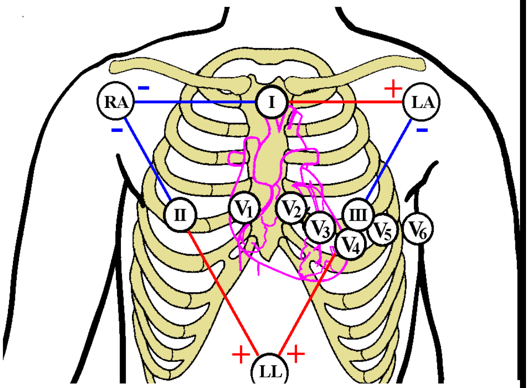
Electrocardiogram (ECG)

- It is a record of the electrical changes of the heart during the cardiac cycle.
- It provides important information about cardiac structure and function.
- ECG is a sensitive galvanometer which records the potential differences by its 2 electrodes.
- As the tissues and tissue fluids are good conductors, there is no need to put ECG electrodes on the heart directly but ECG electrodes are placed **on the skin** of the chest wall and extremities.

Electrocardiogram Leads



- The particular arrangement of the 2 electrodes is called ***the lead.***
- Each leads takes a "snapshot" from a different angle of the heart's net electrical activity. This provides useful information about location of myocardial infarction (MI), assessing for Left Ventricular or Right Ventricular hypertrophy).

Types of ECG leads in the conventional 12 lead ECG:

I. Bipolar leads*: (all are limb leads)*

1) **Lead I:** between the ***right arm*** to the –ve electrode and the ***left arm*** to the +ve electrode. (- R , + L)
2) **Lead II**: between the ***right arm*** to the –ve electrode and the ***left foot*** to the +ve electrode. (- R , + F)
3) **Lead III**: between the ***left arm*** to the –ve electrode and the ***left foot*** to the +ve electrode. (- L , + F)

Einthoven´s law: "the sum of voltages in lead I & III equals the voltage in lead II". Lead II = lead I + lead III

II. Unipolar leads: which include:

A. Limb leads:

1) **aVR**: between the right arm to the +ve electrode and both the left arm & the left foot to the -ve electrode.

2) **aVL**: between the left arm to the +ve electrode and both the right arm & the left foot to the -ve electrode.
3) **aVF**: between the left foot to the +ve electrode and both the right arm & the left arm to the -ve electrode.

B. Chest leads:

1) V_1: right 4th intercostals space near the sternum.
2) V_2: left 4th intercostals space near the sternum.
3) V_3: midway between V_2 & V_4.
4) V_4: left 5th intercostals space midclavicular line.
5) V_5: left 5th intercostals space anterior axillary line.
6) V_6: left 5th intercostals space midaxillary line.

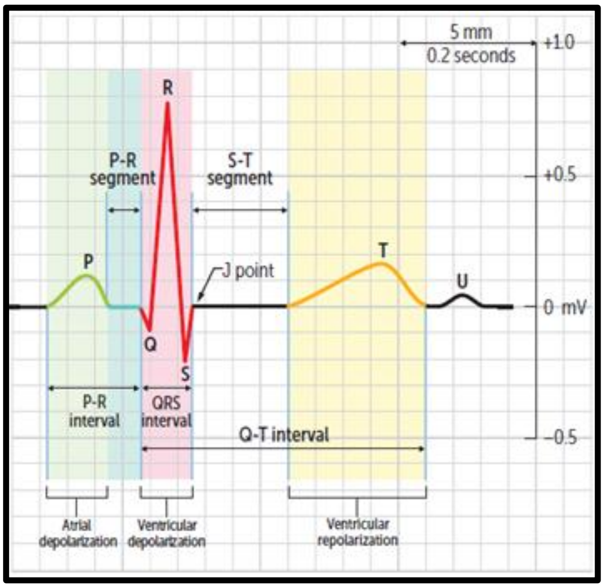
Normal ECG waves:

- There are 3 positive waves (P, R & T waves) and 2 negative waves (Q & S waves) in normal ECG.
- Occasionally, rarely seen tiny wave called (U wave). Appears prominent in hypokalemia (think hyp"U"kalemia) & bradycardia.
- **P wave** represents atrial depolarization.
- **QRS complex** represents ventricular depolarization.
- **T wave** represents ventricular Repolarization.
- **J point**—junction between end of QRS complex and start of ST segment.
- There is no wave for atrial Repolarization because it is masked by the QRS complex and of low voltage.

Key fact

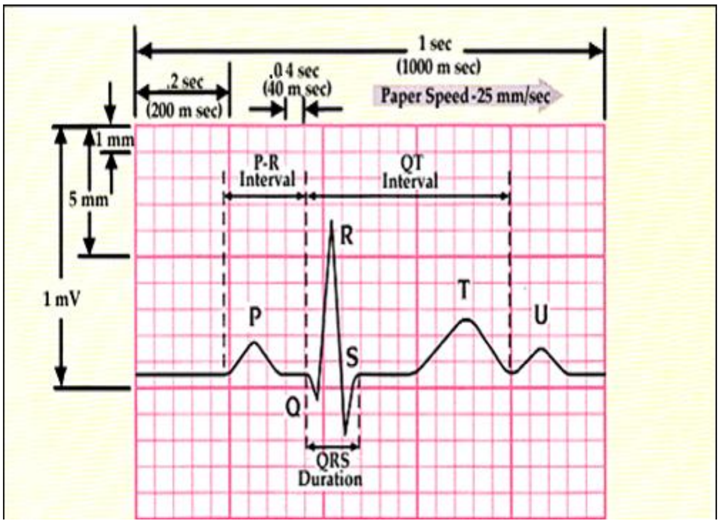
There are four golden rules of ECGs:

1. Depolarization toward a (+) pole of a lead produces an upward deflection on ECG.
2. Depolarization toward a (–) pole of a lead produces a downward deflection on ECG.
3. The magnitude of deflection (up or down) is proportional to how parallel the net electrical vector is to the lead measuring it.
4. A net electrical vector records zero magnitude in any lead perpendicular to it.
5. **Repolarization** toward a (+) and (–) pole produces a downward and upward deflection on ECG, respectively. This is why (T wave) is the same direction as QRS complex.

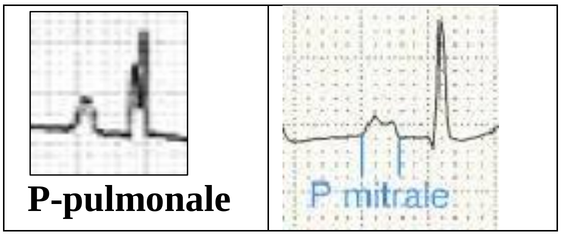


Electrocardiogram Interpretation

Note the x-axis of an ECG strip is time (1 small box = 0.04 sec), and the y-axis of an ECG strip measures electrical potential (1 small box = 0.1 mV).



P wave: (appears clearly in lead II and V1, most parallel to net electrical vector of atrial depolarization)



- ⇨ Represents atrial depolarization.
- ⇨ It precedes atrial systole by 0.02 second.
- ⇨ **Duration** = 0.1 second.
- ⇨ **Voltage** = 0.1- 0.2 mv.
- ⇨ **Abnormalities**:
  - ***Large and/or splitting of P wave***: occurs in atrial hypertrophy.
    - ∗ P-pulmonale (tall and peaked) in right atrial hypertrophy as in tricuspid stenosis.
    - ∗ P-mitrale (tall and bifid or M shaped) in left atrial hypertrophy as in mitral stenosis.
  - ***Absent P wave***: in atrial fibrillation (it is replaced by fine irregular (f waves).
  - ***Abnormal shaped:*** in atrial ectopic.
  - ***Inverted***: in A-V nodal rhythm.

QRS complex:

- ⇨ Represent ventricular depolarization.
- ⇨ It starts 0.02 second before the beginning of ventricular contraction.

- ⇨ **Duration** = 0.08 second. (*Less than that of P wave due to the passage of impulses in high speed Purkinje fibers*).
- ⇨ **Voltage**: 1.2 mv.

Q wave: it is a small (often inconspicuous) downward deflection, caused by depolarization of interventricular septum.

R wave: it is a prominent upward deflection, caused by depolarization of the apex, lateral walls & most of ventricular base.

S wave: it is a downward deflection, caused by depolarization of remaining part of ventricular base.

- ⇨ **Abnormalities**:
  - ➢ ***Large QRS***: occurs in ventricular hypertrophy.
    - ✓ In Left ventricular hypertrophy as in hypertension gives an abnormally tall R wave in V6. In Right ventricular hypertrophy gives an abnormally tall R wave in V1.
    - ✓ Rt or Lt ventricular hypertrophy can be also differentiated by axis deviation.
  - ➢ ***Stunted R wave***: in extensive infarction.
  - ➢ ***Prolonged duration***: in prolongation of ventricular depolarization as in bundle branch block or in ventricular ischemia.

T wave:

- ⇨ Represents ventricular repolarization.
- ⇨ **Duration** = 0.25 second.
- ⇨ **Voltage** = 0.2- 0.3 mv.
- ⇨ **Abnormalities**:
  - ✓ ***Inverted***: in bundle branch block (BBB), in ventricular ischemia or recent MI.

ECG intervals and segments

- ♦ Intervals include a portion of the ECG baseline and at least one wave.
- ♦ Segments (eg, ST segment) only include portions of the ECG baseline and do not include waves.

P-R interval:

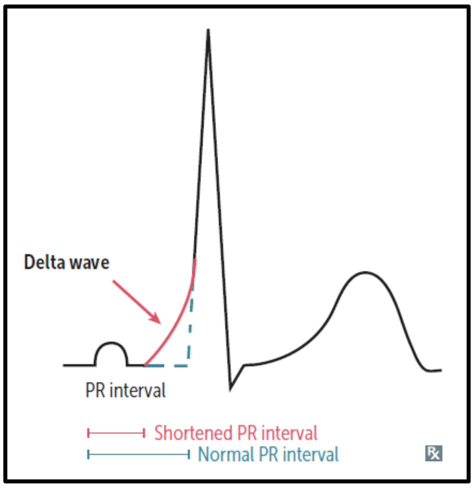
- ⇨ Measured from the beginning of P wave to the beginning of the QRS complex.
- ⇨ It represents the time of conduction of impulses from the atria to the ventricles through the conducting system.

⇨ Normally = 0.12 – 0.20 sec (3–5 small boxes).

⇨ **Prolonged in:** 1st degree heart block or vagal stimulation.

⇨ **Shortened in:**

- ***A-V nodal rhythm.***
- ***pre-excitation syndromes:***
  - ***Wolff-Parkinson-White syndrome:*** the most common type of preexcitation syndrome. It is due to abnormal fast accessory conducting pathway between atrium and ventricle (***bundle of Kent***) predisposing to a re-entry circuit and SVT. ECG shows short PR interval, characteristic delta wave and abnormal shaped and wide QRS.
  - ***Lown-Ganong-Levine (LGL):*** less is known about the structural anomalies underlying the LGL. It may be due to abnormal conducting pathway between SAN & the main stem of AV bundle (bundle of James) → short PR interval with normal QRS.



S-T segment:

⇨ Measured from the end of S wave to the beginning of the T wave.

⇨ It represents the period during which the ventricle is completely depolarized.

⇨ Normally it is on the isoelectric line.

⇨ If displaced above or below this line → this indicates myocardial ischemia or infarction.

Myocardial infarction can be diagnosed by (2 of 3):

- Characteristic compressing or burning diffuse Chest pain that radiate to the left shoulder.
- Raised ST segment in ECG.
- Raised cardiac enzymes in the blood as troponin, creatine phosphate or lactate dehydrogenase.

Other common causes of ST elevation and depression:
ST depression: Hypertrophy**,** Drugs eg, digoxin (J point isoelectric) **&** Hypokalemia
ST elevation: Pericarditis**,** Hyperkalemia & Brugada syndrome (j point elevated).
Brugada syndrome it is a disorder charachterized by sudden death. It is Autosomal dominant disorder most common in Asian males. ECG pattern of pseudo-right bundle

branch block and ST elevations in V1 to V3. Prevent Sudden Cardiac Death with implantable cardioverter-defibrillator (ICD).

QT interval:

- ⇨ The time between the start of the **Q wave** and the end of the **T wave**.
- ⇨ Represents electrical activity of the ventricles & Corresponds to mechanical contraction of the ventricles.
- ⇨ The duration of QT interval is inversely proportional to HR.
- ⇨ Normal duration: when Heart rate between 60–100 bpm: QT ≤ half (R-R distance).
- ⇨ **Prolonged QT interval may be:**
  - ***Hereditary*** (congenital):
    - ➢ Inherited disorder of myocardial repolarization, typically due to ion channel defects.
    - ➢ At risk of sudden cardiac death (SCD) due to torsades de pointes.
    - ➢ Includes:
      - o Romano-Ward syndrome: autosomal dominant disease, pure cardiac phenotype (with **no** deafness)
      - o Jervell and Lange-Nielsen syndrome: autosomal recessive, associated with sensorineural deafness.
  - ***Acquired***:
    - ➢ **Drugs induced (ABCDE):**
      - o Anti**A**rrhythmics (class IA, III)
      - o Anti**B**iotics (eg, macrolides)
      - o Anti“**C**”ychotics (eg, haloperidol)
      - o Anti**D**epressants (eg, TCAs)
      - o Anti**E**metics (eg, ondansetron)
    - ➢ **Electrolyte abnormalities** (↓ K^+, ↓Ca^{++}, ↓Mg^{++}) & may be Hereditary.
- ⇨ First-line of treatment is usually by magnesium sulfate.

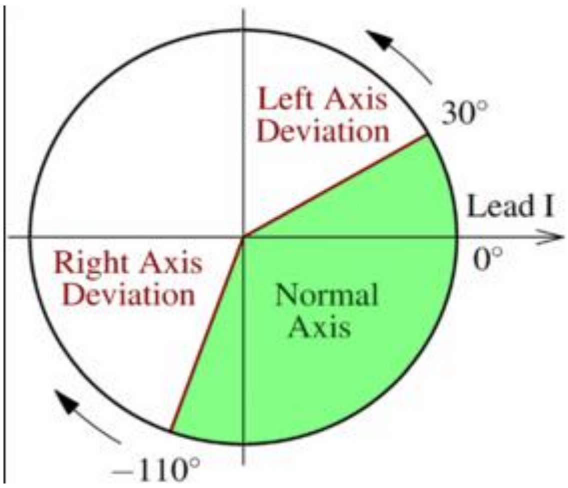
Torsades de pointes = twisting of the points
Uncommon Polymorphic ventricular tachycardia, characterized by a gradual change in the amplitude and twisting of the QRS complexes around the isoelectric line; can progress to ventricular fibrillation (VF) and leads to sudden cardiac death.

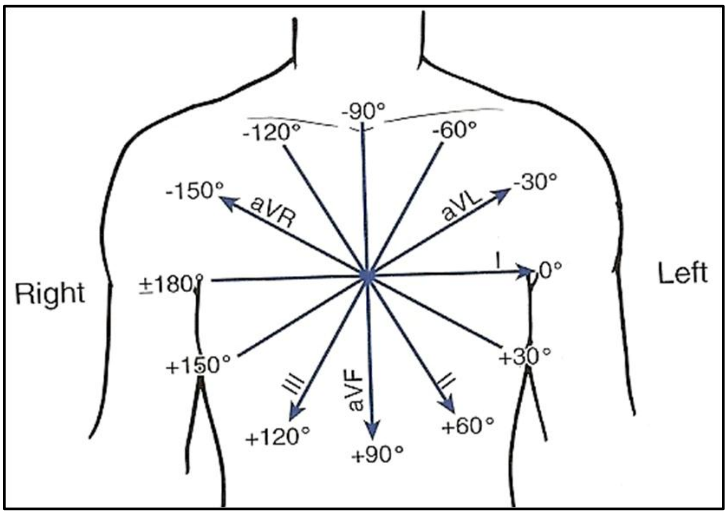
Electrical axis of the heart

- It is the sum of the electrical directions in the heart.
- The net "electrical axis of the heart" is directed downwards and to the left from SAN to the heart's apex.
- Normally it is between -30 : + 110 ° (average 59°).
- Estimation of mean QRS axis is determined by the direction of the QRS complex in leads I and aVF (some texts suggest using leads I and II).
- The axis may be deviated to the right or to the left.

Causes of axis deviation:

Right axis deviation	Left axis deviation
Physiological causes: 1) During inspiration. 2) When the person stands up. 3) Tall and slender person.	1) During expiration. 2) When the person lays down. 3) Short and fatty person.
Pathological causes: 1) Right ventricular hypertrophy. 2) Right bundle branch block. 3) Left ventricular extrasystole.	1) Left ventricular hypertrophy *in some cases.* *2)* Left bundle branch block *(the most common cause).* 3) Right ventricular extrasystole.





<u>How to measure the Heart Rate from the ECG:</u>

H.R = $\frac{60}{R-R\ interval\ (in\ seconds)}$

or $HR = \frac{300}{R-R\ interval\ (NO.of\ large\ squres\ between\ R-R)}$

or HR = $\frac{1500}{R-R\ interval\ (NO.of\ small\ squres\ between\ R-R)}$

If the HR is irregular (average of 2 largest R-R intervals and 2 smallest R-R intervals).
Or HR = # of QRS complexes in 6 seconds × 10