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Cardiovascular Sequence

Electrocardiogram

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Consultant: NIH NHLBI
Electrocardiogram

Key Words: Depolarization, repolarization, EKG leads, electrical axis, ST segment shifts

Objectives:
1. To learn the nomenclature and classification system for ECG interpretation.
2. To learn the major conduction abnormalities seen on ECG interpretation.
3. To diagnose ischemic heart disease patterns on ECG’s.
4. To become familiar with how structural heart conditions affect ECG findings.
Electrocardiogram

The Normal EKG: Outline

Electrical Measurement - Single Cell

EKG Reference System
- Technical Considerations
- Sequence of Activation

Interpretation
- Calibration
- Rhythm
- Rate
- Intervals
- QRS Axis
- P-waves
- QRS
- ST-T wave abnormalities
Electrical Measurement
Single Cell

Key Concepts

- Resting state - polarized
- Depolarization
- Repolarization
- Directionality
EKG recording

CARDIAC MUSCLE CELL

Depolarization
Depolarized portion

Repolarized portion
EKG Lead Reference System

• Unipolar
• Bipolar
• Chest Leads
Unipolar Limb Leads

$\text{aV}_R^+$

$\text{aV}_F$

$\text{aV}_L^+$
Bipolar Limb Leads

I

(-) (+)

II

(-) (+)

III

(-) (+)
Magnitude and Direction of Electrical Activity

Key Principles:

- Electrical force directed at (+) pole of a lead generates upward EKG deflection
- Forces directed away from (+) pole generate downward deflection
- Magnitude of deflection reflects how parallel the electrical force to lead
- Forces directed perpendicular to a lead generate no activity or flat line
Sequence of Normal Cardiac Activation
EKG Interpretation: 8 Steps

1. Check voltage calibration
2. Heart rhythm
3. Heart rate
4. Intervals (PR, QRS, ST)
5. Mean QRS axis
6. Abnormalities of P-waves
7. Abnormalities of QRS (hypertrophy, bundle branch block, infarction)
8. ST and T wave abnormalities
Paper Speed: 25 mm/sec

PR → QT

5 mm = 0.5 mV
(1 mm = 0.1 mV)

5 mm = 0.2 seconds
(1 mm = 1 small box = 0.04 seconds)
Heart Rhythm

- Sinus Rhythm
- Rate $\geq 60$ BPM
  $\leq 100$ BPM
**Method 1**

The standard paper speed = 25 mm/sec. So, count the number of mm between two QRS complexes (i.e., between 2 "beats"). Then:

\[
\text{Heart Rate (beats/min)} = \frac{(25 \text{ mm/sec} \times 60 \text{ sec/min})}{\text{number of mm between beats}} = \frac{1500}{\text{mm/beats}}
\]

On this strip for example, there are 23 mm between the first 2 beats:

23 mm between beats

Therefore, the heart rate = \[\frac{1500}{23}\] = 65 beats/min

Method 1 is particularly helpful for measuring fast heart rates (>100 bpm).
Method 2

The "count-off" method requires memorizing the sequence:

300 - 150 - 100 - 75 - 60 - 50

In the example, count-off the number of large boxes between two consecutive beats:

The second QRS falls between the "75" and "60" beats/min; therefore the heart rate is approximately mid-way between them, ≈ 67 beats/min. Knowing that the heart rate is approximately 60-70 beats/min is certainly close enough.
Method 3

EKG recording paper usually includes 3-second time markers at the top or bottom of the tracing:

To calculate the heart rate, count the number of QRS complexes between the 3 second markers (= 6 beats in this example) and multiply by 20. Thus the heart rate here ≈ 120 beats/min.

It’s even easier (and a bit more accurate) to count the number of complexes between the first and third markers on a strip (representing 6 seconds) and then multiply by 10 to determine the heart rate.

Method 3 is particularly helpful for measuring irregular heart rates.
## Electrocardiographic Intervals

<table>
<thead>
<tr>
<th>Interval</th>
<th>Normal</th>
<th>Decreased in</th>
<th>Increased in</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PR</strong></td>
<td>0.12-0.20 sec (3-5 small boxes)</td>
<td>• Pre excitation syndrome&lt;br&gt;• Junctional rhythm</td>
<td>• First-degree AV block</td>
</tr>
<tr>
<td><strong>QRS</strong></td>
<td>≤ 0.10 sec (&lt; 2.5 small boxes)</td>
<td></td>
<td>• Bundle branch blocks&lt;br&gt;• Ventricular ectopic beat&lt;br&gt;• Toxic drug effect (e.g., quinidine)&lt;br&gt;• Severe hyperkalemia</td>
</tr>
<tr>
<td><strong>QT</strong></td>
<td>Corrected Qt&lt;sup&gt;a&lt;/sup&gt; ≤ 0.44 sec</td>
<td>• Hypercalcemia&lt;br&gt;• Tachycardia</td>
<td>• Hypocalcemia&lt;br&gt;• Hypokalemia (↑ QU interval due to ↑ U wave)&lt;br&gt;• Hypomagnesemia&lt;br&gt;• Myocardial ischemia&lt;br&gt;• Congenital prolongation of QT&lt;br&gt;• Toxic drug-effect (e.g., quinidine)</td>
</tr>
</tbody>
</table>
### Atrial Abnormalities

<table>
<thead>
<tr>
<th></th>
<th>Lead II</th>
<th>Lead V₁</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal</strong></td>
<td><img src="normal_diagram" alt="Diagram" /></td>
<td><img src="normal_diagram" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>RA enlargement</strong></td>
<td><img src="ra_diagram" alt="Diagram" /></td>
<td><img src="ra_diagram" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>LA enlargement</strong></td>
<td><img src="la_diagram" alt="Diagram" /></td>
<td><img src="la_diagram" alt="Diagram" /></td>
</tr>
</tbody>
</table>
Ventricular Hypertrophy

- R > S in lead V1
- Right axis deviation
Ventricular Hypertrophy

LEFT VENTRICULAR HYPERTROPHY

- S in V1 plus
- R in V5 or V6 $\geq$ 35 mm or
- R in aVL $> 11$ mm or
- R in Lead I $> 15$ mm
Bundle Branch Blocks

RBBB
Bundle Branch Blocks

LBBB
The EKG of Myocardial Infarction

• Concept of ST elevation vs. Non STE
• Localization of MI
• Evolution of EKG changes in MI
• Concept of Q waves
Transmural MI

Injured segment is partially depolarized prior to stimulation

Recording electrode

Normal baseline

Heart fully depolarized

Baseline shifted downward
Non-transmural MI

Injured segment is partially depolarized prior to stimulation.

Recording electrode

Baseline shifted upward

Heart fully depolarized

Normal baseline
Localization of MI

Anterior (V_1-V_6)

Anterolateral (V_5-V_6, I, aVL)

Anteroseptal (V_1-V_2)

Anteroapical (V_3-V_4)

Posterior (Tall R in V_1-V_2)

Inferior (II, III, aVF)
<table>
<thead>
<tr>
<th>Anatomic Sites</th>
<th>EKG Leads</th>
<th>Coronary Anatomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inferior</td>
<td>II, III, AVF</td>
<td>RCA</td>
</tr>
<tr>
<td>Septal</td>
<td>V₁, V₂</td>
<td>LAD</td>
</tr>
<tr>
<td>Anterior</td>
<td>V₃, V₄</td>
<td>LAD (distal)</td>
</tr>
<tr>
<td>Anterolateral</td>
<td>I, AVL</td>
<td>LCX</td>
</tr>
<tr>
<td>Anteroapical</td>
<td>V₅, V₆</td>
<td>Any of 3</td>
</tr>
</tbody>
</table>
Normal

Acute

• ST elevation
• ↓ R wave
• Q wave begins

Hours

Day 1-2

• ST elevation
• T wave inversion
• Q wave deeper

Days later

• ST normalizes
• T wave inverted

Weeks later

• ST & T normal
• Q wave persists
Pathologic Q wave