Electrocardiogram

- Recording and analysis of the electrical activity of the heart

- The recording device is made to record a positive (upright) deflection whenever depolarization moves towards the positive electrodes (away from the negative electrode) or repolarization moves away from the positive electrode (towards the negative electrode).

- If the negative electrode were placed over the upper part of the right atrium and the positive electrode over the apex of the ventricle the following will be recorded during each cardiac cycle:
a) A small upright deflection (the P wave) due to atrial depolarization which occurs from the right to left and from above downwards in the direction of the positive electrode or away from the negative electrode.

b) A small negative deflection (the Q wave) resulting in midseptal activation from the left to the right proceeding away from the positive electrode.

c. A tall positive deflection (the R wave) due to activation of the major portion of the ventricle with a mean direction of from right to left above downwards towards the positive electrode. The large amplitude of the wave is due to the large muscle mass and consequently greater voltage difference involved.

d. A small negative deflection (the S wave) due to activation of the upper interventricular septum and the postero-basal of the heart with a net direction of from left to right away from the positive electrode.

e. Another positive deflection due to net repolarization which must have proceeded from below upwards or away from the positive electrode.
Characteristics of Normal ECG:

- **P wave** - caused by electrical potentials generated as the atria depolarize before contraction.

- **QRS complex** – caused by potentials generated when the ventricles depolarize before contraction.

- **T wave** – repolarization

- **P - R interval** = the duration of time between the beginning of the P wave and the beginning of the QRS wave is the interval between the beginning of contraction of the atria and the beginning of contraction of the ventricles. (N=0.16 sec)

- **QT interval** - N= 0.35 sec
  - Contraction of the ventricle lasts almost from the beginning of the Q wave to the end of the T wave.
Voltage and Time Calibration of the ECG:

The smallest divisions are one mm squares.
Upward deflections are called “positive” deflections.
Downward deflections are called “negative” deflections.

ECG Leads:

- **LIMB leads:**
  Bipolar limb leads (I II III)
  Augmented unipolar limb leads (AVR, AVL, AVF)

- **Chest leads (precordial leads):** V1, V2, V3, V4, V5, V6

- **Lead I:** negative terminal – R arm
  positive terminal – L arm

- **Lead II:** negative terminal – R arm
  positive terminal – L leg

- **Lead III:** negative terminal – L arm
  positive terminal - L leg
Einthoven’s law: If the electrical potentials of any 2 of the 3 bipolar limb ECG leads are known at a given instant, the 3rd can be determined mathematically from the 1st 2 by simply summing the first 2.

- Ex. Lead I +0.5 mv
  - Lead II +0.7 mv
  - Lead III + 1.2 mv
Augmented unipolar limb leads:

- positive terminal on the R arm (AVR)
- On the L arm (AVL)
- On the left leg (AVF)
Chest leads

V1 R parasternal 4th ICS
V2 L parasternal 4th ICS
V3 between V2 and V4

V4 5th ICS LMCL
V5 L AAL 5th ICS
V6 L MAL 5th ICS
**ECG Interpretation:**

- Rate
- Rhythm
- Axis
- Hypertrophy
- Infarction
RATE

- Normal = 60-100/min

- Sinus Tachycardia – rate of >100/min (with normal rhythm)
  - General causes:
    - Increased body temperature
    - Stimulation of the heart by the sympathetic nerves
    - Toxic conditions of the heart

Sinus Bradycardia

- rate of < 60/min (with normal rhythm)
- Causes:
  - Sick sinus syndrome
  - MI/ Ischemia
  - Hypothermia
  - Hypothyroidism
  - Cholestatic jaundice
  - Raised ICP
  - Drugs: (Beta Blockers, CCB, Digoxin)
How Do We Obtain Rate:

- Find a specific R wave that falls on a heavy black line then count off “300, 150, 100, 75, 60, 50” for each heavy blank line that follows. Where the next R wave falls determines the rate.
- 1500/no. of small sq.(0.04 sec) in between 2 R waves
- At the top of the ECG are 3 second strips (markings). Get 2 3-sec markings and count no. of cycles in the 6-sec interval (1 cycle is the distance between 2 R waves) multiply the no. of cycles by 10 to get the rate.
RHYTHM

- The normal cardiac rhythm is such that there is a constant distance between similar waves.

Arrhythmias

- Varying rhythms
  - irregular rhythms with a normal sequence of waves, however the rhythm changes continuously.
- Extra Beats
  - (recognized as waves which appear earlier than expected) and Skips (refer to blank areas of baseline)
- Rapid Rhythms
- Heart Blocks
Arrhythmias

I. Varying rhythms
- Sinus Arrhythmia
- Wandering pacemaker
- Atrial Fibrillation

II. Extra Beats and Skips
- Premature Beats
  - Atrial Premature
  - A-V Nodal Premature
  - Premature Ventricular Contractions
- Escape Beats
  - Atrial Escape
  - Nodal Escape Beats
  - Ventricular Escape Beats
- Sinus Arrest

Rapid Rhythms
- Paroxysmal Tachycardia
  - Paroxysmal Atrial Tachycardia
  - Paroxysmal Nodal Tachycardia
  - Paroxysmal Ventricular Tachycardia
- Atrial Flutter
- Ventricular Flutter
- Ventricular Fibrillation

**Heart Blocks**
- SA Block
- AV Block
  - First Second Third
- Bundle Branch Block

**Varying rhythms**

- *Sinus arrhythmia* – varying irregular rhythm often due to coronary artery disease.
- ECG: varying rhythm; P waves are identical

<table>
<thead>
<tr>
<th>Sinus Arrhythmia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
</tr>
<tr>
<td>Usually 60-100 bpm</td>
</tr>
</tbody>
</table>
**Wandering pacemaker** – caused by changing position of the pacemaker

- ECG: varying rhythm; P wave shape changes

<table>
<thead>
<tr>
<th>Heart Rate</th>
<th>Rhythm</th>
<th>P Wave</th>
<th>PR interval (in seconds)</th>
<th>QRS (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually &lt;60 bpm</td>
<td>Irregular</td>
<td>Multiple forms</td>
<td>Variable</td>
<td>&lt;.12</td>
</tr>
</tbody>
</table>

**Atrial Fibrillation** – caused by the firing of multiple foci in the atria

- ECG: varying rhythm; no real P’s, but multiple ectopic atrial spikes
- Tx: electroshock

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<th>P Wave</th>
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</tr>
</thead>
</table>
| A: 350-650 bpm  
V: Slow to rapid | Irregular   | Fibrillatory (fine to course) | N/A                      | <12              |
Extra Beats

- **Premature Beats** (premature contraction, Extrasystole, Ectopic beat) – caused by premature firing of various ectopic foci
  - Possible causes:
    - local areas of ischemia
    - small calcified plaques at different points in the heart
    - toxic irritation of the AV node, Purkinje system, or myocardium

- **Atrial Premature**
  - premature atrial stimulation from an atrial ectopic focus produces an abnormal P wave earlier than expected.
AV nodal Premature
- premature nodal stimulation originates from an ectopic discharge in the AV node
- ECG: P wave is missing.

Premature Ventricular Contractions (PVC’s)– originate from an ectopic focus in a ventricle

- Quadrigeminal PVC’s: every fourth beat is a PVC
- Trigeminal PVC’s: every third beat is a PVC
**ECG:**

- *The QRS complex is usually considerably prolonged.*
- *The QRS complex has a high voltage.*
- *After almost all PVC’s, the T wave has a potential polarity opposite to that of the QRS complex.*

**Escape Beats** – occur when the normal pacemaker fails to elicit stimulus for one or more cycle, so an impatient ectopic focus fires.

- *Atrial escape* – an ectopic focus in the atria may fire an impulse after such a pause stimulating the atria. Conduction then proceeds down the AV node normally.
- *Nodal Escape Beats* – originate in the AV node and stimulate the ventricles via the normal conduction system.
- *Ventricular Escape Beats* – originate in a ventricular ectopic focus resulting in a PVC type of ventricular response after a pause in the rhythm
Sinus Arrest – occurs when the SA node’s pacemaking area suddenly is arrested and does not send out pacemaking stimuli.
Rapid Rhythms

- Paroxysmal Tachycardia – sudden rapid HR which usually arises from an ectopic pacemaker.
  - Paroxysmal Atrial Tachycardia – on ECG: an inverted P wave occurs before each of the QRS-T complexes; P wave is partially superimposed on the normal T wave of the preceding beat.
  - Paroxysmal Nodal Tachycardia – usually causes almost normal QRS-T complexes but missing or obscured P waves.
  - Paroxysmal Ventricular Tachycardia – on ECG: the appearance of a series of ventricular premature beats occurring one after another without any normal beats interspersed.

- Atrial Flutter – originates in an atrial ectopic focus. P waves occur in rapid succession and each is identical to the next.
  - Atrial contraction = 200-350/min
Ventricular Flutter – produced by a single ventricular ectopic focus firing at a rate of 200-300/min.

Ventricular Fibrillation – created by stimuli from many ventricular ectopic foci causing chaotic twitching of the ventricles; totally irregular appearance; no pumping action of the heart.
Heart Blocks

- SA Block – causes the pacemaker to temporarily stop for at least one cycle, but then resumes the pacing activity; the impulse from the sinus node is blocked before it enters the atrial muscle.

- AV Block – creates a delay of the atrial impulse at the AV node, making a longer than normal pause before stimulating the ventricles.
  - ECG: prolonged P-R interval more than 1 large square

What is happening in a SA Block and Sinus Arrest?

**SA Block**
- Pause is multiple of 2 P-P Intervals

**Sinus Arrest**
- Pause NOT multiple of 2 P-P Intervals
- **Incomplete Heart Block**
  - **First Degree AV Block** – P-R interval greater than 0.2 sec (one large square).
  - **Second Degree AV Block** – when conduction through the AV junction is slowed until P-R interval is 0.25-0.45 sec; *the atria beat faster than the ventricles*; it takes 2 or more atrial impulses to stimulate the ventricular response.
- **Third Degree (complete) Block**- occurs when none of the atrial impulses stimulate the AV node (no ventricular response).
Bundle Branch Block – caused by a block of the impulse on the RBB or LBB; on ECG the QRS is 3 small squares wide (0.12 sec) or more and 2 R waves (R and R’) are seen.
- R-R’ in V1 or V2 – RBBB
- R-R’ in V5 or V6 – LBBB

Rhythm – always check P-R for AV Block; QRS for BBB

AXIS

- refers to the direction of depolarization which spreads throughout the heart to stimulate the muscle fibers to contract.

- Vector
  - an arrow that points in the direction of the electrical potential generated by the current flow with the arrowhead in the positive direction.
Abnormal Ventricular Conditions that cause Axis deviation:

- Change in the position of the heart
- Hypertrophy of one ventricle
HYPERTROPHY

- **Atrial hypertrophy:**
  - RAH – the initial component of a diphasic wave in V1 is largest
  - LAH – the terminal portion of a diphasic wave in V1 is large and wide
- **RVH** – there is a large R wave in V1 and it gets progressively smaller in V2 – V6
- **LVH** – large S in V1, large R in V5
  - Depth of S (V1) + R (V5) > 35mm
  - T wave inversion and asymmetry (I, II, III)

INFARCTION

- **Ischemia** – decreased BS; common cause of increased duration of depolarization
  - on ECG: inverted T waves, symmetrical
- **Injury** – indicates acuteness of an infarct; ST segment elevation denotes acute injury
- **Infarction** – Q wave which is one small square wide (0.04 sec) or 1/3 the size of the QRS complex.
- **Anterior infarction** – Q waves in V1-V4, if acute with ST elevation
- **Lateral infarction** – Q waves in I, AVL
- **Inferior infarction** – Q waves in II, III, AVF
- **Acute posterior infarction** – large R wave in V1 V2 and ST depression in V1 V2 V3

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**Sequential Scheme for rapid ECG Interpretation**

- **RATE** 300, 150, 100, 75, 60, 50
  - 1500/# of small sq.
  - Normal 60-100/min.
  - Sinus Tachycardia
  - Sinus Bradycardia
- **RHYTHM** – scan tracing for abnormal waves, pauses and irregularity
  - check for P before each QRS
  - check for QRS after each P
  - measure P-R interval
  - measure QRS interval

- **AXIS**: 
  - QRS above or below the baseline in the following leads: I, AVF for normal against RAD or LAD

- **HYPERTROPHY**: check in V1
  - P wave for atrial hypertrophy
  - R wave for RVH
  - S wave for LVH + R wave in V5 for LVH

- **INFARCTION**: scan all leads for
  - Q waves
  - Inverted T waves
  - Elevated ST segments