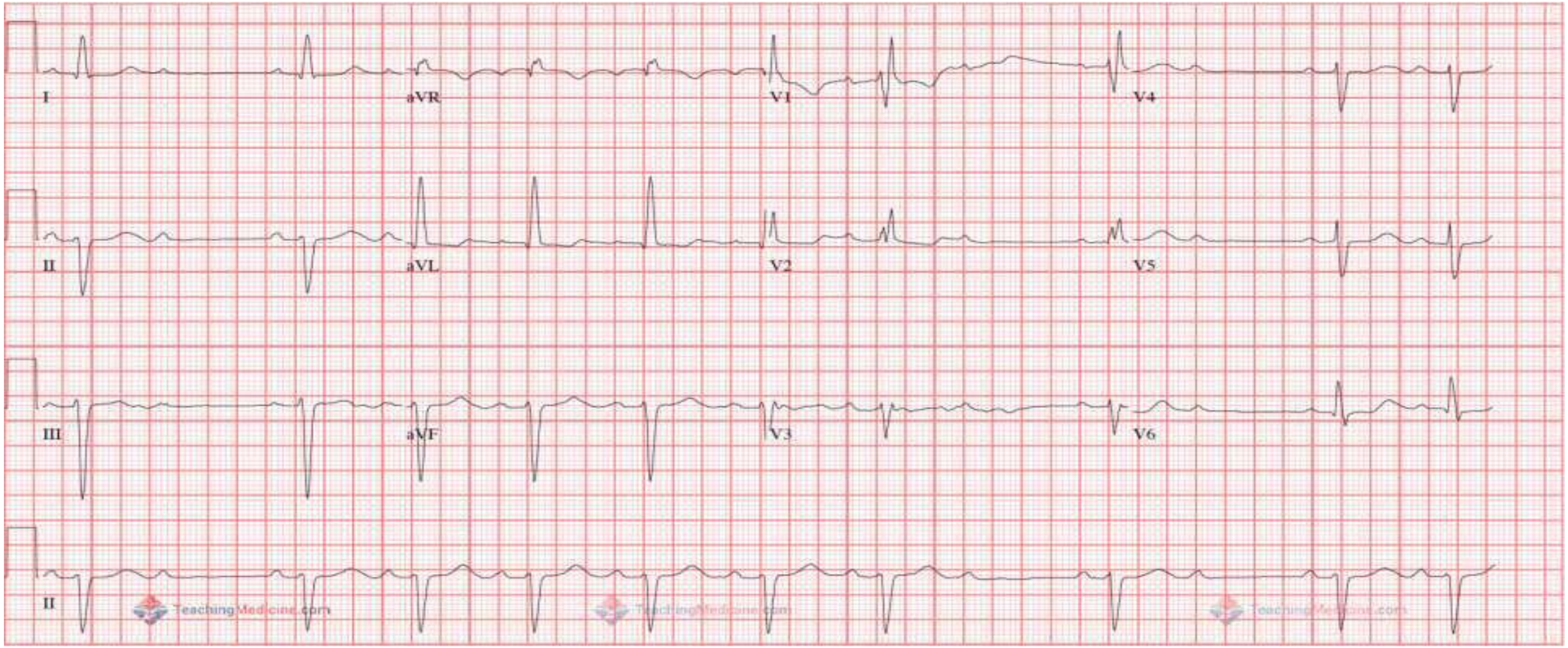
What is the Dx?

Inferior MI



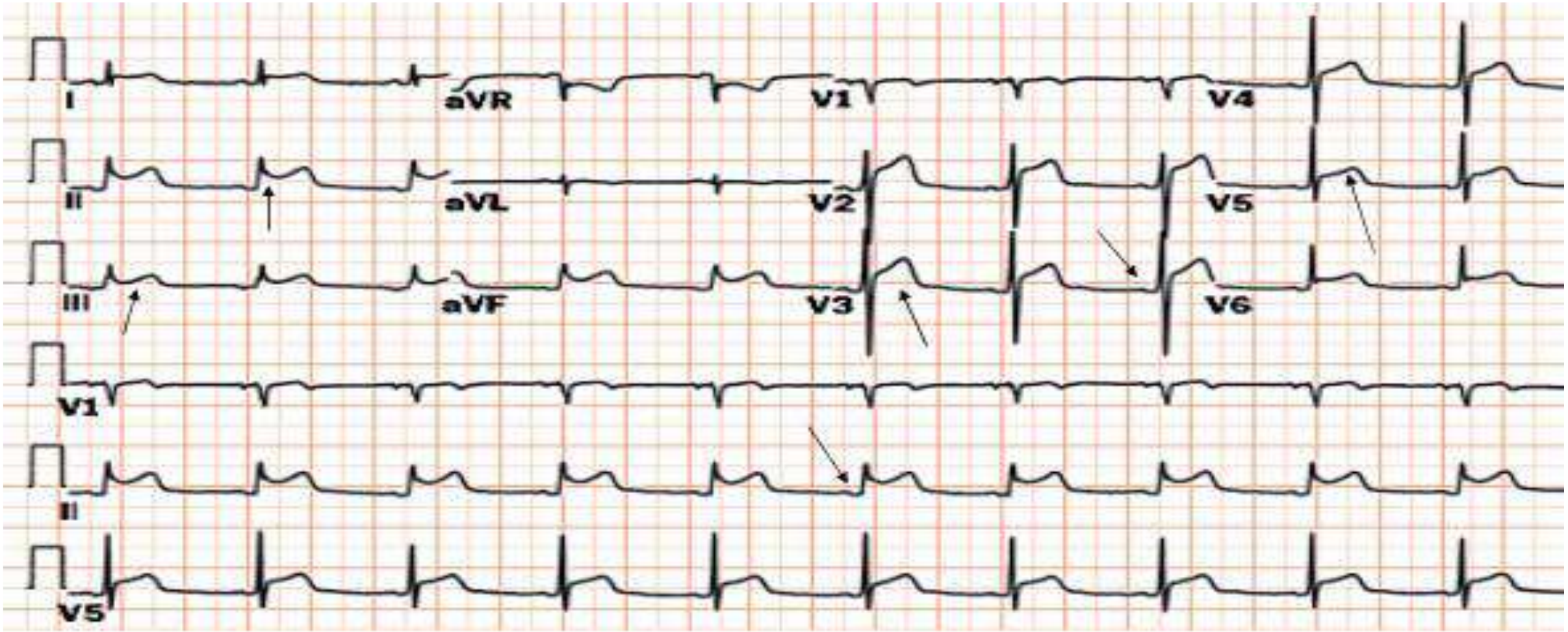
What is the Dx?

2nd degree heart block (Mobitz type II)



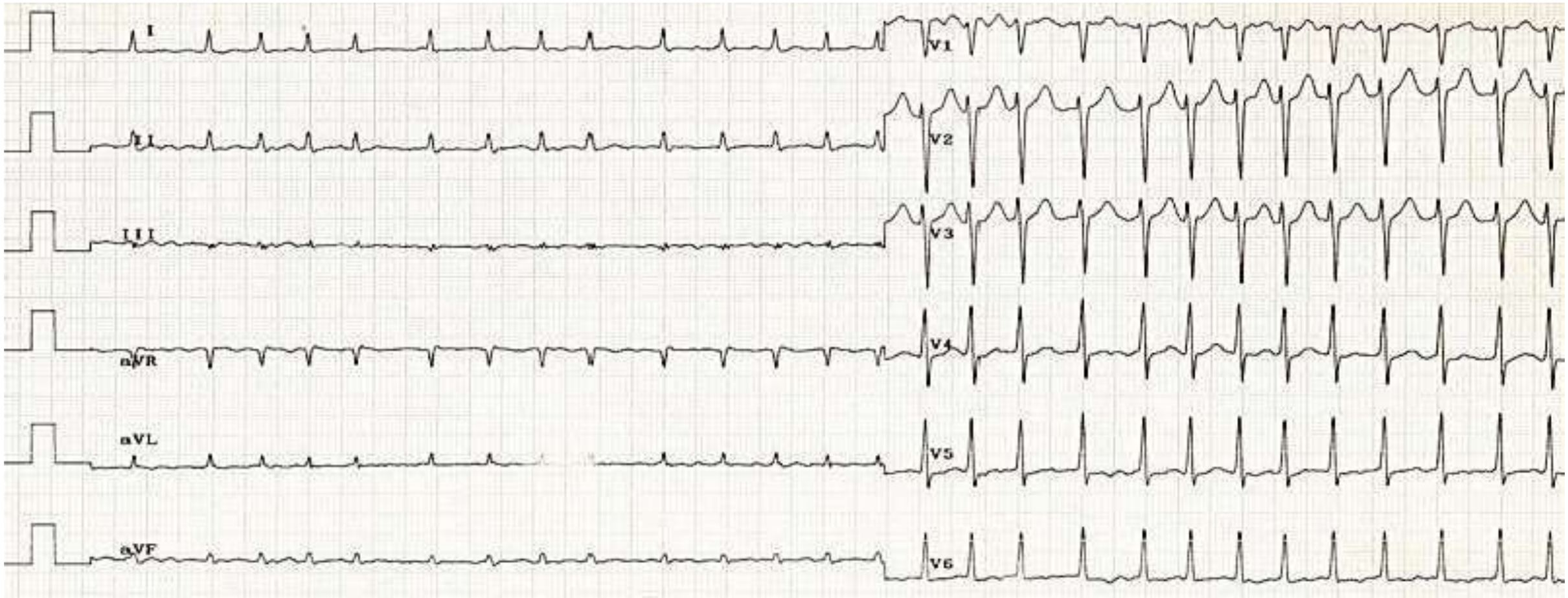
What is the Dx?

Pericarditis



What is the Dx?

Atrial Fibrillation



Thank you.