Fitzgerald
Colibri Healthcare

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.

4

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.

5

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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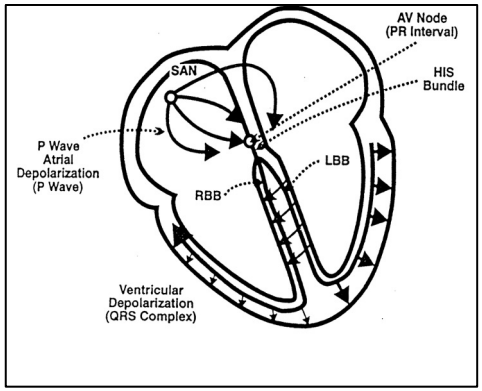
Initiation and Propagation



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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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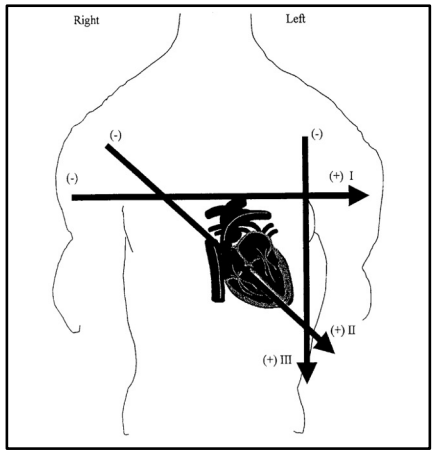

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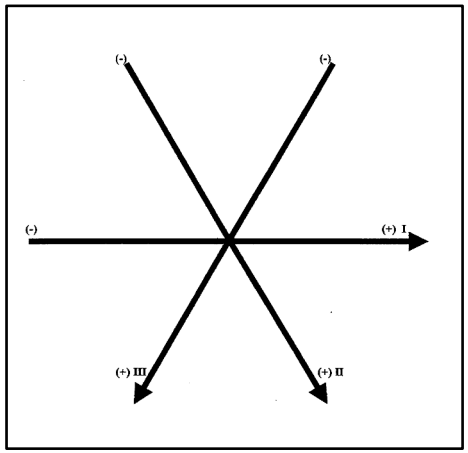
The Hexaxial Plot



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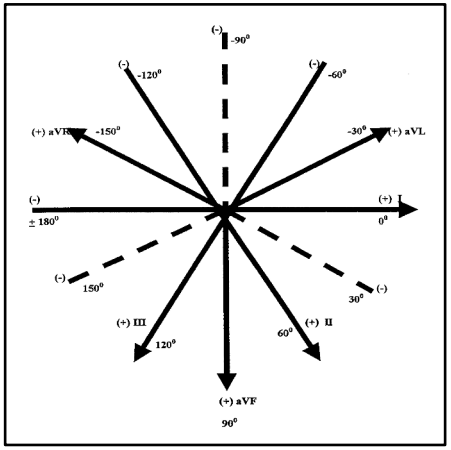
The Hexaxial Plot



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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° 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°, this represents a right axis deviation.

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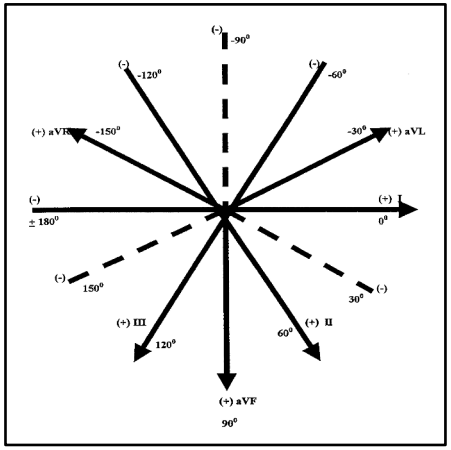
The Hexaxial Plot



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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 <½ 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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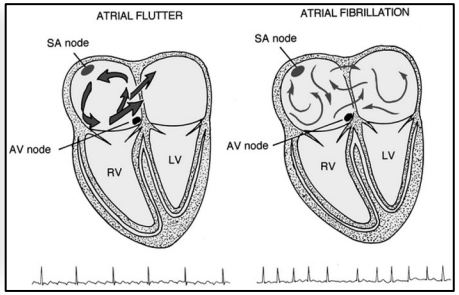
Atrial Flutter/Fibrillation

- 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 (V_1 to V_6), 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.

Inferior Wall	Lateral Wall	Anterior Wall
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 V_1 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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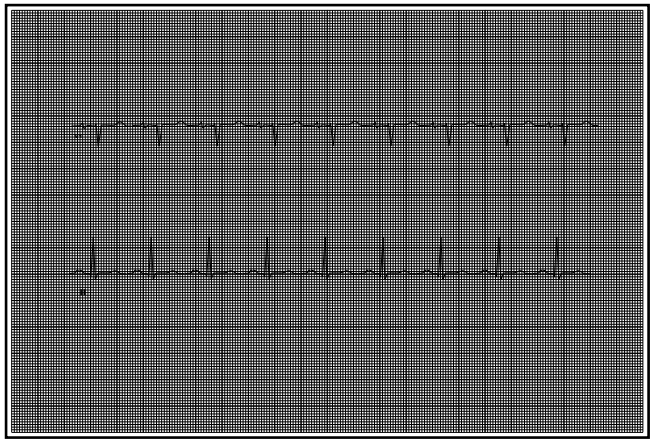

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Right Atrial Abnormalities

- 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. V_1 initial deflection is positive
  - LV depolarization produces a downward deflection in V_1.
  - 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 V_1.
    - This is followed by normal LV activation, but right bundle is blocked.
    - Late current LV to RV results in second upward deflection in V_1.
    - After RV activation, return to baseline.

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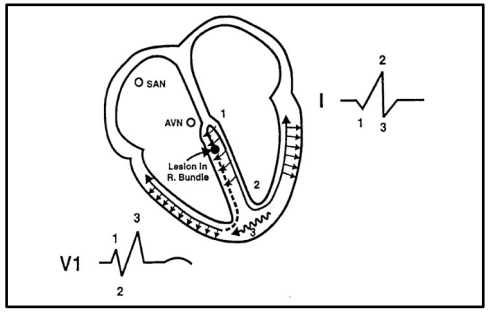
Right Bundle Branch



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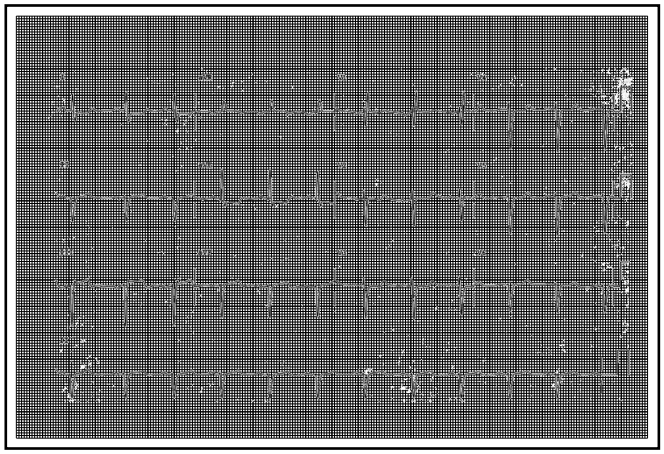

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Incomplete RBBB

- 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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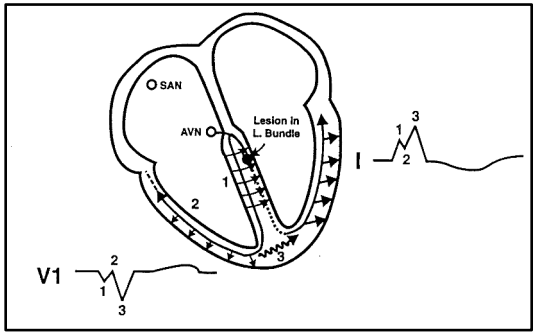
LBBB



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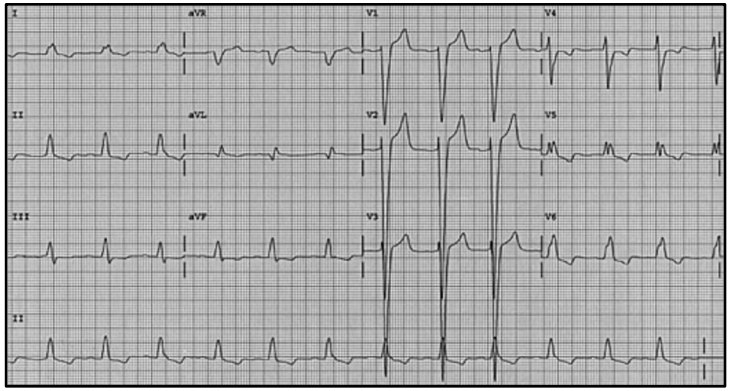

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Fascicular Blocks

- 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^{o} and not caused by IWMI.
- LPFB is diagnosed by right axis deviation, at least >90^{o}, usually >110^{o} to 120^{o}.

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LAFB

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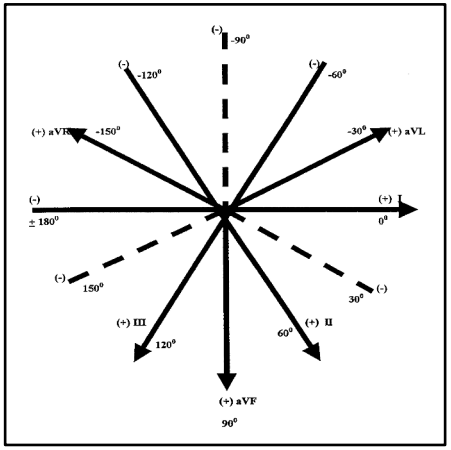
The Hexaxial Plot



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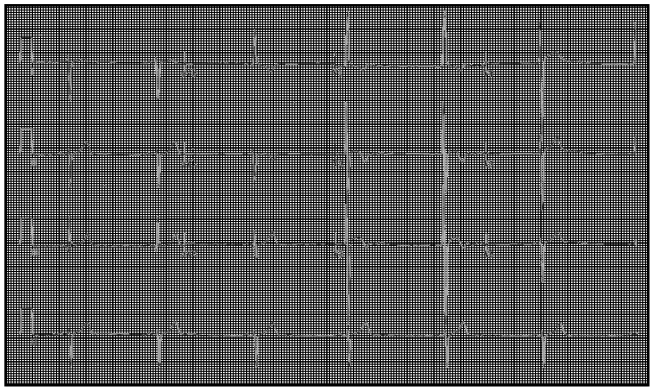
LPFB



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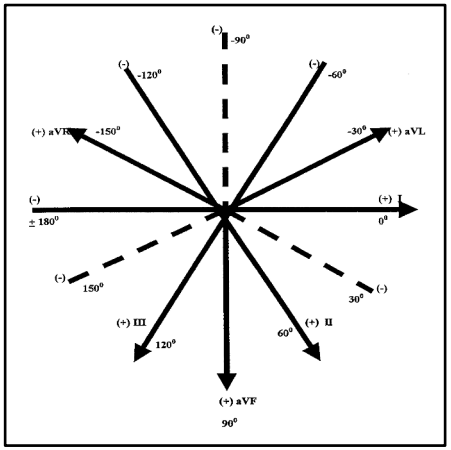
The Hexaxial Plot



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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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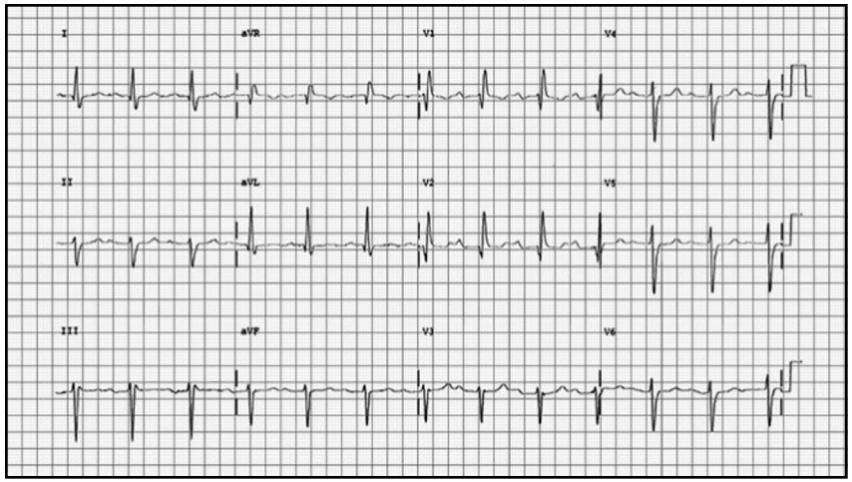

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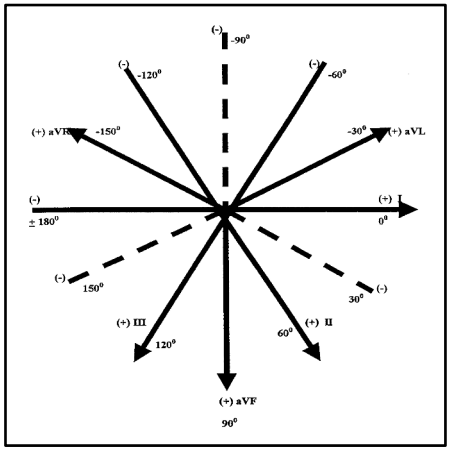
The Hexaxial Plot



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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 ≥30 mm
  - R wave in V_5 or V_6 ≥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 > -30º= **2** points
- QRS duration ≥0.09 sec= **1** point
- Intrinsicoid deflection in V_5 or V_6 ≥0.05 sec= **1** point

5 or more points= LVH
4 points= Probable LVH

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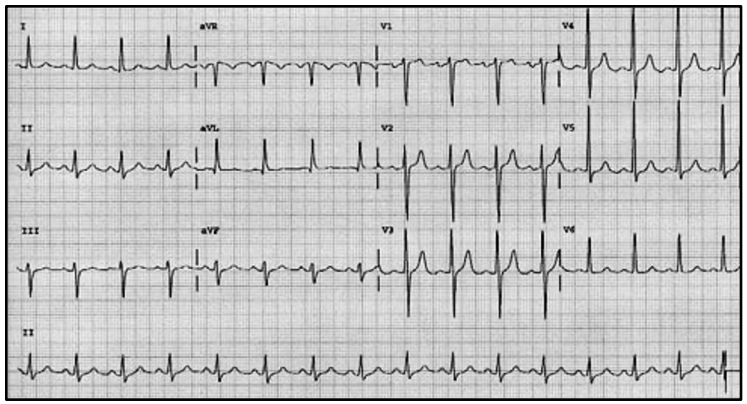

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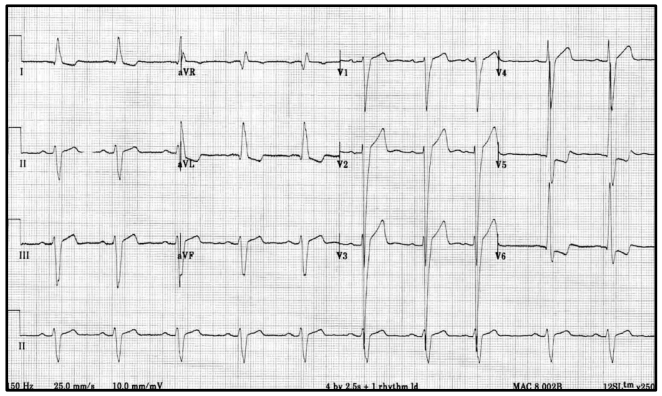

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Right Ventricular Hypertrophy

- 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 ≥110°
  - Right atrial abnormality
  - ST depression + T wave inversion in V_1 or V_2

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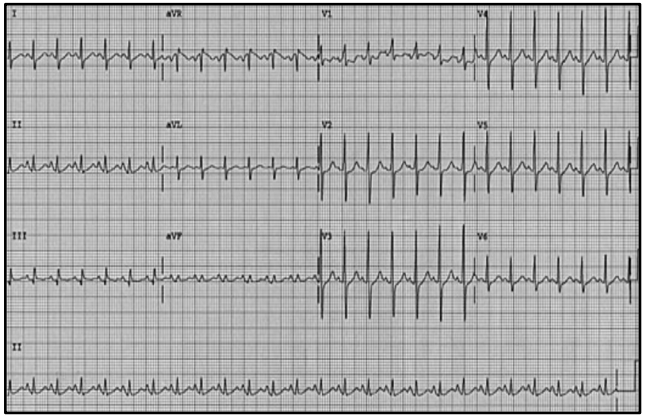

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Poor R Wave Progression

- 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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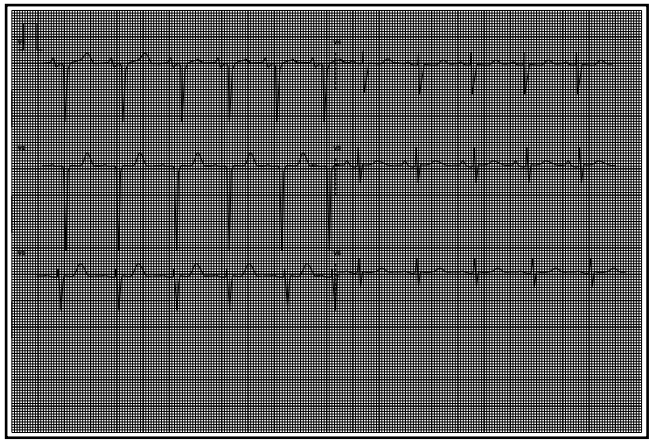

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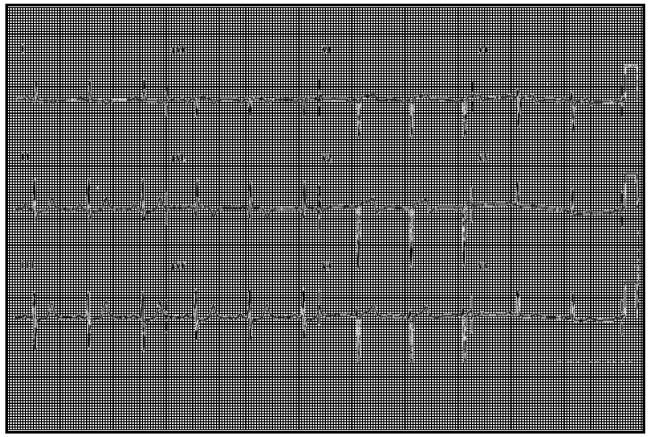

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Causes of PRWP

- 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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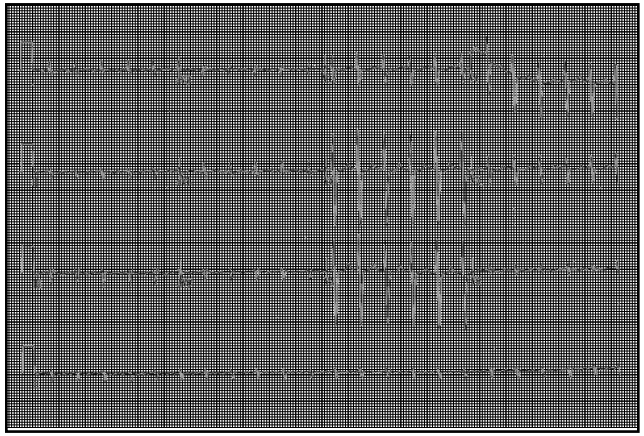

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Causes of Low QRS Voltage

- 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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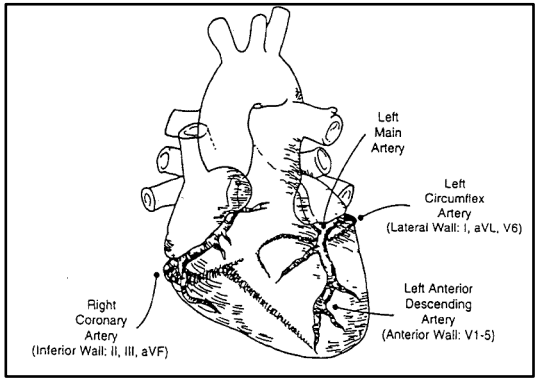
Arteries and Corresponding Leads



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ST Segment Depression

- Stenosed artery with some retrograde flow
- O_2 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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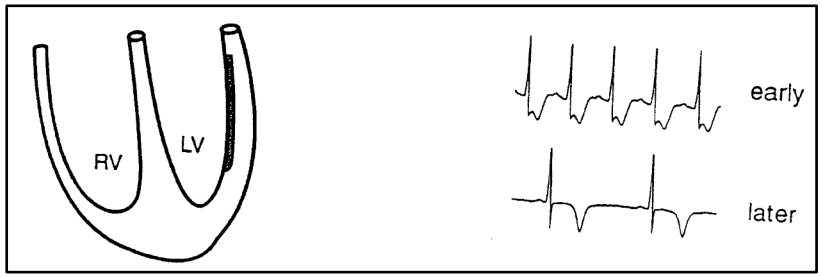
Subendocardial Injury



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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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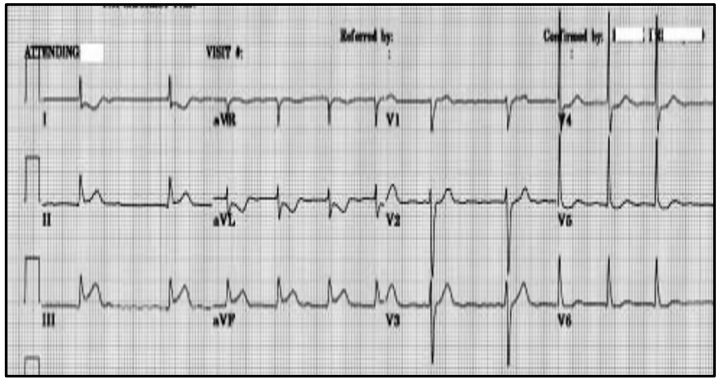
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VISIT #:
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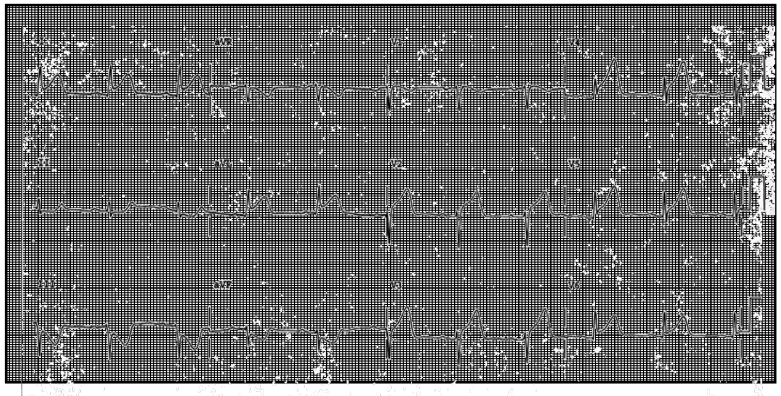

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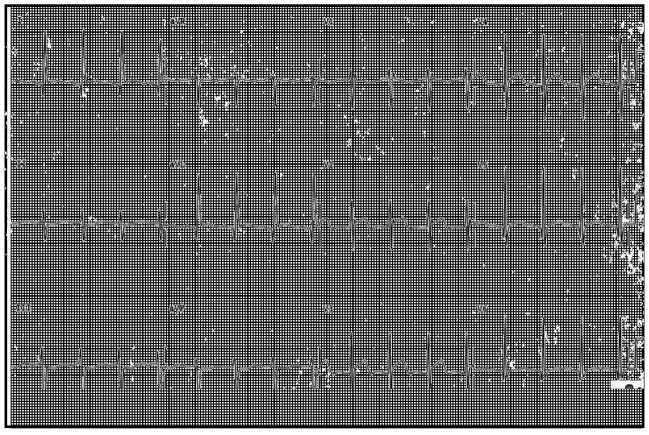

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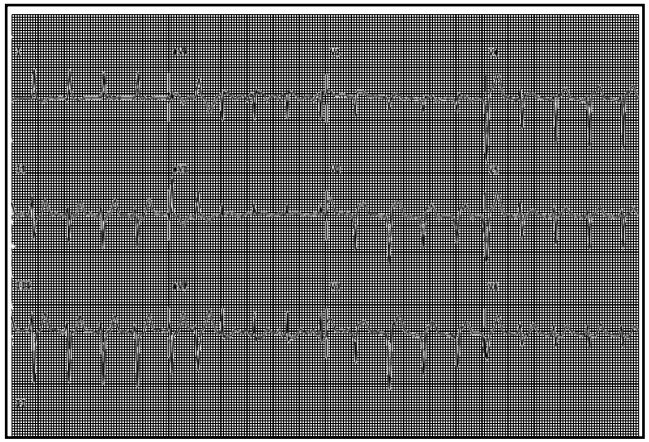

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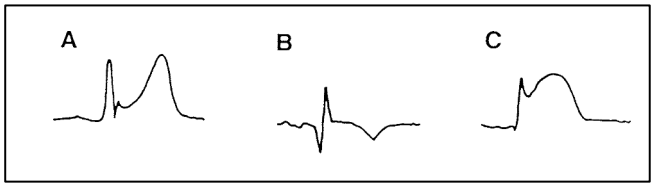
Other Causes of ST Elevation

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



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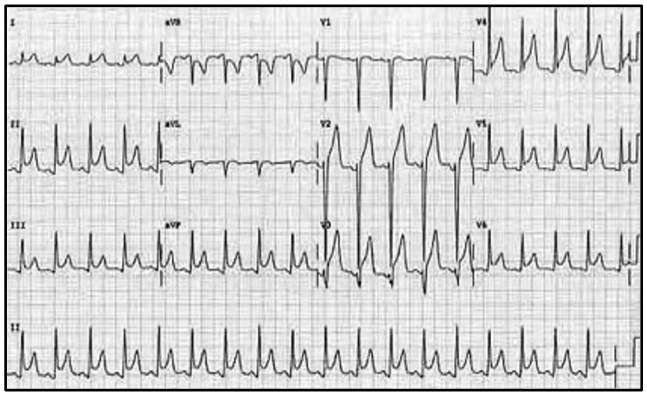

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Non-specific ST Changes

- 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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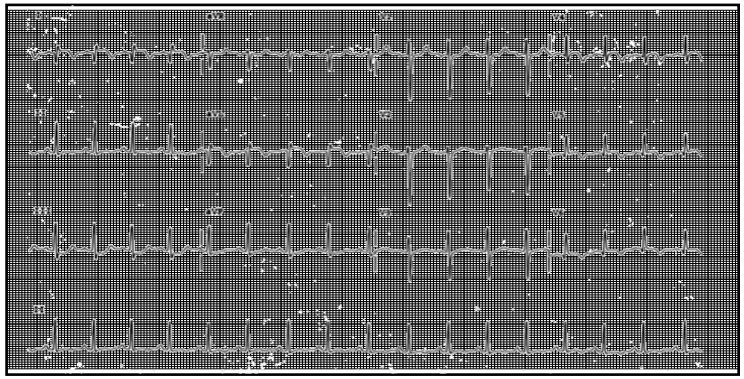

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Q Waves

- 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 V_6
- A Q wave indicates transmural injury.

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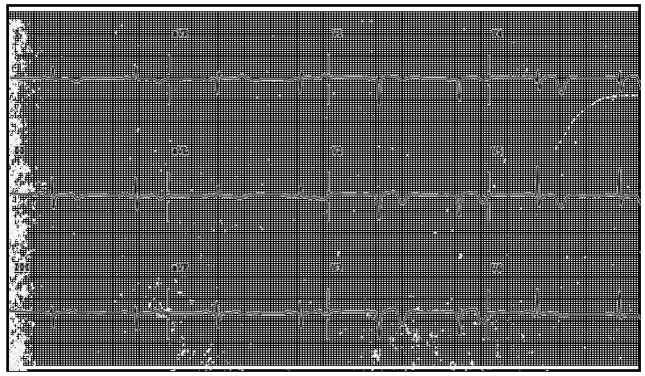

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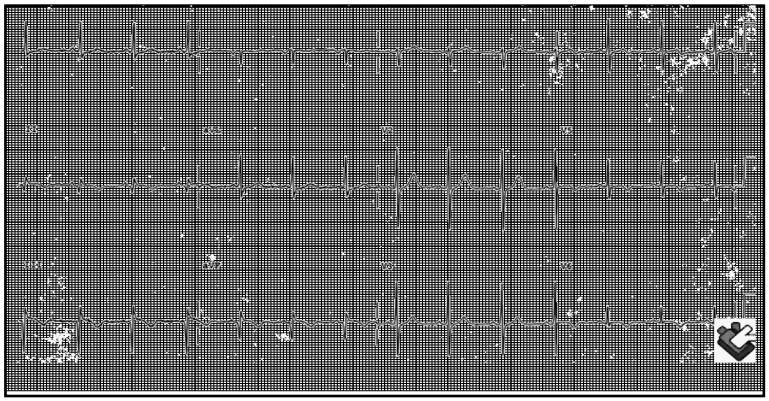

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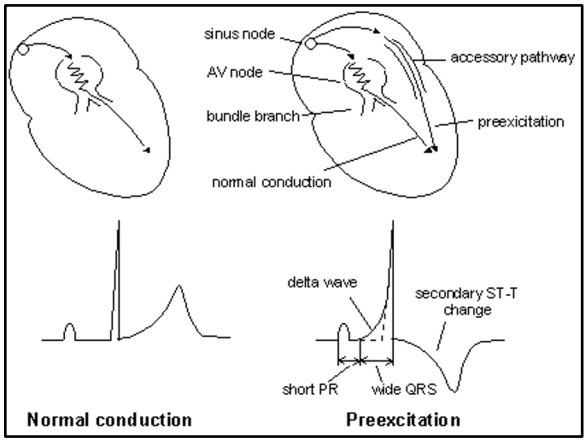
WPW Syndrome

- 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

94



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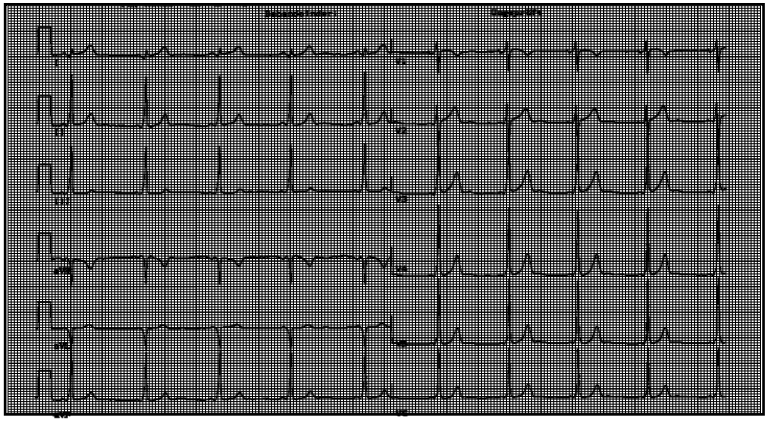

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Case Study

41-year-old Female

97

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.

98

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.

99

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.

100

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

101

Review of Systems

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

102

PMH/PSH

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

103

Medications

- Vitamin B_{12} 500 mcg daily
- Vitamin D and calcium combination supplement daily
- MVI daily

104

Family Hx

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

105

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

106

Case Study (continued)

Physical exam

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

107

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 S_2

108

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.

109

Case Study (continued)

Physical exam (cont.)

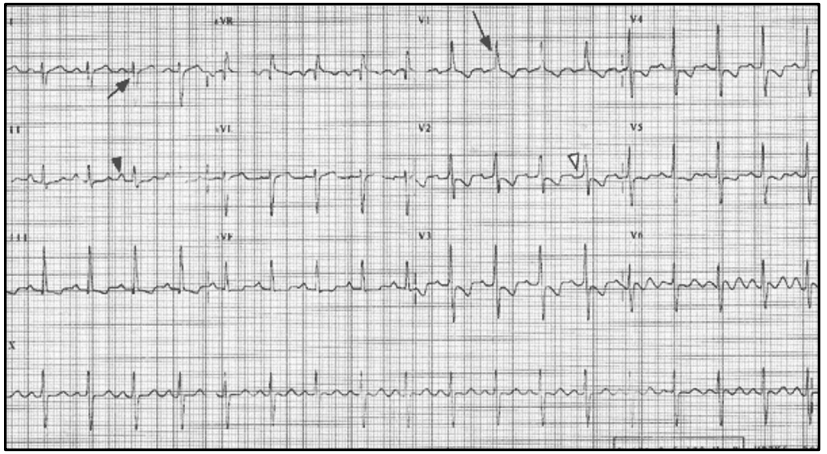
- The abdomen is basically normal. Organ palpation is limited due to large amount of excess skin.
  - Large well-healed scar is apparent.
  - No bruit
  - No organomegaly
  - No pulsations

110

Office Diagnostics

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

111



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Office Spirometry

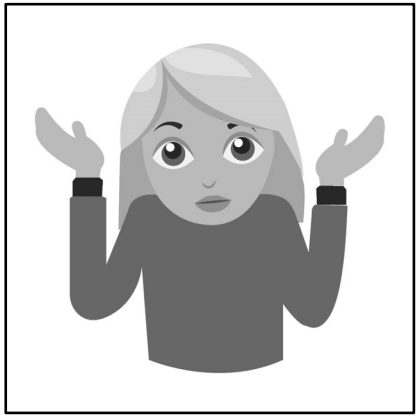
- Essentially WNL
- No obstructive dysfunction
- Total lung capacity (TLC) 72% predicted

113

Laboratory Results

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

114



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Case Study

44-year-old Male

116

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

117

Case Study (continued)

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

118

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.

119

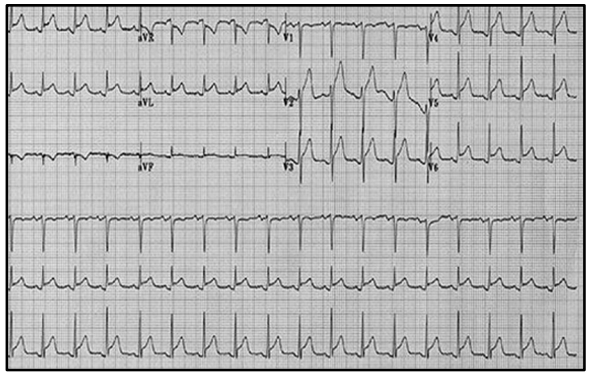
Case Study (continued)

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.

120

What are the findings on the ECG?



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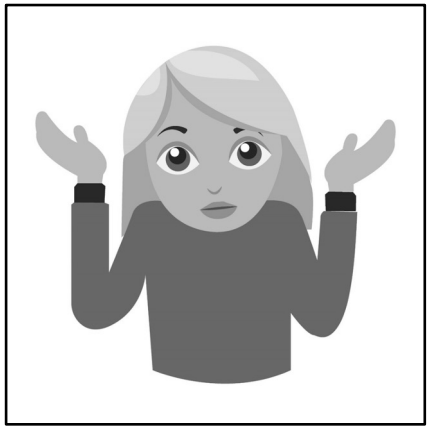
Aortic Dissection



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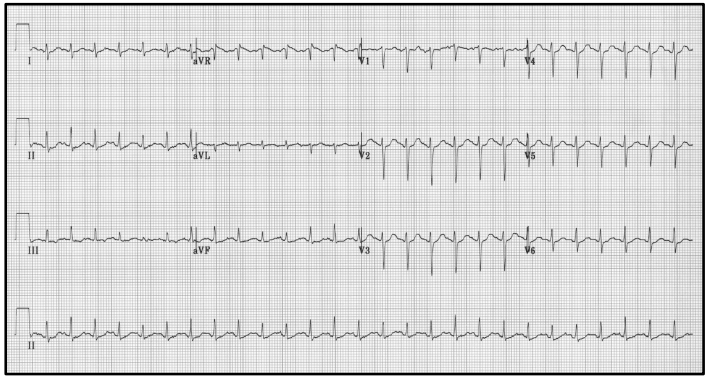
Myocarditis



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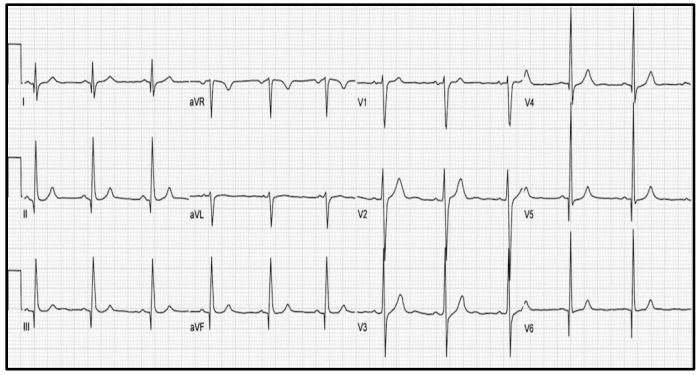
Hypertrophic Cardiomyopathy



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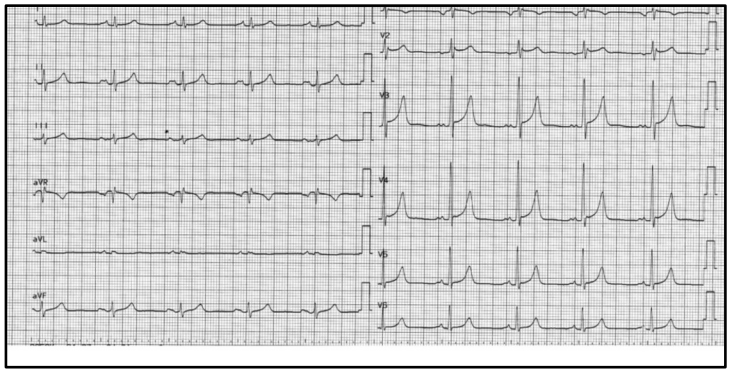
Mitral Valve Prolapse



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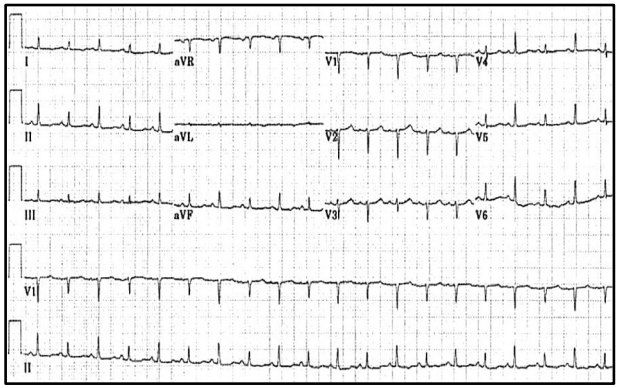
Effusion



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End of Presentation!

Thank you for your time and attention.

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