



Evaluating the 12-lead ECG: Concepts for interpretation of acute and chronic changes with case study analysis

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Disclosure

No real or potential conflict of interest
to disclose.

No off-label, experimental or investigational
use of drugs or devices will be presented.

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Objectives

At the conclusion
of this session,
the attendee will
be able to:

- 01 Describe a systematic approach
to assessing the 12-lead ECG.
- 02 Identify critical ECG changes seen
in ischemia, injury, and infarct.
- 03 Analyze axis using the hexaxial plot.

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Objectives (continued)

At the conclusion of this session, the attendee will be able to: (cont.)

- 04 Evaluate morphologic changes consistent with chronic disease and insult.
- 05 Perform a case study analysis of conditions characterized by ECG changes.

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Tips



- References
 - Listed throughout and at the end of the presentation
- To facilitate your learning
 - Specific tables/images can be viewed full page at the end of your handout.

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Vector Analysis and Axis Determination

- Initiation and propagation – Sequence of cardiac activation
 - The SA node depolarizes spontaneously.
 - Atrial muscle depolarizes rapidly.
 - The wave of depolarization funnels to AV node where it is delayed.
 - Current travels to the bundle of His.

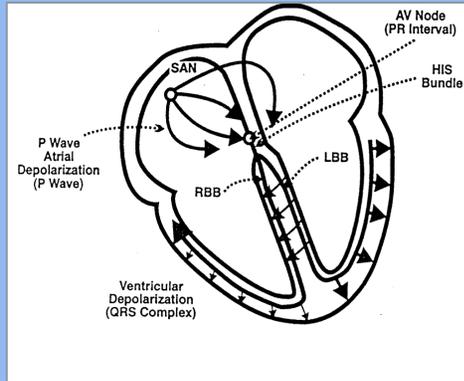
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Vector Analysis and Axis Determination (continued)

- Initiation and propagation (cont.)
 - Current divides into right and left bundles.
 - Depolarization of interventricular septum is left to right.
 - Current moves simultaneously through the right and left bundle branches.
 - Ventricles repolarize.

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Initiation and Propagation



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Limb Leads

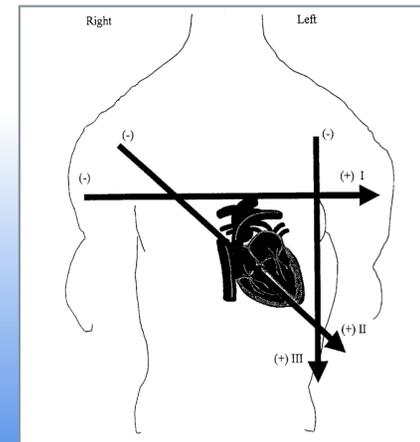
- Vector is a voltage force that has direction as well as amplitude.
 - Electrical events in the heart occur in three dimensions.
 - ECG paper converts those dimensions to a two-dimensional picture – hence 12 leads.
 - Using 12 leads allows us to visualize events from the anterior, inferior, and lateral perspective.

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Limb Leads (continued)

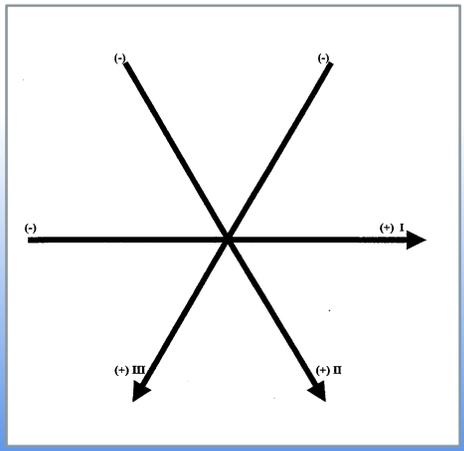
- The limb leads
 - Offer a lateral and inferior view
 - Axis is plotted based on the hexaxial system.
 - Find the limb lead with the voltage closest to 0.
 - Identify its right-angle lead.
 - On the ECG, see if that lead is positive (+) or negative (-).

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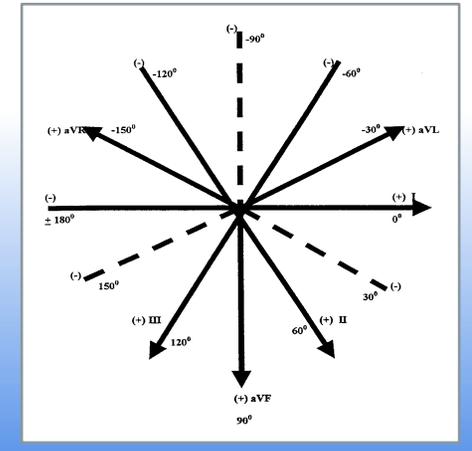
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The Hexaxial Plot



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The Hexaxial Plot

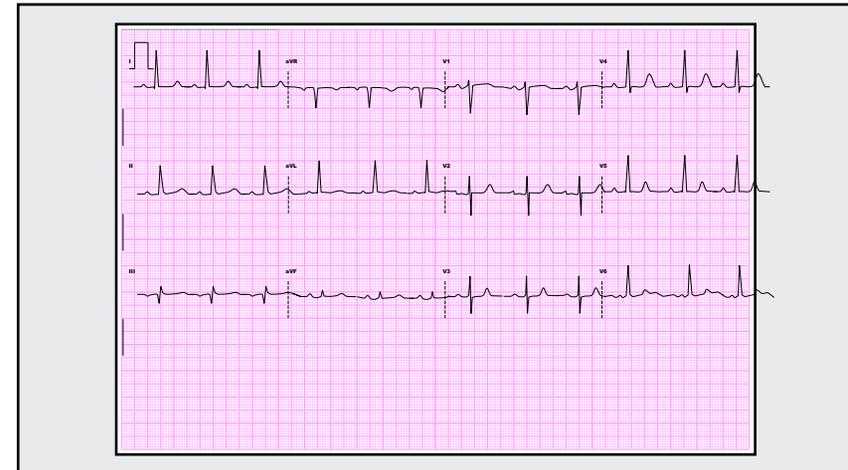


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Axis Determination

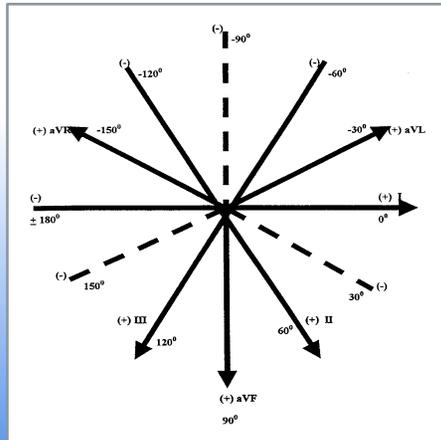
- Determine the corresponding direction on the hexaxial plot.
- Because the net vector is normally down and to the left, the normal axis should be in the vicinity of 60° ; a range of -30° to $+110^\circ$ is normal.
- If the axis deviates to the left of -30° , this represents a left axis deviation.
- If the axis deviates to the right of $+110^\circ$, this represents a right axis deviation.

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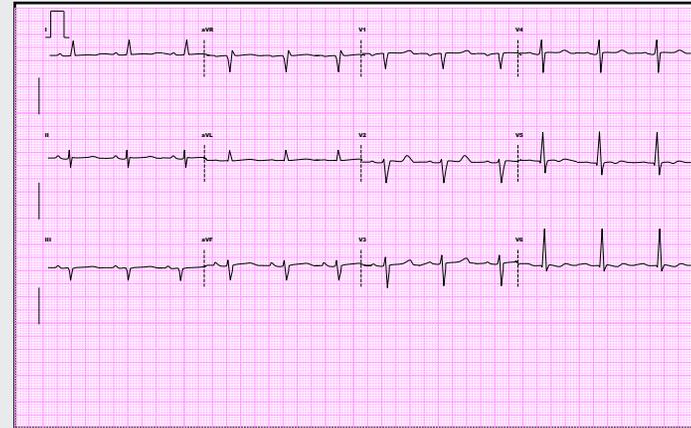


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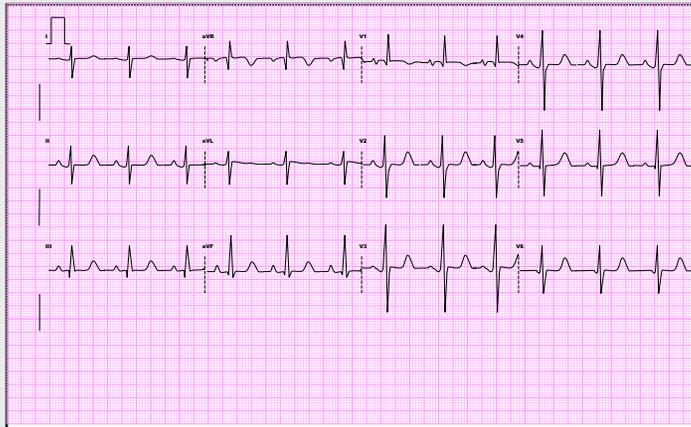
The Hexaxial Plot



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The System of ECG Interpretation

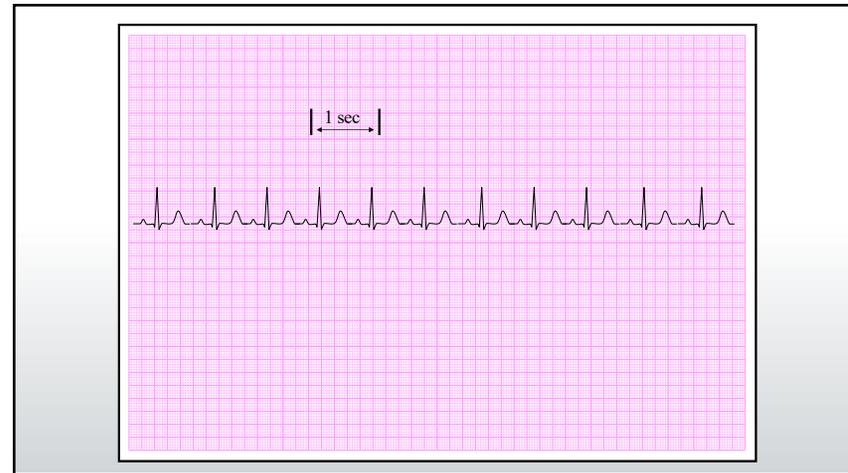
1. Rate
2. Rhythm
3. Intervals
4. Axis
5. Morphology

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Rate

- Determine the R-R interval.
- Each large square is 0.2 seconds.
- Divide the number of large squares between R waves into 300 to determine rate.
- Normal rate is 60 to 100 bpm.

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Rhythm

- Rhythm interpretation is presumed as a prerequisite to this presentation.
- The second step in 12-lead ECG assessment is identification of the rhythm, e.g., NSR, SB, ST, A-V block, atrial dysrhythmia, ventricular dysrhythmia, etc.

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Intervals

- P-R interval represents A-V conduction.
 - Should be 0.12 to 0.22 seconds
 - Prolonged P-R interval indicates a first-degree block.
 - Shortened P-R interval indicates a junctional rhythm with retrograde conduction.
- QRS duration represents ventricular depolarization.
 - Should be <0.12 seconds
 - Prolonged duration indicates a block in the bundle branches or a ventricular ectopic foci.

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Intervals (continued)

- Q-T(c) interval represents repolarization of the ventricle
 - Q-T interval should be $< \frac{1}{2}$ the R-R interval
 - Long Q-T interval increases the risk of ventricular dysrhythmia and sudden death

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QRS Axis

- Identify the lead where the net voltage of the QRS is closest to 0.
- Look for the perpendicular lead.
- If the deflection of the perpendicular lead is +, then the axis is at the positive end of the pole.
- If the deflection of the perpendicular lead is -, then the axis is toward the negative end of the pole.

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Abnormalities Caused by Drugs and Metabolic Conditions

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Abnormalities of Rate

- Sinus bradycardia
 - Beta-adrenergic antagonists
 - Calcium channel antagonists
 - Digitalis
 - Adenosine
 - Hypoxemia
 - Hypothyroidism
 - Hypothermia
 - Hyperkalemia

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Sinus Tachycardia

- Catecholamines
- Caffeine
- Amphetamines
- Hyperthyroidism
- Anemia
- Fever

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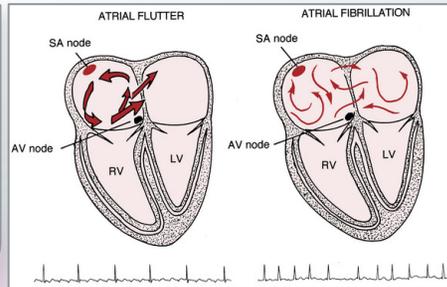
Heart Block

- Digitalis
- Beta adrenergic blockers
- Calcium channel blockers
- Adenosine
- Hyperkalemia

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Atrial Flutter/Fibrillation

- Both are conditions of aberrant atrial discharge.
- Some degree of physiologic AV block typically present.



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Ventricular Tachycardia – Torsade de pointe

- Electrical dysfunction**
- Class I antidysrhythmic drugs
- Amiodarone
- Phenothiazine derivatives
- Tricyclic overdose
- Long QT syndrome

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Ventricular Fibrillation

- Most antidysrhythmic drugs
- Digoxin
- Tricyclic overdose
- Hypokalemia
- Hypomagnesemia
- Hypocalcemia

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Analysis of the 12-Lead ECG Part 2

Morphologic Changes

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Morphologic Changes

- The V leads (V₁ to V₆), aka precordial leads, represent the anterior wall of the heart.
 - V leads may be referred to as “anterior” leads.
 - The limb leads represent the inferior and lateral walls of the heart.

<u>Inferior Wall</u>	<u>Lateral Wall</u>	<u>Anterior Wall</u>
II, III, aVF	I, aVL, (V ₆)	V leads

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P Wave Abnormalities

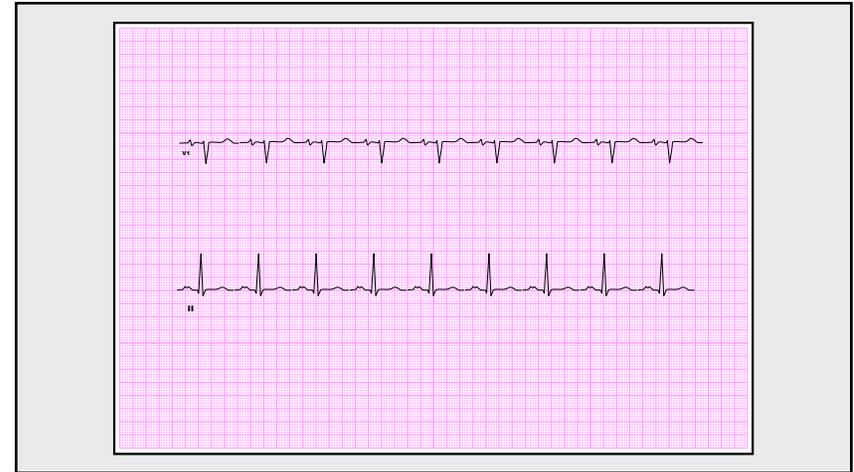
- The P wave represents atrial depolarization. An abnormal P wave would logically suggest an atrial abnormality.
- Left atrial abnormalities
 - Biphasic P wave in V₁ is most common; must be 1 × 1 mm to be significant
 - Biphasic P waves occur in conditions that increase LVEDP.
 - CHF, LVH, hypertensive heart disease may all cause this abnormality.

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P Wave Abnormalities (continued)

- Broad, notched P waves in limb leads suggest left atrial dilation.
- These occur in conditions such as mitral stenosis and regurgitation.

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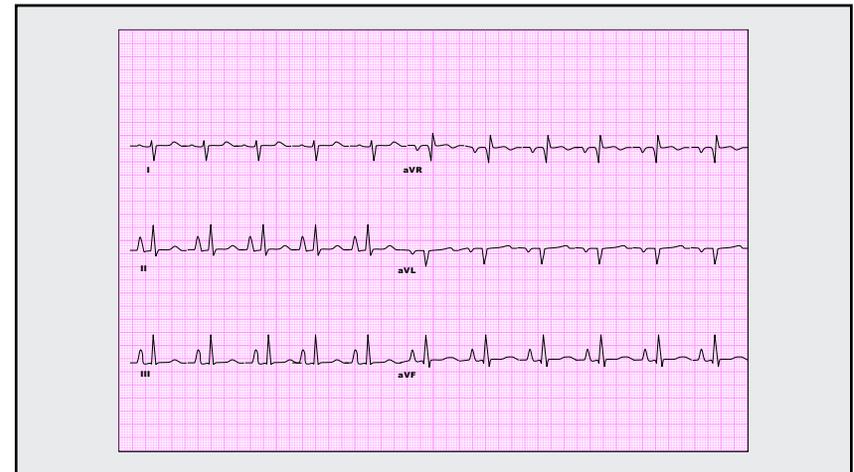


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Right Atrial Abnormalities

- P wave >2.5 mm in any lead
- Occurs in conditions such as lung disease and pulmonary artery hypertension

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QRS Abnormalities

- Remember the normal flow of current and how it reflects on an ECG.
 - ECG will record normal left to right activation. V₁ initial deflection is positive
 - LV depolarization produces a downward deflection in V₁.
 - LV and RV depolarize simultaneously, so LV depolarization dominates the picture.
 - After ventricles repolarize, return to baseline.

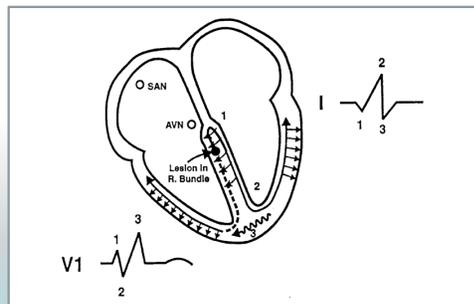
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QRS Abnormalities (continued)

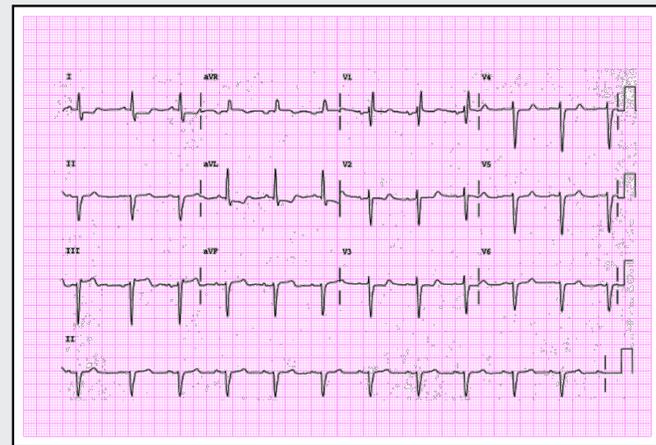
- Right bundle branch block (RBBB)
 - QRS >0.12 seconds
 - Current normally moves left to right in the intraventricular septum.
 - ECG will record normal left to right activation in V₁.
 - This is followed by normal LV activation, but right bundle is blocked.
 - Late current LV to RV results in second upward deflection in V₁.
 - After RV activation, return to baseline.

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Right Bundle Branch



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Incomplete RBBB

- Usually a normal variant
- May reflect RV hypertrophy or dilation
- Very common with atrial septal defect
- RSR pattern in V_1
- QRS is <0.12 seconds.

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Left Bundle Branch Block

- Sequence is opposite RBBB.
- Loss of initial normal left to right activation
- Interventricular septum is activated from right to left, causing an abnormal upward deflection in the left lateral leads.
- QRS is >0.12 seconds.
- Septum is activated from right to left, but the blocked left bundle limits the impulse.

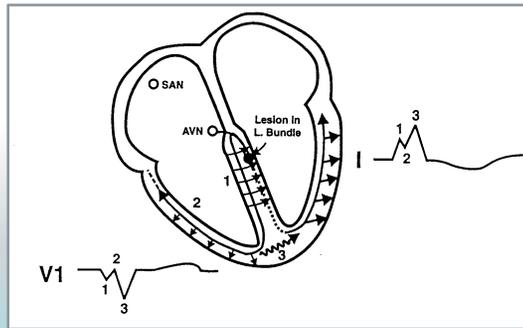
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LBBB (continued)

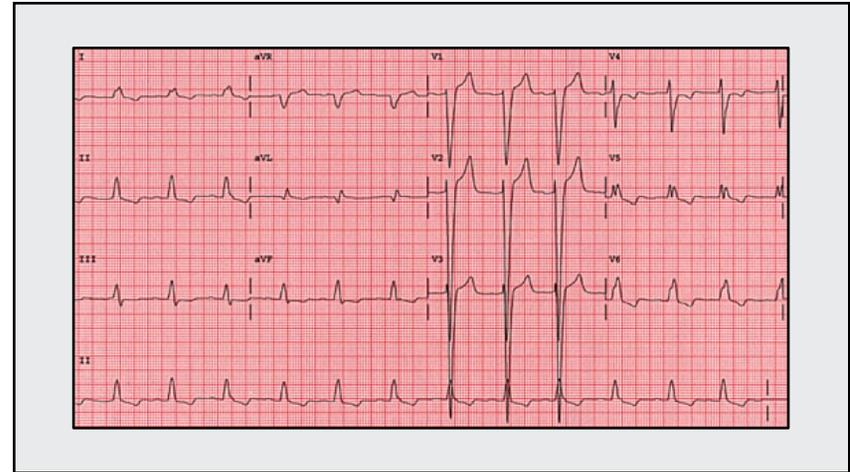
- Right side depolarizes first. It is thin walled, so it produces a small current.
- After RV depolarization, the current travels around to left ventricle.
- Late left depolarization produces terminal QRS force.

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LBBB



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Fascicular Blocks

- The left bundle branch divides into two fascicles: the anterior and posterior.
- LBBB is when both fascicles are blocked. QRS is wider than 0.12 seconds.
- When only one of the fascicles is blocked, the diagnosis is either “left anterior fascicular block” or “left posterior fascicular block.”

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Fascicular Blocks (continued)

- Diagnosis of fascicular block is made when there is a shift in axis.
- The QRS is not necessarily wider than normal.
- LAFB is extreme left axis deviation, at least -45° and not caused by IWMI.
- LPFB is diagnosed by right axis deviation, at least $>90^\circ$, usually $>110^\circ$ to 120° .

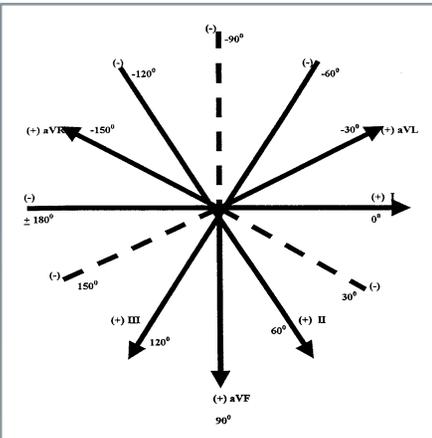
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LAFB



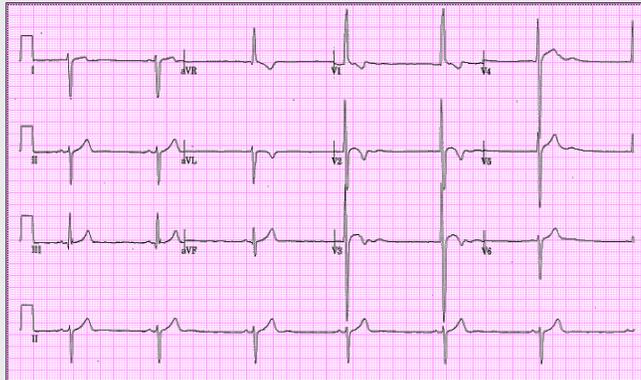
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The Hexaxial Plot



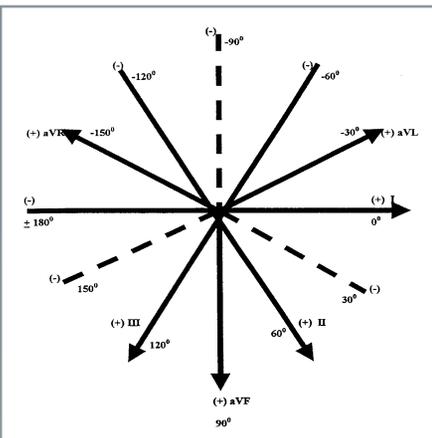
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LPFB



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The Hexaxial Plot

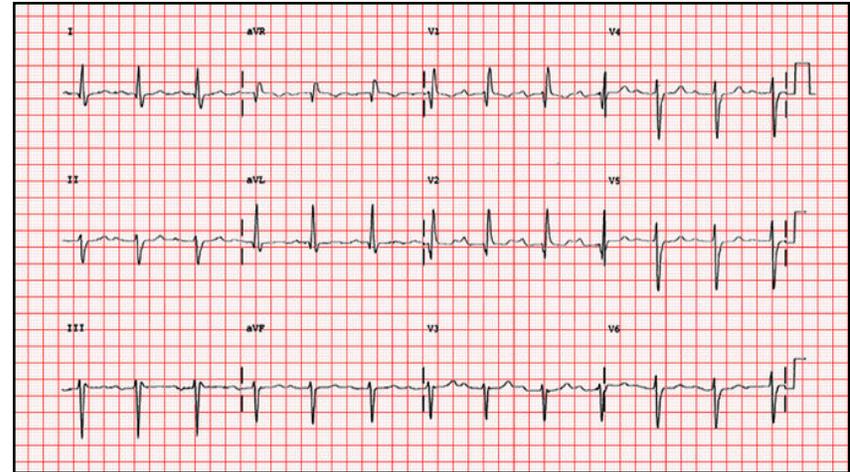


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Bifascicular Block

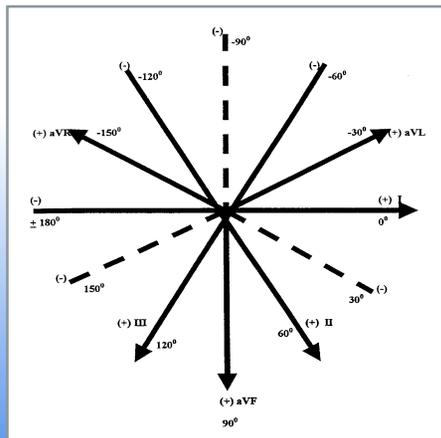
- A right bundle branch block
 - RSR pattern in V_1
 - QRS >0.12 seconds
- A coincident block of either the left anterior or posterior fascicle
- AKA – a RBBB with either left or right axis deviation

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The Hexaxial Plot



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Left Ventricular Hypertrophy

- When you have hypertrophy of muscle a variety of changes occur.
 - The larger muscle mass produces more voltage.
 - The increased size changes axis of electrical conduction.
 - Resultant high pressure in left atria may change character of voltage movement through left atria.

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Romhilt + Estes Point Score System

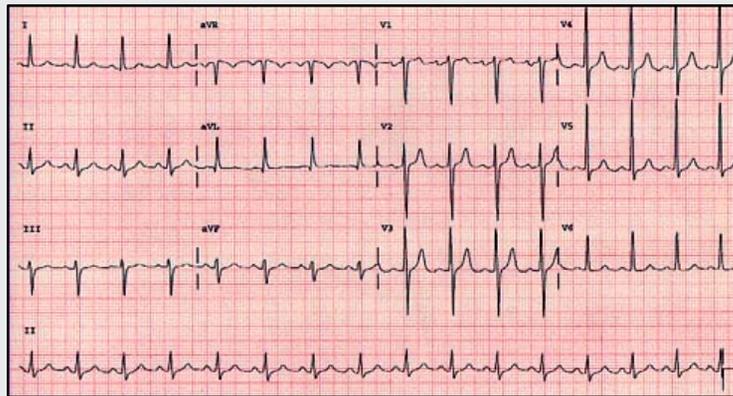
- Amplitude – any of the following= **3** points
 - Largest R or S wave in any limb lead ≥ 20 mm
 - S wave in V_1 or $V_2 \geq 30$ mm
 - R wave in V_5 or $V_6 \geq 30$ mm
- ST-T strain (change in lateral leads)
 - On digitalis= **1** point
 - Not on digitalis= **3** points

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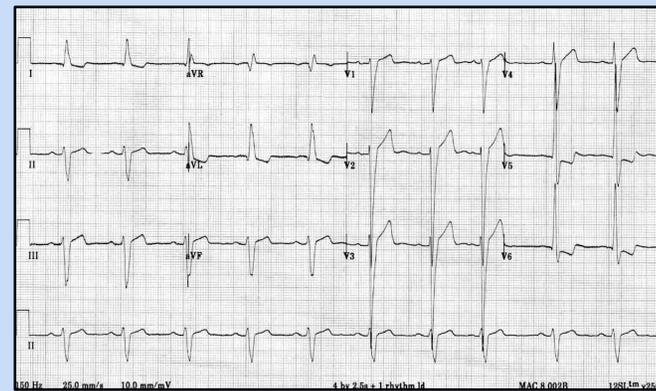
Romhilt + Estes Point Score System (continued)

- Left atrial abnormality= **3** points
 - LAD $> -30^\circ$ = **2** points
 - QRS duration ≥ 0.09 sec= **1** point
 - Intrinsicoid deflection in V_5 or $V_6 \geq 0.05$ sec= **1** point
- 5 or more points= LVH
4 points= Probable LVH

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Right Ventricular Hypertrophy

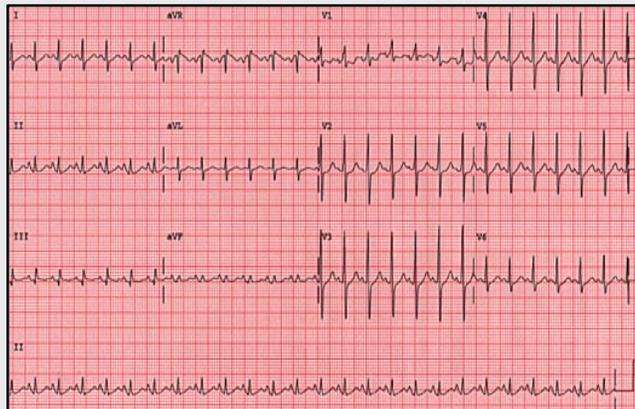
- Most voltage in the QRS generated by LV
- When the right ventricle hypertrophies significantly, it can generate a lot of voltage. A more “rightward shift” occurs in V_1 .

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RVH

- Diagnostic criteria
 - R/S in $V_1 \geq 1$ **or**
 - R in $V_1 + S$ in $V_6 > 10.5$ mm
- Supportive criteria
 - Right axis deviation $\geq 110^\circ$
 - Right atrial abnormality
 - ST depression + T wave inversion in V_1 or V_2

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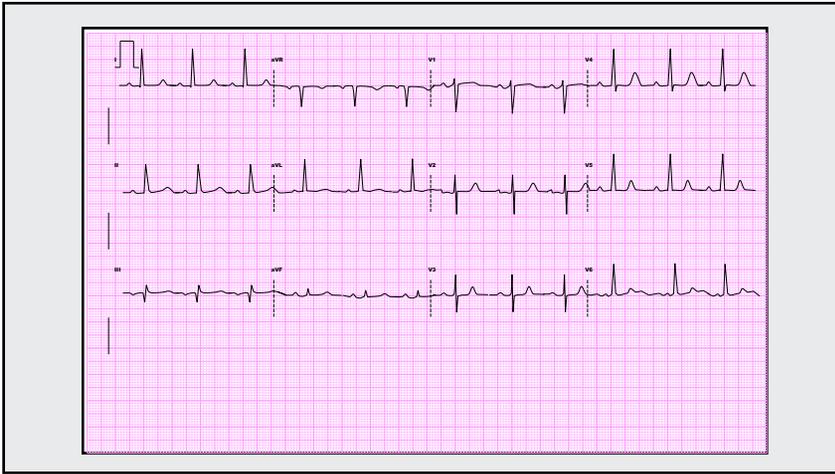


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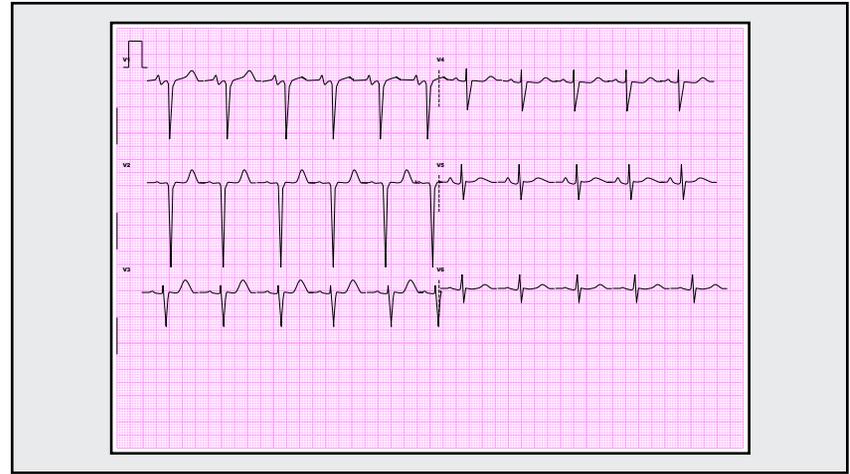
Poor R Wave Progression

- In the normal ECG, the transition from negative V_{1-2} to positive V_{5-6} deflection occurs during V_{3-4} .
- A delay or absence of this transition on ECG just means that anatomically the transition point has moved.

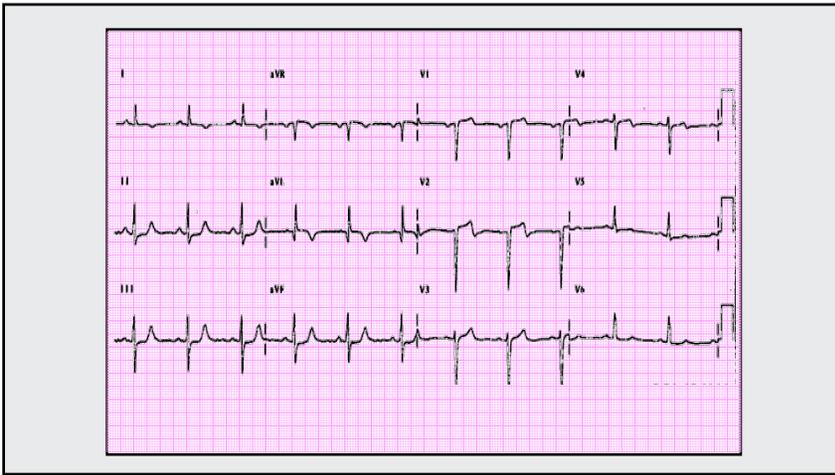
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Causes of PRWP

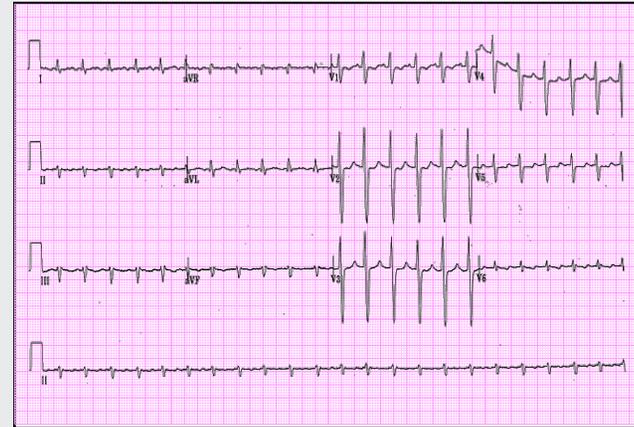
- COPD
- LV dilation
- Anterior wall MI
- Misplaced precordial leads

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Low QRS Voltage

- QRS amplitude <5 mm in all limb leads
- QRS amplitude in V leads usually <10 mm, but not necessary for diagnosis

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Causes of Low QRS Voltage

- Effusion
- Cardiomyopathy
- Hypothyroidism
- Obesity
- Emphysema
- Normal variant

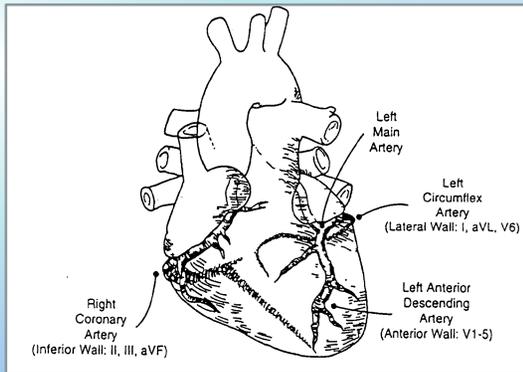
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ST-T Wave Abnormalities

- Ischemia and infarction tend to be regional events.
- Depending upon anatomy, there may be some overlap.
- An event in a large RCA that loops around the lateral wall might cause inferolateral ECG changes
- An event in a large anterior descending artery that has branches to the lateral wall may cause an anterolateral event
- An event in the left main artery may cause an anterolateral event
- Global ST-T changes are more typically caused by pericarditis.

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Arteries and Corresponding Leads



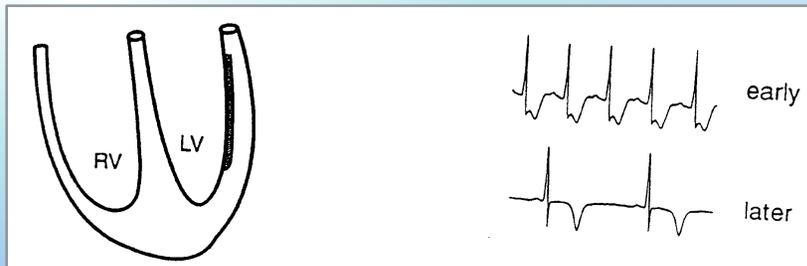
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ST Segment Depression

- Stenosed artery with some retrograde flow
- O₂ demand exceeds supply.
- Subendocardial ischemia
- Region of myocardium furthest from the stenosed artery is occluded.
- If ischemia persists and myocardial injury occurs, a subendocardial MI occurs.
 - Later changes will show T wave inversion.

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Subendocardial Injury

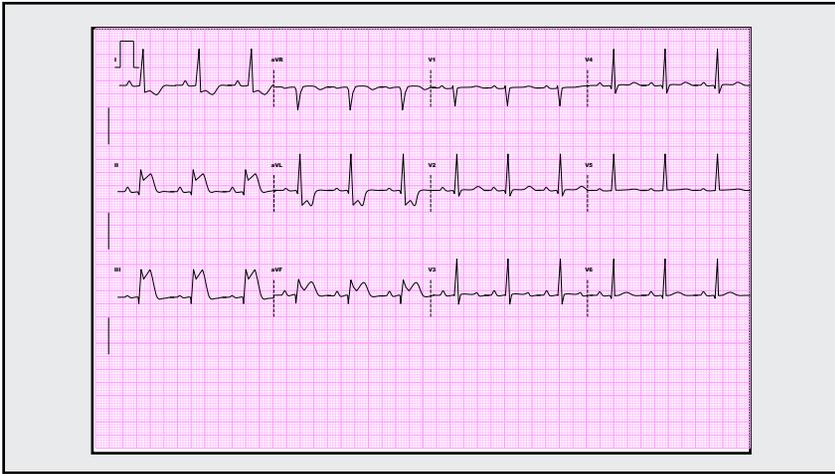


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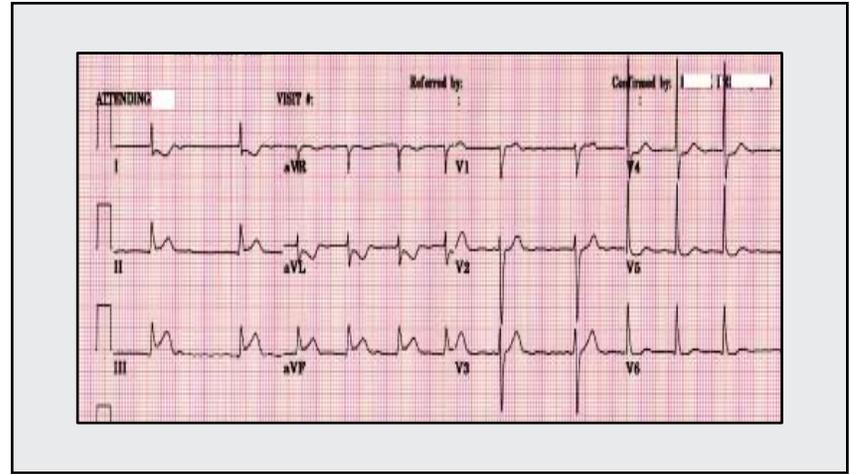
ST Segment Elevation

- Most common cause is transmural MI.
- Affected artery is totally occluded.
- Is the primary ECG indication for thrombolytic therapy
- Prinzmetal's angina (acute vasospasm) usually produces complete vessel occlusion; will produce ST segment elevation if ECG recorded during event
- The size of the inferior and lateral MI is proportional to the sum of the elevation in the appropriate leads.
- The size of the anterior wall MI is proportionate to the number of anterior leads with elevation.

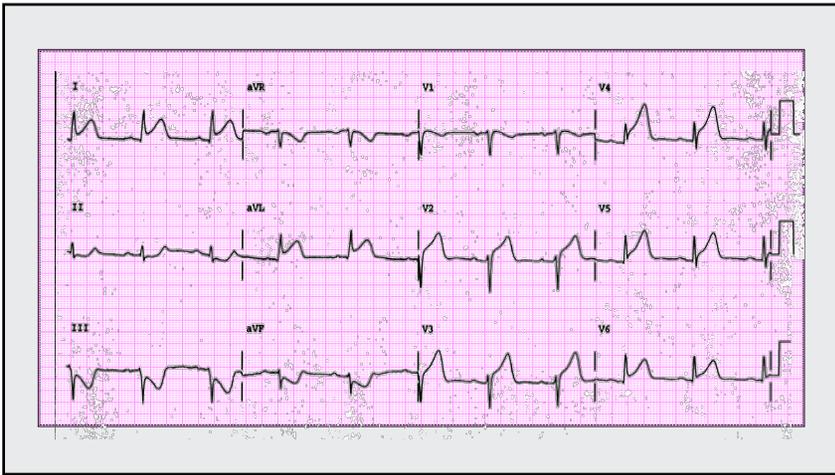
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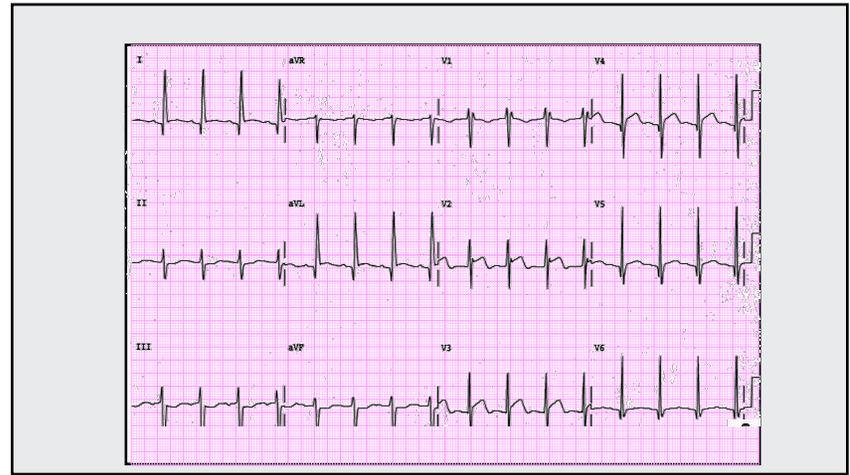
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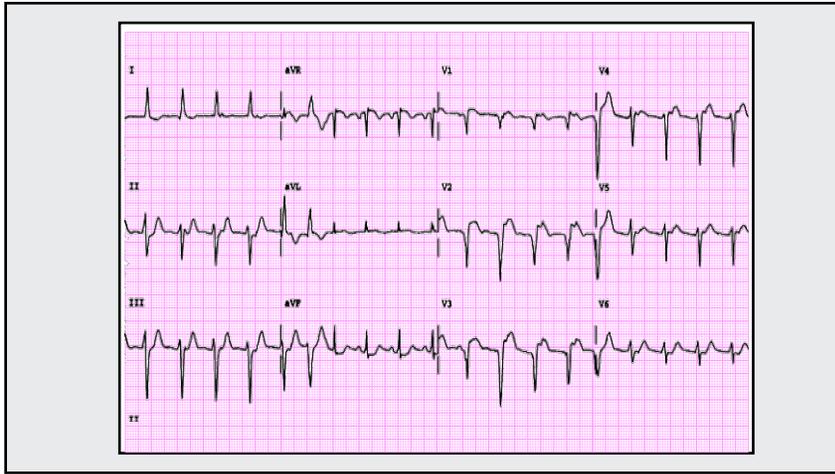
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Other Causes of ST Elevation

- There are causes of ST elevation that are not specific to myocardial damage.
 - Pericarditis
 - Early repolarization



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Non-specific ST Changes

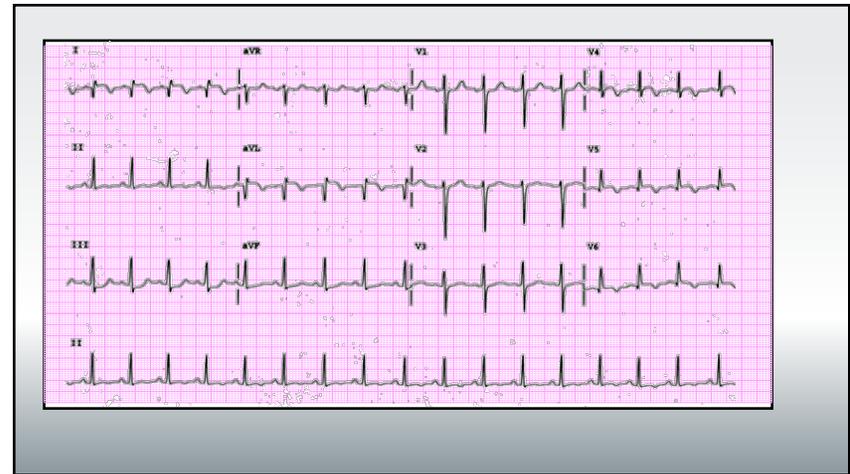
- A label typically applied to ST depression that is not placed in a clinical context
- Specific ST changes
 - During exercise ECG
 - During chest pain

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T Wave Inversion

- Reflects altered repolarization of ventricular muscle during ischemia/injury event
- May reflect permanent injury with scar formation and loss of muscle; permanent atypical path of repolarization

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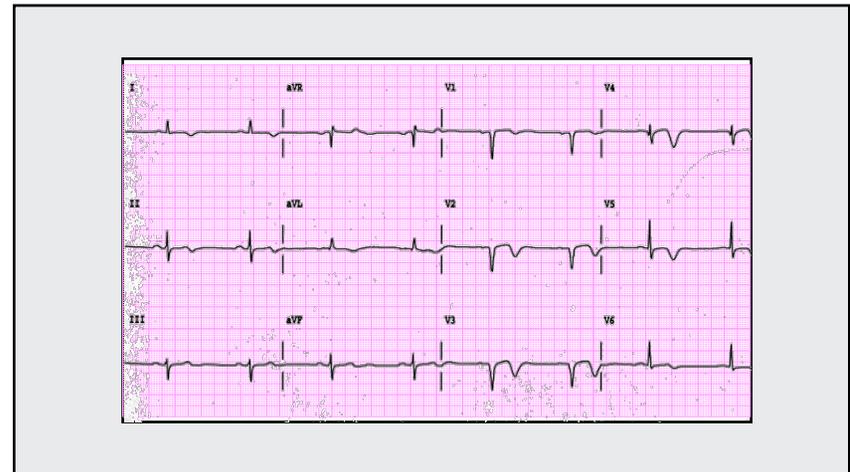


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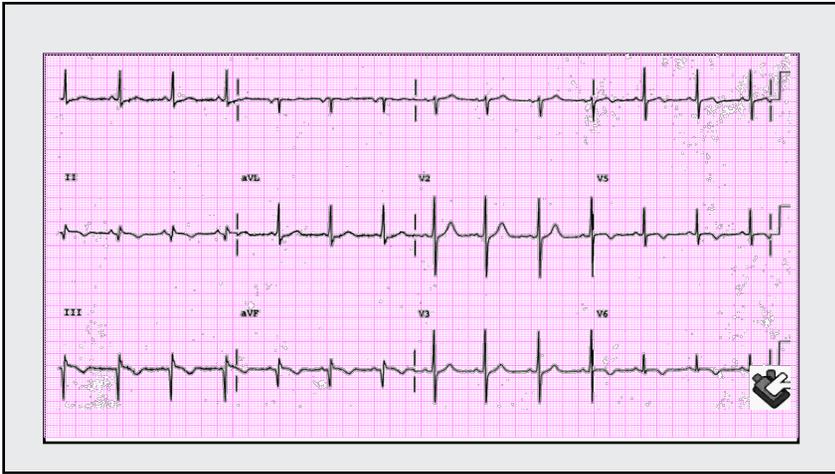
Q Waves

- Initial negative deflection of the QRS complex
- Must be 1 mm deep and 1 mm wide to be significant
- May be normal in leads III and V₆
- A Q wave indicates transmural injury.

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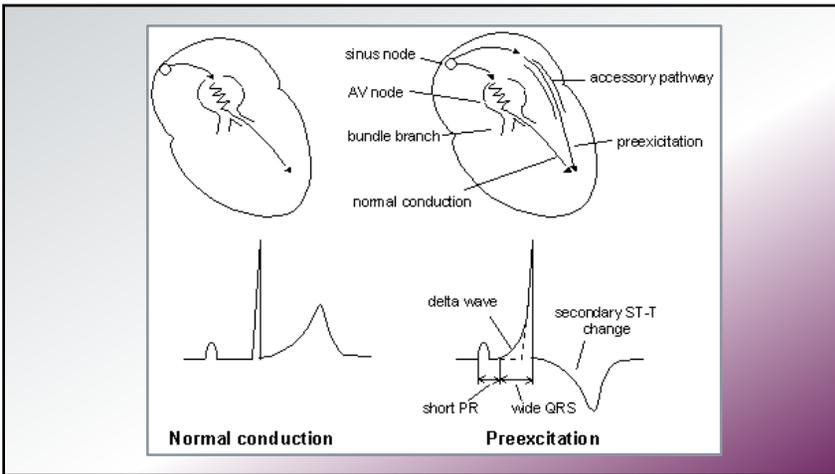


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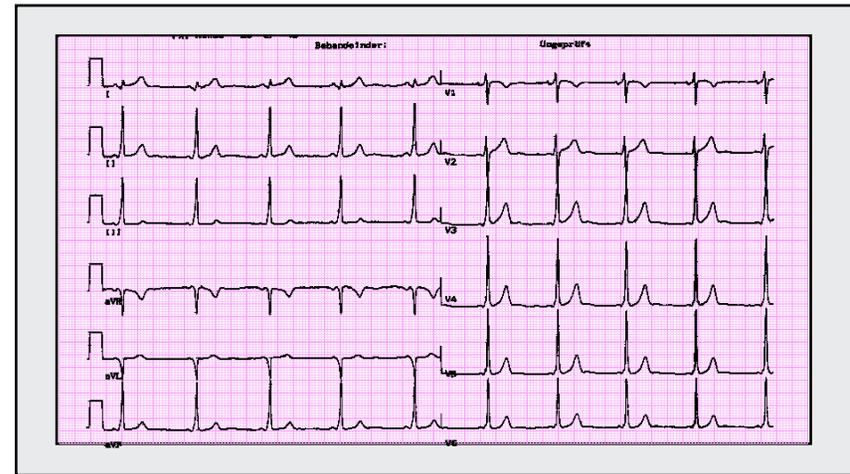
WPW Syndrome

- Activation of accessory pathway results in preexcitation of the ventricle
- Delta wave may appear to be a Q wave
- No history of MI
- Normal echocardiogram
- Short P-R interval

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Case Study

41-year-old Female

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Chief Complaint

- A 41-year-old female presents with a chief complaint of chest pain and getting out of breath too easily.
- She power walks/jogs each day and actually had to stop because she was so out of breath.

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History of Present Illness

- The patient reports that she is generally in good health. She has just noticed that in the last few weeks or so she gets tired easily.
- She was finally prompted to seek care when she had to stop her job for SOB.

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History of Present Illness (continued)

- She admits to a kind of “dull” chest discomfort that is hard to describe. She is aware of it. It comes and goes but it doesn't really stop her from doing anything.
- It is not sharp or easy to localize.

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History of Present Illness

- She specifically denies
 - Radiation of the discomfort
 - Pain or discomfort to neck, arm, jaw
 - No associated sx, e.g., diaphoresis, n/v
 - Association with rest or activity

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Review of Systems

- Otherwise, noncontributory
- She was queried specifically regarding history of
 - Constitutional sx
 - Other cardiopulmonary sx
 - Hemoptysis
 - Bleeding (skin, GI, GYN)

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PMH/PSH

- Dyslipidemia
- Hypertension
- Gastric bypass procedure 2 years ago
 - Her two previous medical problems resolved entirely with wt loss.

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Medications

- Vitamin B₁₂ 500 mcg daily
- Vitamin D and calcium combination supplement daily
- MVI daily

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Family Hx

- Mother aged 70 y
 - Obesity
 - Dyslipidemia
 - T2DM
 - HTN
- Father died age 52 y of MI
- Brother aged 48 y
 - Obesity
 - HTN
 - T2DM

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Social Hx

- Pt lives with her husband. She has no children.
- Works as a telephone tech support person
- Denies tobacco or recreational drug use
- Rare ETOH <6 × year
- Monogamous with husband

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Case Study (continued)

Physical exam

- 41-year-old female 5'3" (160 cm) 164 lbs (74.4 kg)
- 97.5 °F (36.4°C) P=60 bpm, RR=16 bpm, BP=134/82 mm Hg
- Well-groomed
- In NAD
- Skin color normal, warm/dry

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Case Study (continued)

Physical exam (cont.)

- CN II-XII grossly normal
- HEENT WNL
- Neck without nodes, bruit, thyromegaly but + minimal JVD
- Lung sounds are clear
- Cardiac exam reveals
 - A grade II/VI systolic murmur at 4th ICS LSB
 - Very loud S₂

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Case Study (continued)

Physical exam (cont.)

- Peripheral pulses are normal.
- Examination of the extremities reveals 1+ pitting edema from mid-calf down. There is no hyperpigmentation.

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Case Study (continued)

Physical exam (cont.)

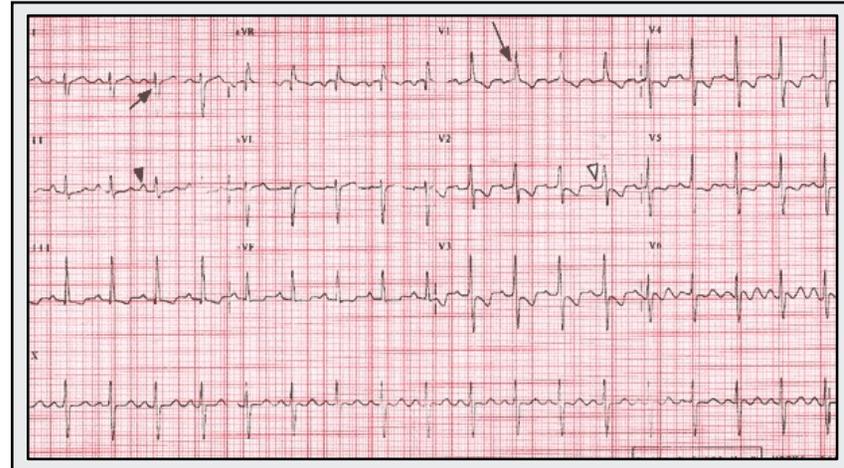
- The abdomen is basically normal. Organ palpation is limited due to large amount of excess skin.
 - Large well-healed scar is apparent.
 - No bruit
 - No organomegaly
 - No pulsations

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Office Diagnostics

- Routine labs are drawn.
- 12-lead ECG
 - Right atrial abnormality
 - Right bundle branch block
 - Right axis deviation

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Office Spirometry

- Essentially WNL
- No obstructive dysfunction
- Total lung capacity (TLC) 72% predicted

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Laboratory Results

- CMP was WNL.
- CBC
 - Significant for Hgb/ HCT of 17.8 g/dL (178 g/L)/ 53%
 - WBC differential was normal.

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Case Study 44-year-old Male

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Case Study: 44-year-old Male

- The patient presents with dull retrosternal chest pain.
 - Began acutely with a tearing sensation
 - 3 days duration
- Unable to "get comfortable"
- Denies any recent viral infection or significant medical history

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Case Study (continued)

- No family history of cardiovascular disease
- The patient is taking no medications and he denies illicit drug use.

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Case Study (continued)

Physical exam

- The patient is alert, uncomfortable, and afebrile.
- Blood pressure is 160/102 mm Hg.
- Equal and symmetric pulses in both carotid and brachial arteries.

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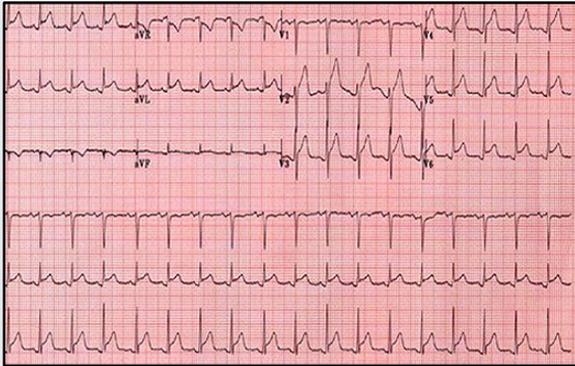
Case Study (continued)

Physical exam (cont.)

- There is a diastolic murmur in the aortic region.
 - No gallop or pericardial rub
- Heart sounds are distant.
- The patient's pulmonary, abdominal, and neurologic examinations are unremarkable.

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What are the findings on the ECG?



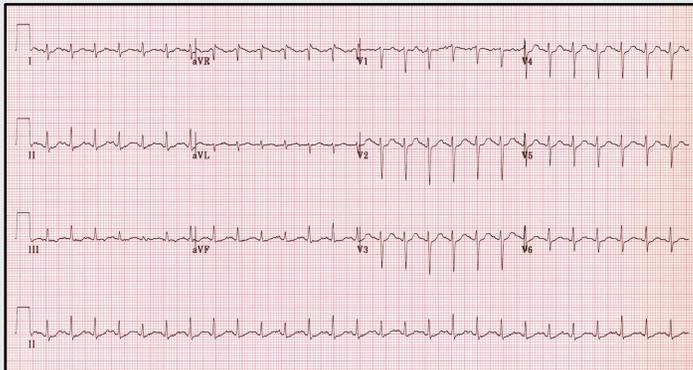
121

Aortic Dissection



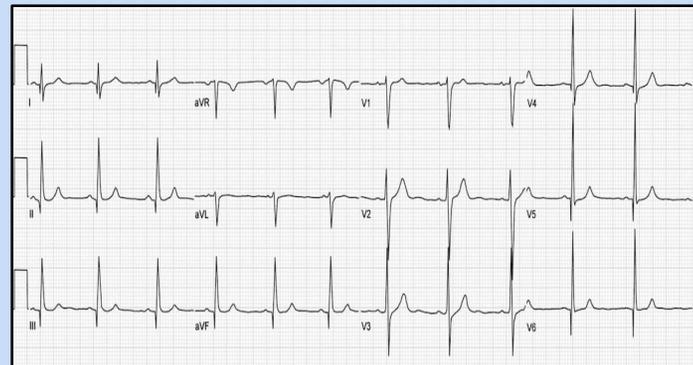
122

Myocarditis



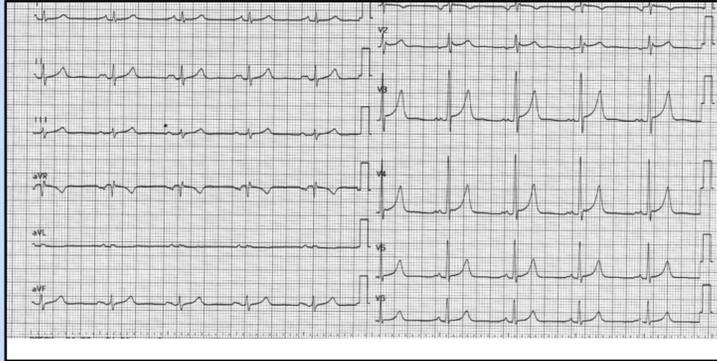
123

Hypertrophic Cardiomyopathy



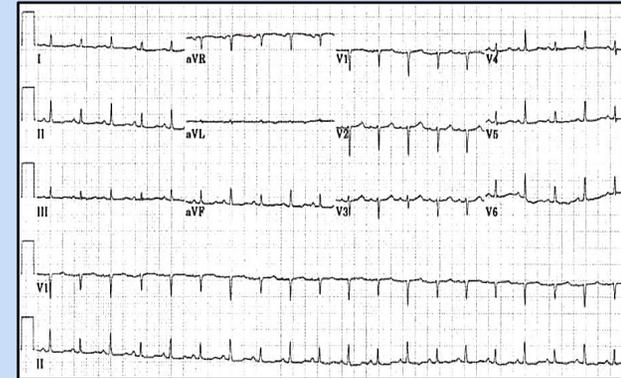
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Mitral Valve Prolapse



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Effusion



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End of Presentation!
Thank you for your time and attention.

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