Introduction to ECGs

R. Gentry Wilkerson, MD
Asst. Professor
Department of Emergency Medicine
Objectives

- Lead Placement
- Hexaxial System
- ECG Paper
- Systematic Approach to Reading an ECG
Lead Placement
Hexaxial System

- Limb Leads (Bipolar): RA, LA, RL, LL
- Forms Einthoven’s Triangle
  - I : 0°
  - II : 60°
  - III : 120°
Hexaxial System

- Augmented Leads (Unipolar)
  - Utilize a central negative terminal
  - aVL : -30°
  - aVF : 90°
  - aVR : -120°
Hexaxial System
Precordial Leads
ECG Paper

Height = millivolts
Width = Time

1 mm x 1 mm
Calibration

<table>
<thead>
<tr>
<th>Vertical Axis ‘y’</th>
<th>1 Small Square = 1 mm (0.1 mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Large Square = 5 mm (0.5 mV)</td>
</tr>
<tr>
<td></td>
<td>2 Large Squares = 10 mm (1 mV)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizontal Axis ‘x’</th>
<th>1 Small Square = 0.04 sec</th>
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<tbody>
<tr>
<td></td>
<td>1 Large Square = 0.2 sec</td>
</tr>
<tr>
<td></td>
<td>5 Large Squares = 1 sec</td>
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ECG Complex

[Diagram of an ECG complex with labels for P Wave, PR, QRS, QT, RR Interval, ST Segment, T Wave, U Wave]
Interpreting the ECG

- Rate
- Rhythm
  - Ectopic beats?
- Axis
- Intervals
  - Blocks?
- Atrial Abnormalities
- Ventricular hypertrophy
- ST/T changes
The Rate

- 5 big boxes = 1 sec
- 300 big boxes = 60 sec
- Rate = \(\frac{300}{\#\text{ big boxes}}\)
• Multiply # beats on rhythm strip x 5
The Rhythm

- Is it fast or slow?
- Is it regular or irregular?
- Are there p waves present?
  - Are all p waves the same?
  - Does each QRS have a p wave?
- Is the PR interval constant?
The Rhythm

• Are the p waves and QRS complexes associated with each other?

• Are the QRS complexes narrow or wide?

• Are the QRS complexes grouped or not?

• Are there dropped beats?
The Rhythm

Supraventricular Rhythms
Normal Sinus Rhythm

- Rate: 60 - 100 bpm
- Regular
- P wave present
- P:QRS ratio: 1:1

- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None
Sinus Bradycardia

- Rate: Less than 60
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None
Sinus Tachycardia

- Rate: Greater than 100
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None
Sinus Arrhythmia

- Rate: 60 - 100
- Varies with respiration
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None
Sinus Pause / Arrest

- Rate: Varies
- Irregular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None
Sinoatrial Block

- Rate: Varies
- Irregular
- P present except in areas of dropped beat
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: Yes
Ectopic Atrial Tachycardia

- Rate: Greater than 100
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None
Ectopic Atrial Tachycardia
Wandering Atrial Pacemaker

- Rate: Less than 100
- Irregularly irregular
- P wave $\geq 3$ morphologies
- P:QRS ratio: 1:1
- PR Interval: Varies
- QRS width: Normal
- Grouping: None
- Dropped: None
Multifocal Atrial Tachycardia

- Rate: Greater than 100
- Irregularly irregular
- P wave $\geq 3$ morphologies
- P:QRS ratio: 1:1
- PR Interval: Varies
- QRS width: Normal
- Grouping: None
- Dropped: None
Atrial Flutter

- Rate: atrial- 250-350, ventricular 125-175
- Usually regular
- P wave- flutter waves
- P:QRS ratio: Often 2:1
- PR Interval: Variable
- QRS width: Normal
- Grouping: None
- Dropped: None
Atrial Fibrillation

- Rate: Variable
- Irregularly irregular
- P waves chaotic
- P:QRS ratio: None
- PR Interval: None
- QRS width: Normal
- Grouping: None
- Dropped: None
- Rate: 40-60
- Regular
- P waves- none, antegrade, retrograde
- P:QRS ratio: None or 1:1
Junctional Rhythm

- PR Interval: None, short or negative
- QRS width: Normal
- Grouping: None
- Dropped: None
Accelerated Junctional Rhythm

- Rate: 60-130 bpm
- Regular
- P waves - none, ante-, retrograde
- P:QRS ratio: none or 1:1
- PR Interval: None, short or neg
- QRS width: Normal
- Grouping: None
- Dropped: None
The Rhythm

Ventricular Rhythms
Idioventricular Rhythm

- Rate: 20 - 40 bpm
- Regular
- P wave absent
- P:QRS ratio: None
- PR Interval: None
- QRS width: Wide, bizarre
- Grouping: None
- Dropped: None
Accel. Idioventricular Rhythm

- Rate: 40 - 100 bpm
- Regular
- P wave absent
- P:QRS ratio: None
- PR Interval: None
- QRS width: Wide, bizarre
- Grouping: None
- Dropped: None
Ventricular Tachycardia

- Rate: 100 - 200 bpm
- Regular
- P wave: Buried
- P:QRS ratio: None
- PR Interval: None
- QRS width: Wide, bizarre
- Grouping: None
- Dropped: None
Ventricular Tachycardia

- Fusion Beats
  - Mix between V-tach and sinus morphologies
- Capture Beats
  - Sinus morphology
Ventricular Tachycardia

- Josephson’s Sign
  - Small notching near the low point of S wave
- Brugada’s Sign
  - Interval from R wave to bottom of S wave is $\geq 0.10$ seconds
Torsades de Pointes

- Rate: 200 - 250 bpm
- Irregular
- P wave: None
- P:QRS ratio: None
- PR Interval: None
- QRS width: Variable
- Grouping: N/A
- Dropped: None
Ventricular Fibrillation

- Rate: Indeterminate
- Irregular
- P wave: None
- P:QRS ratio: None
- PR Interval: None
- QRS width: None
- Grouping: None
- Dropped: No beats
Axis
### Axis

<table>
<thead>
<tr>
<th></th>
<th>V1</th>
<th></th>
<th>V2</th>
<th></th>
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<tbody>
<tr>
<td>I</td>
<td>VR</td>
<td></td>
<td>V4</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>VL</td>
<td></td>
<td>V5</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>VF</td>
<td></td>
<td>V6</td>
<td></td>
</tr>
</tbody>
</table>
Axis

- The axis is the direction of the sum vector of ventricular depolarization
Axis
Axis
Axis
Intervals
PR Interval

- Normal: 0.12 to 0.20 sec
- Short PR interval
  - Wolff-Parkinson-White
  - Lown-Ganong-Levine
- AV Junctional Rhythm (see arrhythmia lecture)
Wolff-Parkinson-White

- Defined by:
  - Short PR (<0.12 sec) with normal P wave
    - May be normal in 12%
  - Wide QRS complex (≥0.11 sec)
  - Presence of a delta wave
- ST-T wave changes
- Association with paroxysmal tachycardias
PR Interval

• Normal: 0.12 to 0.20 sec
  • Long PR interval – 1\textsuperscript{st} Degree AV Block
    • AV nodal disease
    • Enhanced vagal tone
    • Myocarditis
    • Myocardial infarction (especially inferior MIs)
    • Electrolyte imbalance
    • Drugs (Beta Blockers, CCBs, cardiac glycosides)
QRS Duration

- Normal: 0.06 to 0.10 sec
  - Hyperkalemia
  - Ventricular tachycardia
  - Idioventricular rhythms
  - Drug effects and overdoses
  - Wolff-Parkinson-White
  - BBBs and Intraventricular conduction delay
  - PVCs
  - Aberrantly conducted complexes
QT Interval

- Must be corrected for rate = $\text{QT}_c$
  - Bazett’s Formula
  - Fridericia’s Formula
  - Hodge’s Formula
- Normal is < 440

$$\text{QT}_c = \frac{\text{QT}}{\frac{3}{\sqrt{R-R}}} + 1.75 (\text{HR} - 60)$$
$\text{QT}_c$

- Causes of shortened $\text{QT}_c$
  - Hypercalcemia
  - Digitalis
  - Tachycardia
QTc

- Causes of prolonged QTc
  - Hypocalcemia
  - Drugs (Quinidine, Procainamide, Psychotropics, Tricyclics, Pentamidine)
  - CNS
  - Hypothermia
  - Hypothyroidism
  - Ischemic Heart Disease
  - Genetic (Long QT Syndrome)
Torsades de Pointes

• Increased risk when QTc > 500 msec
Heart Blocks

Sinus Node

STOP

Atrioventricular Node

Left Bundle Branch

Right Bundle Branch
Atrioventricular (AV) Block

- Conduction between the atria and ventricles is altered
- Abnormality can be located anywhere in the AV node, His bundle, or bundle branches
- May result in either a partial or complete block
1st Degree AV Block

- Every atrial impulse conducts to the ventricles and a regular ventricular rate is produced
- PR interval exceeds 0.20 sec (5 boxes) in adults
- Almost always asymptomatic

Etiology
- Medications
- Age
- Increased vagal tone
1st Degree AV Block

First-Degree Block

Long PR interval
2nd Degree AV Block (Mobitz I- Wenckebach)

- Progressive prolongation of AV conduction (and the P-R interval) until an atrial impulse is completely blocked
- Conduction ratios are used to indicate the ratio of atrial to ventricular depolarizations
  - 3:2 indicates that two of three atrial impulses are conducted into the ventricles
2nd Degree AV Block (Mobitz I- Wenckebach)
2nd Degree AV Block (Mobitz II)

- P-R interval remains constant before and after the non-conducted atrial beats
- Usually occur in the infranodal conducting system
- Often have co-existing fascicular or BB blocks
- Often due to permanent structural defects in the infranodal conducting system
- May progress suddenly to complete heart block
2nd Degree AV Block (Mobitz II)

- RR interval surrounding the dropped beat(s) is an exact multiple of the preceding RR interval
- If there is 2:1 conduction, one cannot differentiate between Mobitz I and II
3rd Degree AV Block (Complete Heart Block)

- Complete absence of AV conduction
- Perfusing rhythm is maintained by a junctional or ventricular escape rhythm
- Regular P-P intervals, R-R intervals
- Variable P-R intervals
AV Dissociation

- Term indicates only the occurrence of independent atrial and ventricular contractions
  - Passive Type - default or "escape" like in third-degree AV block
  - Active Type - when the ventricular rhythm usurps control
- May be caused by entities other than complete heart block
  - Accelerated Idioventricular Rhythm
  - Ventricular Tachycardia
Right Bundle Branch Block
Right Bundle Branch Block

- Major Criteria
  - \( \text{QRS} \geq 0.12 \text{ sec} \)
  - Slurred S wave in leads I and V6
  - RSR' pattern in V1
    - May get a QR' pattern if there is previous anteroseptal infarct
Right Bundle Branch Block

- Electrode $V_1$
  - $V(III)$
  - $V(I)$
  - $V(II)$
  - Variable M-shaped complex

- Electrode $V_6$
  - $V(II)$
  - Slurred S wave
  - $V_{III}$, lead I
Right Bundle Branch Block
Left Bundle Branch Block

- Major Criteria
  - $\text{QRS} \geq 0.12 \text{ sec}$
  - Broad, monomorphic R waves in I and V6 with no Q waves
  - Broad, monomorphic S waves in V1
    - May have a small r wave
Left Bundle Branch Block
Left Bundle Branch Block
Left Bundle Branch Block
Left Ventricular Hypertrophy
Left Ventricular Hypertrophy

Compare these two 12-lead ECGs. What stands out as different with the second one?
Left Ventricular Hypertrophy

As the heart muscle wall thickens there is an increase in electrical forces moving through the myocardium resulting in increased QRS voltage
# Criteria for LVH

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Year</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gubner-Ungerleider</td>
<td>1943</td>
<td>( R_I &gt; 15 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( R_I + S_{III} &gt; 25 )</td>
</tr>
<tr>
<td>Sokolow-Lyon</td>
<td>1949</td>
<td>( S_{V1} + R_{(V5 \text{ or } V6)} &gt; 35 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( R_{aVL} &gt; 11 )</td>
</tr>
<tr>
<td>Siegel</td>
<td>1982</td>
<td>Total 12-Lead voltage &gt; 175</td>
</tr>
<tr>
<td>Murphy</td>
<td>1984</td>
<td>( S_{(V1 \text{ or } V2)} + R_{(V5 \text{ or } V6)} &gt; 35 )</td>
</tr>
<tr>
<td>Cornell (Casale)</td>
<td>1985</td>
<td>( S_{V3} + R_{aVL} &gt; 28 (♂) 20 (♀) )</td>
</tr>
</tbody>
</table>
Right Ventricular Hypertrophy
Right Ventricular Hypertrophy

- Right Axis Deviation
- R > S in V1
- Deep S in left precordial leads
- Slight prolongation of QRS up to 120 msec
- Strain pattern in V1-3
- May have right atrial abnormality
Causes of $R > S$ in V1

- Right Ventricular Hypertrophy
- True Posterior MI
- Lead Misplacement
- RBBB
- WPW Type A
- Normal variant
Q Waves

- Significant if:
  - More than 1/3 height of QRS
  - Wider than 0.03 sec
- Septal Qs (normal variant)
  - Result of initial depolarization occurring in the septum from left to right
- Often found in left sided leads: I, aV_L and V6
Q Waves
ST Segment

- ST segment is at baseline.
- ST segment is elevated.
- ST segment is depressed.
ST Segment Elevation

• ST elevation $> 1$ mm in limb leads and $> 2$ mm in chest leads indicates an evolving acute MI until proven otherwise.

• Other primary causes:
  • Early repolarization (normal variant)
  • Pericarditis
  • Ventricular aneurysm
  • Pulmonary embolism
### STEMI Localization

**Location of MI by ECG Leads**

<table>
<thead>
<tr>
<th>I lateral</th>
<th>aVR</th>
<th>V₁ septal</th>
<th>V₄ anterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>II inferior</td>
<td>aVL lateral</td>
<td>V₂ septal</td>
<td>V₅ lateral</td>
</tr>
<tr>
<td>III inferior</td>
<td>aVF inferior</td>
<td>V₃ anterior</td>
<td>V₆ lateral</td>
</tr>
</tbody>
</table>
ST Segment Depression

- Primary Causes
  - Myocardial Ischemia
  - LVH
  - Intraventricular conduction defects
  - Medication (digitalis)
  - Reciprocal changes in leads opposite area of acute MI
Sgarbossa Criteria

- For detecting an AMI in the setting of LBBB
- Derived from the GUSTO-1 trial
- Not perfect in screening for AMI. Use as another data point for risk-stratifying.
- Sgarbossa criteria hold true for LBBB pattern seen in pacemaker patients
### Sgarbossa Criteria

<table>
<thead>
<tr>
<th>Sgarbossa Criteria</th>
<th>Positive LR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ST elevation ( \geq 1 \text{ mm} ) concordant with QRS complex</td>
<td>9.54 (3.1-17.3)</td>
</tr>
<tr>
<td>[Most predictive of AMI]</td>
<td></td>
</tr>
<tr>
<td>2. ST depression ( \geq 1 \text{ mm} ) in lead V1, V2, or V3</td>
<td>6.58 (2.6-16.1)</td>
</tr>
<tr>
<td>3. ST elevation ( \geq 5 \text{ mm} ) where discordant with QRS complex</td>
<td>3.42 (0.18-6.5)</td>
</tr>
<tr>
<td>[Positive LR crosses 1.0 – may not be significant criteria]</td>
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</tbody>
</table>

**Diagram:**
- **Sgarbossa’s Criteria**
  - LBBB / Paced Rhythm
  - Criteria 1
  - Criteria 3
  - Criteria 2

**Legend:**
- V1, V2, V3
- \( \geq 5 \text{ mm} \)
Pericarditis
Pericarditis

- Stage I
  - First few days $\rightarrow$ 2 weeks
  - ST elevation, PR depression
  - Up to 50% of pt with symptoms / rub do NOT have or evolve into stage I
Pericarditis – Stage I
Pericarditis – Stage II

- Stage II
  - Lasts days → weeks
  - Normalization of ST and PR segments
  - ST returns to baseline, flat T waves
Pericarditis – Stage II

[ECG images showing changes in electrical activity across different leads (I, aVR, II, aVL, III, aVF, V1, V4, V2, V5, V3, V6).]
Pericarditis – Stage III

- Stage III
- Begins after 2-3 weeks, lasts several weeks
- Widespread T wave inversion
Pericarditis – Stage III
Pericarditis – Stage IV

- Stage IV
  - Lasts up to several months
  - Gradual resolution of T wave changes
Osborn Waves

- Positive deflections occurring at the junction between the QRS complex and the ST segment, the J point, has a myocardial infarction-like elevation
- Associated with hypothermia
Osborn Waves
Last night....
Questions?