EXECUTIVE ELECTROCARDIOGRAM EDUCATION
Definitions, Criteria, and Guidelines at a Glance

ARRHYTHMIAS

See individual arrhythmias

ATRIAL ABNORMALITIES

- Left Atrial Abnormality:
  - P wave V1: >1 box deep; >1 box wide
  - P wave 2: >0.12 sec (3 boxes); notched
- Right Atrial Abnormality:
  - P wave 2 (inferior leads) : >2.5 mm tall; >2 boxes wide; peaked
  - P waves V1: >1.5 mm tall
- Biatrial Abnormality:
  - Combination of criteria for left atrial abnormality and right atrial abnormality

ATRIAL ARRHYTHMIAS

- Premature atrial complexes (PAC):
  - An impulse that originates in the atrium and comes earlier than the expected normal sinus beat
- Atrial couplet:
  - Two (2) premature atrial complexes in a row
- Atrial triplet:
  - Three (3) premature atrial complexes in a row
- Atrial bigeminy:
  - PACs occurring every other beat
- Atrial trigeminy:
  - PACs occurring every third beat
- Atrial bradycardia:
  - Rhythm originating in the atrium at a rate of < 60 bpm
- Atrial tachycardia:
  - Rhythm originating in the atrium at a rate of 100-250 bpm
- Atrial flutter:
  - Rhythm originating in the atrium at a rate of 250-350 bpm
- Atrial fibrillation:
  - Rhythm originating in the atrium at a rate of > 350 bpm

➢ (These rates reflect the rate of atrial beats and not necessarily the rate of the ventricular beats (e.g. There may be atrial fibrillation with a rapid ventricular response indicating the atrial rate is > 350 bpm, and the ventricular rate is > 100 bpm))

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ATRIOVENTRICULAR (AV) BLOCKS

- FIRST DEGREE AV BLOCK:
  - PR interval > 0.2 seconds
- SECOND DEGREE AV BLOCK:
  - MOBITZ TYPE 1 (Wenckebach):
    - AV node fatigues which lengthens the PR interval and then drops a QRS complex
      - P to P interval: Constant
      - PR interval: Lengthens
      - RR interval: Shortens
      - Dropped QRS complex
  - MOBITZ TYPE 2:
    - AV node works some of the time, but can suddenly stop working and drop QRS complexes
      - P to P interval: Constant
      - PR interval: Constant
      - RR interval: Constant
      - Dropped QRS complex
      - (Sometimes there can be multiple P wave without QRS complexes intermingled with occasional P waves that conduct through the AV node and result in QRS complexes)
- THIRD DEGREE AV BLOCK (Complete Heart Block):
    - Atrioventricular (AV) node does not function resulting in independent atrial and ventricular rhythms superimposed
      - P to P interval: Constant
      - PR interval: Variable
      - RR interval: Constant
- 2:1 AV BLOCK (Two (2) P waves for every QRS complex [e.g. P wave, QRS, P wave, Dropped QRS (repeating)]):
  - Could be Mobitz type 1 or Mobitz type 2

ATRIOVENTRICULAR (AV) DISSOCIATION

- Atria and Ventricles beat independently from one another, and there is no communication between them through the atrioventricular (AV) node
  - Complete Heart Block (Third Degree Heart Block):
    - The AV node is not functioning which prevents the atrial beats to stimulate the ventricular beats through the AV node.
    - Typically: Atrial rate > ventricular rate
- AV Dissociation due to the beats originating below the AV node (e.g. low junction or ventricles) inhibiting the AV node. In this case, the AV node functions normally, but the impulses are blocked. Occasionally the presence of capture beats will help identify AV dissociation.
  - Typically: Ventricular rate > atrial rate

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AXIS

- NORMAL AXES
  - P wave axis: 0 to +75 degrees
  - QRS axis: -30 to +90 degrees
  - T wave axis: 0 to +90 degrees (within 45 degrees of the QRS axis)
- CAUSES OF ABNORMAL AXES
  - P waves:
    - Ectopic atrial beats/rhythms; dextrocardia; lead reversal
  - QRS complexes:
    - Left axis deviation:
      - Left ventricular hypertrophy; inferior wall myocardial infarction; primum atrial septal defect; tricuspid atresia; left anterior fascicular block; ventricular ectopy; ventricular pacemaker beats/rhythms; ventricular preexcitation (Wolff Parkinson White)
    - Right axis deviation:
      - Right ventricular hypertrophy; anterior wall myocardial infarction; lateral wall myocardial infarction; apical myocardial infarction; left posterior fascicular block; acute right heart strain (acute pulmonary embolus); chronic lung disease; Secundum atrial septal defect; sodium channel blockade (e.g. tricyclic toxicity); dextrocardia; ventricular ectopy; preexcitation (Wolff Parkinson White); infants and young children (normal); normal variant in young slender adults with a horizontally positioned heart
    - Superior (Extreme Right) axis deviation:
      - Right ventricular hypertrophy; apical myocardial infarction; hyperkalemia; ventricular ectopy
  - T waves:
    - Primary changes:
      - Ischemia
    - Secondary changes:
      - Conduction abnormalities (left ventricular hypertrophy; left bundle branch block); ventricular ectopy; preexcitation (Wolff Parkinson White)
- DETERMINING THE AXIS (P waves; QRS complexes; or T waves)
  - "Isoelectric Method"
    1. Find the complex that is isoelectric (the axis will be perpendicular to the direction of this lead)

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2. Look at the complex that is in the lead that is perpendicular to the isoelectric lead (e.g. Corresponding perpendicular leads: 1 and aVF; 2 and aVL; 3 and aVR)
    a. If this complex is upright (positive), then the impulse is traveling toward this lead.
    b. If this complex is downward (negative), then the impulse is traveling away from this lead.
3. Determine the axis based on the direction of the lead in step 2.

- "Graph Method"
    1. Use leads 1 and aVF
    2. Sum the direction of the complex in lead 1 and put it on the x-axis of a graph.
    3. Sum the direction of the complex in lead aVF and put it on the y-axis of a graph.
    4. Determine where these points intersect.
    5. Draw an arrow from the center of the graph to the intersection point. This will be the direction of the axis.

BRUGADA SYNDROME

- Autosomal dominant disorder characterized by a defective loss of function of cardiac sodium channels
- Increased risk for ventricular tachyarrhythmias, syncope and sudden cardiac death
- There are three (Type 1, Type 2, Type 3), however, only type 1 seems to have the increased risk of sudden cardiac death.
    - Type 1:
        - Increased risk of sudden cardiac death
        - Widened QRS complexes in which the terminal portion are upright in V1 and V2; appear as a bizarre right bundle branch block; terminal portion of the QRS complexes usually has a steep, straight decent.

BUNDLE BRANCH BLOCKS

- Left Bundle Branch Block (LBBB):
    - QRS > 0.12 sec
    - QRS down going V1 and V2
    - QRS upright V5, V6, 1 and/or aVL
- Right Bundle Branch Block (RBBB):
    - QRS > 0.12 sec
    - QRS upright in V1 and V2 (terminal portion)
    - S waves in V5, V6, 1 and/or aVL
- Nonspecific Intraventricular Conduction Delay (IVCD):
    - QRS > 0.12 sec
    - Does not meet criteria for RBBB or LBBB
- Incomplete Left Bundle Branch Block (ILBBB):
    - QRS = 0.11 sec
    - QRS down going in V1 and V2
    - QRS upright V5, V6, 1 and/or aVL

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- Incomplete Right Bundle Branch Block (IRBBB):
  - QRS = 0.11 sec
  - QRS upright in V1 and V2 (terminal portion) (often rSR')
  - S waves in V5, V6, 1 and/or aVL

CAPTURE BEATS

- An atrial beat "captures" the ventricle in the midst of atrioventricular (AV) dissociation

CNS (Central nervous system) EFFECTS

- Intracranial Hemorrhage:
  - Diffuse, symmetrical T wave inversion
  - Prolonged QTc interval
  - U waves
  - Arrhythmias:
  - Sinus bradycardia or sinus tachycardia

COMPENSATORY PAUSE

- A PVC occurs and interferes with the next sinus beat, but the timing of the sinus rhythm is not affected. There is a PVC, followed by a pause, but the next sinus beat, after the PVC, is on time and exactly 2 cycles past the previous sinus beat.

DEXTROCARDIA

- Electrocardiogram Characteristics: (appears like right arm/left arm limb lead reversal in the limb leads, with abnormal R wave progress in the precordial (chest) leads)
  - Limb leads:
    - Lead 1 appears upside down (Inverted P wave; inverted QRS complex)
    - Leads 2 and 3 are switched in position on the electrocardiogram
    - Leads aVR and aVL are switched in position on the electrocardiogram
    - Lead aVF appears normal
  - Chest leads:
    - Prominent R waves in leads V1 and V2
    - The R waves get smaller and nearly nonexistent by lead V6

DRUG EFFECTS

- DIGOXIN:
  - Diffuse ST segment scooping and depression
  - QT shortening
  - Flattening of the T wave or biphasic T wave
  - U waves
  - Arrhythmias:
  - Atrioventricular (AV) blocks (1st, 2nd or 3rd degree)
  - Regular junctional rhythm in the setting of atrial fibrillation (3rd degree AV block with a junctional escape rhythm)
  - Almost any arrhythmia

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- ANTIARRHYTHMIC AGENTS
  - CLASS 1a:
    - Wide QRS; prolonged QTc interval; flattening or inversion of the T waves; U waves
  - CLASS 1b:
    - Shortening of QTc interval; Shortening of PR interval
  - CLASS 1c:
    - Wide QRS; prolonged QTc interval; prolonged PR interval
  - CLASS III:
    - Wide QRS; prolonged QTc interval; prolonged PR interval
  - CLASS II:
    - Little effect on the ECG; can cause bradycardia or atrioventricular (AV) blocks
  - CLASS IV:
    - Little effect on the ECG; can cause bradycardia or atrioventricular (AV) blocks

Class 1a, 1c, and III agents are pro-arrhythmic

ELECTRICAL ALTERNANS

- The height of the QRS complexes vary between beats (can also occur with P waves or T waves)
- Causes:
  - Large pericardial effusion
  - Tachycardia
  - Hypertrophic cardiomyopathy
  - Myocardial infarction
  - Myocarditis
  - Other arrhythmias

ELECTROCARDIOGRAM BASICS

- Time is represented by the X-axis (Standard paper speed is 25mm/second)
- Millivolts is represented by the Y-axis (Standard calibration is 10mm/millivolt)
- Variations in calibrations:
  - Half-standard calibration: 5 mm/mV
  - Double-standard calibration: 20 mm/mV
  - Split scale/calibration: Any combination of standard, half-standard or double-standard calibration together.
- Waveforms:
  - P waves:
    - Deflection on the ECG that represents sinus node, atrial and atrioventricular (AV) node depolarization
  - QRS complex:
    - Deflection on the ECG that represents ventricular depolarization

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- Q waves:
  - First downward deflection before an R wave of the QRS complex
- R waves:
  - First upward deflection of the QRS complex
- S waves:
  - First downward deflection after an R wave of the QRS complex
- R prime (R'):
  - Second upward deflection of the QRS complex
- S prime (S'):
  - Second downward deflection after an R wave of the QRS complex
- R double prime (R''):
  - Third upward deflection of the QRS complex
- S double prime (S''):
  - Third downward deflection after an R wave of the QRS complex
- QS waves:
  - A single downward deflection of a QRS complex
- ST segments:
  - Deflection on the ECG that occurs between the QRS complex and the T wave
- J point:
  - The area where the QRS complex becomes the ST segment
- T waves:
  - Deflection on the ECG after the ST segment
- (The ST and T waves represent ventricular repolarization)
- U waves:
  - Deflection on the ECG that can occur after the T waves

- Intervals:
  - PR Interval
    - Period of time from the beginning of the P wave to the beginning of the QRS complex (Normal: 0.12 - 0.20 seconds)
      - Short PR Interval:
        - Enhanced Atrioventricular Node Conduction (EAVNC); Lown-Ganong-Levine Syndrome
      - Prolonged PR Interval:
        - First degree atrioventricular blocks
  - QRS Interval:
    - Period of time from the beginning of the QRS complex to the end of the QRS complex (Normal: 0.06 - 0.12 seconds)
      - Wide QRS Interval: Bundle branch blocks; intraventricular conduction delays; ventricular beats/rhythms; preexcitation (Wolff Parkinson White)
  - QT Interval:
  - Period of time from the beginning of the QRS complex to the end of the T wave (do not include U waves)

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- Corrected QT (QTc) Interval:
  - Measured QT interval corrected for the heart rate. Most common formula used is Bazett's Formula (QTc = measured QT / square root of the RR interval)
  - Normal QTc:
    - Men: 0.35 - 0.45 seconds
    - Women: 0.36 - 0.46 seconds
  - Short QT Interval:
    - < 0.35 seconds in men and < 0.36 seconds in women
    - Typically not clinically significant unless < 0.33 seconds
    - Causes:
      - Electrolyte abnormalities (hypercalcemia)
      - Drug effects (digoxin excess)
      - Congenital short QT syndrome (risk of atrial fibrillation, ventricular fibrillation and sudden cardiac death)
  - Prolonged QT Interval:
    - 0.45 seconds in men and > 0.46 seconds in women
    - Typically not clinically significant unless > 0.50 seconds
    - Patients are at risk of ventricular tachyarrhythmias (ventricular tachycardia, ventricular fibrillation, Torsades de pointes)
    - Causes:
      - Electrolyte abnormalities (hypokalemia, hypocalcemia, hypomagnesemia)
      - Myocardial infarction, myocardial ischemia, increased intracranial pressure
      - Drug effects (antiarrhythmic agents, tricyclic antidepressants, certain antibiotics, multiple other)
      - Congenital prolonged QT syndromes

- Electrocardiogram Formatting:

1	aVR	V1	V4
2	aVL	V2	V5
3	aVF	V3	V6

- Lead Groupings:
  - Inferior leads: 2, 3 and aVF
  - Septal/Posterior leads: V1 and V2
  - Anterior leads: V3 and V4
  - Lateral leads: V5 and V6
  - High lateral leads: 1 and aVL

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ELECTROCARDIOGRAM SETUP AND LEAD/ELECTRODE PLACEMENT

- Ten (10) electrodes are used for a 12-lead electrocardiogram
- Six (6) leads are limb leads; Six (6) leads are chest leads
- The limb leads demonstrate the cardiac vectors in the coronal or vertical plane of the body
- The chest leads demonstrate the cardiac vectors in the transverse or horizontal plane of the body
- Leads 1, 2 and 3 are bipolar leads which use one electrode as a negative pole and another electrode as a positive pole
- The remaining leads (aVR, aVL, aVF, V1, V2, V3, V4, V5, and V6) are considered unipolar leads, which use each respective electrode as the positive pole and Wilson's Central Terminal (WCT) as the negative pole. Wilson's Central Terminal is produced by averaging the measurements from the right arm electrode, the left arm electrode and the left leg electrode to give an average potential across the body

- The electrodes are placed as follows:
  - RA, or right arm, is placed on the right arm, avoiding the thick muscle.
  - LA, or left arm, is placed on the left arm in a similar place as the RA electrode.
  - RL, or right leg, is placed on the right lateral calf muscle.
  - LL, or left leg, is placed on the left lateral calf muscle in a similar place as the RL electrode.
  - V1 is placed in the fourth intercostal space, between ribs 4 and 5, just to the right of the sternum or breastbone.
  - V2 is placed in the fourth intercostal space, between ribs 4 and 5, just to the left of the sternum.
  - V3 is placed exactly between leads V2 and V4.
  - V4 is placed in the fifth intercostal space, between ribs 5 and 6, in the mid-clavicular line. When setting up the electrodes, always place leads V2 and V4, before placing lead V3.
  - V5 is placed, in the 5th intercostal space, even with V4, in the left anterior axillary line. Finally, V6 is placed in the 5th intercostal space, with V4 and V5 in the mid-axillary line.
- To set up a "right-sided" electrocardiogram you first attach the limb leads as normal, but then put the chest leads opposite of normal and over the right chest.
  - Right V1 is placed in the fourth intercostal space, between ribs 4 and 5, just to the left of the sternum or breastbone.
  - Right V2 is placed in the fourth intercostal space, between ribs 4 and 5, just to the right of the sternum. This is exactly opposite to the normal placement of V1 and V2.
  - Right V4 is placed next, in the fifth intercostal space, between ribs 5 and 6, in the right mid-clavicular line.
  - Right V3 is then placed exactly between leads right V2 and V4.
  - Right V5 is placed, in the 5th intercostal space, even with right V4, in the right anterior axillary line. Finally, right V6 is placed in the 5th intercostal space, with V4 and V5 in the right mid-axillary line.

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- Posterior leads also referred to as leads V7, V8 and V9 are typically place on the left posterior chest. All are placed in the same horizontal line as leads V4 through V6. Lead V6 can be used as a reference point for this horizontal plane. The posterior leads can be used to help detect posterior wall myocardial infarctions.
  - V7 is placed at the left posterior axillary line
  - V8 is placed at the mid scapular line
  - V9 is place at the left spinal border
- Lewis lead (may help study right atrial activity):
  - Bipolar leads are used
  - RA electrode - manubrium (top of the breastbone)
  - LA electrode - right sternal border, 5th intercostal space
  - RL electrode - right, lower, rib margin
  - The electrocardiogram is set up to read lead 1
- Transesophageal lead (to help study or treat left atrial rhythms):
  - Special wire that is inserted in the nose or mouth and typically inserted to the level of the left atrium
- Modified Chest Leads (MCL)
  - Bipolar leads that simulate unipolar chest leads
- MCL1 (which simulates V1) and MCL6 (which simulates V6) are the two most common MCLs used
- MCL1:
  - Positive electrode - 4th intercostal space (ICS), right sternal border
  - Negative electrode - near the left shoulder
  - Ground electrode - anywhere away from the active, or positive, lead
  - Monitor the lead that corresponds to the positive electrode
  - (E.g. LA electrode at the 4th ICS, right sternal border; RA electrode near the left shoulder; Monitor lead 1)
- MCL6:
  - Positive electrode - 5th intercostal space (ICS), lateral-axillary line
  - Negative electrode - left anterior chest around the mid-clavicular region
  - Ground electrode - anywhere away from the active, or positive, lead
  - Monitor the lead that corresponds to the positive electrode
  - (E.g. LA electrode at the 5th ICS, lateral-axillary line; RA electrode on the left anterior chest around the mid-clavicular region; Monitor lead 1)

ELECTROLYTE ABNORMALITIES

- Hyperkalemia:
  - (ECG changes seen as serum potassium levels rise and worsen)
  - Tall, peaked, narrow T waves
  - Short QT interval
  - QRS widening
  - PR interval lengthening
  - Flattened or nonexistent P waves
  - Sine wave pattern

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- Hypokalemia:
  - T wave flattening or T wave inversion
  - U waves
  - QRS widening
  - QT interval prolongation
  - Arrhythmias (supraventricular tachycardia, atrial flutter, atrial fibrillation, ventricular tachycardia, ventricular flutter, ventricular fibrillation and torsades de pointes)
  - Atrioventricular blocks
- Hypercalcemia:
  - QT interval shortening due to shortening of the ST segment (T waves appear normal)
  - Possible QRS and P wave widening
- Hypocalcemia:
  - QT interval prolongation due to lengthening of the ST segment (T waves appear normal)
- Hypermagnesemia:
  - Little effect on the electrocardiogram, but can cause bradycardia or other arrhythmias
- Hypomagnesemia:
  - Little effect on the electrocardiogram, but often associated with hypokalemia
  - Can cause tachyarrhythmias (e.g. Torsades de pointes)
- Hypernatremia and hyponatremia:
  - Little effect on the electrocardiogram

EPSILON WAVES

- Small upward deflections ("blips") on the end of QRS complexes
- May indicate arrhythmogenic right ventricular dysplasia (ARVD)

FASCICULAR BLOCKS

- Left Anterior Fascicular Block (LAFB)/Left Anterior Hemiblock (LAHB):
  - Prolonged QRS (0.08-0.11 sec)
  - Left axis deviation (usually > -45 degrees)
  - Leads 1 and aVL: small Q waves and tall R waves
  - Leads 2, 3 and aVF: small R waves and deep S waves
  - No other obvious cause of these findings (e.g. left ventricular hypertrophy or inferior wall myocardial infarction)
- Left Posterior Fascicular Block (LPFB)/Left Posterior Hemiblock (LPHB):
  - Prolonged QRS (0.08-0.11 sec)
  - Right axis deviation > +90 degrees
  - Leads 1 and aVL: small R waves and deep S waves
  - Leads 2, 3 and aVF: small Q waves and tall R waves
  - No other explanation for the right axis deviation (e.g. right ventricular hypertrophy or anterior wall myocardial infarction)

FUSION BEATS

- A normal beat combined with a PVC

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GUIDELINES TO ACCURATE ELECTROCARDIOGRAM INTERPRETATION

- Steps for Interpreting an Electrocardiogram:
  - Patient's name, age and gender
  - ECG Scale (sweep speed and voltage calibration)
  - Heart Rate
  - Rhythm
  - Axes (P, QRS and T)
  - Intervals:
    - PR
    - QRS
    - QT
  - Waveforms:
    - P waves
    - Q waves
    - QRS complexes
    - ST segments
    - T waves
  - Electrocardiogram Final Diagnosis
  - Clinical Diagnosis

HEART RATE

DETERMINING THE HEART RATE

(Assumes a normal sweep speed of 25 mm/second)

1. Multiply the number of beats across the ECG x 6
2. Multiply the number of beats in a 6 second period x 10
3. Count the number of big lines between beats and divide that into 300 (e.g. 300 / # of big boxes)
4. Memorize the number of beats per big box and then estimate the heart rate (300, 150, 100, 75, 60, 50, 42, 37 etc.)

HYPOTHERMIA AND OSBORN WAVES

- Initially: Sinus tachycardia
- Later: Sinus bradycardia; Prolongation of the PR interval, QRS complexes and QT interval
- Later: Atrial arrhythmias (e.g. ectopic atrial beats/rhythms; atrial fibrillation); Osborn waves (extra deflection at the end of the QRS complexes [aka: J waves; camel-hump waves; hypothermic waves])
- Later: QRS widening; Ventricular fibrillation

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INTERNAL CARDIAC DEFIBRILLATORS (ICDs)

- Characteristics:
  - Anti-tachycardia pacing:
    - The ICD will try to pace the heart at a rate faster than the ventricular tachycardia and then stop pacing suddenly in hope that the ventricular tachycardia self-terminates and sinus rhythm resumes.
  - Will see pacing spikes (usually 8 spikes) on top of during ventricular tachycardia
- Shock therapy:
  - There is a large vertical line on the rhythm strip produced by the shock during ventricular tachycardia/fibrillation. Hopefully, the ventricular rhythm now stops and a sinus rhythm resumes.

INTERPOLATED PVC

- PVC that occurs between two sinus beats and does not interfere with the underlying sinus rhythm

JUNCTIONAL RHYTHMS

- Junctional bradycardia:
  - Rhythm originating in the atrioventricular (AV) node (junction) at a rate of < 40 bpm
- Ectopic junctional rhythm:
  - Rhythm originating in the atrioventricular (AV) node (junction) at a rate of 40 - 60 bpm
- Accelerated junctional rhythm:
  - Rhythm originating in the atrioventricular (AV) node (junction) at a rate of 60-100 bpm
- Junctional tachycardia:
  - Rhythm originating in the atrioventricular (AV) node (junction) at a rate of > 100 bpm

LEAD REVERSAL

- LIMB LEAD REVERSAL
  - Rule of thumb: One of the unipolar limb leads (aVR, aVL or aVF) is normal appearing; the bipolar lead (lead 1, 2 or 3), directly across from the unchanged unipolar lead on Einthoven's Triangle is upside down; the other two unipolar leads are switched in position on the ECG; the other two bipolar leads are switched in position on the ECG. In essence, it is like turning Einthoven's triangle over around an axis consisting of the unchanged unipolar lead (aVR, aVL or aVF) and the midpoint of the bipolar lead (lead 1, 2 or 3) directly across from the unchanged unipolar lead.
- Left arm/Right arm reversal:
  - aVF appears normal
  - Lead 1 appears upside down
  - Leads 2 and 3 are switched in position on the ECG
  - Leads aVR and aVL are switched in position on the ECG

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- Left arm/leg reversal:
  - aVR appears normal
  - Lead 2 appears upside down
  - Leads 1 and 3 are switched in position on the ECG
  - Leads aVF and aVL are switched in position on the ECG
- Right arm/leg reversal:
  - aVL appears normal
  - Lead 3 appears upside down
  - Leads 1 and 2 are switched in position on the ECG
  - Leads aVF and aVR are switched in position on the ECG

LOW QRS VOLTAGE

- Limb Leads:
  - All of the QRS complexes < 5 mm tall (from the top of the R wave to the bottom of the S wave) or
- Precordial (Chest) Leads:
  - All of the QRS complexes < 10 mm tall (from the top of the R wave to the bottom of the S wave)
- Differential Diagnosis of Low QRS Voltage:
  - Leads are far away from the heart:
    - Obesity
    - Chronic obstructive pulmonary disease (COPD)
    - Pneumothorax
  - Electrical impulses are impeded by fluid around the heart or infiltrative disease within the myocardium:
    - Pericardial effusion/Cardiac tamponade
    - Amyloidosis
    - Sarcoidosis
    - Scleroderma
    - Hemochromatosis
    - Wilson's disease
  - States of slow metabolism:
    - Severe hypothyroidism (myxedema)
    - Hypothermia
  - Little viable myocardium to conduct impulses:
    - Extensive myocardial infarction
    - Myocarditis
- Emergent Diagnoses That May Be Immediately Treatable:
  - Tension Pneumothorax
  - Cardiac Tamponade
  - Hemochromatosis
  - Severe Hypothyroidism
  - Hypothermia
  - Acute Myocardial Infarction
  - Acute Myocarditis

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NONCOMPENSATORY PAUSE

- A premature beat (usually a premature atrial complex (PAC)) affects and resets the sinus node timing. There is a premature beat, followed by a pause, and the next sinus beat, after the premature beat, occurs earlier than 2 cycle lengths.

OSBORN WAVES

- See "Hypothermia and Osborn Waves

PACEMAKERS

Pacemaker Nomenclature (5 Column System)

I	II	III	IV	V
Chamber Paced	Chamber Sensed	PM response to a sensed beat	Programmability	Anti-tachycardia function
A	A	I	P	P
V	V	T	M	S
D	D	D	R	D
O	O	O		

Columns 1, 2: A = Atrium; V = Ventricle; D = Dual; O = none
Column 3: I = Inhibited; T = Triggered; D = Dual (both I + T); O = none
Column 4: P = Simple Programmable; M = Multi-programmable; R = Rate adaptive
Column 5: P = Pacing; S = Shock; D = Dual (P + S)

- Fusion Beat:
  - A native beat combined with a paced beat
- Pseudofusion Beat:
  - A normal appearing native beat, with a pacemaker spike on it
- Unipolar pacing characteristics:
  - Large spikes
- Bipolar pacing characteristics:
  - Small spikes
- Lower rate limit:
  - Minimum rate that the pacemaker is programmed to pace
- Upper rate tracking limit:
  - The fastest ventricular rate that the pacemaker is allowed to pace in response to atrial activity (used in dual chamber pacemakers)
- Pacemaker Malfunction:
  - Failure to capture: The pacemaker produces a jolt of electricity and a spike on the ECG, but no complex follows the spike.
  - Failure to sense: The pacemaker does not sense a native beat, and therefore does not inhibit the pacemaker. Subsequently, the pacemaker gives an inappropriate spike.

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PERICARDITIS

- Four (4) Stages on the Electrocardiogram:
  1. Diffuse ST segment elevation; possible PR segment depression
  2. Normalization of the ST and PR segment changes
  3. Diffuse, isolated, symmetrical T wave inversion
  4. Normalization of the T waves

POOR R WAVE PROGRESSION (PRWP)

- Definition: R wave in lead V3 < 3 mm tall
- PRWP Algorithm:
  1. If the R wave in lead V3 is less than 3 mm tall
     a. Exclude known causes of PRWP:
        (Left bundle branch block; right bundle branch block; left ventricular hypertrophy; right ventricular hypertrophy; Wolff Parkinson White (Preexcitation))
  2. If none of the above is present, then look at the R wave in lead 1
     a. If the R wave is > 5 mm tall - consider a normal variant
     b. If the R wave is < 5 mm tall then look at the R to S ratio:
        i. If the R wave is > S wave - consider anterior myocardial infarction
        ii. If the R wave is < S wave - consider right ventricular hypertrophy

PREEXCITATION / WOLFF PARKINSON WHITE

- Preexcitation:
  - Delta wave; short PR interval; widened QRS complex
- Wolff Parkinson White:
  - Preexcitation associated with a tachyarrhythmia
  - Orthodromic Conduction:
    - Conduction into the ventricles goes down the AV node normally, and the reentrant conduction goes up the bypass tract.
  - Antidromic Conduction:
    - Conduction into the ventricles goes down the bypass tract and the reentrant conduction goes up the AV node.
- Atrioventricular Nodal Bypass Tract:
  - Due to proposed James fiber
  - Produces shortened AV conduction time (short PR interval)
- Lown-Ganong-Levine (LGL) Syndrome:
  - Short PR interval and clinical tachycardia

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PULMONARY DISEASE PATTERN

- Suggest right ventricular strain
- Common findings:
  - Right axis deviation or vertical axis of the QRS complex
  - Right axis deviation of the P waves
  - Prominent P waves in the inferior leads (right atrial abnormality)
  - Late transition (clockwise rotation)
  - Persistent S waves in lead V6
  - Absence of R waves in leads V1 through V3 (S_{V1}, S_{V2}, S_{V3} pattern)
  - PR and ST segment sagging (exaggerated atrial depolarization)
  - Low QRS voltage (especially in the precordial leads)

PULMONARY EMBOLUS

- S1, Q3, T3 pattern
- Tachycardia (sinus tachycardia, possible atrial fibrillation)

RHYTHMS (NAMING RHYTHMS)

- "Normal" refers to the native rate of depolarization of that particular tissue
- "Bradycardia" refers to a rate less than the native rate of depolarization of that particular tissue
- "Accelerated" refers to a rate greater than the native rate of depolarization of that particular tissue, but less than 100 bpm
- "Tachycardia" refers to a rate greater than 100 bpm (and usually less than 250 bpm)
- "Flutter" refers to a rate between 250 and 350 bpm
- "Fibrillation" refers to a rate greater than 350 bpm

- Sinus Node ("normal" rate 60-100)
  - <60 BPM Sinus Bradycardia
  - 60-100 BPM Normal Sinus Rhythm
  - >100 BPM Sinus Tachycardia
- AV Node ("normal" rate 40-60 BPM)
  - <40 Junctional bradycardia
  - 40-60 "Normal" Junctional Rhythm
  - 60-100 Accelerated Junction Rhythm
  - >100 Junctional Tachycardia
- Ventricle ("normal" rate 20-40 BPM)
  - 20-40 BPM Idioventricular Rhythm
  - 40-100 BPM Accelerated Idioventricular Rhythm
  - 100-250 BPM Ventricular Tachycardia
  - 250-350 BPM Ventricular Flutter
  - >350 BPM Ventricular Fibrillation
- Atrial Rhythms ("Normal" rate 55-100 BPM)
  - <55 BPM Atrial bradycardia
  - 55-100 BPM Ectopic atrial rhythm
  - 100-250 BPM Atrial tachycardia
  - 250-350 BPM Atrial Flutter
  - >350 BPM Atrial Fibrillation

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- Atrial Fibrillation and ventricular response
  - Ventricular response <60 BPM — Afib with slow ventricular response
  - Ventricular response 60-100 BPM — Afib with controlled ventricular response
  - Ventricular response >100 BPM — Afib with rapid ventricular response

R ON T PHENOMENON

- Premature ventricular complex (PVC) occurs on the T wave of the previous beat
- Can be the precursor to ventricular tachyarrhythmias (ventricular tachycardia, ventricular fibrillation, Torsades de pointes)

SHORT PR INTERVAL

- Normal PR interval: 0.12 - 0.20 seconds
- Short PR interval: < 0.12 seconds
- Causes of a short PR interval:
  - Normal variant
  - Enhanced atrioventricular nodal conduction (EAVNC)
  - Infra-nodal connection between the atria and the bundles (James Fiber)
  - Lown-Ganong-Levine syndrome (Short PR interval; narrow QRS complex; clinical tachycardia

SINUS RHYTHMS AND SINUS/SINOATRIAL BLOCKS

- Sinus Bradycardia:
  - A rhythm originating from the sinus node at < 60 bpm
- Normal Sinus Rhythm:
  - A rhythm originating from the sinus node at 60 - 100 bpm
- Sinus Tachycardia:
  - A rhythm originating from the sinus node at > 100 bpm
- Sinus Arrhythmia:
  - A rhythm originating from the sinus node with a variable rate (typically at least a 0.16 sec variation between the fastest and slowest beats)
- Sinus Pause:
  - A sinus beat is not present and skips during a sinus rhythm
- Sinus Arrest:
  - A long pause devoid of sinus beats
- Sinoatrial (SA) Exit Blocks:
  - First Degree SA Exit Block:
    - Delay from the time the SA node creates an action potential to the time the atrium actually depolarizes
    - Not recognizable on the ECG (may simply look like a sinus rhythm or sinus bradycardia)

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- Second Degree SA Exit Block:
  - Mobitz 1: Progressive shortening of the P to P interval until a P wave is blocked in the SA node (shortening of the PP interval then a dropped P wave)
  - Mobitz 2: Consistent P to P interval until a P wave is blocked in the SA node (Constant PP interval then a dropped P wave)
- Third Degree SA Exit Block:
  - No SA nodal action potentials are able to leave the SA node (no P waves seen). Appears as sinus arrest and can actually only be diagnosed with a sinus node electrode during an electrophysiology study

ST AND T CHANGES

- Primary ST and T changes:
  - Localized process
  - Generally involves the T waves alone
  - T wave axis generally similar to the QRS axis
  - Typical example:
    - ischemia
- Secondary ST and T changes:
  - Diffuse process
  - Generally involves both the ST and T waves
  - T wave axis is opposite from the QRS axis
  - Typical examples:
    - Left ventricular hypertrophy, left bundle branch block, others
- Primary ST and T changes can occur on top of secondary changes

SUPRAVENTRICULAR TACHYCARDIAS (SVT)

- Any tachyarrhythmia that originates from above the atrioventricular node, but usually it refers to two (2) reentrant arrhythmias: Atrioventricular Nodal Reentrant Tachycardia (AVNRT); and Atrioventricular Reentrant Tachycardia (AVRT)
- Atrioventricular Nodal Reentrant Tachycardia (AVNRT):
  - Most common SVT
  - Occurs due to reentrant circuit within the AV node
  - Narrow QRS complexes
  - May have retrograde P waves
  - If P waves are present the R to P interval is usually < 50% of the R to R interval
- Atrioventricular Reentrant Tachycardia (AVRT):
  - Occurs due to reentrant circuit with one pathway within the AV node, and one pathway outside of the AV node (bypass tract)
    - Orthodromic:
      - Reentrant circuit goes down the AV node and up the bypass tract
      - Narrow QRS complexes
      - May have retrograde P waves
      - If P waves are present the R to P interval is usually > 50% of the R to R interval

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- Antidromic:
  - Reentrant circuit goes down the bypass tract and up the AV node
  - Wide QRS complexes
  - May resemble ventricular tachycardia

TRANSITION

- A measure of the axis of the heart in the transverse (horizontal) plane (that is, from the view of the precordial or chest leads).
- Normal Transition:
  - QRS complex is isoelectric in lead V3 or V4
- Early Transition (counterclockwise rotation):
  - QRS complex is isoelectric in lead V2 or V1
- Late Transition (clockwise rotation):
  - QRS complex is isoelectric in lead V5 or V6

VENTRICULAR ARRHYTHMIAS

- Premature ventricular complexes (PVCs):
  - A beat that originates in the ventricle that comes early
- Ventricular couplet:
  - Two (2) PVCs in a row
- Ventricular triplet:
  - Three (3) PVCs in a row
- Ventricular run:
  - Three or more PVCs in a row
- Ventricular bigeminy:
  - PVCs occurring every other beat
- Ventricular trigeminy:
  - PVCs occurring every third beat
- Monomorphic:
  - All of the complexes look alike
- Multifocal (multiform, polymorphic):
  - The complexes look different
- Idiopathic ventricular rhythm:
  - Rhythm originating in the ventricle at a rate of 20-40 bpm
- Accelerated Idioventricular rhythm (AIVR):
  - Rhythm originating in the ventricle at a rate of 40-100 bpm
- Ventricular tachycardia:
  - Rhythm originating in the ventricle at a rate of 100-250 bpm
- Ventricular flutter:
  - Rhythm originating in the ventricle at a rate of 250-350 bpm
- Ventricular fibrillation:
  - Rhythm originating in the ventricle at a rate of > 350 bpm
- Torsades de pointes:
  - Polymorphic ventricular tachycardia associated with a prolonged QT interval

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- Fusion beats:
  - A normal beat combined with a PVC
- Capture beats:
  - An atrial beat "captures" the ventricle in the midst of atrioventricular (AV) dissociation
- Interpolated PVC:
  - PVC that occurs between two sinus beats and does not interfere with the underlying sinus rhythm
- Compensatory Pause:
  - A PVC occurs and interferes with the next sinus beat, but the timing of the sinus rhythm is not affected. There is a PVC, followed by a pause, but the next sinus beat, after the PVC, is on time and exactly 2 cycles past the previous sinus beat.
- Noncompensatory Pause:
  - A premature beat (usually a premature atrial complex (PAC)) affects and resets the sinus node timing. There is a premature beat, followed by a pause, and the next sinus beat, after the premature beat, occurs earlier than 2 cycle lengths.

VENTRICULAR BEATS/RHYTHMS VS. SUPRAVENTRICULAR BEATS/RHYTHMS WITH ABERRANCY

- Characteristics That Favor Ventricular Beats/Rhythms
  - Concordance
  - Superior QRS axis
  - Atrioventricular (AV) dissociation
  - QRS complex > 140 ms
  - Monophasic R wave in V1
  - Capture beats
  - Fusion beats
  - QRS morphologies in V1:
    - Right bundle branch block-type pattern:
      - Monophasic R wave
      - qR pattern
      - rS pattern
      - Rr' (where the R, or first "rabbit ear," is bigger than the r', or second "rabbit ear.")
    - Left bundle branch block-type pattern:
      - Notched S-descent
      - R wave > 30 ms wide
      - Late nadir > 60 ms
- Characteristics That Favor Supraventricular Beats/Rhythms
  - Ashman's phenomenon
  - QRS morphologies:
    - Right bundle branch block-type pattern:
      - rSR' (where the first r is small, and the R' is large)
      - rR' (where the r, or first "rabbit ear," is smaller than the R', or second "rabbit ear.")

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- Left bundle branch block-type pattern:
  - Straight S-descent
  - R wave < 30 ms wide
  - Late nadir < 60 ms

VENTRICULAR HYPERTROPHY

- Left Ventricular Hypertrophy (LVH):
  - Sokolov-Lyon Criteria:
    - (S_{V1} + $R_{V5\ or\ V6}$) ≥ 35 mm or
    - (S_{V2} + R_{V6}) > 35 mm
  - aVL > 11 mm Criterion
  - The Lewis Index
    - (R_1 - S_1) + (S_3 - R_3) ≥ 17
  - Cornell Criteria
    - Men: (R_{aVL} + S_{V3}) ≥ 28
    - Women: (R_{aVL} + S_{V3}) ≥ 20

- Right Ventricular Hypertrophy (RVH)
  - Right Axis Deviation of the QRS
  - R_{V1} > S_{V1} (R:S > 1)
  - R_{V1} > 7 mm
  - S_{V6} > R_{V6}. (R:S < 1)
  - R_{aVR} ≥ 5 mm
  - R > Q in aVR
  - qR pattern in V1
  - R_{V1} + $S_{V5\ or\ V6}$ ≥ 10 mm
  - $R_{V5\ or\ V6}$ < 5 mm
  - $S_{V5\ or\ V6}$ > 7 mm
  - Secondary ST and T changes (inverted T waves) in V1 - V3

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