The ABCs of ECG Interpretation

Thomas H. Cawthon, Jr, M.D.
Cardiology, P.C.
Evolution

- **1887** - British physiologist Augustus D. Waller publishes the first human electrocardiogram
Evolution

- **1901 - Einthoven** invents a new galvanometer for producing electrocardiograms using a fine quartz string coated in silver - 600 lbs
Evolution
Evolution
Conduction System

- Sinoatrial (SA) Node
- Anterior Internodal Tract
- Middle Internodal Tract
- Posterior Internodal Tract
- Atrioventricular (AV) Node
- Bachmann's Bundle
- Left Bundle Branch
- Right Bundle Branch
- Conduction Pathways
Atrial depolarization
Ventricular depolarization
Standard ECG
Lead System

Standard Limb Leads
Lead System

Augmented Limb Leads
Lead System

Precordial Leads

V1 V2 V3 V4 V5 V6
Routine of Analysis

- Patient name
- Strip speed (25mm/s)
- Rate
- Rhythm
- P wave
  - Axis
  - Duration
  - Amplitude
  - Morphology
- PR interval
- QRS complex
  - Axis
  - Duration
  - Amplitude
  - Morphology
- ST segment
- T wave/U wave
- QT interval
Rhythm/Rate

- Regular
- Irregular
  - Definite pattern
  - Erratic
- Rate (depends on pacemaker level)
  - Sinus node = 60-100 bpm
  - AV node (junctional) = 40-60 bpm
  - Idioventricular = 35-40 bpm (10-20 bpm)
Determining the rate

- Memorize sequence of rates for each large square
  (300-150-100-75-60-50-43-37-33-30)
- 300 ÷ # large squares (1/5 sec) between 2 QRS complexes = # bpm

Closer to 100 than 150 bpm or 300/2.9 = 103.4 (103 bpm)
Determining the rate
P wave

- **Axis**
  - Inferior and leftward (0° to +75°)
  - **Positive in I, II, aVF, V3-V6**
  - Negative in aVR
- **Duration:** 0.08 - 0.11 sec
- **Amplitude**
  - Limb leads: ≤ 0.25 mV (2.5 mm)
  - Prec. leads: ≤ 0.15 mV (1.5 mm)
Atrial depolarization
P wave

- **Morphology**
  - Diphasic (+/-): V1 and V2
  - Diphasic (-/+): aVL
  - Notched: II
PR interval

- Duration: 0.12 - 0.20 sec (adults)
  - 3 to 5 little squares
  - Shorter in children & increased HR
  - Longer in the elderly
  - Measured in lead II (or lead with widest P)
QRS complex

• Axis
  – $I$ and $aVF$ positive = normal axis
  – $I$ and $aVF$ negative = Northwest Territory
  – $I$ neg. and $aVF$ pos. = right axis deviation
QRS complex

- **Axis**
  - Look at leads I and aVF
  - If axis in “left” quadrant, look at lead II
QRS complex

- **Axis**
  - I pos. and aVF neg.: “left” quadrant
  - Lead II pos. = normal axis
  - Lead II neg. = abnormal left axis deviation
QRS complex
QRS complex
QRS complex

- **Duration**: 0.06 - 0.11 sec

- **Amplitude**
  - Men > Women
  - Blacks > Whites
  - Obesity - most common cause of decreased amplitude

- **Morphology**
  - Bundle branch block
  - Pre-excitation
  - Source of electrical impulse
QRS complex

- **Q wave**
  - Duration: $\leq 0.03$ sec ($\leq 0.05$ sec in III)
  - Amplitude $\leq 4$ mm (limb), $\leq 2$ mm (prec.)

- **Transitional zone**
  - V3-V4: normal
  - V1- V2: counterclockwise rotation
  - V5-V6: clockwise rotation
ST segment

- **Level**
  - Baseline - TP or PR segments

- **Limb leads**
  - Elevation/depression 1 mm - normal
  - Elevation more common in inf. leads

- **Precordial leads**
  - Any ST depression is abnormal
  - Some elevation in > 90% of young adults (males>females, V2-V3 may reach 3 mm)
ST segment

- **Shape**
  - Normal - smooth transition with T wave
  - Abnormal - sharp angle with T wave
T wave

- Potential of ventricular repolarization
- Axis
  - Vector orientation similar to QRS
  - Upright in I, II, V3-V6
  - Inverted in aVR
- Amplitude
  - Limb leads: <6 mm
  - Precordial leads: <10 mm
**T wave**

**Morphology**
- Asymmetrical (initial gradual slope)
- Notched in children (inverted right precordial).
- Symmetrical, pointed: MI
- Tall, sharply pointed: hyperkalemia

![Graphs showing different T wave morphologies](image)
T wave

- Morphology
  - Persistent juvenile pattern
U wave

- Origin
  - Occurrence of early afterdepolarizations
  - Late repolarization of Purkinje system
  - Long action potential duration of M-cells
- Same polarity as T wave
- Best seen in V3
U wave

- Frequently inverted with LV overload
- Increased with hypokalemia, hypercalcemia, thyrotoxicosis, intracranial hemorrhage, long QT syndrome
QT interval

- Total ventricular electrical systole
- Duration: 0.46-0.30 sec (HR 45-115 bpm)
  - Autonomic influence (longer in sleep)
  - Varies with heart rate
  - QT corrected for HR (QTc) - \( QT/{\sqrt{RR}} \)
    Normal \( \leq 0.44 \) sec
QT interval

- Prolonged
  - Results from delayed repolarization
  - Idiopathic/congenital
  - Acquired (heart/cerebrovascular dz, electrolyte imbalance, drugs, hypothermia)

- Shortened
  - Digitalis
  - Hyperkalemia, hypercalcemia
Normal variants

- S1, S2, S3 pattern
  - Over 20% of normal adults
  - S2>S3 (opposite in abn left axis)
  - R/S ratio >1 in I, II, III
  - DDx: Emphysema, RVH
Normal variants

- RSR' pattern in V1
  - QRS duration <0.12 sec
  - R’ usually <R
Normal variants

- Early repolarization syndrome
  - Elevation of J point 1-4 mm
  - Notching of terminal R wave
  - Upward concavity of ST
  - Asymmetrical, tall T waves.
Normal variants

- Early repolarization syndrome
  - Association with sudden cardiac arrest
  - Present in 31% of survivors, 5% of controls
  - Increased amplitude before VF
  - Only subset of patients are at risk
  - EP mapping: VF site = ER site

Normal variants

- Poor R wave progression
  - Young adults (<30 yo)
  - More in women
  - V3 R wave <3 mm
  - LVH, RVH, COPD, LAFB, CM, CW deformity, lead position