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Physiological Basis of ECG

M1 – Cardiovascular/Respiratory Sequence
Louis D’Alecy, Ph.D.
Physiological Basis of ECG 1

16 slides, 50 min.

1. Wave of depolarization
2. Pacemaker potentials
3. LV action potential
4. Mechanical event
5. Surface electrical (ECG) event
SA Node Action Potential = Primary Pacemaker

- Phase 4:
  - Progressive decrease in K+ perm
  - Increase in Na+ perm
  - Modified by Sym & Para Sym

Note Phase 4
Parasympathetic

Similar to M&H Fig 2.6
Sympathetic/parasympathetic nerve stimulation

- **NE** -- **Na⁺ Perm** (more “+” leak in)
- **Ach** -- **K⁺ Perm** (more “+” leak out)

+/− Chronotropic
Comparison of action potentials

(a) No pacemaker potential

(b) Pacemaker potential

Phase 4 diastolic depolarization
Membrane potential of ventricular muscle

1. Na⁺ perm 0
2. Ca²⁺ perm (sustained)
3. K⁺ perm
4. Na⁺ perm 1

Time (s)

Membrane potential (mV)
Phase 2 = gain Ca$^{++}$ and retain K$^+$
Absolute Refractory Period (ARP)

Relative Refractory Period (RRP)

Electrical activity recorded with surface electrode
Action potential recorded intracellularly

ARP
RRP

Mechanical response

0.5 g
150 mV

Source Undetermined
So why can’t heart muscle develop tetanic contractions?

Ventricular action potential lasts almost as long as the mechanical tension development so there is little or no tension left (after Refractory period) to build upon.
So why is the ECG so small (1 mv) and action potential so big (110 mv)?

Bag of batteries?

AC and DC Coupling

Entire heart
At Body Surface = 1 MV

One LV cell AP = 110 MV
What are the waves of the ECG?

P wave = atrial depolarization
QRS = ventricular depolarization
T = ventricular repolarization
Segments are “baseline
Intervals have waves

4.1 MH

Physiological Basis of ECG 2
22 slides, 50 min

1. Limb leads
2. Hidden assumptions
3. Rate and Rhythm
4. Axis
5. 12 Lead = 6 Frontal + 6 Precordial
6. Basic examples
12 Lead

Figure 4.28. 12-lead ECG (normal). The rectangular upward deflection at the beginning of each line is the voltage calibration signal (1 mV). Rhythm: normal sinus. Rate: 70 bpm. Intervals: PR, 0.17; QRS, 0.06; QT, 0.40 sec. Axis: 0° (QRS is isoelectric in lead aVF). The P wave, QRS complex, ST segment, and T waves are normal. Notice the gradual increase in R wave height between leads V1 through V6.

Conventions

Einthoven’s Triangle

chart recorder
lead selector
and amplifier

voltage scale
10 mm upward = +1 mV

paper speed
25 mm = 1 s

right arm
- lead I +
left arm
lead II
left leg
lead III

4.2 MH

Source Undetermined
“Hidden” assumptions ECG:

Every lead measures voltage between **two points**.

Every lead has a “agreed upon” (+) and (-).

Depolarizations are set for upward deflections.

When a wave of depolarization (+) moves to (+) electrode it gives upward (+) deflection

Dubin’s “Rapid Interpretation of EKG’s” “+ + + +”
ECG

P wave = atrial depolarization
QRS = ventricular depolarization
T = ventricular repolarization

The repolarization of the ventricle or T wave must retrace the QRS in the reverse direction in order to give a positive or upward deflection!! (see bottom of page 76)

Last to depolarize are first to repolarize!
Dubin “Rapid Interpretation of EKG’s”

Rate = beats/min

Rhythm = regularity of recurrence

Mean Electrical Axis = orientation of most intense depolarization

?? size

?? location

?? meaning
Mean Electrical Axis of the Heart:

Occurs at the instant of most intense depolarization.

Follows the general direction of the “R” wave of depolarization.

Size is determined by:

- the greater the e-wave == the greater the deflection
- the greater the mass of tissue == the greater the deflection
- the greater the coordination == the greater the deflection
Effect of Mass on Mean Electrical Axis

Mass (effective, electrical)

- normal anatomy, atria vs. ventricles
- hypertrophy, atrophy
- infarct (dead tissue)
- ischemia (inadequate blood flow)
Effect of Electrical coordination on Mean Electrical Axis

Atria
Ventricles
  AV Node
  Bundle of His
  Purkinje System
Damaged Purkinje
Bundle Branch Block

The basic 3 limb leads provide much information BUT........
12 Lead ECG allows a more detailed electrical assessment of heart

Frontal Plane (6 Leads)
  3 Regular Limb
  3 Augmented

Cross Sectional Plane (6 leads)
Precordial (chest) Leads

Source Undetermined
Conventions for 6 Frontal Lead ECG

<table>
<thead>
<tr>
<th>Lead Name</th>
<th>Positive Electrode</th>
<th>Negative Electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead I</td>
<td>Left Arm</td>
<td>Right Arm</td>
</tr>
<tr>
<td>Lead II</td>
<td>Left Leg</td>
<td>Right Arm</td>
</tr>
<tr>
<td>Lead III</td>
<td>Left Leg</td>
<td>Left Arm</td>
</tr>
<tr>
<td>aVR</td>
<td>Right Arm</td>
<td>Indifferent (1)</td>
</tr>
<tr>
<td>aVL</td>
<td>Left Arm</td>
<td>Indifferent (1)</td>
</tr>
<tr>
<td>aVF</td>
<td>Left Leg (Foot)</td>
<td>Indifferent (1)</td>
</tr>
</tbody>
</table>

Indifferent lead (1) is the remaining two limb leads combined.
Augmented (unipolar) limb leads

To gain increased sensitivity and additional electrical perspective three “Augmented Voltage” leads have been devised from original RA, LA and LL leads.

They are aVR, aVL and aVF. The abbreviation defines the positive electrode.

aVR has Right arm +
aVL has Left arm +
aVF has Foot +

Lead I
Lead II
Lead III
Frontal Plane

aV = augmented voltage
6 Frontal Plane Leads
Call it:

Q if 1st  ↓  e.g. V4, V5, V6
R if 1st  ↑  e.g. V1, V2, V3
S if 1st  ↓  after R  e.g. all
## Conventions for 6 Precordial (V1-V6) Lead ECG

<table>
<thead>
<tr>
<th>Lead Name</th>
<th>Positive Electrode</th>
<th>Negative Electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>V1</td>
<td>Indifferent (2)</td>
</tr>
<tr>
<td>V2</td>
<td>V2</td>
<td>Indifferent (2)</td>
</tr>
<tr>
<td>V3</td>
<td>V3</td>
<td>Indifferent (2)</td>
</tr>
<tr>
<td>V4</td>
<td>V4</td>
<td>Indifferent (2)</td>
</tr>
<tr>
<td>V5</td>
<td>V5</td>
<td>Indifferent (2)</td>
</tr>
<tr>
<td>V6</td>
<td>V6</td>
<td>Indifferent (2)</td>
</tr>
</tbody>
</table>

**Indifferent lead (2)**

*is all three limb leads combined.*
Segments are “baseline

Intervals have waves

4.1 MH
12 Lead

Figure 4.28. 12-lead ECG (normal). The rectangular upward deflection at the beginning of each line is the voltage calibration signal (1 mV); Rhythm: normal sinus. Rate: 70 bpm; intervals: PR, 0.17; QRS, 0.06; QT, 0.40 sec. Axis: 0° (QRS is isoelectric in lead aVF). The P wave, QRS complex, ST segment, and T waves are normal. Notice the gradual increase in R wave height between leads V1 through V6.

Supraventricular arrhythmias

Why is this 1. Normal sinus rhythm “Normal”

1- frequency 1/sec or 60 BPM
2- QRS “shape” normal and duration <120 ms
3- QRS preceded by P
4- PR interval < 200ms
5- QT interval < 1/2 RR interval
6- no extra P waves

MH Fig 5.1
Supraventricular arrhythmias

1. normal sinus rhythm
2. supraventricular tachycardia
3. first-degree block
4. second-degree block
5. third-degree block
6. atrial fibrillation

MH Fig 5.1
Ventricular arrhythmias

1. normal sinus rhythm
2. bundle branch block
3. premature ventricular depolarization
4. ventricular tachycardia
5. long QT syndrome with “twisting of points”
6. ventricular fibrillation

MH Fig 5.3

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Slide 22: Source Undetermined
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Slide 30: Source Undetermined