University of Diyala/ College of Medicine
Department of Physiology
Physiology Lab

Electrocardiography (ECG)

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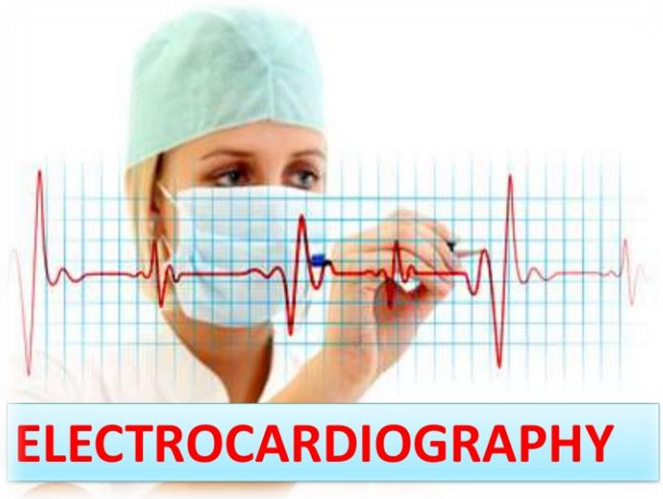
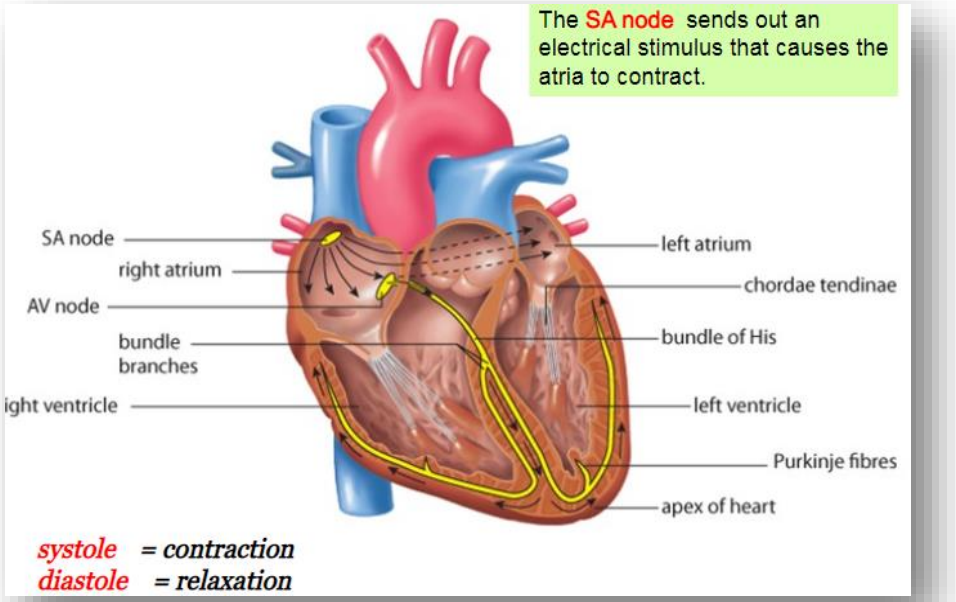


Introduction

The Cardiac Cycle

1. The sinoatrial (SA) node (a.k.a. the pacemaker) located in the R. atrium stimulates muscle cells to contract and relax rhythmically.
2. It generates an electrical signal that spreads over the atria so they contract simultaneously.
3. The signal reaches the atrioventricular (AV) node, which transmits the signal through a bundle of fibers called the bundle of His.
4. The signal is relayed to Purkinje fibers; these fibers initiate the simultaneous contraction of the ventricles.



Electrocardiography

- ECG = Electrocardiogram (Tracing of heart's electrical activity)
- Since the body is made up of conducting fluids, electrodes may be placed on the body to detect the electrocardiographic waves. ECG thus is the summation of the changes in the electrical potential of the heart conducting through the body and recorded at surface.
- These changes can be recorded by means of electrodes attached to the right arm, left arm, and left leg. Other exploring electrodes are attached to different points on the chest.
- The purpose of recording the ECG from several leads is to look at the heart activity from several directions.
- It is important to designate the position of surface electrodes because the spread of excitation (depolarization) and recovery (repolarization) over the whole heart involves directivity , each electrode configuration records different areas of electrical activity of myocardium.

Electrocardiogram

- ECG machine is made up from the following parts : the leads, the amplifier, the recorder.
- ***A standard ECG consists of 12 leads:***

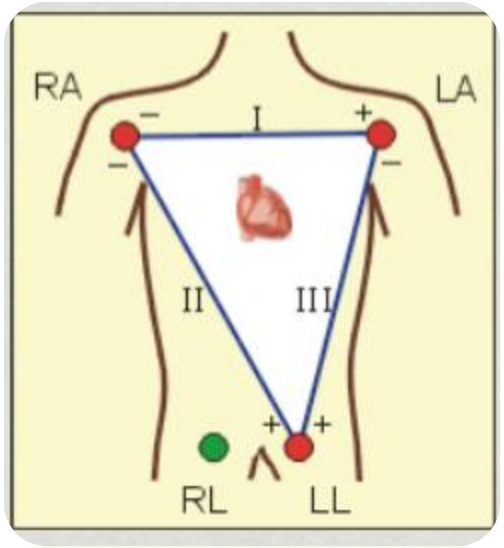
- 3 Bipolar standard limb leads (I, II, III).
- 3 unipolar limb leads (aVR, aVL, aVF).
- 6 unipolar chest leads.

- ***Bipolar standard limb leads (I, II, III):*** The 3 standard bipolar limb leads are:

- ***Lead I:*** records difference between potential in left arm (LA) & that in right arm (RA).
- ***Lead II:*** records difference between potential in right arm (RA) & that in left leg (LL).
- ***Lead III:*** records difference between potential in left leg (LL) & that in left arm (LA).

Bipolar Standard Limb Leads

- These leads are attached to the wrists and ankles, the principle of use them was developed by Willem Einthoven, a Dutch physiologist who pioneered the study of ECG. He postulated that all tissues conduct current uniformly and that the heart is located in the center of an electrically equilateral triangle with extremities at the apices. The electrical force produced by depolarization has certain magnitude and direction so it is a vector. A wave of depolarization advancing toward the positive electrode produces an upward pen deflection on the recording device and the magnitude of that deflection is directly related to how closely the lead axis parallels the direction of the electrical force. For example , lead II would be expected to provide a large pen deflection than lead III because it is almost parallel to the direction of the electrical force (cardiac axis) .

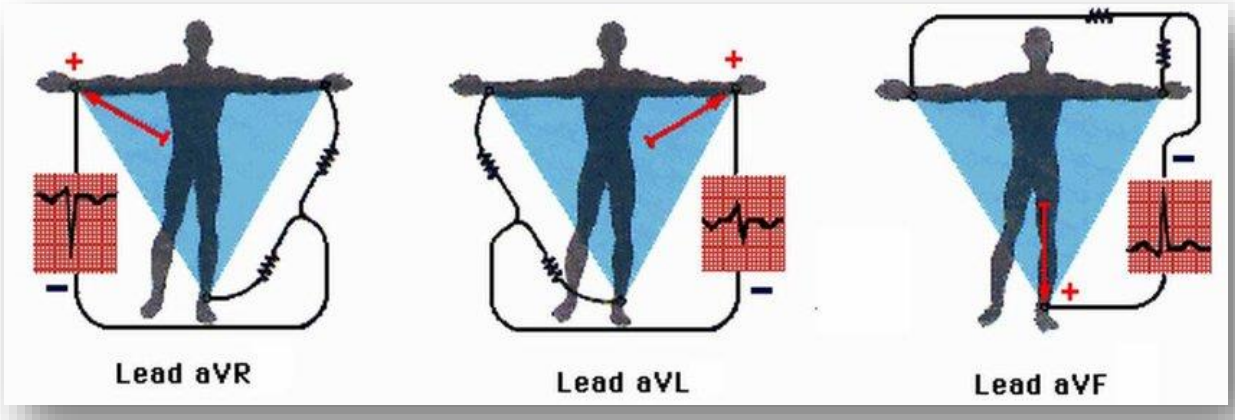


Unipolar (Augmented) Limb Leads

➢ **Unipolar limb leads (aVR, aVL, aVF):**

- measure absolute potential at a certain point, by applying one electrode to desired point (it is active, +ve or exploring electrode) while the other electrode represents a common reference point inside instrument; it is -ve electrode (0 potential) .
- i.e. unipolar leads measure potential differences between active electrodes & zero potential.
- They are augmented unipolar limb leads that have magnified amplitudes by about 50 % without any change in their configuration, so they are called aVR, aVL & aVF (a = augmented).

- ***aVR :*** Right arm is positive compared to the sum of the left arm and left leg.
- ***aVL:*** Left arm is positive with respect to the sum of right arm and left leg.
- ***aVF:*** left foot is positive compared to the sum of the right arm and left arm.



Unipolar Chest Leads (Precordial leads)

- These leads are placed over the anterior surface of the lower part of the thorax. They are designated by the letter (V) and are oriented in the horizontal plane of the body. They record absolute potential at 6 standard points on anterior chest wall:

  Lead V1: At right margin of sternum in 4th right intercostal space.

  Lead V2: At left margin of sternum in 4th left intercostal space.

  Lead V3: Midway between V2 & V4.

  Lead V4: At left midclavicular line in 5th intercostal space.

  Lead V5: At left anterior axillary line in 5th intercostal space.

  Lead V6: At left midaxillary line in 5th intercostal space.

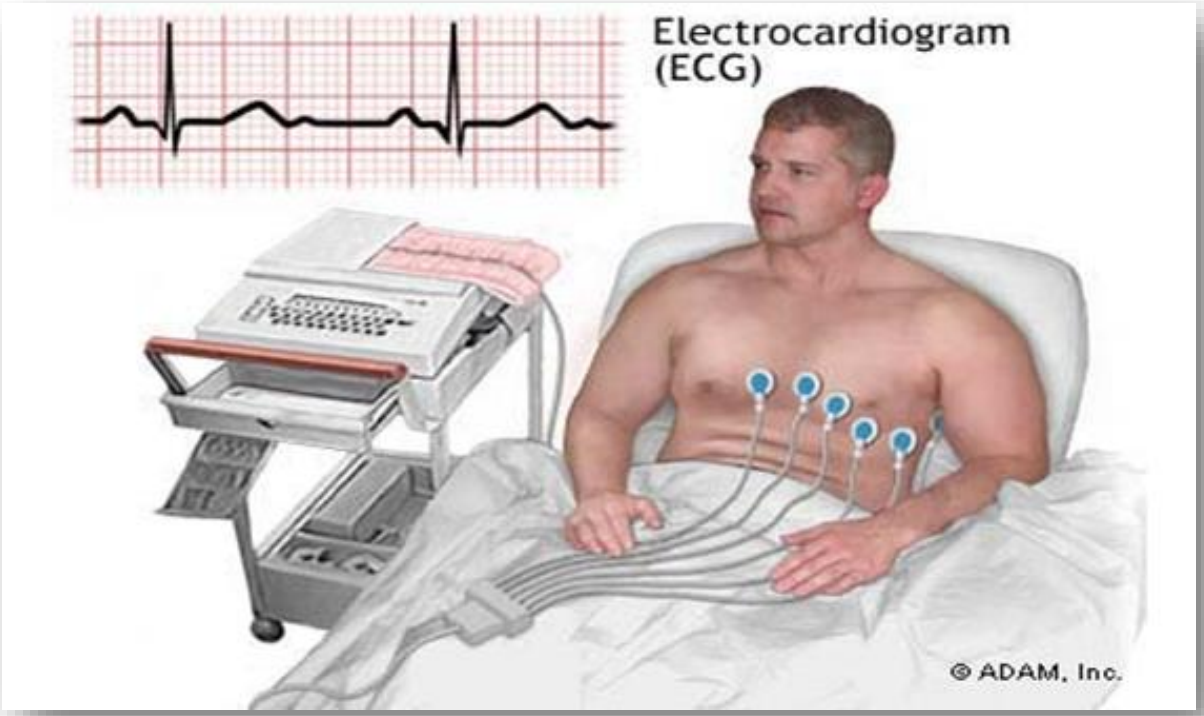
- Precordial leads look at heart in a horizontal plane from front & left sides.

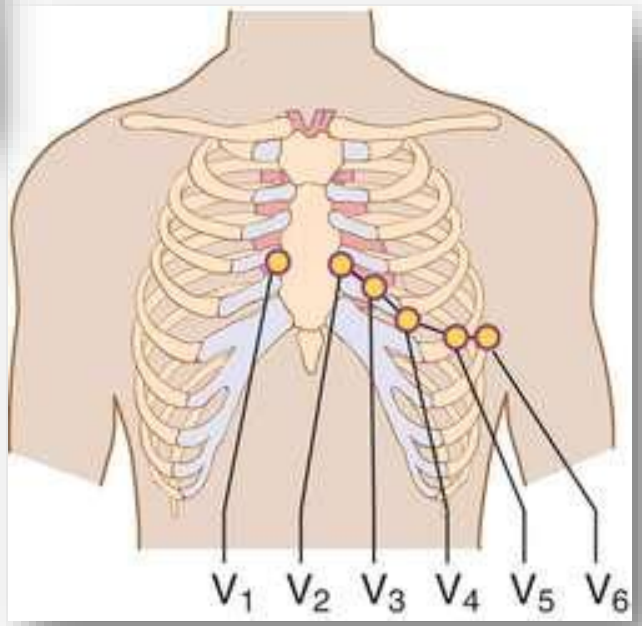
Leads V1 & V2 look at ***right ventricle*** & reflect its activity.

Leads V3 & V4 look at ***interventricular septum*** & reflect its activity.

Leads V5 & V6 look at ***left ventricle*** & reflect its activity.

Unipolar Chest leads (Precordial leads)

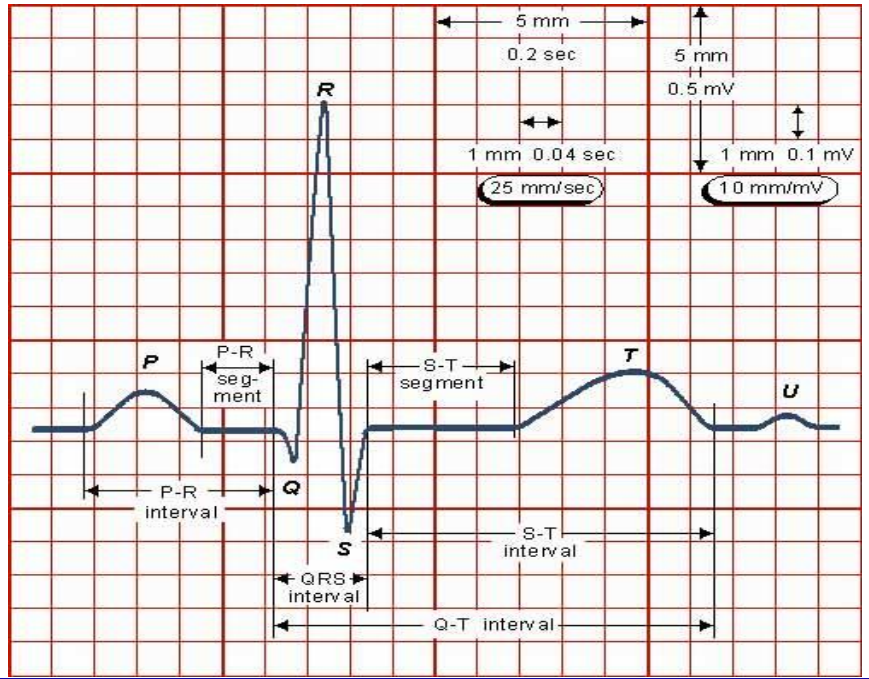




Electrocardiogram

➢ Calibration of ECG

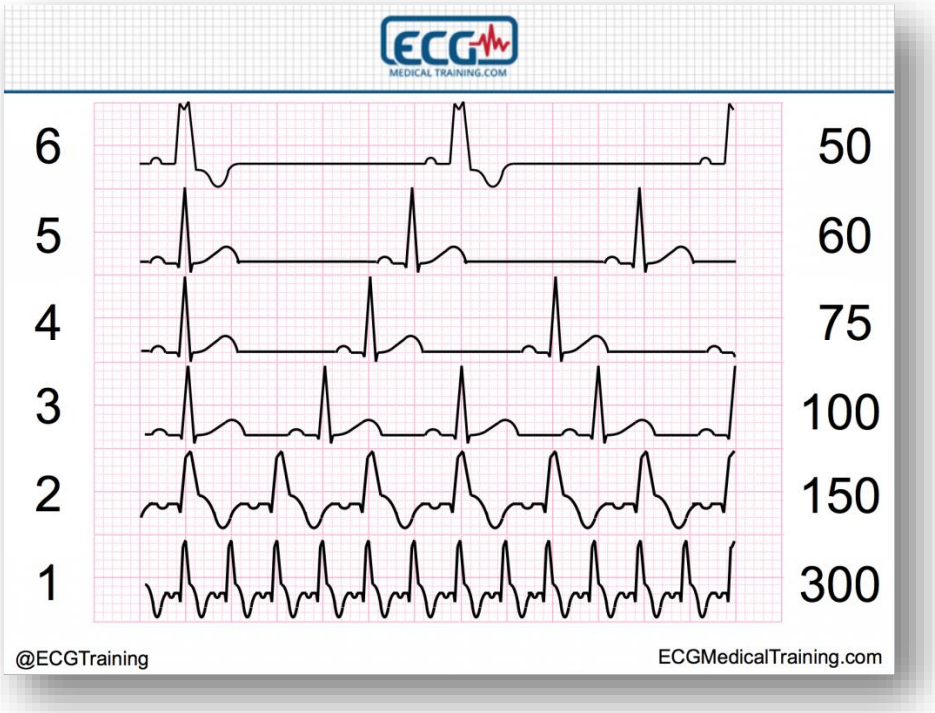
- A change of 1 mV upward or downward produces a deflection of 10 mm amplitude (10 small squares; 2 large squares),
- Each mm between horizontal lines (voltage calibration lines) equals 0.1 mV.
- Thin horizontal lines calibrated at 1 mm interval &
- Thick horizontal lines at 5 mm intervals.
- Vertical lines are time calibration lines
- Duration of each mm (small square) equals 0.04 second,
- Each large square (5 small squares) represents 0.20 second.



Electrocardiogram

Calculation of heart rate (HR) from ECG paper:

- **If the heart rhythm is regular,** All you do is find an R-wave that is lined up with a large block on the ECG paper and count the number of large blocks between that cardiac cycle and the next one . In other words, you measure the RR interval in large blocks.
  - **HR=** 300/number of big squares within RR interval *OR*
  - **HR=**1500/number of small squares within RR interval.
- **If rhythm is irregular**, multiply number of complexes (R waves) in 6 seconds (30 big boxes) by 10.



Electrocardiogram

- **Speed:**

- It is the speed at which chart paper moves.
- Standard speed is 25 mm/sec.

- **Sensitivity:**

- It means mm deflection for 1 mV (range; 5-10-20).
- The higher the sensitivity of instrument, the more the deflection & vise versa.
- Standard sensitivity is 10 mm/mV (2 large squares).

ECG Waves and Intervals

- ***P wave***

- Best seen in lead II . It is caused by atrial depolarization just before contraction (i.e, not atrial contraction).
- Duration: less than 0.12 sec, amplitude less than 2.5 mm and increases in atrial contraction.

- ***PR (or PQ interval)***

- From the beginning of atrial depolarization to the beginning of ventricular depolarization (QRS) and represents atrial depolarization and conduction through AV node.
- Duration: Normally it is about 3-5 small squares (0.12-0.2 sec).
- Abnormal PR interval is longer than normal in 1st degree heart block .

- ***QRS complex***

- Represents ventricular depolarization.
- Average duration is 0.08 sec (max . 0.12 sec) or 3 small squares.

- ***Q wave***

- Initial negative deflection of the QRS complex.
- Average duration is less than 0.04 sec and about ½ small square in amplitude.
- The presence of large Q wave in certain leads is an important finding in myocardial infarction MI diagnosis.

ECG Waves and Intervals

- ***R wave***
- First positive deflection of QRS complex.
- Average duration about 1 small square.
- Up to 11 mm in aVL , 20 mm in AVF , and 27 mm in V5 and V6. if more , it suggests right ventricular hypertrophy.

- ***S wave***
- Second negative deflection of the QRS complex.
- Average duration about ½ small square.

- ***T wave***
- caused by repolarization of ventricles. Duration (usually less than or equal 0.12 sec, amp: 2.5-3 mm).
- In general, T wave and QRS complex in leads are concordant (when QRS are upright, T waves are upright and when QRS are negative, T waves are negative).
- Tallest T wave seen in V3 and V4.

- ***ST segment***
- From the end of S wave to the beginning of T wave. Represents the isoelectric period when the ventricles are in between depolarization and repolarization.
- Should be less than 1 mm above and below the isoelectric line .

ECG Waves and Intervals

- ***QT interval***

- It represents total time from onset of ventricular depolarization to completion of repolarization.
- It indicates duration of ventricular systole i.e. contraction of ventricle lasts from beginning of Q wave to end of T wave.
- Normally it is about 0.35 sec; range 0.28 – 0.44 seconds.

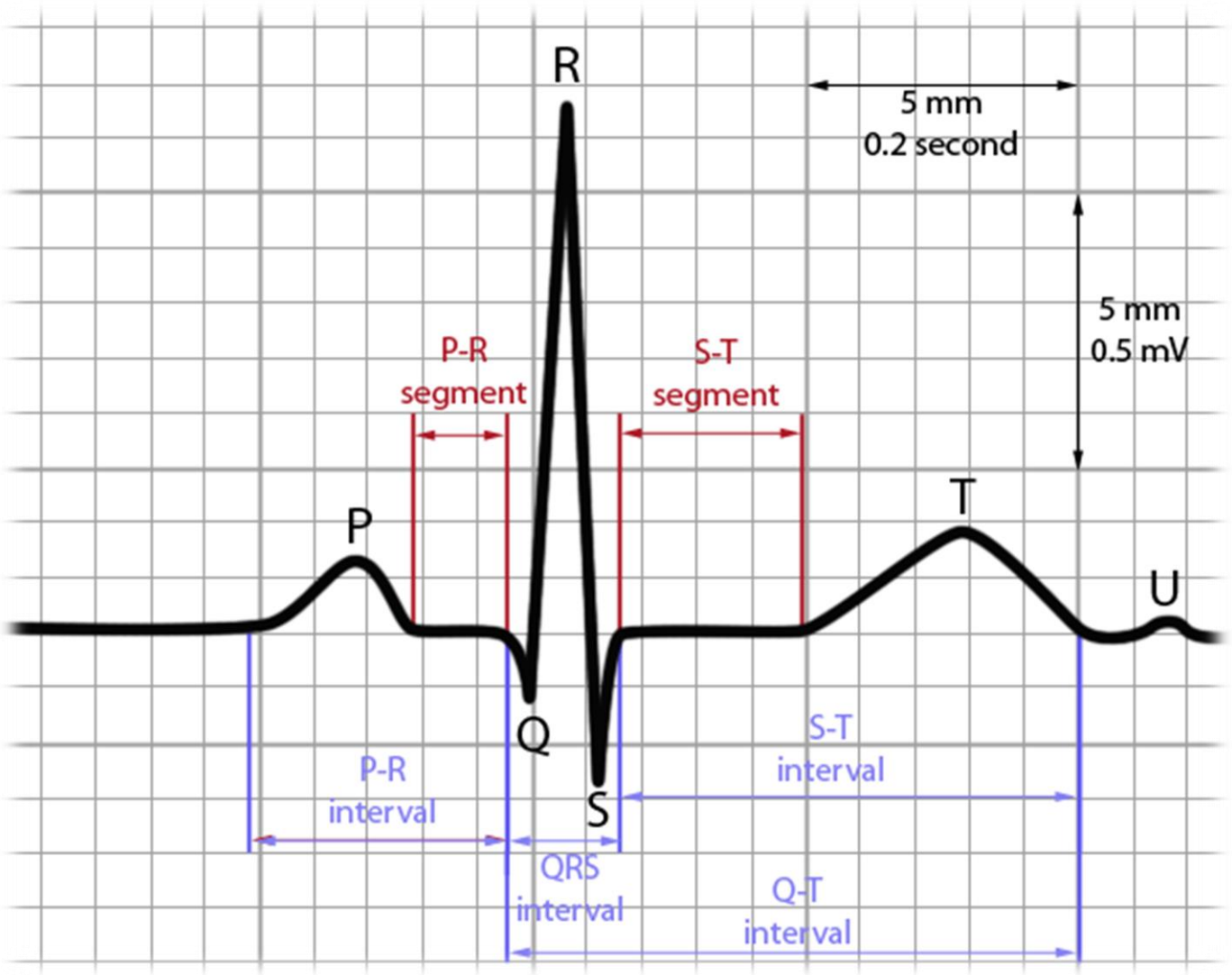
- ***U wave***

- The deflection seen between the end of T wave and the following P wave.
- Highest in V3.
- Seen usually in hypokalemia.

- ***Note:*** to localize the lesion in the heart according to ECG abnormalities, remember that different leads look at different aspects of the hear.

View of heart	Leads
Inferior	II, III, aVF
Lateral	I, aVL, V5, V6
Anterior	V3, V4
Septal	V1, V2

ECG Waves and Intervals



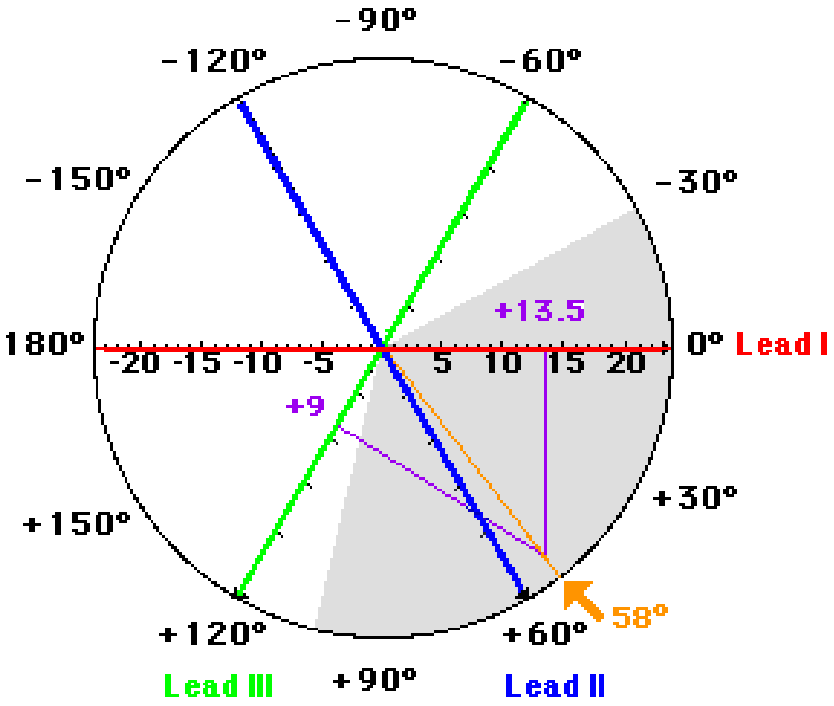
Cardiac Axis (Vector)

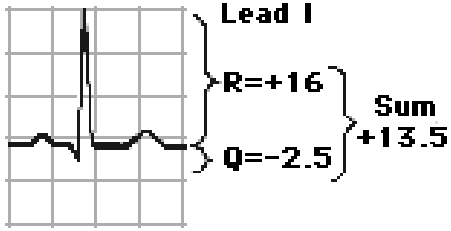
- It is defined as the net direction of the electrical activity, usually summed over the entire duration of atria and ventricular activation. The cardiac axis is usually determined by the QRS axis which represents ventricular depolarization.
- The normal cardiac axis is from +105 to -30 . Cardiac axis further right than +105 considered as **right axis deviation (RAD)** , while an axis further left than -30 is considered as **left axis deviation (LAD).**

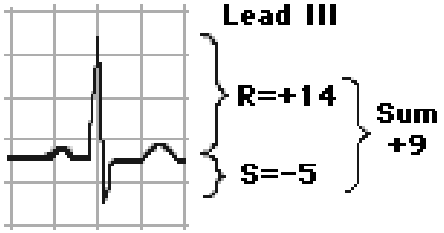
- ***Measurement of the cardiac axis :*** Clinically, electrical axis of heart is determined from standard bipolar limb leads; lead I & III:

- Record maximum potential (that of QRS wave; R wave) & polarity (+ve or –ve), net QRS deflection in each lead calculated by subtracting amplitude of largest -ve wave in QRS from that of R wave.
- A distance equal to net deflection in each lead is drawn as an arrow on corresponding axis of bipolar limb lead.
- Draw perpendicular lines form both ends of arrows; apices of two net potentials of lead I & III, point of intersection of these two lines represents mean electrical axis or mean QRS vector of ventricles.

Cardiac Axis Measurement







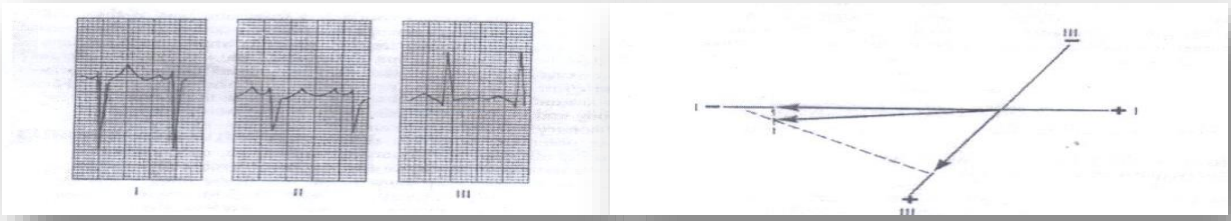
Cardiac Axis (Vector)

- **Right axis deviation**: Normally occurs in vertical hearts (e.g. in tall slender subjects), pathologically, it is common in right ventricular hypertrophy.

- Projection of mean QRS axis:

toward -ve pole in lead I = deep -ve waves (S waves) in lead I

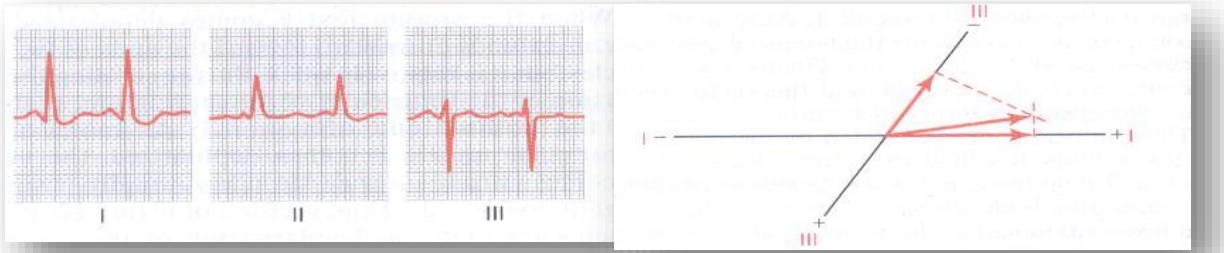
toward +ve pole in lead III = high +ve waves (R waves) in lead III.



- **Left axis deviation:** Normally occurs in horizontal hearts (e.g. in short obese subjects & pregnant women), pathologically, it is common in left ventricular hypertrophy.

- Projection of mean QRS axis

toward +ve pole in lead I = high +ve waves (R wave) in lead I & toward -ve pole in lead III=deep -ve waves (S wave) in lead III.



Cardiac Arrhythmia

- **The causes** are usually one or combination of the following abnormalities in rhythmicity-conduction:

1. Abnormal rhythmicity of the pacemaker.
2. Shift of the pacemaker from the sinus node to other parts of the heart.
3. Blocks at different points in the transmission of the impulse through the heart.
4. Abnormal pathways of impulse transmission through the heart.
5. Spontaneous generation of abnormal impulses in almost any part of the heart.

- **Types of arrhythmias**

1. Abnormal sinus rhythms (tachycardia, bradycardia, sinus arrhythmia).
2. Conduction block (sinoatrial , Atrioventricular block).
3. Premature Contractions (atrial & ventricular ectopic beat or called extrasystole).
4. Paroxysmal tachycardia (supraventricular or ventricular).

Cardiac Arrhythmia

Tachycardia: Heart rate faster than 100 beats per minute. ECG is normal except that rate of heartbeat is increased. ***The general causes of tachycardia are:*** ↑ body temperature, & Stimulation of the heart by the sympathetic nerves.

Sinus tachycardia, HR = 150 (300/2)

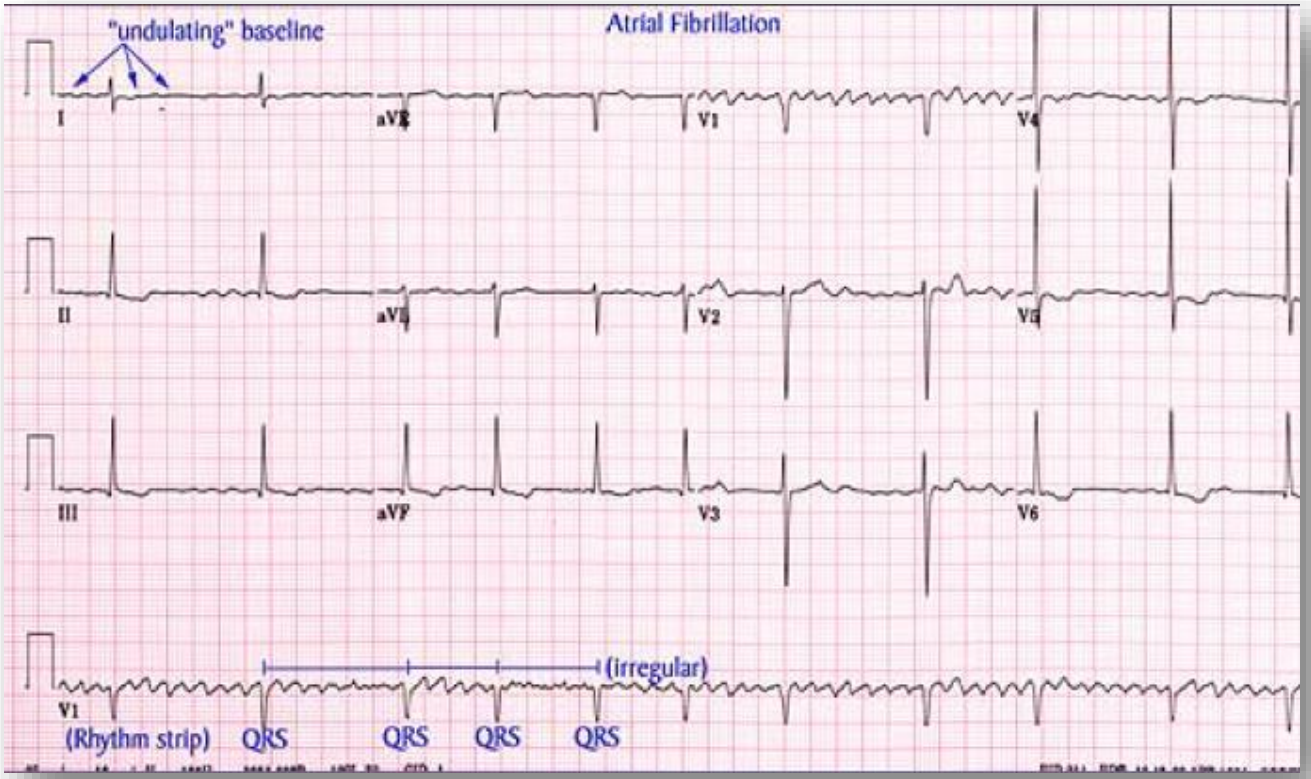
Bradycardia: A slow heart rate, usually defined as less than 60 beats per minute. ***Examples:*** Bradycardia in Athletes, & Vagal Stimulation.

Sinus bradycardia of 40 beats per minute. (300/7.5 = 40)

Cardiac Arrhythmia

Atrial fibrillation (Afib)

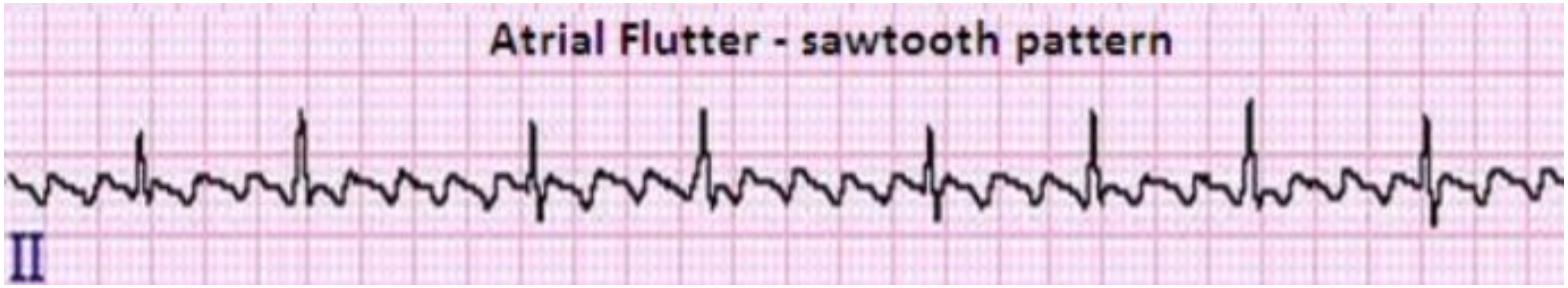
Atrial fibrillation is an irregular and often rapid heart rate that can increase your risk of stroke, heart failure and other heart-related complications.It is irregular irregularity of the rhythm with no or obscured P-wave. During atrial fibrillation, the heart's two upper chambers (the atria) beat chaotically and irregularly — out of coordination with the two lower chambers (the ventricles) of the heart.



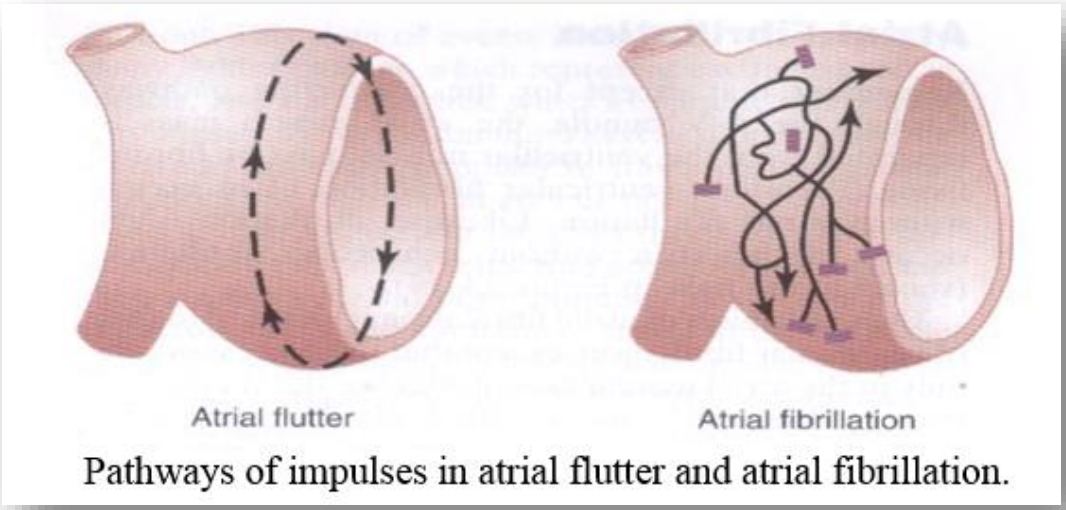
Cardiac Arrhythmia

Atrial flutter (AF)

In Atrial flutter ECG trace, P waves are strong (saw-teeth appearance), QRS-T complex follows an atrial P wave only once for every two to three beats of the atria, giving a 2:1 and a 3: 1 rhythm. Atrial rate 250/min .This is created by circular circuits of depolarization set up in the atria



Atrial flutter; saw-teeth appearance of the P-wave



Pathways of impulses in atrial flutter and atrial fibrillation.

Cardiac Arrhythmia

Ventricular tachycardia (VT)

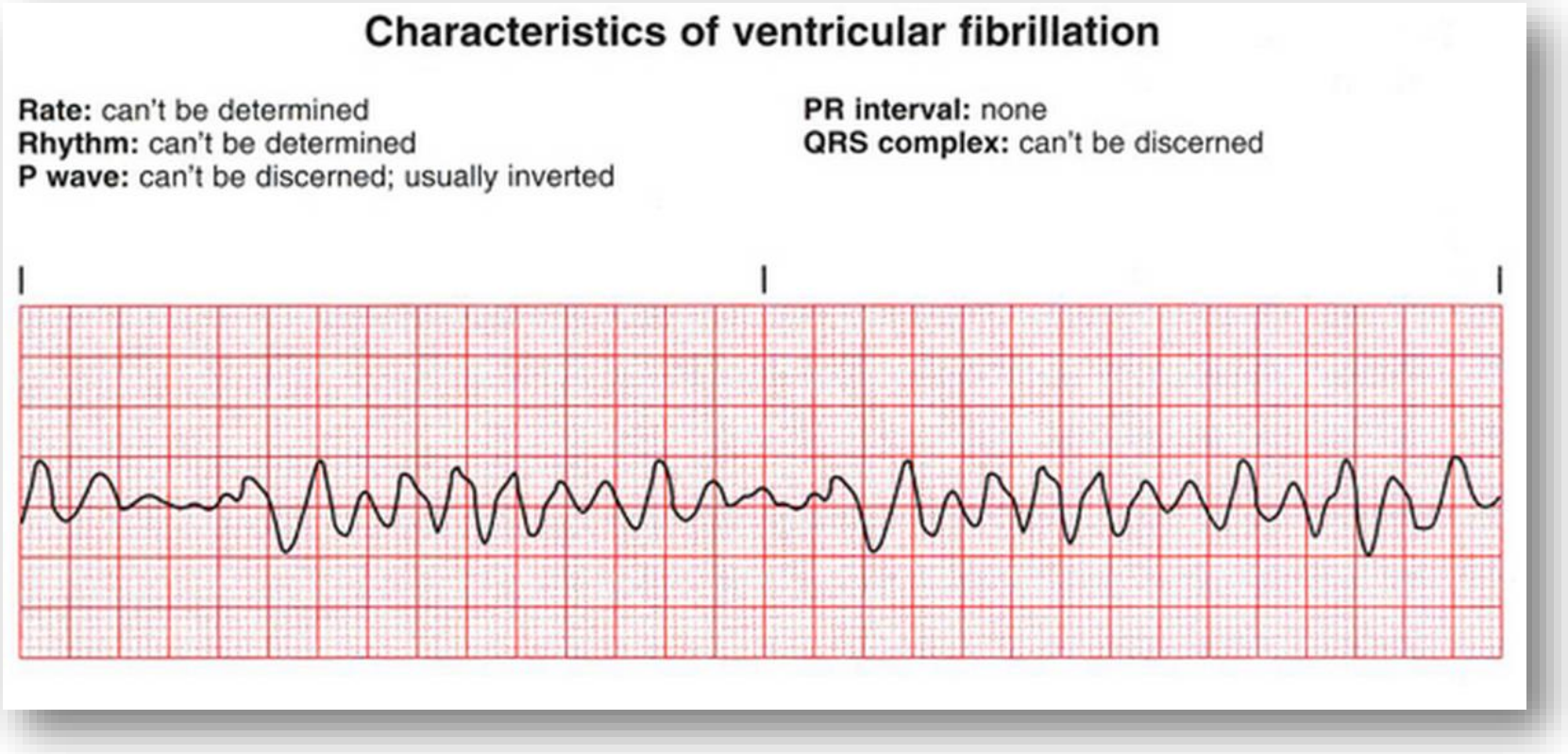
VT refers to a rhythm originating from a ventricular ectopic focus at a rate greater than 100 beats per minute. The ECG shows a wide-QRS complex with no associated P-wave.

Figure 1: ECG showing ventricular tachycardia.

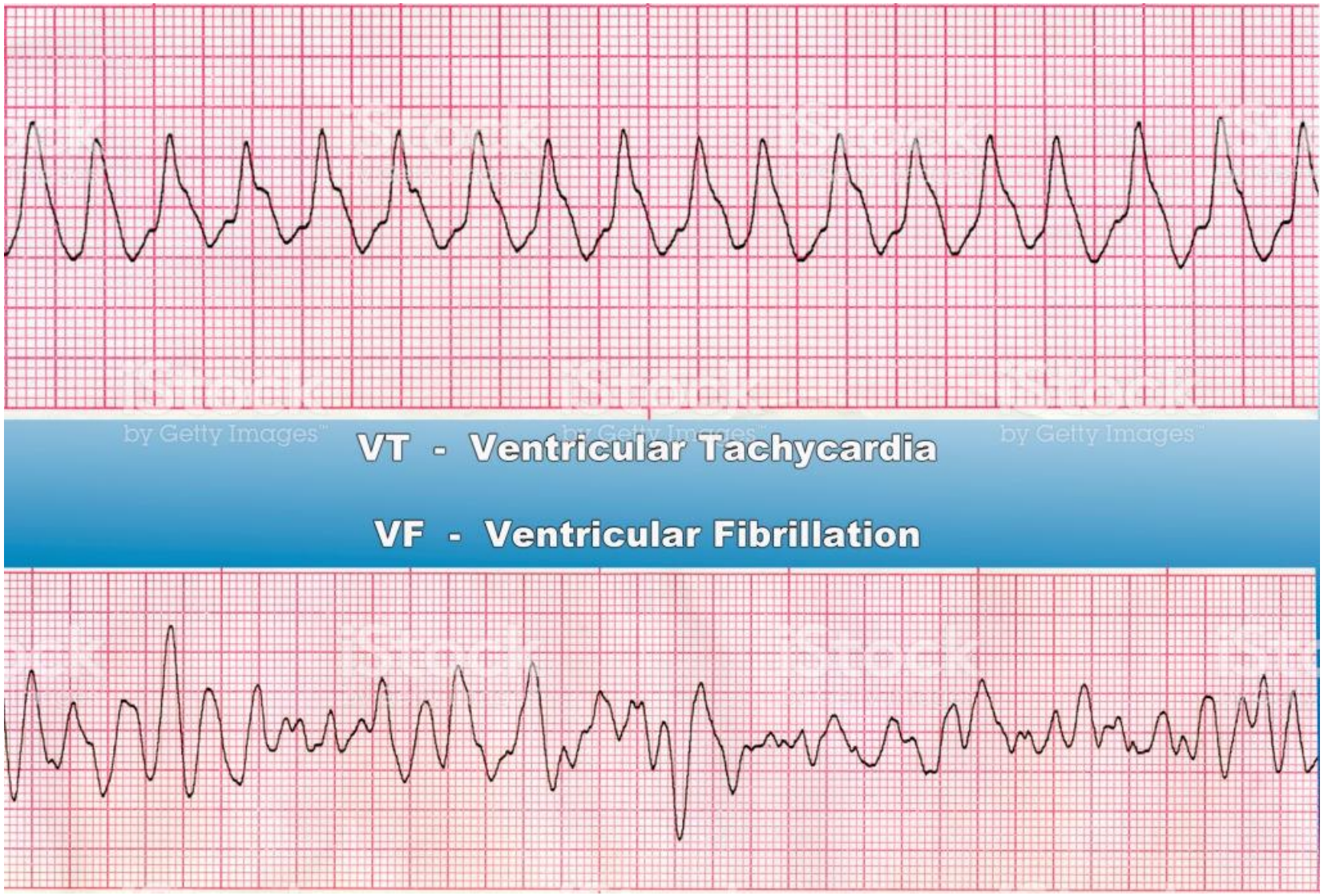
Cardiac Arrhythmia

Ventricular fibrillation (VF)

It results from cardiac impulses that have gone here & there within ventricular muscle mass. Stimulating first, one portion of ventricular muscle, then another portion, then another, & eventually feeding back onto itself to re-excite the same ventricular muscle over & over.

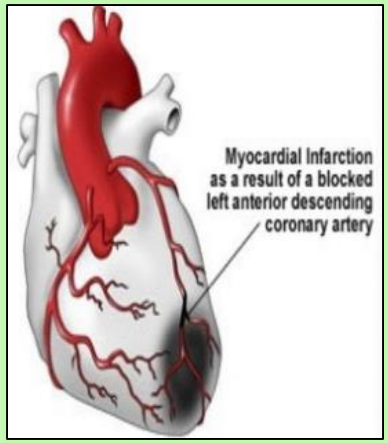


Cardiac Ventricular vs Cardiac Arrhythmia



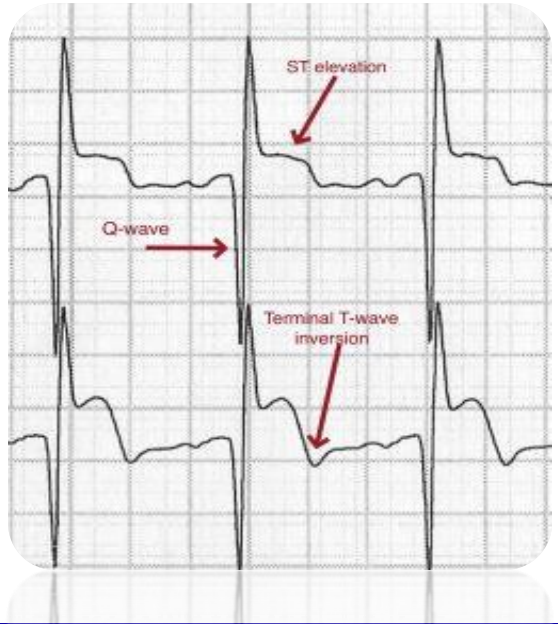
Myocardial Infarction (MI)

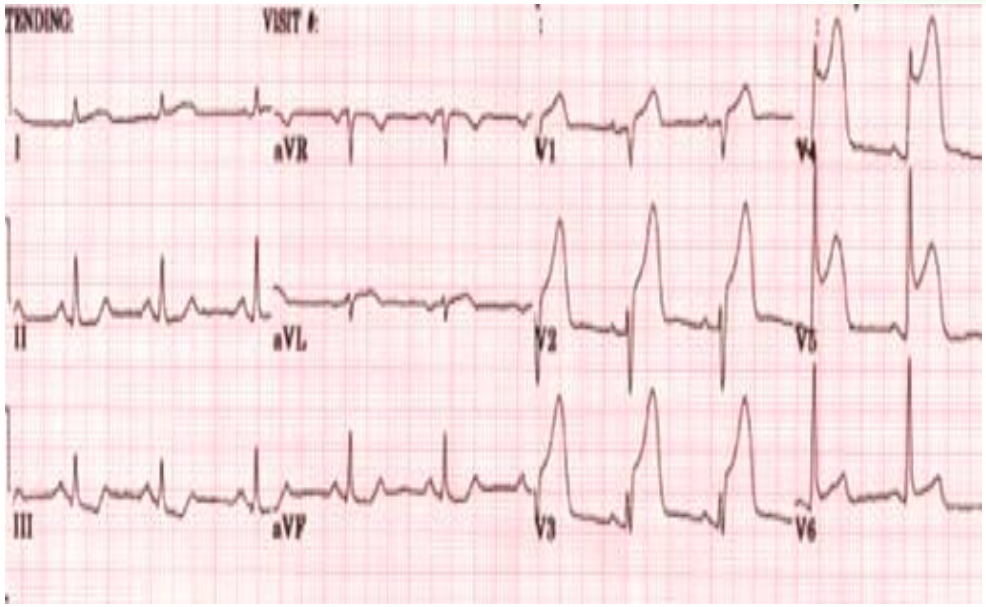
- Myocardial infarction (MI) refers to the process by which areas of myocardial cells in the heart are permanently destroyed.
- It occurs when myocardial tissues are abruptly and severely deprived of oxygen.
- MI is a diseased condition which is caused by reduced blood flow in a coronary artery due to atherosclerosis and occlusion of an artery by an embolus or thrombus.



- ***The classic ECG changes:***

- T wave inversion
- ST segment elevation
- Abnormal Q wave





Heart Block Types

- **1st degree :** constant PR >0.2 seconds.
- **2nd degree type 1 (Wenckebach):** PR widens over subsequent beats then a QRS is dropped.
- **2nd degree type 2:** PR is constant then a QRS is dropped.
- **3rd degree:** No discernable relationship between p waves and QRS complexes

Heart Block Types

ECG Basics - Heart Blocks

First Degree AV Block

Rhythm:	Regular
PR interval:	Prolonged >0.20 sec
P Wave:	Normal
QRS:	<0.11 sec

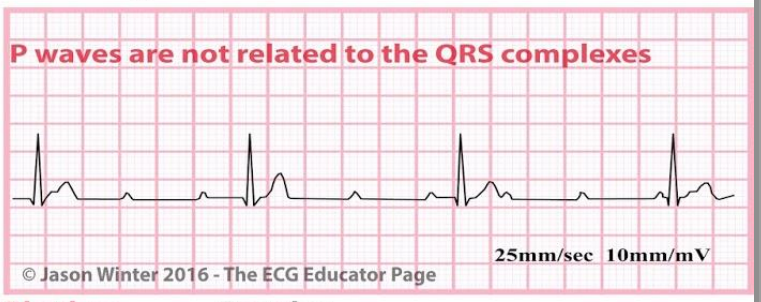
Second Degree AV Block - Type 1 (aka Mobitz 1, Wenckebach):

Rhythm:	Increasingly Prolonged
PR interval:	Irregular
P Wave:	Normal
QRS:	<0.11

Second Degree AV Block - Mobitz Type 2

Rhythm:	Irregular
PR interval:	Normal (more P waves then QRS)
P Wave:	Normal
QRS:	Usually wide >0.10

3rd Degree AV Block



Rhythm:	Regular
PR interval:	None
P Wave:	Normal does not relate to QRS
QRS:	Normal or wide

ECG Tip

- The best way to read 12-lead ECG is to develop a step-by-step approach:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
6. Look for evidence of INFARCTION

Cool Human Body Facts

1. The brain is much more active at night than during the day.
2. During your lifetime, you will produce enough saliva to fill two swimming pools.
3. Your nose can remember 50,000 different scents.
4. Women's hearts beat faster than men's.
5. Your eyes are always the same size from birth (but your nose and ears never stop growing).
6. The brain itself cannot feel pain.
7. The largest internal organ is the small intestine.
8. Sneezes regularly exceed 100 mph & nerve impulses to and from the brain travel as fast as 170 miles per hour.
9. It takes 17 muscles to smile and 43 to frown.
10. The average human brain has about 100 billion nerve cells.
11. The only jointless bone in your body is the hyoid bone in your throat
12. It's impossible to sneeze with your eyes open.