Understanding the Electrocardiogram

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Overview

1. History
2. Review of the conduction system
3. EKG: Electrodes and Leads
4. EKG: Waves and Intervals
5. Determining heart rate
6. Determining Rhythm
7. Determining QRS Axis
8. To be continued
History

- Luigi Galvani (1786)
  - Studying the effects of electricity on animal tissue
  - Notes that a dissected frog leg twitches when exposed to an electric field
- Galvinometer
  - Instrument for measuring and recording electricity
  - EKG is essentially a sensitive Galvinometer
History

- Willem Einthoven (1893)
  - Introduces the term *electrocardiogram* at a meeting of the Dutch Medical Society
  - Later he credits A.D. Waller (1895) using an improved electrometer
  - Distinguishes five deflections: P, Q, R, S, T
Augustus D. Waller

- (1887) Publishes the first recorded human ECG in 1887
  - Capillary electrometer
- (1889) First International Congress of Physiologists
  - Willem Einthoven sees Waller demonstrate the technique on “Jimmy”
History

■ Evolution
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It’s Electric
The Cardiac Conduction System
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EKG Electrodes

- The EKG records the electrical activity of the heart using skin sensors called electrodes.
EKG Electrodes

As a positive wave of depolarization within the heart cells advances TOWARD a positive electrode, an UPWARD deflection is recorded on the EKG.
EKG Electrodes

- As a positive wave of depolarization within the heart cells advances AWAY from positive electrode, a DOWNWARD deflection is recorded on the EKG.
EKG Electrodes

- If a wave of depolarization within the heart cells occurs at a 90 degree angle respective to a positive electrode, an ISOELECTRIC deflection is recorded on the EKG.
EKG Electrodes

Therefore, the size and direction of the recorded impulse is directly related to the direction of depolarization as viewed from the POSITIVE electrode.
EKG Electrodes

- The EKG uses multiple electrode combinations (Leads) to record:
  - The SAME cardiac impulse…
  - From DIFFERENT perspectives
  - Gives the observer (you) more information about the electrical activity of the heart
EKG Leads

- Leads measure the difference in electrical potential between either:
  - Two different points on the body
  - Bipolar Leads
EKG Leads

- OR:
  - One point on the body and a virtual reference point with zero electrical potential, located in the center of the heart
    - Unipolar Leads
### Summary of Leads

<table>
<thead>
<tr>
<th></th>
<th>Limb Leads</th>
<th>Precordial Leads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bipolar</strong></td>
<td>I, II, III (standard limb leads)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Unipolar</strong></td>
<td>aVR, aVL, aVF (augmented limb leads)</td>
<td>V₁-V₆</td>
</tr>
</tbody>
</table>
Lead Placement: Limb Leads

- White on RIGHT ARM
- Black to LEFT ARM
- Red to LEFT LEG
- Green to RIGHT LEG
Lead Placement: Precordial Leads

V1: Right 4th intercostal space, parasternal
V2: Left 4th intercostal space, parasternal
V4: Left 5th intercostal space, mid-clavicular line
V3: Halfway between V2 and V4
V5: Horizontal to V4, anterior axillary line
V6: Horizontal to V5, mid-axillary line
Anatomic Groups
(Summary)
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The electrocardiogram (EKG) is a representation of the electrical events that occur during the cardiac cycle. Each event has a distinctive waveform, the study of which can lead to insight into a patient’s cardiac pathophysiology.
What types of pathology can we identify and study from EKGs?

- Arrhythmias
- Myocardial ischemia and infarction
- Pericarditis
- Chamber hypertrophy
- Electrolyte disturbances (i.e. hyperkalemia, hypokalemia)
- Drug toxicity (i.e. digoxin and drugs which prolong the QT interval)
EKG: Standard

- The calibration box

25 mm/sec; 10 mm/mV
EKG: Standard

- When set to run at 25mm/sec
  - 0.2 sec wide
- When set at 10mm/mV
  - 10 boxes high
EKG: Standard

- When set to run at 50mm/sec
  - 0.4 sec wide
- Can help sort out underlying rhythms when heart rate is fast
EKG: Standard

- Can be set to run at $\frac{1}{2}$ standard
  - 5mm/mV
- Useful in children or when voltage is high
Waveforms and Intervals
Waveforms and Intervals: P Wave

- Best viewed in Lead II or V1
  - Upright in Lead II
  - Biphasic in V1
- Max height should be less than 2.5 mm
- Duration should be less than 0.12 sec
Waveforms and Intervals: PR Interval

- **PR interval**
  - Includes the P wave and the PR segment
- **PR interval should be between 0.12 and 0.2 seconds**
- **Depression of PR segment is pathomnemonic for pericarditis**
Waveforms and Intervals: QRS Complex

- **Q wave**
  - First deflection below isoelectric line
  - Should be less than one box (0.04 sec wide) and less than 1/4 the height of R wave

- **R Wave**
  - Any deflection above the isoelectric line

- **S wave**
  - Any deflection below the isoelectric line that is NOT a Q wave

- Entire QRS complex should be less than 0.1 seconds
Waveforms and Intervals: ST segment

- Begins at the junction or J point
  - End of QRS complex
  - Start of T wave
- Morphology
  - Myocardial Injury
Waveforms and Intervals: T wave

- Represents ventricular repolarization
  - Beginning of QRS to apex of T wave
    - ABSOLUTE refractory period
  - Last half of T wave
    - RELATIVE refractory period
Waveforms and Intervals: T wave

- **Morphology**
  - Follows the direction of the QRS complex
  - Asymmetrical
    - Normal
  - Symmetrical peaked
    - Hyperkalemia
  - Flat
    - Hypokalemia
  - Inverted
    - Ischemia, CNS abnl
Waveforms and Intervals: QT interval

- Indicates how fast the ventricles are repolarized
  - How fast they are ready for the next cardiac cycle
- QT interval can be prolonged in the presence of:
  - Meds, ischemia, electrolyte imbalances
- Prolongation of the QT interval can lead to:
  - Torsades de Pointes
  - Ventricular fibrillation
Waveforms and Intervals: QT interval

- The QT interval is rate related
  - QTi gets shorter as the heart rate increases
- Calculating the corrected QTi (QTc)

$$\text{QTc} = \frac{\text{QT}}{\sqrt{\text{RR}}}$$

QTc men < 450 msec
QTc women < 470 msec
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Rule of 300

- Identify an R wave that falls on or near a heavy red line
- Where the NEXT R wave falls determines the ventricular rate
- MEMORIZE
  - 300, 150, 100, 75, 60, 50
- REGULAR RHYTHM
What is the heart rate?

- What is the ventricular rate?
- What is the atrial rate?
10 Second Rule

- Most EKG’s record 10 seconds of rhythm per page
  - Count the number of beats present
    - **Rhythm strip**
  - Multiply by 6 to get the number of beats per minute
- This method works well for **IRREGULAR RHYTHMS**
What is the heart rate?

33 beats in 10 sec $\times 6 = 198$ bpm
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Rhythm: Normal Sinus

- Is there a P wave?
- Is there a P attached to every QRS?
- For NSR there must be a P wave for every QRS complex and QRS complex for each P wave

A. Normal sinus rhythm

Impulses originate at SA node at normal rate.

All complexes evenly spaced; rate 60 to 100/minute.
Rhythm: Sinus Arrythmia

- P wave for every QRS and vice versa
- IRREGULAR RHYTHM
- Respiratory pattern

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<tr>
<th>Heart Rate</th>
<th>Rhythm</th>
<th>P Wave</th>
<th>PR interval</th>
<th>QRS</th>
</tr>
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<tr>
<td>Usually 60-100 bpm</td>
<td>Irregular</td>
<td>Before each QRS, identical</td>
<td>.12 to .20</td>
<td>&lt;.12</td>
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Rhythm: Sinus Tachycardia

- P wave for every QRS and vice versa
- Rate > 100 bpm
Rhythm: Sinus Bradycardia

- P wave for every QRS and vice versa
- Rate < 60 bpm
Rhythm: Atrial Flutter

- Atrial rate 200-400 bpm
- Saw tooth pattern
  - Best seen in lead II
- Common pattern (2:1 conduction)
  - Atrial rate 300
  - Ventricular rate 150 bpm
Rhythm: Atrial Fibrillation

- Highly irregular rhythm
- No discernable P waves
- Ventricular rate depends on conduction
  - Rapid
  - Slow
Rhythm: Junctional Rhythm

- Regular Rhythm
- Inverted, absent or after QRS
- Ventricular rate (40-60 bpm)
Rhythm: Wandering Pacemaker

- Irregular Rhythm
- At least 3 P wave morphologies
- Rate > 100 bpm
  - Multifocal Atrial Tachycardia
Rhythm: PSVT

- Regular Rhythm
- Rate: 120-150 bpm
- P waves hidden or retrograde
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The QRS Axis

- The QRS axis represents the net overall direction of the heart’s electrical activity.
- Abnormalities of axis can hint at:
  - Ventricular enlargement
  - Conduction blocks (i.e. hemiblocks)
The QRS Axis

- Normal axis is defined as -30° to 90°
- LAD is -30° to -90°
- RAD is 90° to 180°
- NWA is 180° to 270°
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