Understanding the 12-lead ECG, part 1

The heart's electrical conduction

- Electrical activity
  - precedes mechanical activity
  - coordinates all parts of the heart to contract at the same time
  - initiated in the sinoatrial (SA) node
    - specialized group of cells in the right atrium
    - depolarizes at a rate of 60 to 100 times/minute
    - makes the atria contract and propel blood into the ventricles

Normal ECG waveform

Atrial depolarization

- produces the P wave
  - first element on the ECG
  - first part of the cardiac cycle
  - appears as a small semicircular bump

- atrioventricular (AV) node
  - receives the atrial impulse and (after a brief pause to let the ventricles fill) transmits it to the ventricles via the bundle of His

- bundle of His
  - collection of cardiac conduction fibers that splits into the right and left bundle branches

P-Wave

- Depolarization of atrial muscle
- Low voltage (2-3mm in amplitude)
- Duration <.11 seconds

Abnormal P Waves

- P – Pulmonale
  - Tall Peaked
  - Right atrial enlargement secondary to pulmonary HTN (COPD)

- P-Mitrale
  - Broad notched
  - LA enlargement secondary to mitral valve disease
Bundle branches
- high-speed conducting fibers that run down the intraventricular septum
- transmit cardiac impulse to the Purkinje fibers
  - complex network that mingles with ventricular myocardial cells
  - rapidly stimulating ventricular muscle resulting in ventricular depolarization

Ventricular depolarization
- generates the QRS complex—the electrical equivalent of ventricular systole
  - Remember that electrical activity precedes mechanical activity and ECG shows only electrical activity.
  - You should be able to palpate a pulse with each QRS complex on the ECG monitor.

QRS complex
- normal duration is 0.06 to 0.1 second
- duration greater than 0.12 seconds usually indicates prolonged ventricular conduction caused by a bundle branch block
- can look different among different patients or among leads in the same patient

The width of the QRS complex should not exceed 110 ms, less than 3 little squares
**T wave**
- is larger than the P wave
- is rounded or slightly peaked
- represents ventricular repolarization or metabolic rest periods between heartbeats

**PR interval**
- consists of the period from the beginning of the P wave to the beginning of the QRS complex
- represents SA node depolarization to ventricular depolarization
- has normal duration of 0.12 to 0.2 second; if longer than 0.2 second, a disease process may be affecting the cardiac conduction pathway

**PR interval**
- PR interval should be 120 to 200 milliseconds or 3 to 5 little squares

**ST segment**
- consists of the isoelectric line between the end of the QRS complex and the beginning of the T wave
- reveals information about the heart’s oxygen status
- when elevated, is a key indicator of myocardial infarction (MI)

**Examining a 12-lead ECG**
- Some QRS complexes have upward spike, others have downward deflections.
- Each lead has a positive electrode and a negative electrode, which acts as an anchor.
- When energy is directed toward the positive electrode, the QRS complex spikes up; when directed toward the negative electrode, the QRS complex spikes down.

**QRS waveform nomenclature**
- Q, R, r, qR, qRs, Qrs, Qs, rSr, rSR
**Limb leads I to III**

- First six leads of the 12-lead ECG
  - come from four electrodes on the patient’s arms and legs
  - called bipolar or standard leads

**Lead I**

- consists of positive electrode on the left arm looking toward the negative electrode on the right arm for electrical energy
- produces upward deflection of the QRS

**Lead II**

- consists of positive electrode on the left foot, negative electrode on the right arm
- shows most upright QRS complexes and most prominent P waves
- is favorite monitoring lead in many ICUs and telemetry units

**Lead III**

- consists of positive electrode on the left foot, negative electrode on the left arm
- produces upward QRS deflection

**Limb leads aVR to aVF**

- Next set of leads
  - use single positive monitoring electrode
  - called augmented or unipolar leads

**Lead aVR**

- consists of positive electrode on the right arm—only limb lead on the right side of the body
- is the only lead with downward deflected QRS (in normal ECG)
Lead aVL
- consists of positive electrode on the left arm, looks to the right and down
- produces the least upright QRS among the limb leads

Lead aVF
- consists of positive electrode on the left leg and looks straight up to the center of the chest
- has very upright QRS complexes with prominent P waves
- known as inferior lead (along with leads II and III) because all look upward

Chest leads V₁ to V₆
- Chest (or precordial) leads:
  - lie across anterior chest
  - measure the mean vector in the horizontal plane
- Lead V₁:
  - located at right sternal border, fourth intercostal space
  - lies above right ventricle and septum
- Lead V₂:
  - located at the left side of sternum, fourth intercostal space
- Lead V₃:
  - located midway between leads V₂ and V₄
- Lead V₄:
  - located at the midclavicular line, fifth intercostal space
- Lead V₅:
  - located at the anterior axillary line, fifth intercostal space
- Lead V₆:
  - located at the midaxillary line, fifth intercostal space, above lateral wall of the left ventricle

Chest leads
- Lead V₁:
  - located at right sternal border, fourth intercostal space
  - lies above right ventricle and septum
- Lead V₂:
  - located at the left side of sternum, fourth intercostal space
- Lead V₃:
  - located midway between leads V₂ and V₄

Arrangement of Leads on the EKG

<table>
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<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>aVR</td>
<td>V₁</td>
<td>V₄</td>
<td>V₆</td>
</tr>
<tr>
<td>aVL</td>
<td>V₂</td>
<td>V₅</td>
<td></td>
</tr>
<tr>
<td>aVF</td>
<td>V₃</td>
<td>V₆</td>
<td></td>
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</tbody>
</table>
### Anatomic Groups

<table>
<thead>
<tr>
<th></th>
<th>I Lateral</th>
<th>aVR None</th>
<th>$V_1$ Septal</th>
<th>$V_4$ Anterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>II Inferior</td>
<td>aVL Lateral</td>
<td>$V_2$ Septal</td>
<td>$V_5$ Lateral</td>
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</tr>
<tr>
<td>III Inferior</td>
<td>aVF Inferior</td>
<td>$V_3$ Anterior</td>
<td>$V_6$ Lateral</td>
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</tr>
</tbody>
</table>

### Determining the Heart Rate

- **Rule of 300**
- **10 Second Rule**
Rule of 300

Take the number of “big boxes” between neighboring QRS complexes, and divide this into 300. The result will be approximately equal to the rate.

Although fast, this method only works for regular rhythms.

What is the heart rate?

(300 / 6) = 50 bpm

(300 / 4) = ~75 bpm

(300 / 1.5) = 200 bpm

The Rule of 300

It may be easiest to memorize the following table:

<table>
<thead>
<tr>
<th># of big boxes</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
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<tr>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
</tr>
</tbody>
</table>

10 Second Rule

As most EKGs record 10 seconds of rhythm per page, one can simply count the number of beats present on the EKG and multiply by 6 to get the number of beats per 60 seconds.

This method works well for irregular rhythms.
What is the heart rate?

33 x 6 = 198 bpm

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

By near-consensus, the normal QRS axis is defined as ranging from -30° to +90°.

-30° to -90° is referred to as a left axis deviation (LAD)

+90° to +180° is referred to as a right axis deviation (RAD)

Determining the Axis

The Quadrant Approach

1. Examine the QRS complex in leads I and aVF to determine if they are predominantly positive or predominantly negative. The combination should place the axis into one of the 4 quadrants below.
The Quadrant Approach

2. In the event that LAD is present, examine lead II to determine if this deviation is pathologic. If the QRS in II is predominantly positive, the LAD is non-pathologic (in other words, the axis is normal). If it is predominantly negative, it is pathologic.

Quadrant Approach: Example 1

Negative in I, positive in aVF → RAD

Quadrant Approach: Example 2

Positive in I, negative in aVF → Predominantly positive in II → Normal Axis (non-pathologic LAD)