ECG Interpretation in Clinical Practice

Presentation Objectives

- To recognize the normal rhythm of the heart - “Normal Sinus Rhythm.”
- To recognize the 13 most common rhythm disturbances.
- To recognize an acute myocardial infarction on a 12-lead ECG.

The Learning Module

- **ECG Basics**
- How to Analyze a Rhythm
- Normal Sinus Rhythm
- Heart Arrhythmias
- Diagnosing a Myocardial Infarction
- Advanced 12-Lead Interpretation

Normal Impulse Conduction

Sinoatrial node

↓

AV node

↓

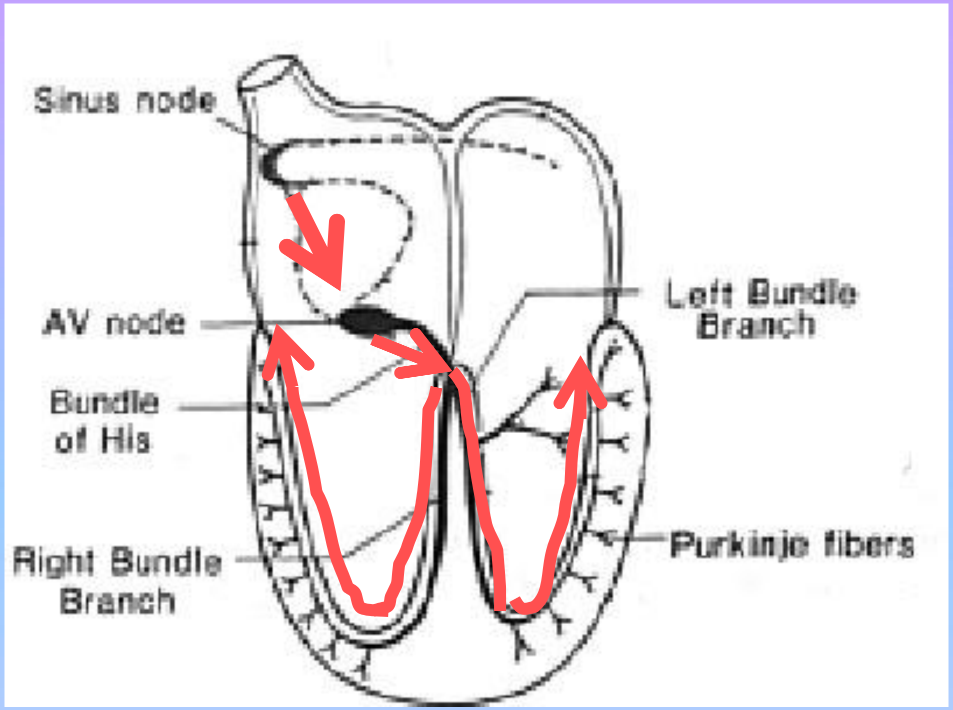
Bundle of His

↓

Bundle Branches

↓

Purkinje fibers



Impulse Conduction & the ECG

Sinoatrial node

↓

AV node

↓

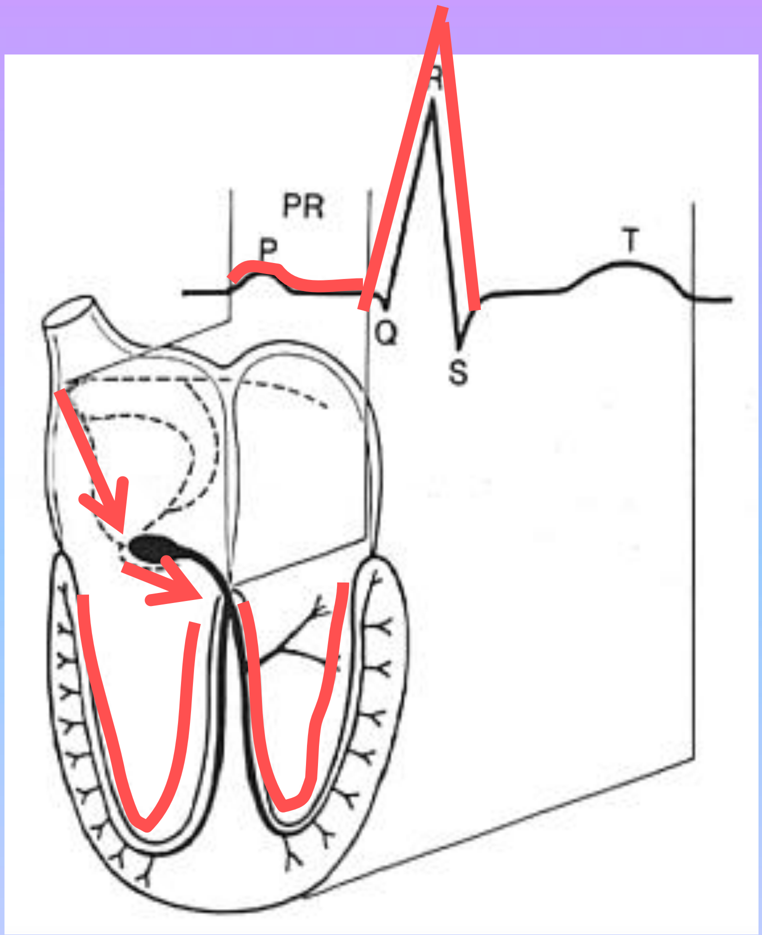
Bundle of His

↓

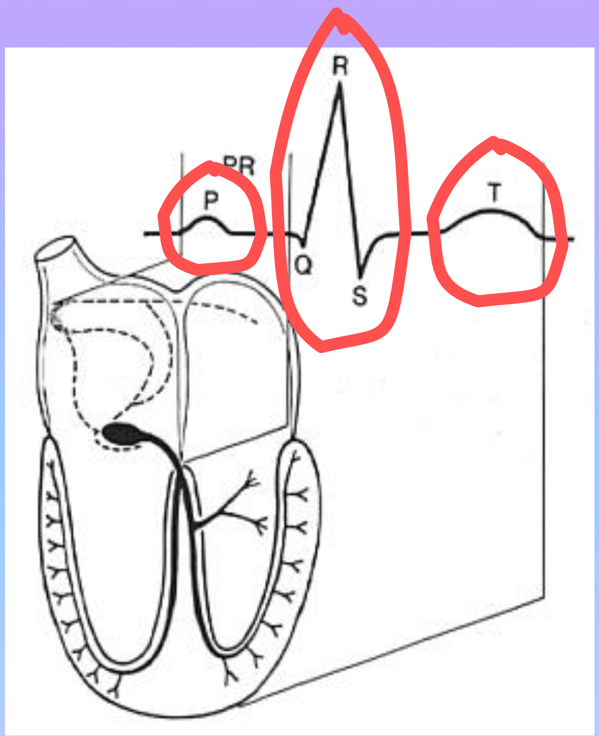
Bundle Branches

↓

Purkinje fibers



The "PQRST"



- P wave - Atrial depolarization
- QRS - Ventricular depolarization
- T wave - Ventricular repolarization

The PR Interval

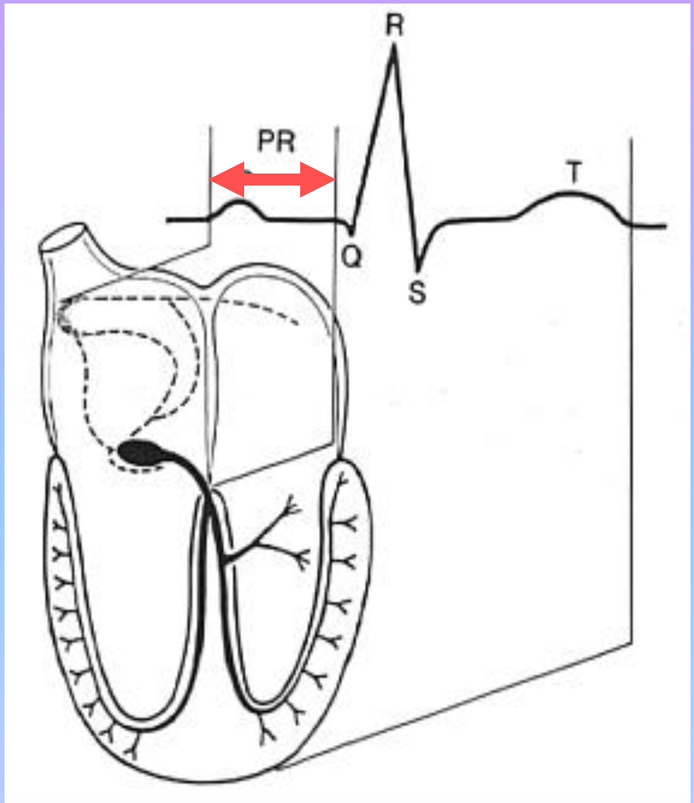
Atrial depolarization

+

delay in AV junction

(AV node/Bundle of His)

(delay allows time for the atria to contract before the ventricles contract)

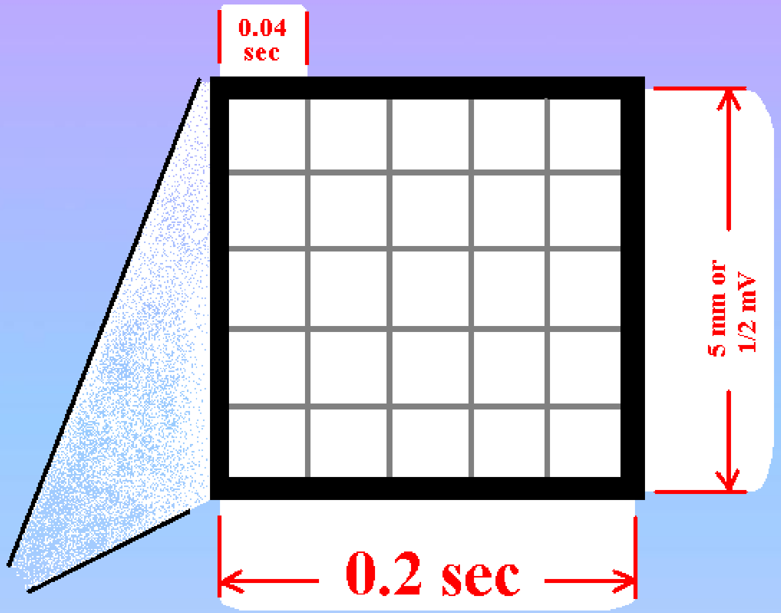


Pacemakers of the Heart

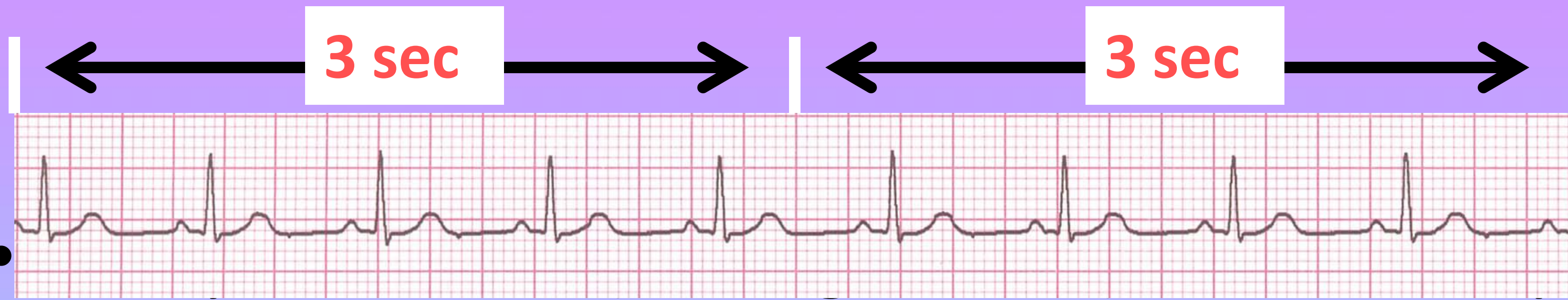
- SA Node - Dominant pacemaker with an intrinsic rate of 60 - 100 beats/minute.
- AV Node - Back-up pacemaker with an intrinsic rate of 40 - 60 beats/minute.
- Ventricular cells - Back-up pacemaker with an intrinsic rate of 20 - 45 bpm.

The ECG Paper

- Horizontally
  - One small box - 0.04 s
  - One large box - 0.20 s
- Vertically
  - One large box - 0.5 mV



The ECG Paper (cont)



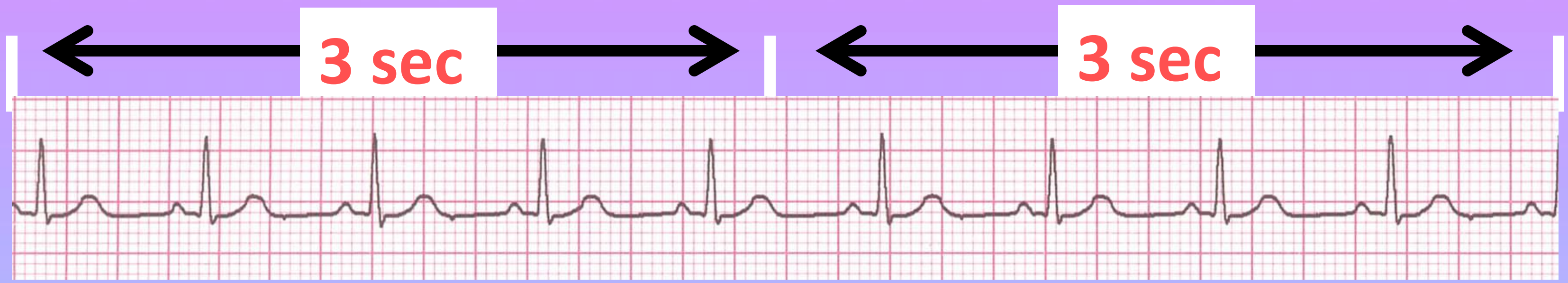
- a vertical line.
- This helps when calculating the heart rate.

NOTE: the following strips are not marked but all are 6 seconds long.

Rhythm Analysis

- Step 1: Calculate rate.
- Step 2: Determine regularity.
- Step 3: Assess the P waves.
- Step 4: Determine PR interval.
- Step 5: Determine QRS duration.

Step 1: Calculate Rate



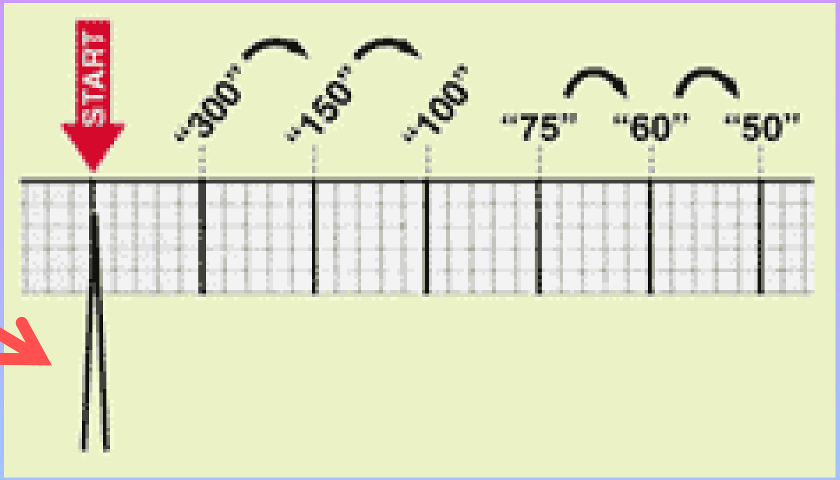
- Option 1
  - Count the # of R waves in a 6 second rhythm strip, then multiply by 10.
  - Reminder: all rhythm strips in this Module are 6 seconds in length.

Interpretation?

9 x 10 = 90 bpm

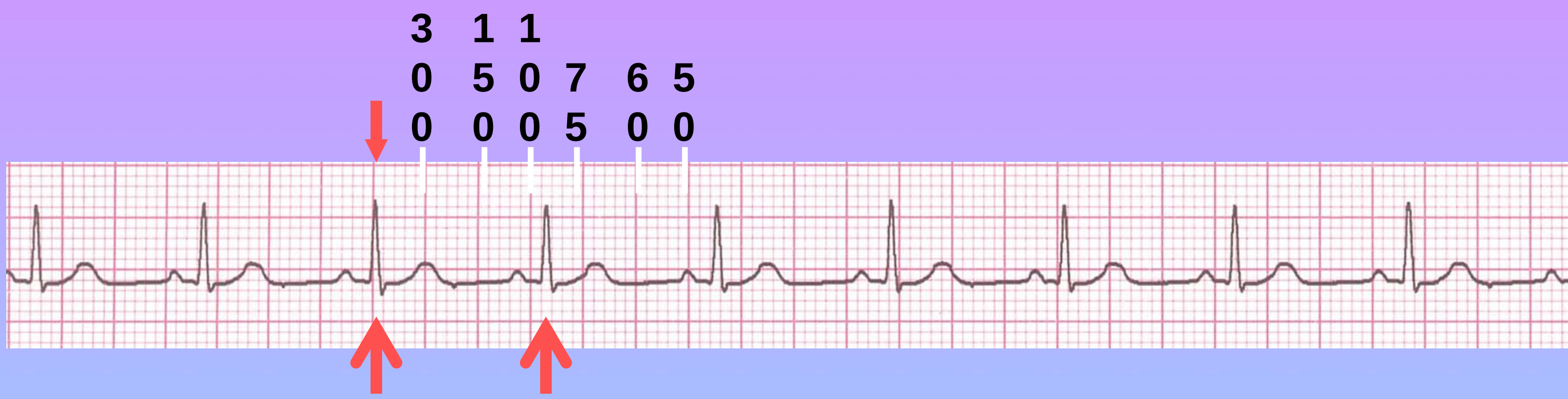
Step 1: Calculate Rate

R wave



- Option 2
  - Find a R wave that lands on a bold line.
  - Count the # of large boxes to the next R wave. If the second R wave is 1 large box away the rate is 300, 2 boxes - 150, 3 boxes - 100, 4 boxes - 75, etc. (cont)

Step 1: Calculate Rate



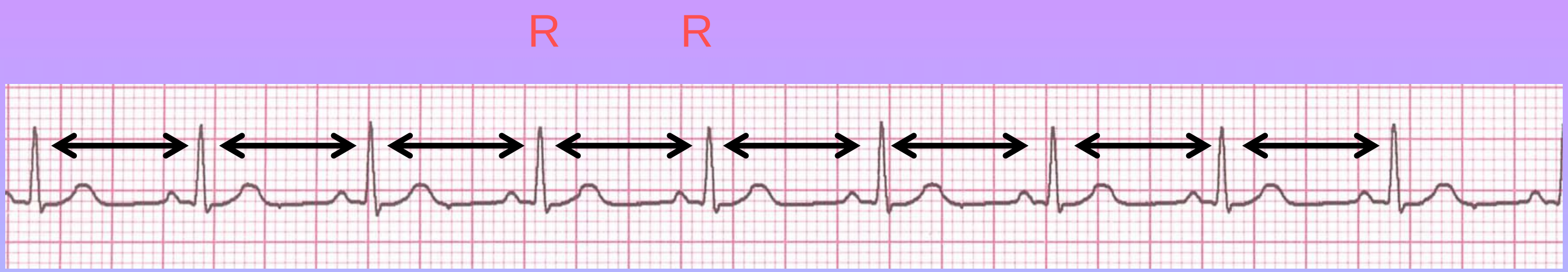
- Option 2 (cont)
  - Memorize the sequence:

300 - 150 - 100 - 75 - 60 - 50

Interpretation?

Approx. 1 box less than 100 = 95 bpm

Step 2: Determine regularity



- Look at the R-R distances (using a caliper or markings on a pen or paper).
- Regular (are they equidistant apart)? Occasionally irregular? Regularly irregular? Irregularly irregular?

Interpretation?

Regular

Step 3: Assess the P waves

- Are there P waves?
- Do the P waves all look alike?
- Do the P waves occur at a regular rate?
- Is there one P wave before each QRS?

Interpretation?

Normal P waves with 1 P wave for every QRS

Step 4: Determine PR interval

- Normal: 0.12 - 0.20 seconds.

  (3 - 5 boxes)

Interpretation?

0.12 seconds

Step 5: QRS duration

- Normal: 0.04 - 0.12 seconds.

  (1 - 3 boxes)

Interpretation?

0.08 seconds

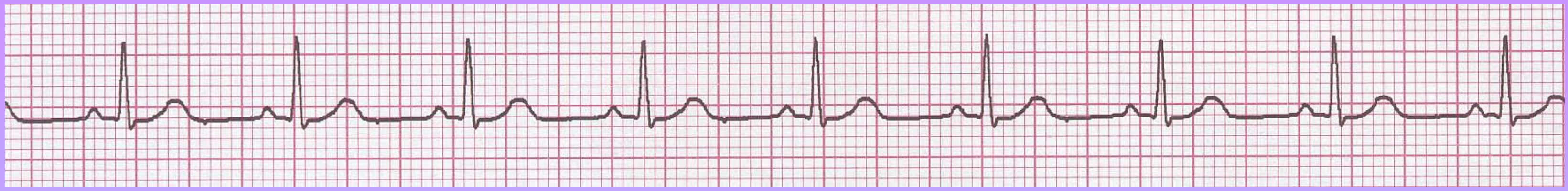
Rhythm Summary

• Rate	90-95 bpm
• Regularity	regular
• P waves	normal
• PR interval	0.12 s
• QRS duration	0.08 s
Interpretation?	*Normal Sinus Rhythm*

Normal Sinus Rhythm (NSR)

- Etiology: the electrical impulse is formed in the SA node and conducted normally.
- This is the normal rhythm of the heart; other rhythms that do not conduct via the typical pathway are called arrhythmias.

NSR Parameters



- Rate 60 - 100 bpm
- Regularity regular
- P waves normal
- PR interval 0.12 - 0.20 s
- QRS duration 0.04 - 0.12 s

<u>Any deviation from above is sinus tachycardia, sinus bradycardia or an arrhythmia</u>

Arrhythmia Formation

Arrhythmias can arise from problems in the:

- Sinus node
- Atrial cells
- AV junction
- Ventricular cells

SA Node Problems

The SA Node can:

- fire too slow — *Sinus Bradycardia*
- fire too fast — *Sinus Tachycardia*

Sinus Tachycardia may be an appropriate response to stress.

Atrial Cell Problems

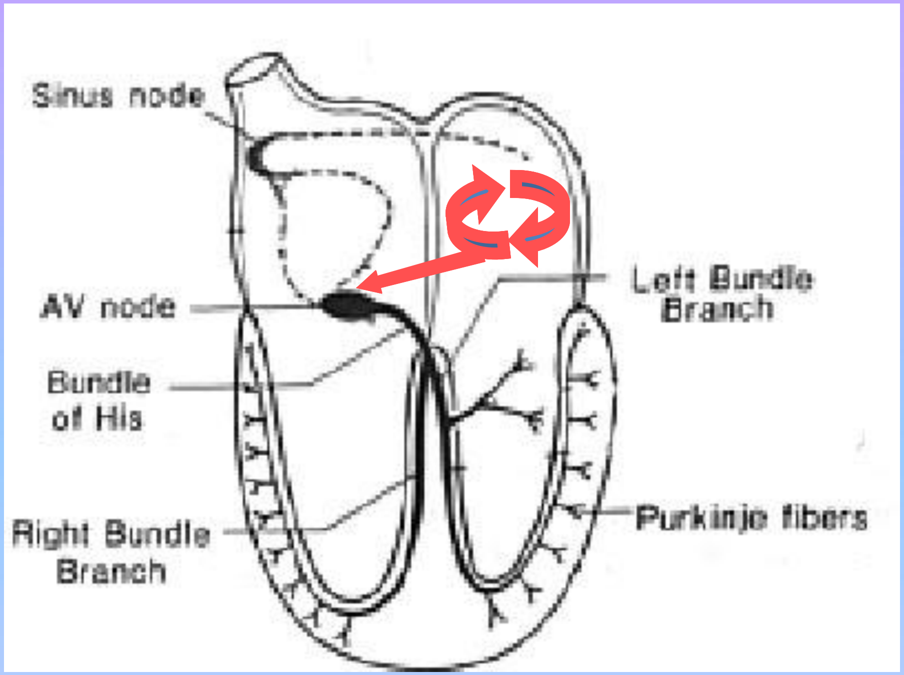
Atrial cells can:

- fire occasionally from a focus — *Premature Atrial Contractions (PACs)*

- fire continuously due to a looping re-entrant circuit — *Atrial Flutter*

Teaching Moment

- A re-entrant pathway occurs when an impulse loops and results in self-perpetuating impulse formation.



Atrial Cell Problems

Atrial cells can also:

• fire continuously from multiple foci

Atrial Fibrillation

or

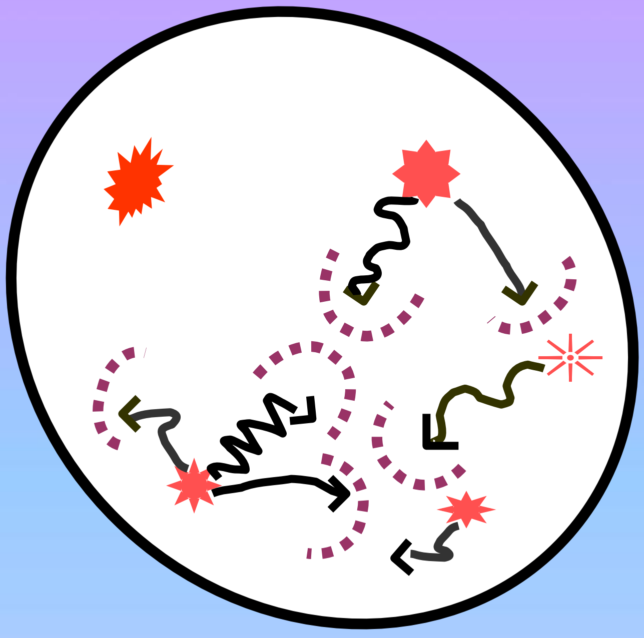
fire continuously due to multiple micro re-entrant "wavelets"

Atrial Fibrillation

Teaching Moment

Multiple micro re-entrant "wavelets" refers to wandering small areas of activation which generate fine chaotic impulses. Colliding wavelets can, in turn, generate new foci of activation.

Atrial tissue



AV Junctional Problems

The AV junction can:

- fire continuously due to a looping re-entrant circuit

Paroxysmal Supraventricular Tachycardia

- block impulses coming from the SA Node

AV Junctional Blocks

Ventricular Cell Problems

Ventricular cells can:

- fire occasionally from 1 or more foci — ***Premature Ventricular Contractions (PVCs)***
- fire continuously from multiple foci — ***Ventricular Fibrillation***
- fire continuously due to a looping re-entrant circuit — ***Ventricular Tachycardia***

Arrhythmias

- Sinus Rhythms
- Premature Beats
- Supraventricular Arrhythmias
- Ventricular Arrhythmias
- AV Junctional Blocks

Sinus Rhythms

- *Sinus Bradycardia*
- *Sinus Tachycardia*

Rhythm #1

- Rate? 30 bpm
- Regularity? regular
- P waves? normal
- PR interval? 0.12 s
- QRS duration? 0.10 s

Interpretation? *Sinus Bradycardia*

Sinus Bradycardia

- Deviation from NSR
  - Rate < 60 bpm

Sinus Bradycardia

- **Etiology:** SA node is depolarizing slower than normal, impulse is conducted normally (i.e. normal PR and QRS interval).

Rhythm #2

- Rate? 130 bpm
- Regularity? regular
- P waves? normal
- PR interval? 0.16 s
- QRS duration? 0.08 s

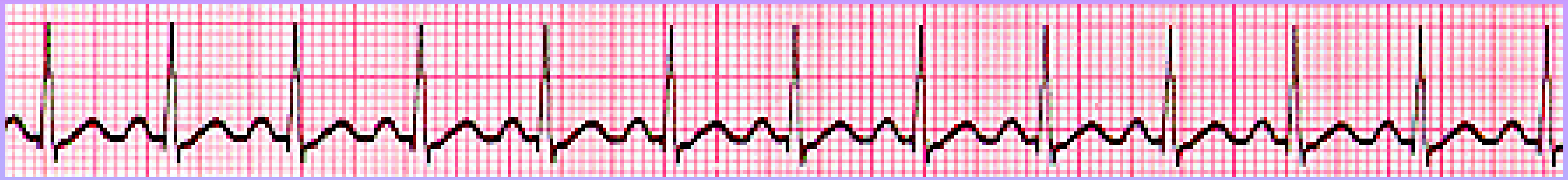
Interpretation? ***Sinus Tachycardia***

Sinus Tachycardia

- Deviation from NSR

  - Rate > 100 bpm

Sinus Tachycardia



- Etiology: SA node is depolarizing faster than normal, impulse is conducted normally.
- Remember: sinus tachycardia is a response to physical or psychological stress, not a primary arrhythmia.

Premature Beats

- *Premature Atrial Contractions*
  (PACs)
- *Premature Ventricular Contractions*
  (PVCs)

Rhythm #3

- Rate? 70 bpm
- Regularity? occasionally irreg.
- P waves? 2/7 different contour
- PR interval? 0.14 s (except 2/7)
- QRS duration? 0.08 s

Interpretation? *NSR with Premature Atrial Contractions*

Premature Atrial Contractions

- Deviation from NSR
  - These ectopic beats originate in the atria (but not in the SA node), therefore the contour of the P wave, the PR interval, and the timing are different than a normally generated pulse from the SA node.

Premature Atrial Contractions

- Etiology: Excitation of an atrial cell forms an impulse that is then conducted normally through the AV node and ventricles.

Teaching Moment

- When an impulse originates anywhere in the atria (SA node, atrial cells, AV node, Bundle of His) and then is conducted normally through the ventricles, the QRS will be narrow (0.04 - 0.12 s).

Rhythm #4

- Rate? 60 bpm
- Regularity? occasionally irreg.
- P waves? none for 7th QRS
- PR interval? 0.14 s
- QRS duration? 0.08 s (7th wide)

Interpretation? *Sinus Rhythm with 1 PVC*

PVCs

- Deviation from NSR
  - Ectopic beats originate in the ventricles resulting in wide and bizarre QRS complexes.
  - When there are more than 1 premature beats and look alike, they are called “uniform”. When they look different, they are called “multiform”.

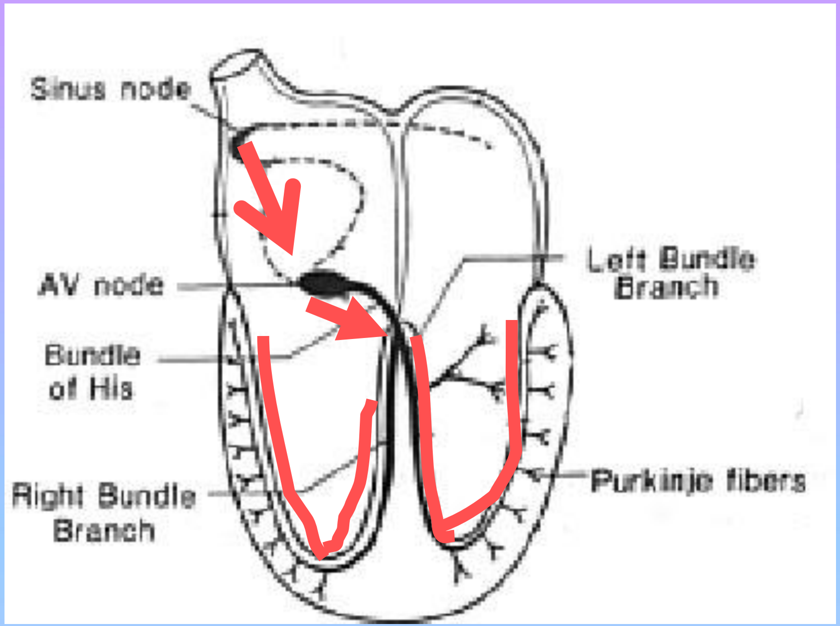
PVCs

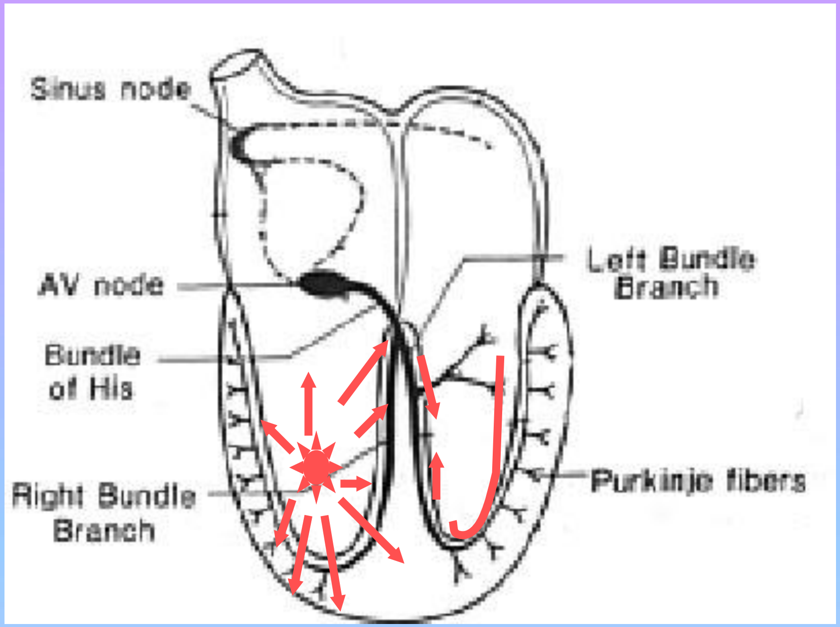
- Etiology: One or more ventricular cells are depolarizing and the impulses are abnormally conducting through the ventricles.

Teaching Moment

- When an impulse originates in a ventricle, conduction through the ventricles will be inefficient and the QRS will be wide and bizarre.

Ventricular Conduction





Normal

Signal moves rapidly through the ventricles

Abnormal

Signal moves slowly through the ventricles

Arrhythmias

- Sinus Rhythms
- Premature Beats
- Supraventricular Arrhythmias
- Ventricular Arrhythmias
- AV Junctional Blocks

Supraventricular Arrhythmias

- *Atrial Fibrillation*
- *Atrial Flutter*
- *Paroxysmal Supraventricular Tachycardia*

Rhythm #5

- Rate? 100 bpm
- Regularity? irregularly irregular
- P waves? none
- PR interval? none
- QRS duration? 0.06 s

Interpretation? *Atrial Fibrillation*

Atrial Fibrillation

- Deviation from NSR
  - No organized atrial depolarization, so no normal P waves (impulses are not originating from the sinus node).
  - Atrial activity is chaotic (resulting in an irregularly irregular rate).
  - Common, affects 2-4%, up to 5-10% if > 80 years old

Atrial Fibrillation

- Etiology: Recent theories suggest that it is due to multiple re-entrant wavelets conducted between the R & L atria. Either way, impulses are formed in a totally unpredictable fashion. The AV node allows some of the impulses to pass through at variable intervals (so rhythm is irregularly irregular).

Rhythm #6

• Rate?	70 bpm
• Regularity?	regular
• P waves?	flutter waves
• PR interval?	none
• QRS duration?	0.06 s

Interpretation? *Atrial Flutter*

Atrial Flutter

- Deviation from NSR
  - No P waves. Instead flutter waves (note “sawtooth” pattern) are formed at a rate of 250 - 350 bpm.
  - Only some impulses conduct through the AV node (usually every other impulse).

Atrial Flutter

- Etiology: Reentrant pathway in the right atrium with every 2nd, 3rd or 4th impulse generating a QRS (others are blocked in the AV node as the node repolarizes).

Rhythm #7

- Rate? 74 → 148 bpm
- Regularity? Regular → regular
- P waves? Normal → none
- PR interval? 0.16 s → none
- QRS duration? 0.08 s

Interpretation? *Paroxysmal Supraventricular Tachycardia (PSVT)*

PSVT

- Deviation from NSR
  - The heart rate suddenly speeds up, often triggered by a PAC (not seen here) and the P waves are lost.

PSVT

- Etiology: There are several types of PSVT but all originate above the ventricles (therefore the QRS is narrow).

- Most common: abnormal conduction in the AV node (reentrant circuit looping in the AV node).

Ventricular Fibrillation

- Etiology: The ventricular cells are excitable and depolarizing randomly.

- Rapid drop in cardiac output and death occurs if not quickly reversed

AV Nodal Blocks

- *1st Degree AV Block*
- *2nd Degree AV Block, Type I*
- *2nd Degree AV Block, Type II*
- *3rd Degree AV Block*

Rhythm #10

- Rate? 60 bpm
- Regularity? regular
- P waves? normal
- PR interval? 0.36 s
- QRS duration? 0.08 s

Interpretation? *1st Degree AV Block*

1st Degree AV Block

- Deviation from NSR
  - PR Interval > 0.20 s

1st Degree AV Block

- Etiology: Prolonged conduction delay in the AV node or Bundle of His.

Rhythm #11

- Rate? 50 bpm
- Regularity? regularly irregular
- P waves? nl, but 4th no QRS
- PR interval? lengthens
- QRS duration? 0.08 s

Interpretation? *2nd Degree AV Block, Type I*

2nd Degree AV Block, Type I

- Deviation from NSR
  - PR interval progressively lengthens, then the impulse is completely blocked (P wave not followed by QRS).

2nd Degree AV Block, Type I

- Etiology: Each successive atrial impulse encounters a longer and longer delay in the AV node until one impulse (usually the 3rd or 4th) fails to make it through the AV node.

Rhythm #12

- Rate? 40 bpm
- Regularity? regular
- P waves? nl, 2 of 3 no QRS
- PR interval? 0.14 s
- QRS duration? 0.08 s

Interpretation? *2nd Degree AV Block, Type II*

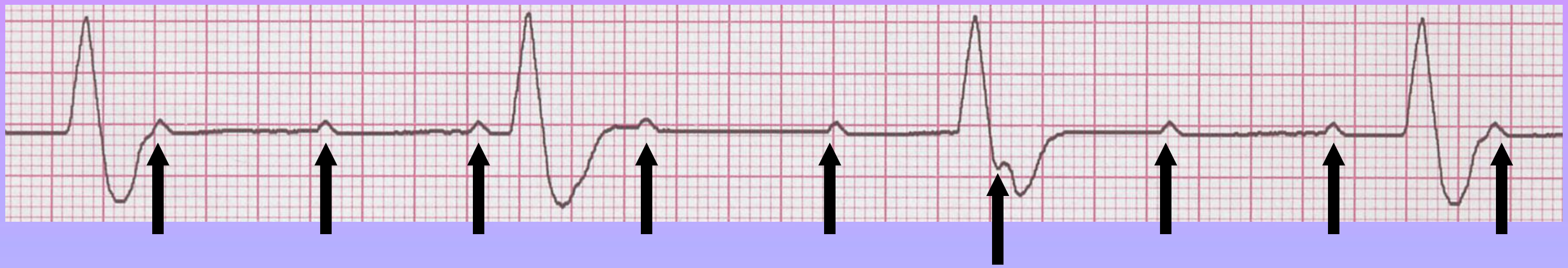
2nd Degree AV Block, Type II

- Deviation from NSR
  - Occasional P waves are completely blocked (P wave not followed by QRS).

2nd Degree AV Block, Type II

- Etiology: Conduction is all or nothing (no prolongation of PR interval); typically block occurs in the Bundle of His.

Rhythm #13



- Rate? 40 bpm
- Regularity? regular
- P waves? no relation to QRS
- PR interval? none
- QRS duration? wide (> 0.12 s)

Interpretation? *3rd Degree AV Block*

3rd Degree AV Block

- Deviation from NSR
  - The P waves are completely blocked in the AV junction; QRS complexes originate independently from below the junction.

3rd Degree AV Block

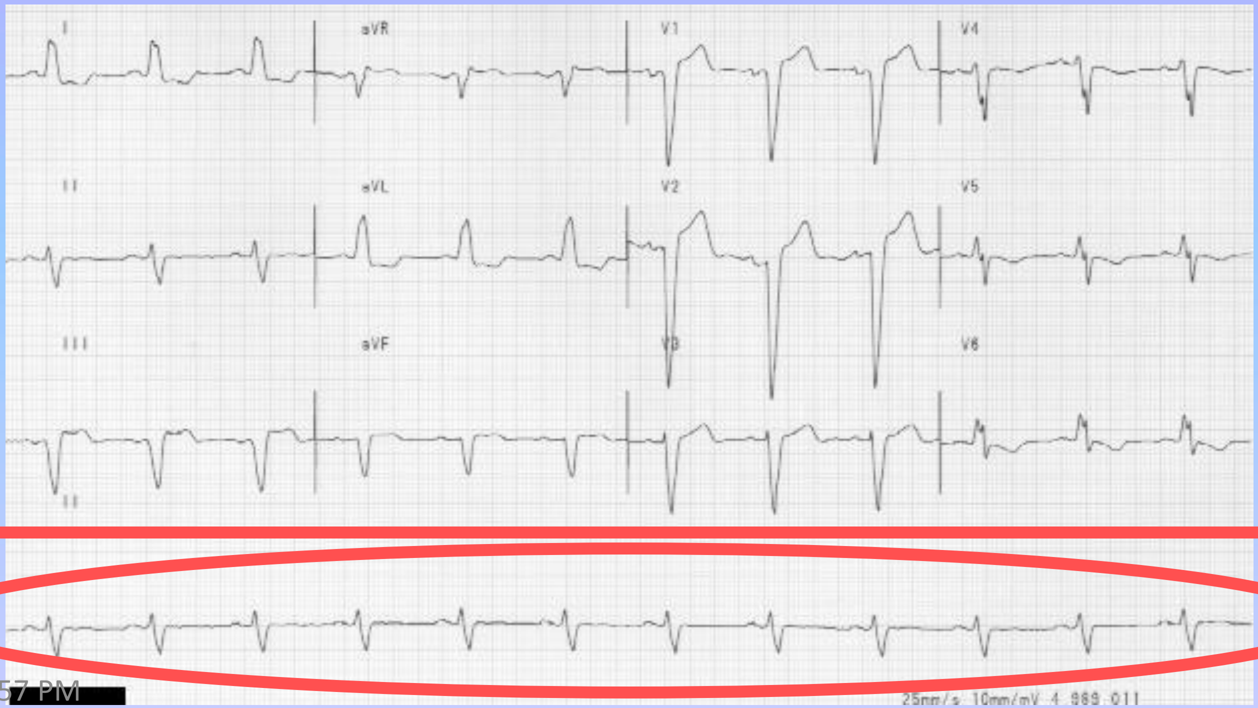
- Etiology: There is complete block of conduction in the AV junction, so the atria and ventricles form impulses independently of each other. Without impulses from the atria, the ventricles own intrinsic pacemaker kicks in at around 30 - 45 beats/minute.

Remember

- When an impulse originates in a ventricle, conduction through the ventricles will be inefficient and the QRS will be wide and bizarre.

Diagnosing a MI

To diagnose a myocardial infarction you need to go beyond looking at a rhythm strip and obtain a 12-Lead ECG.



12-Lead ECG

Rhythm Strip

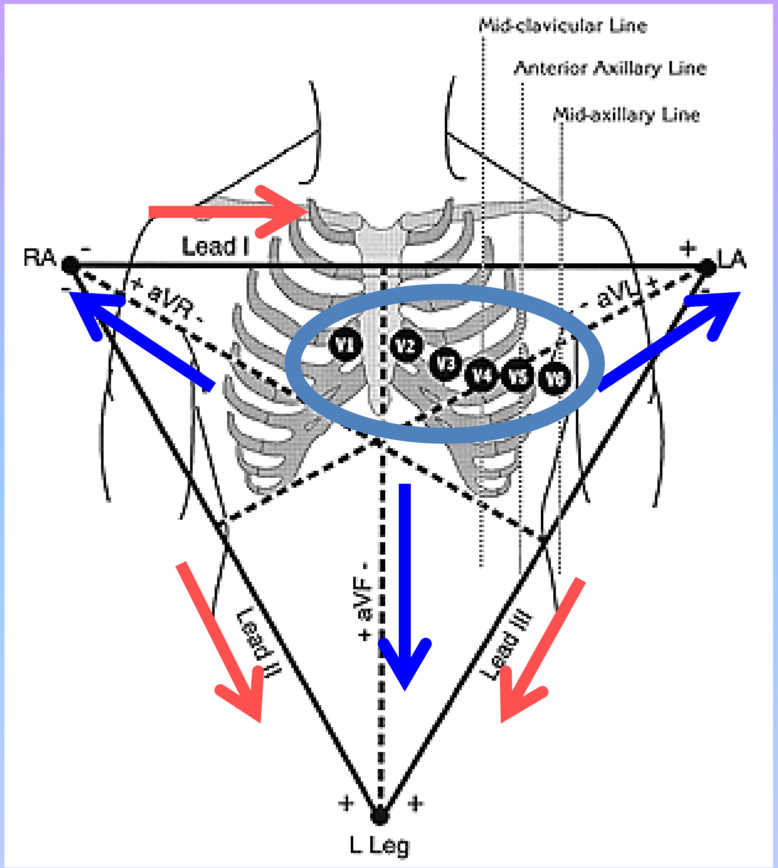
The 12-Lead ECG

- The 12-Lead ECG sees the heart from 12 different views.
- Therefore, the 12-Lead ECG helps you see what is happening in different portions of the heart.
- The rhythm strip is only 1 of these 12 views.

The 12-Leads

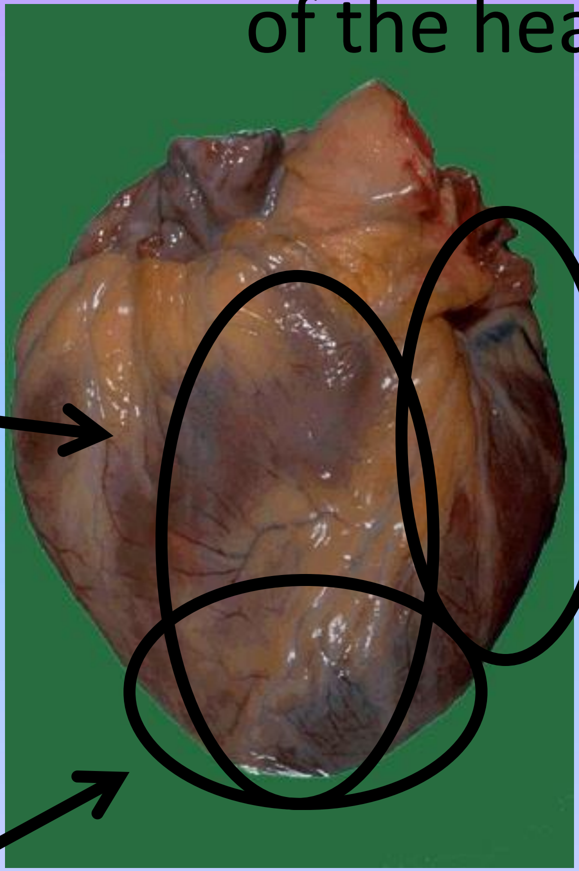
The 12-leads include:

- 3 Limb leads (I, II, III)
- 3 Augmented leads (aVR, aVL, aVF)
- 6 Precordial leads (V_1- V_6)



Views of the Heart

Some leads get a good view of the:



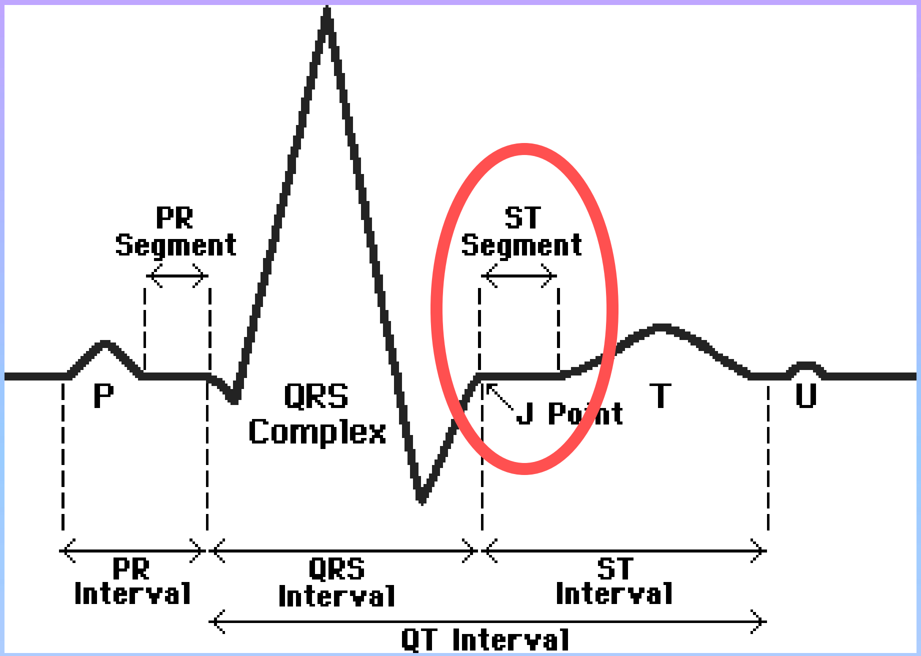
Lateral portion of the heart

Anterior portion of the heart

Inferior portion of the heart

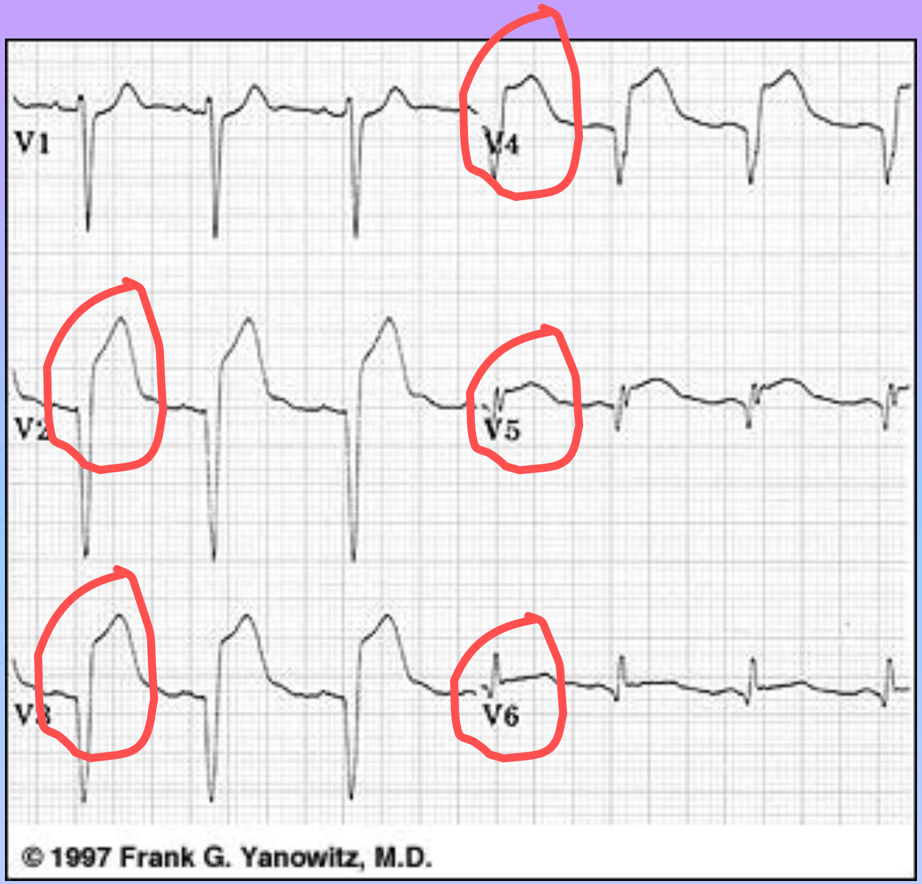
ST Elevation

One way to diagnose an acute MI is to look for elevation of the ST segment.



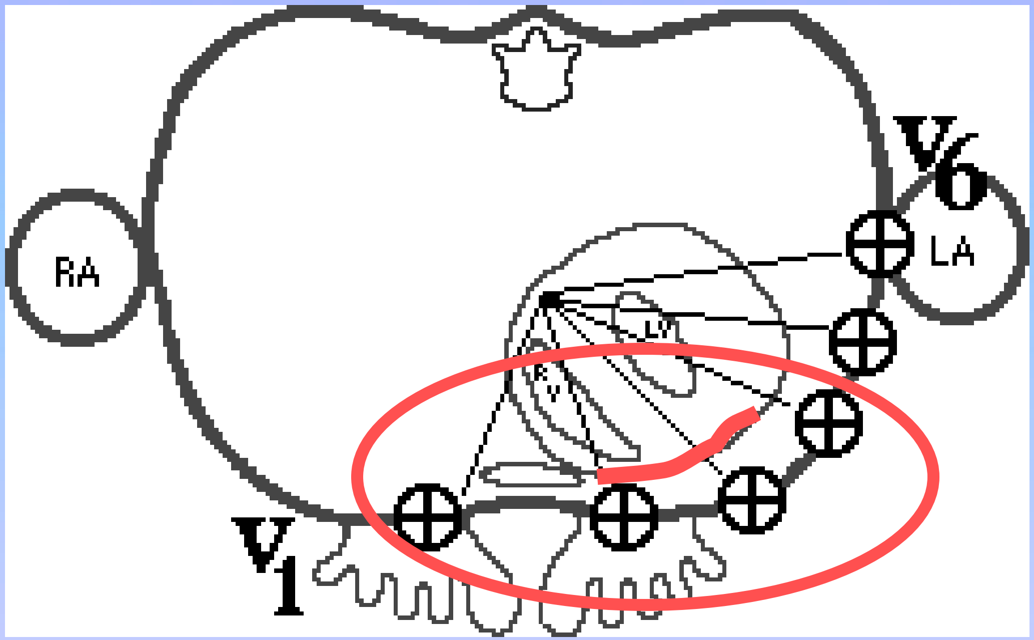
ST Elevation (cont)

Elevation of the ST segment (greater than 1 small box) in 2 leads is consistent with a myocardial infarction.



Anterior View of the Heart

The anterior portion of the heart is best viewed using leads V_1- V_4.

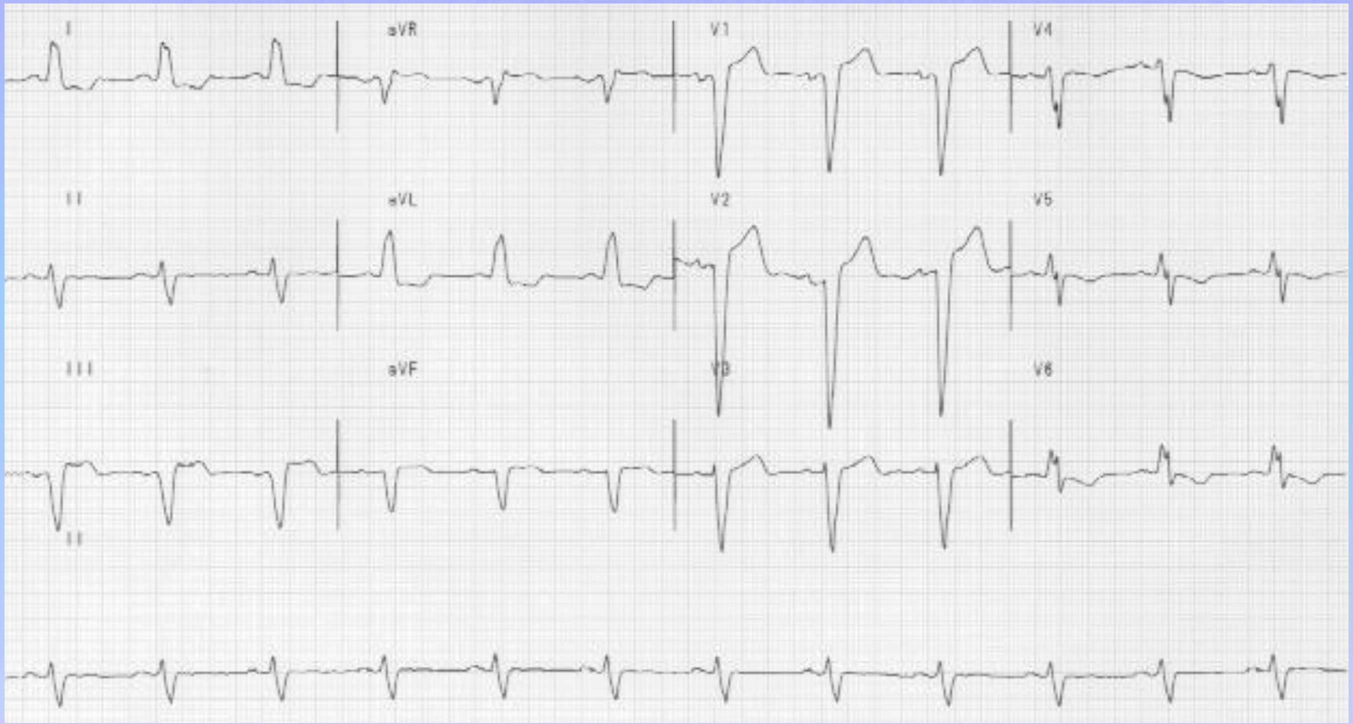


Anterior Myocardial Infarction

If you see changes in leads V_1 - V_4 that are consistent with a myocardial infarction, you can conclude that it is an anterior wall myocardial infarction.

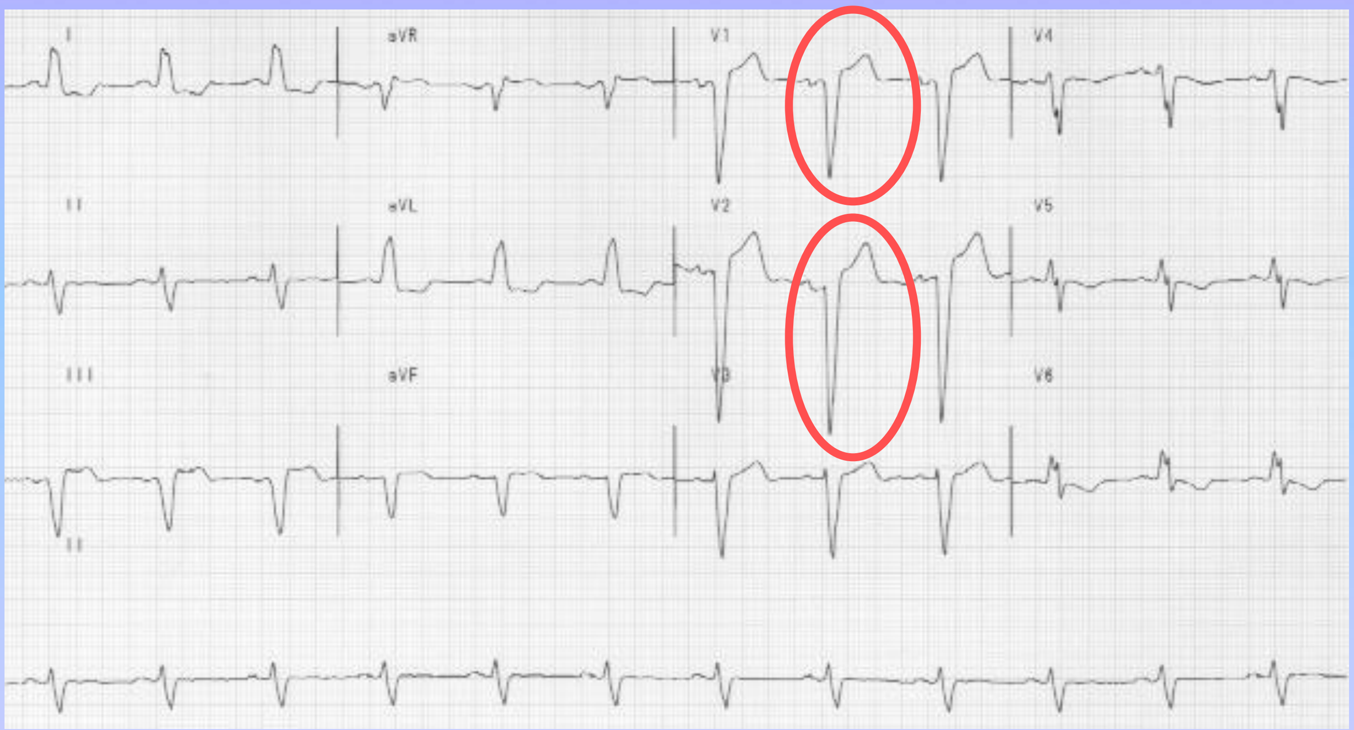
Putting it all Together

Do you think this person is having a myocardial infarction. If so, where?



Interpretation

Yes, this person is having an acute anterior wall myocardial infarction.

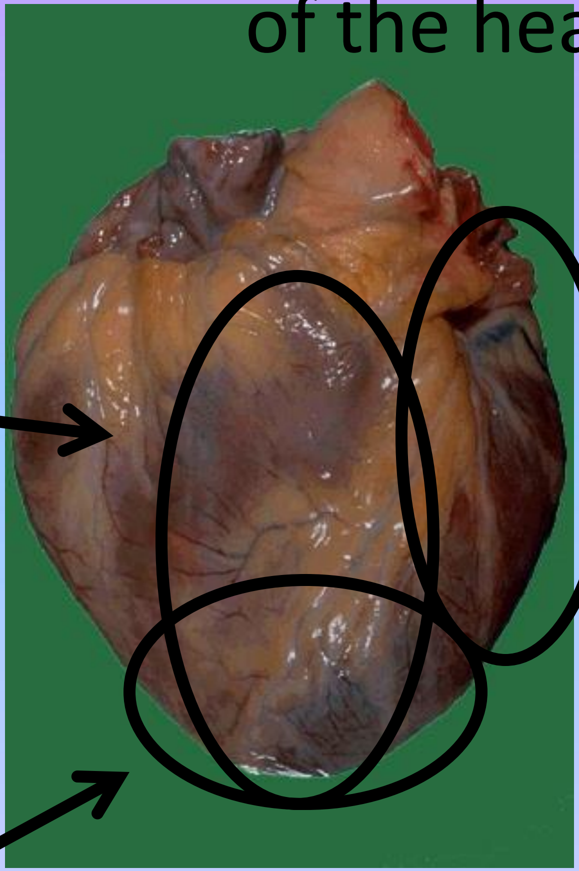


Other MI Locations

Now that you know where to look for an anterior wall myocardial infarction let’s look at how you would determine if the MI involves the lateral wall or the inferior wall of the heart.

Other MI Locations

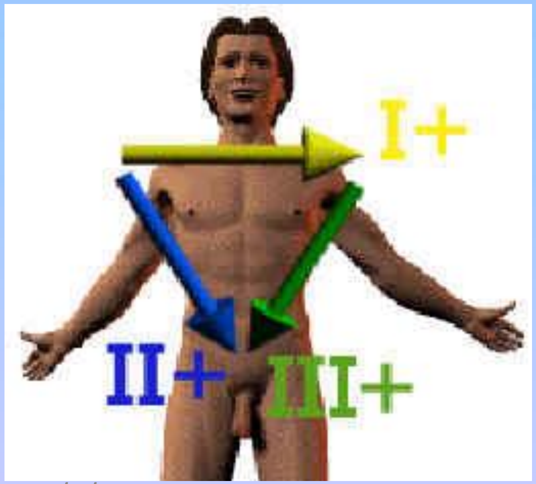
First, take a look again at this picture of the heart.



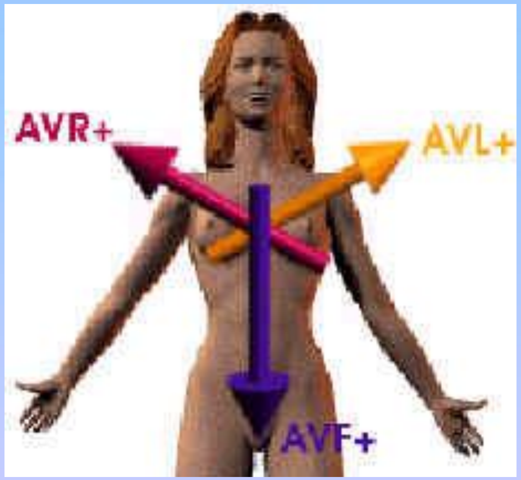
Other MI Locations

Second, remember that the 12-leads of the ECG look at different portions of the heart. The limb and augmented leads "see" electrical activity moving inferiorly (II, III and aVF), to the left (I, aVL) and to the right (aVR). Whereas, the precordial leads "see" electrical activity in the posterior to anterior direction.

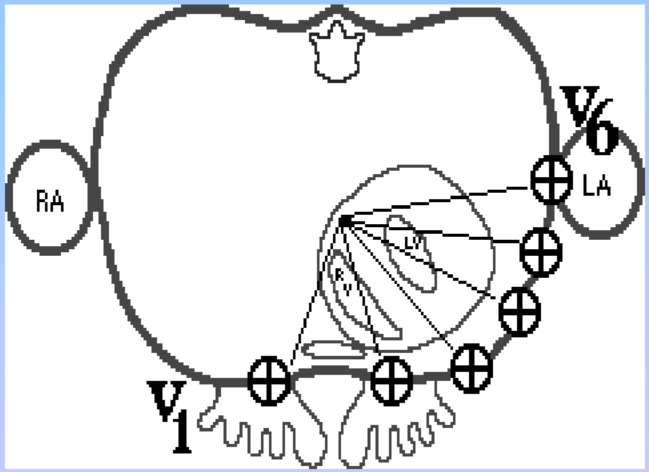
Limb Leads



Augmented Leads



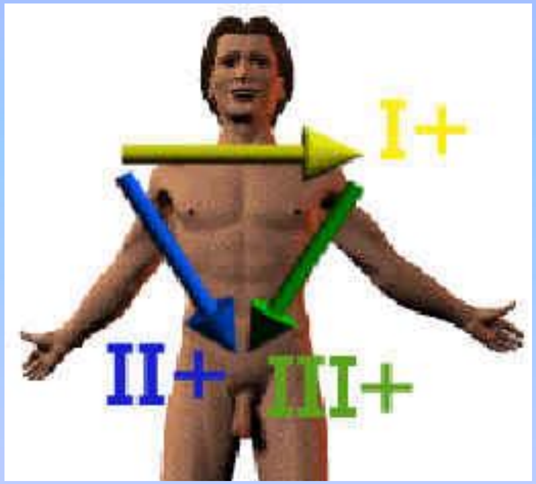
Precordial Leads



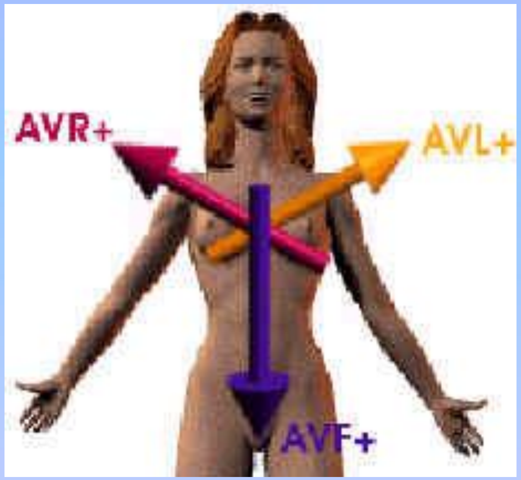
Other MI Locations

Now, using these 3 diagrams let's figure where to look for a lateral wall and inferior wall MI.

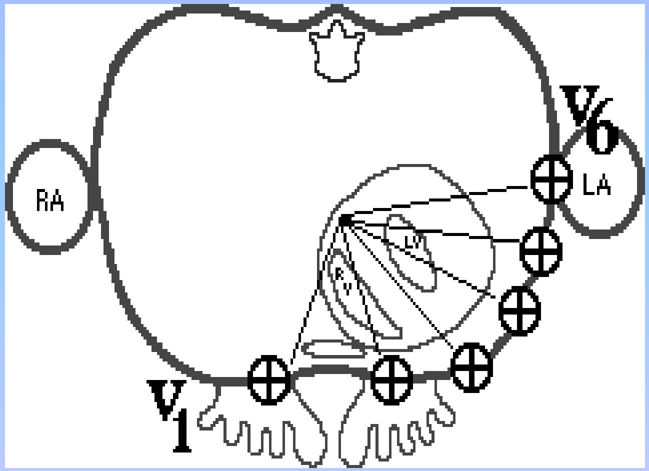
Limb Leads



Augmented Leads



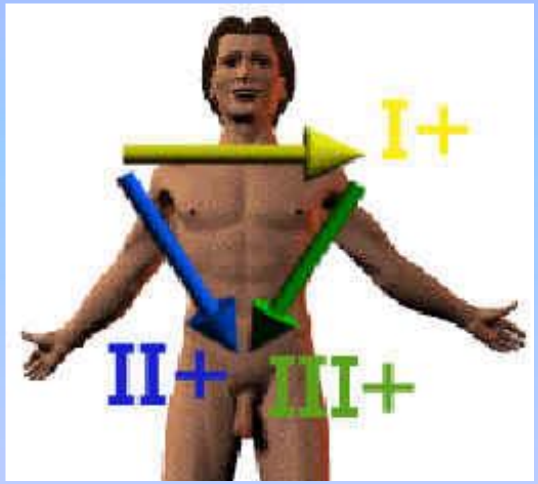
Precordial Leads



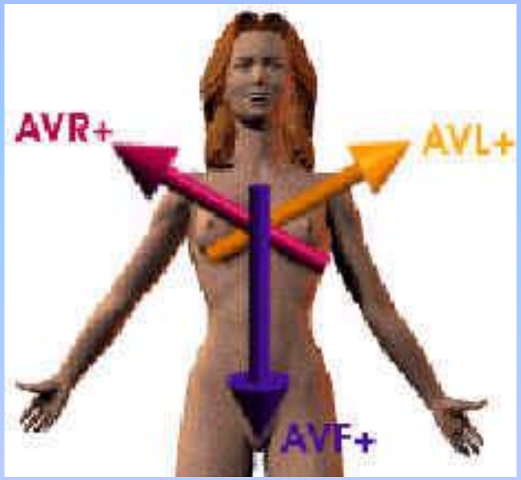
Anterior MI

Remember the anterior portion of the heart is best viewed using leads V_1- V_4.

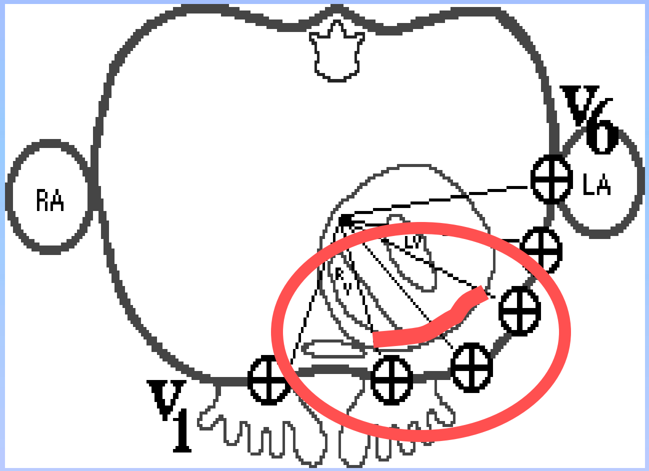
Limb Leads



Augmented Leads



Precordial Leads

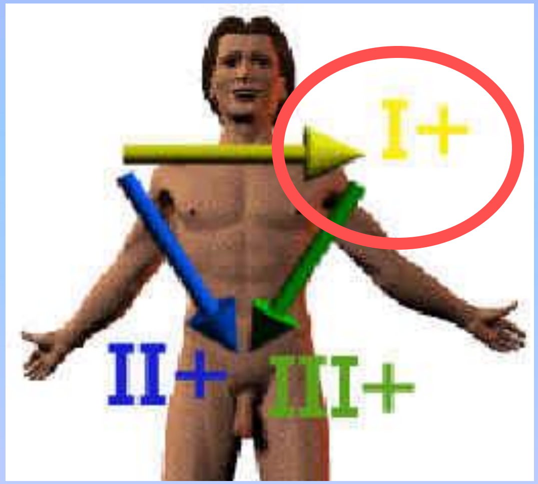


Lateral MI

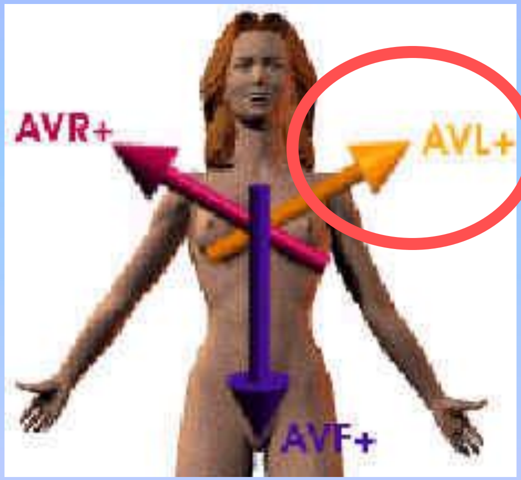
So what leads do you think the lateral portion of the heart is best viewed?

Leads I, aVL, and V_5- V_6

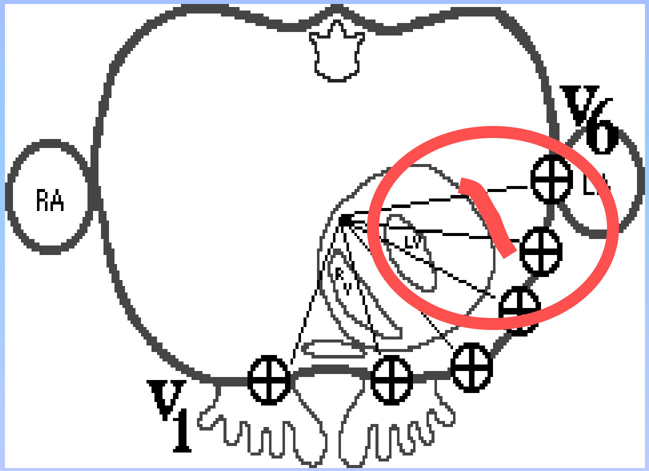
Limb Leads



Augmented Leads



Precordial Leads

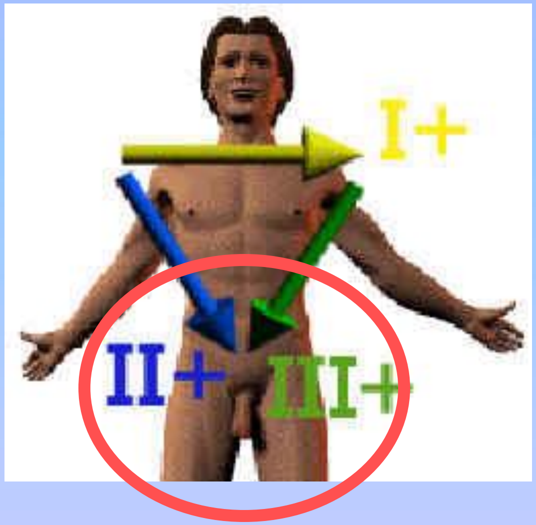


Inferior MI

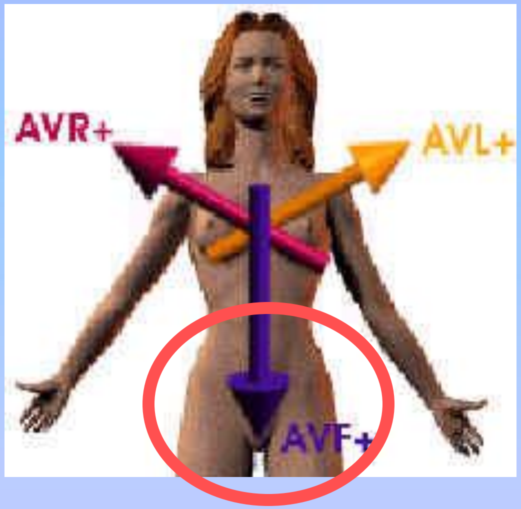
Now how about the inferior portion of the heart?

Leads II, III and aVF

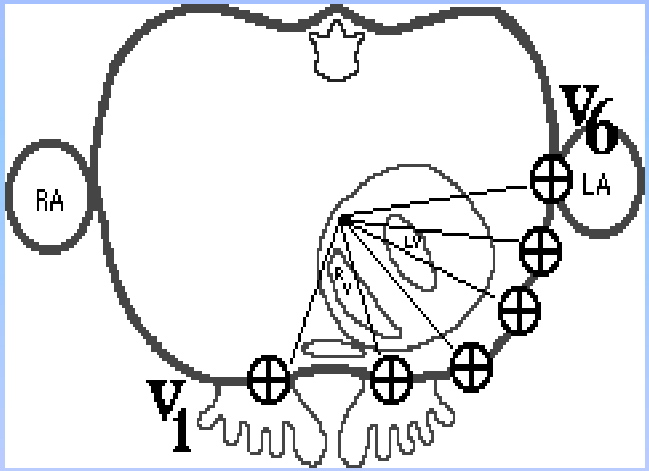
Limb Leads



Augmented Leads

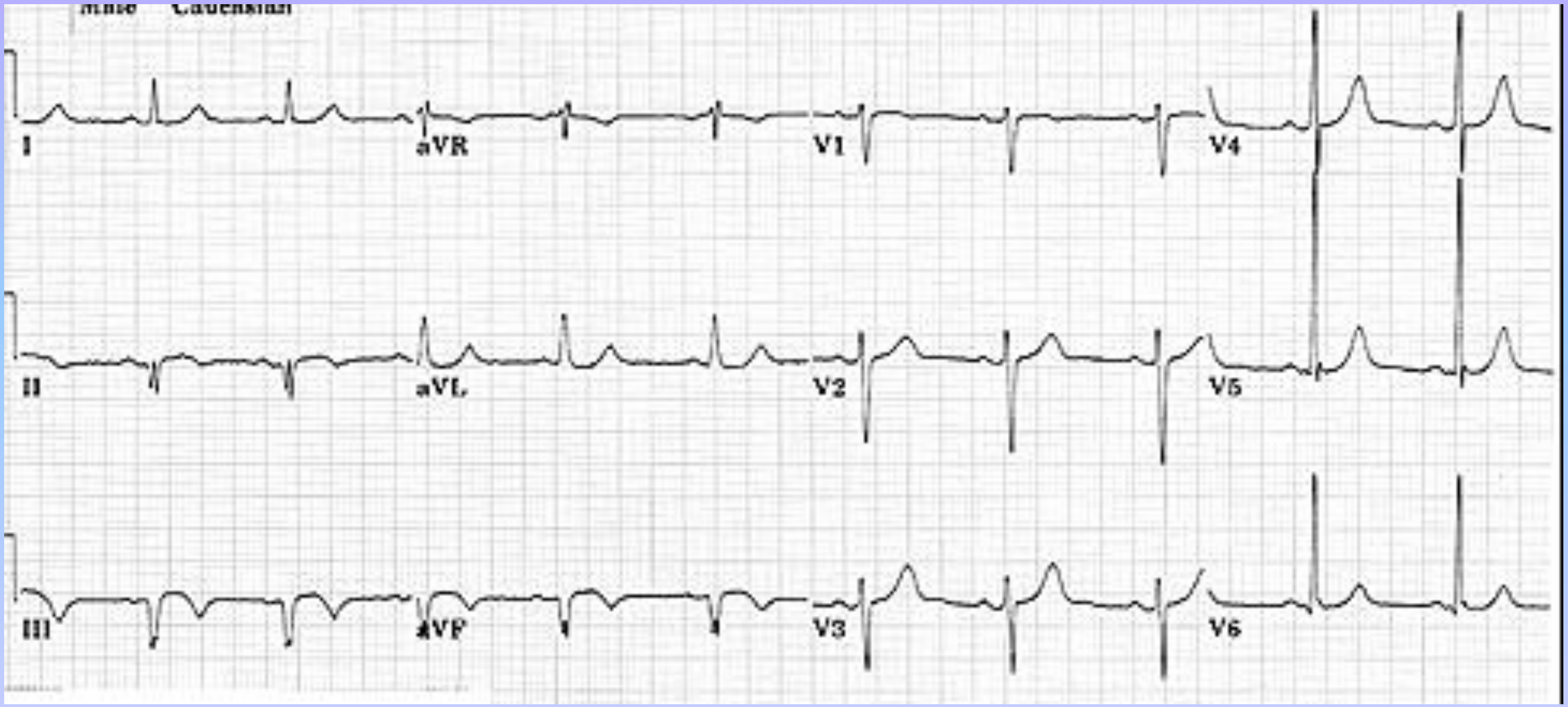


Precordial Leads



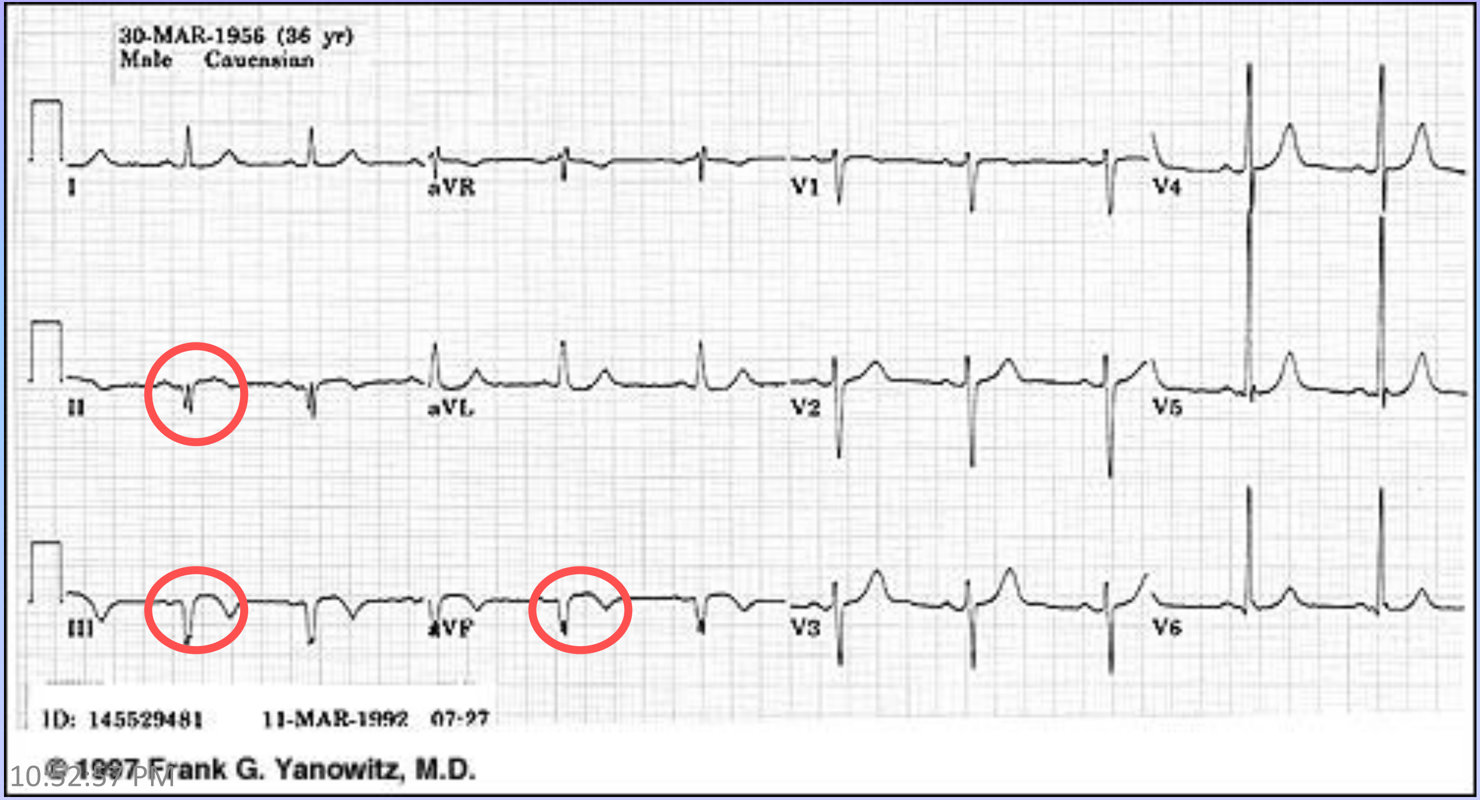
Putting it all Together

Now, where do you think this person is having a myocardial infarction?



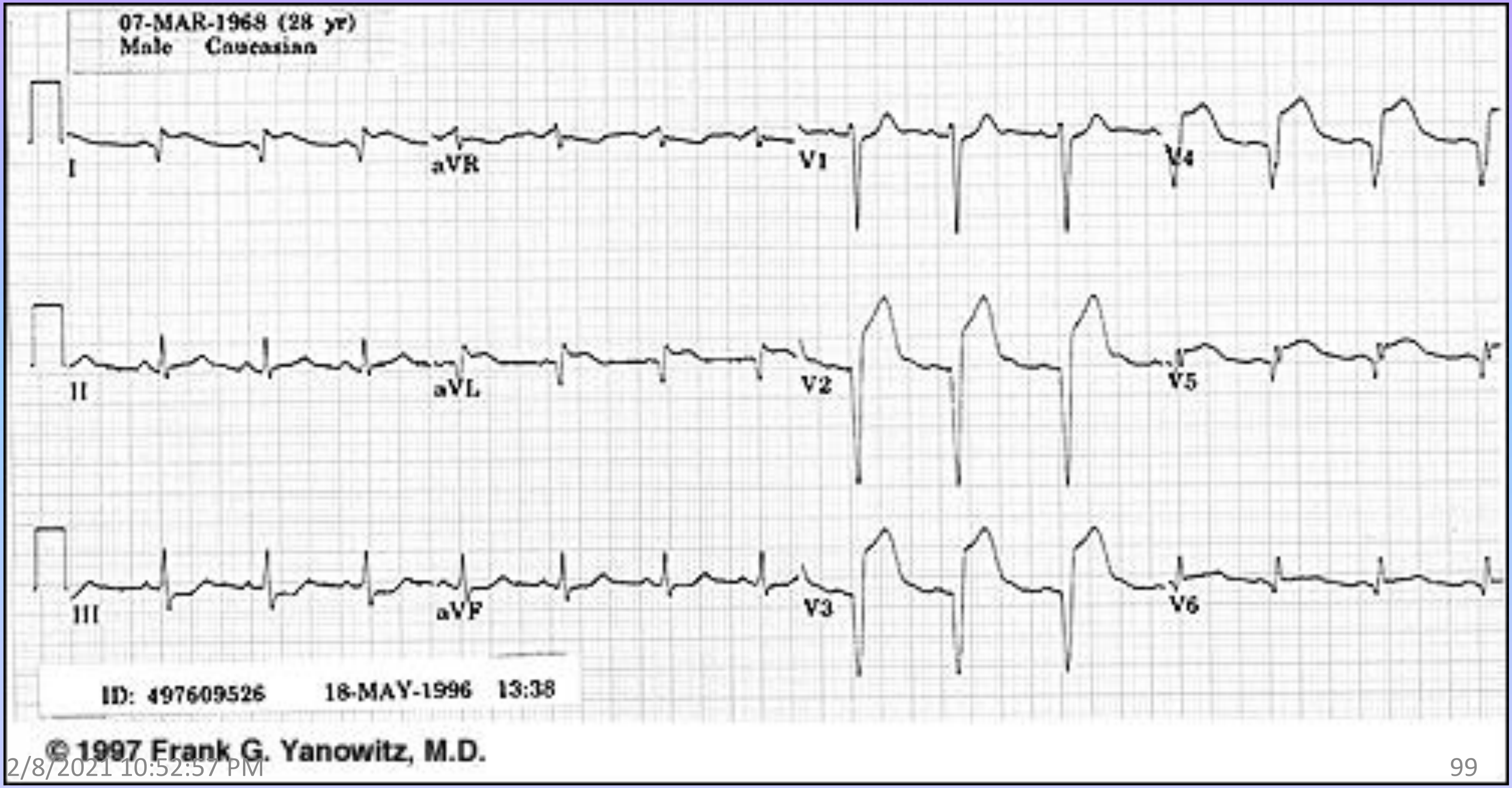
Inferior Wall MI

This is an inferior MI. Note the ST elevation in leads II, III and aVF.



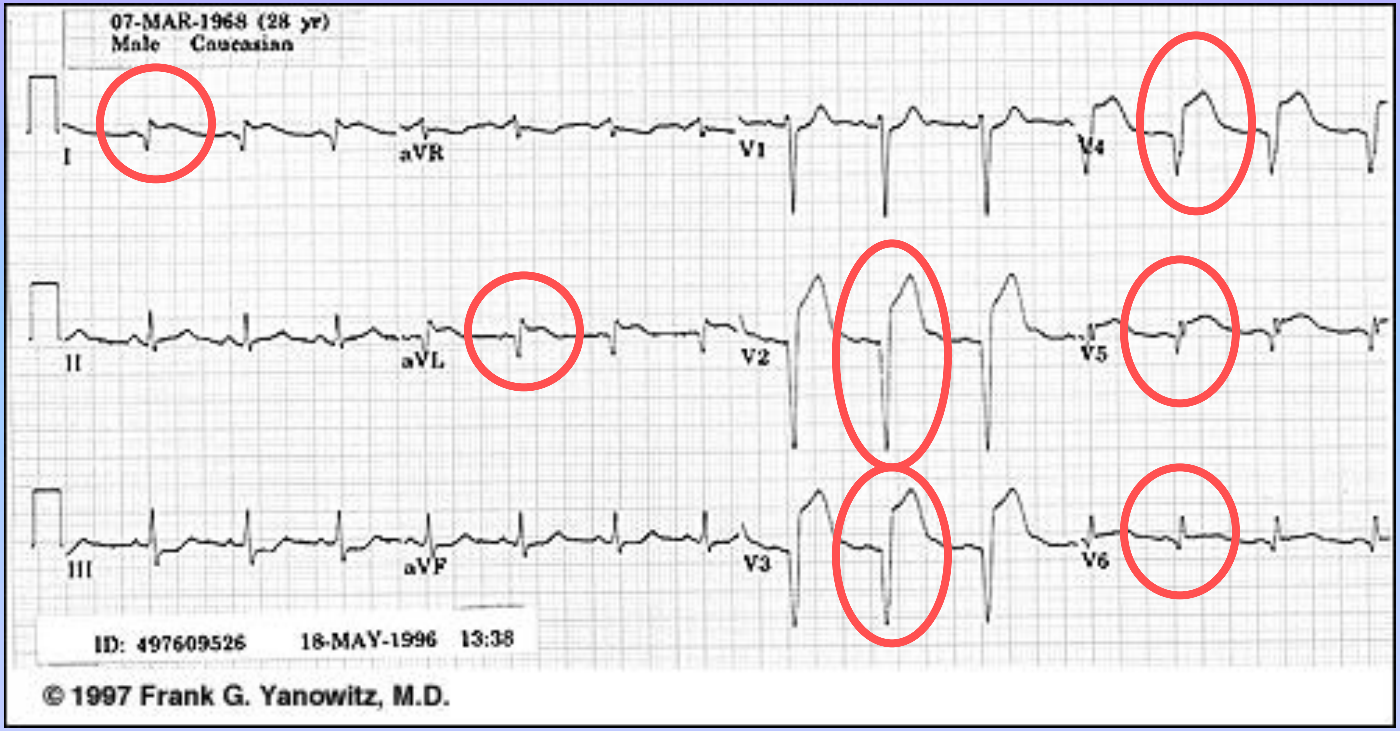
Putting it all Together

How about now?



Anterolateral MI

This person's MI involves both the anterior wall (V_2-V_4) and the lateral wall (V_5-V_6, I, and aVL)!



ST Elevation and non-ST Elevation MIs

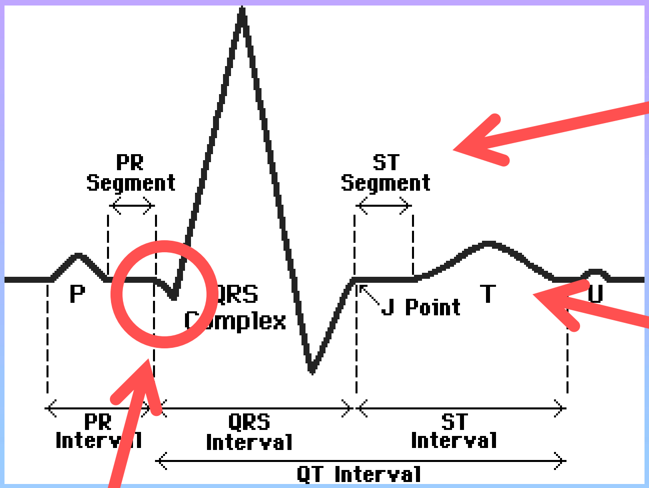
ST Elevation and non-ST Elevation MIs

- When myocardial blood supply is abruptly reduced or cut off to a region of the heart, a sequence of injurious events occur beginning with ischemia (inadequate tissue perfusion), followed by necrosis (infarction), and eventual fibrosis (scarring) if the blood supply isn't restored in an appropriate period of time.

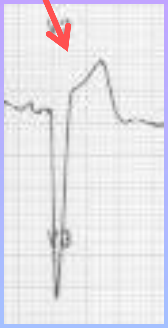
- The ECG changes over time with each of these events…

ECG Changes

Ways the ECG can change include:



ST elevation &
depression

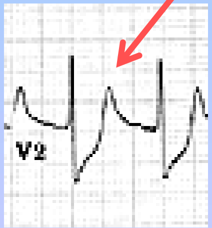


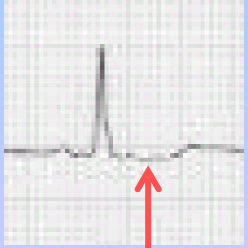
T-waves

peaked

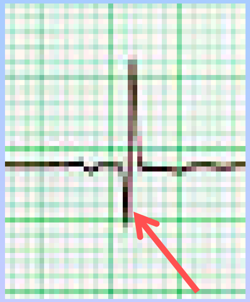
flattened

inverted



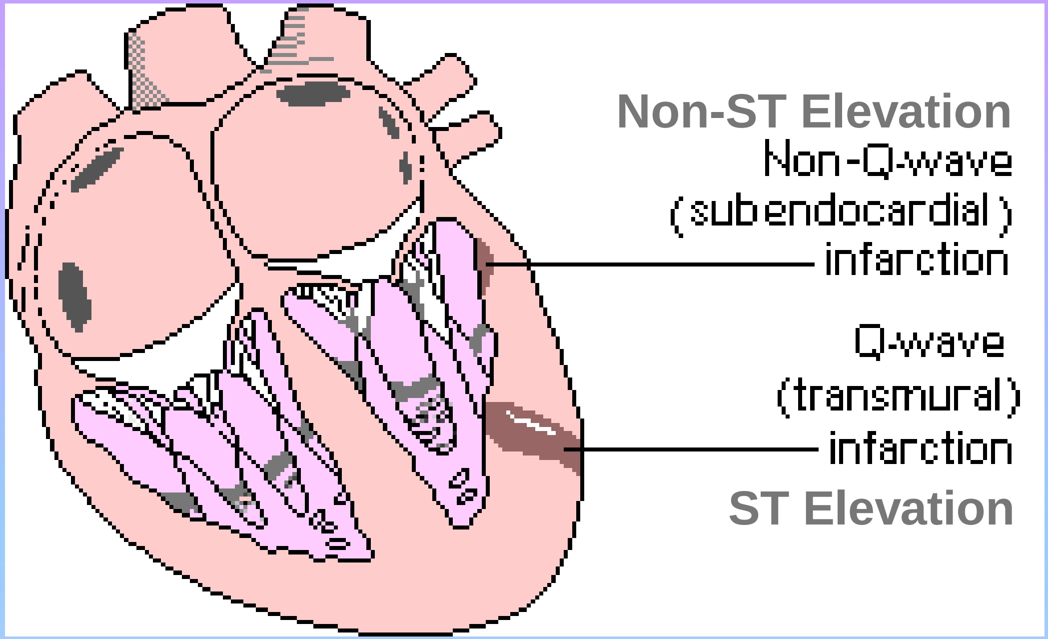


Appearance
of pathologic
Q-waves



ECG Changes & the Evolving MI

There are two distinct patterns of ECG change depending if the infarction is:



- –ST Elevation (Transmural or Q-wave), or
- –Non-ST Elevation (Subendocardial or non-Q-wave)

ST Elevation Infarction

The ECG changes seen with a ST elevation infarction are:

Before injury **Normal ECG**

Ischemia **ST depression, peaked T-waves, then T-wave inversion**

Infarction **ST elevation & appearance of Q-waves**

Fibrosis **ST segments and T-waves return to normal, but Q-waves persist**

ST Elevation Infarction

Here' s a diagram depicting an evolving infarction:

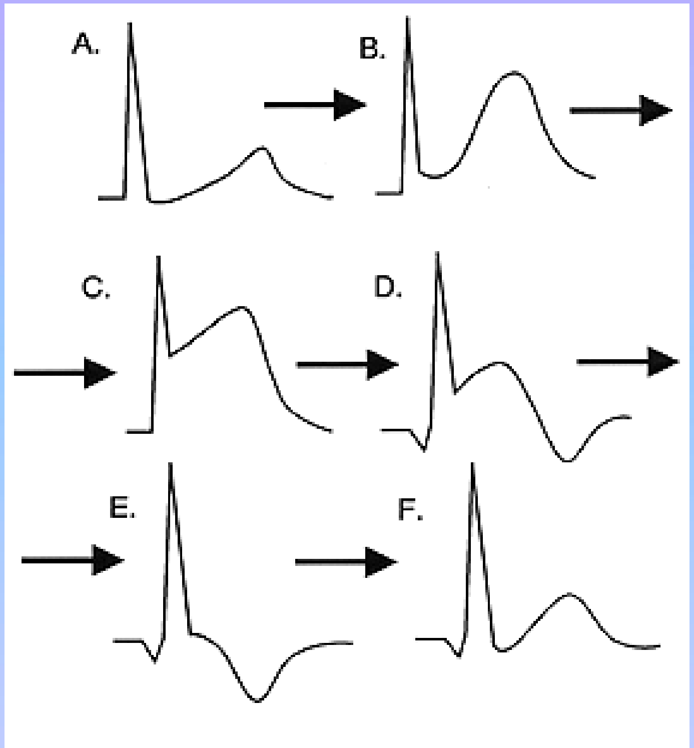
A. Normal ECG prior to MI

B. Ischemia from coronary artery occlusion results in ST depression (not shown) and peaked T-waves

C. Infarction from ongoing ischemia results in marked ST elevation

D/E. Ongoing infarction with appearance of pathologic Q-waves and T-wave inversion

F. Fibrosis (months later) with persistent Q- waves, but normal ST segment and T- waves



ST Elevation Infarction

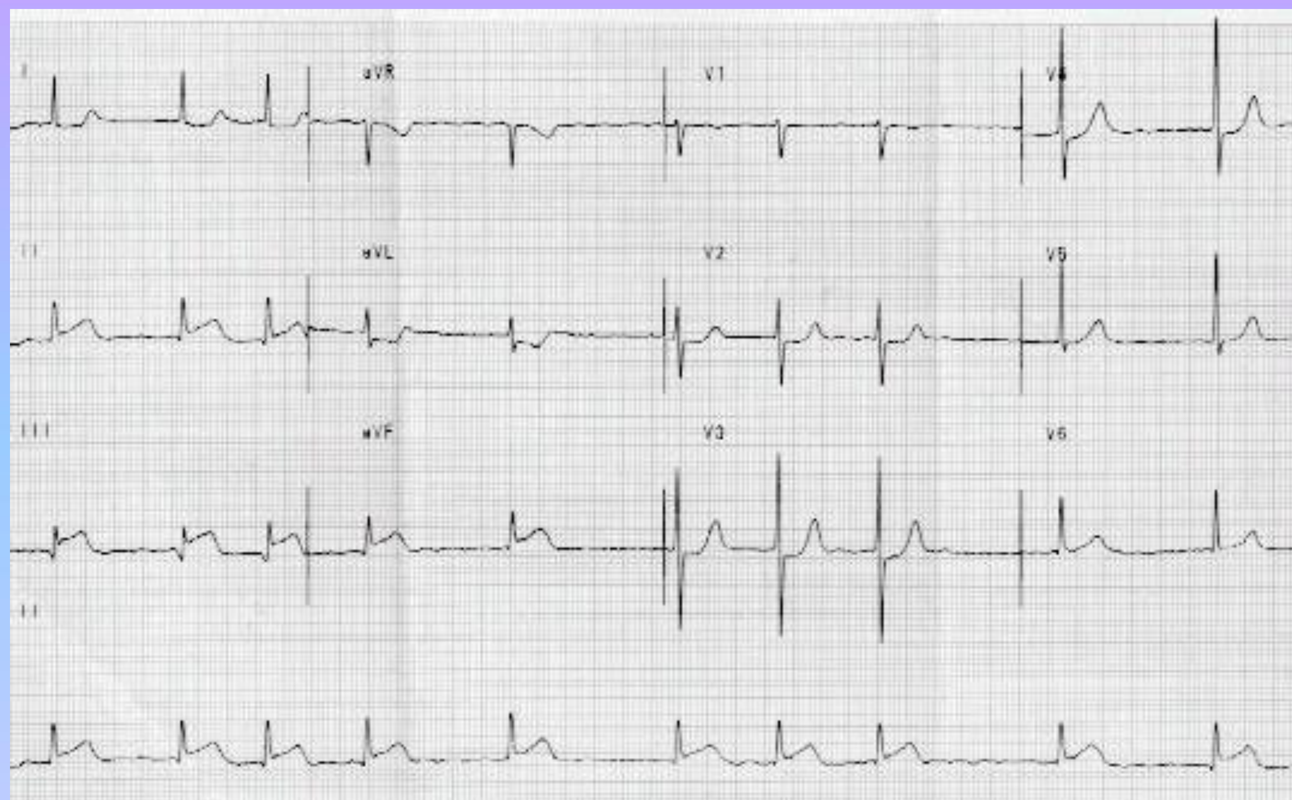
Here' s an ECG of an inferior MI:

Look at the inferior leads (II, III, aVF).

Question:
What ECG changes do you see?

ST elevation and Q-waves

Extra credit:
What is the rhythm?



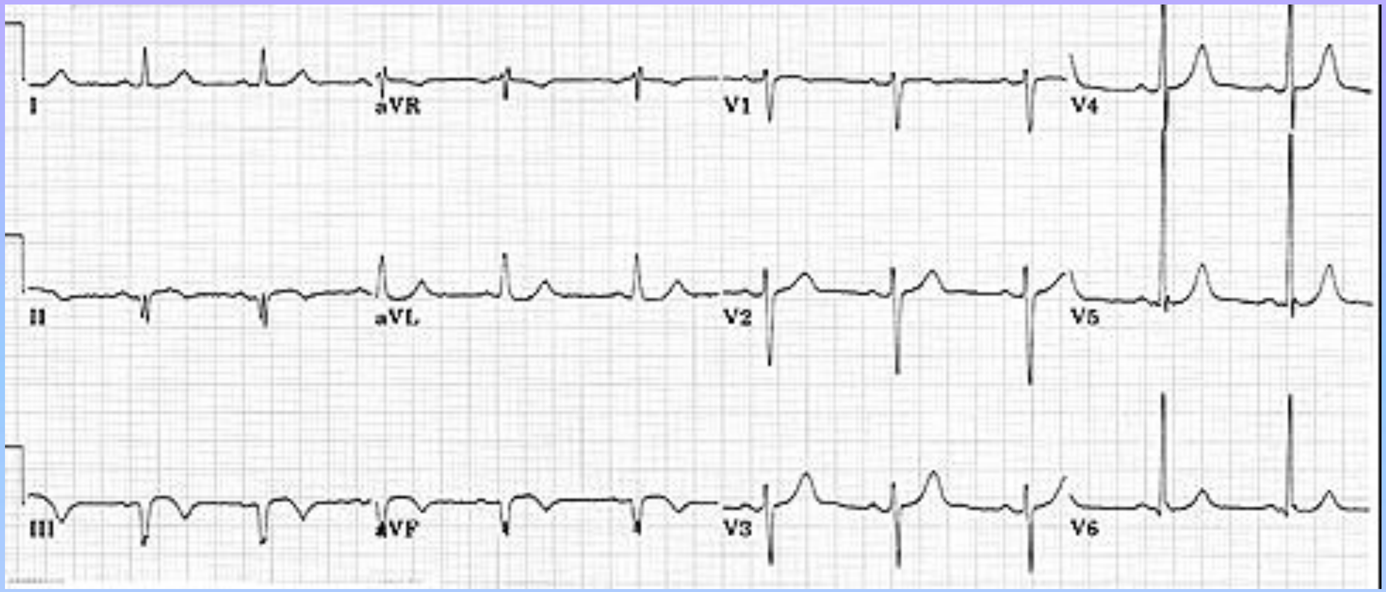
Atrial fibrillation (irregularly irregular with narrow QRS)!

Non-ST Elevation Infarction

Here's an ECG of an inferior MI later in time:

Now what do you see in the inferior leads?

ST elevation, Q-waves and T-wave inversion



Non-ST Elevation Infarction

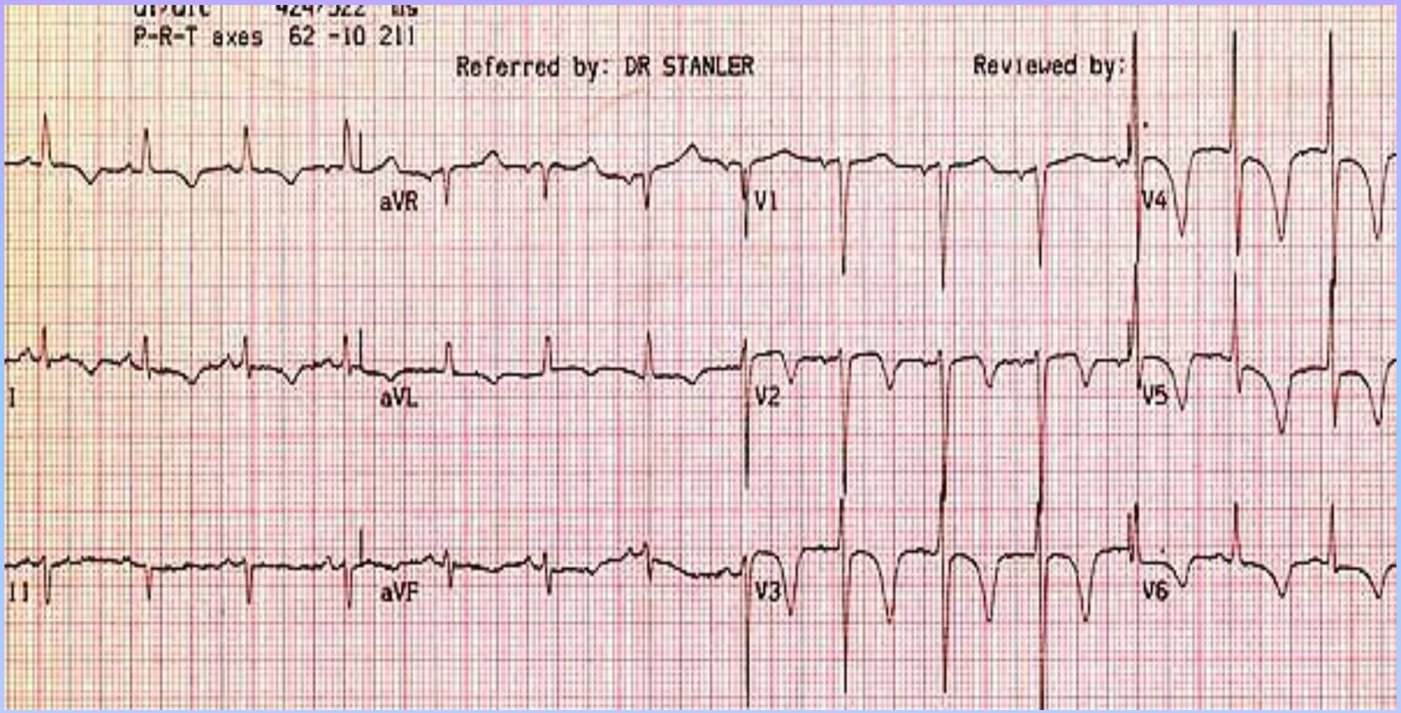
The ECG changes seen with a non-ST elevation infarction are:

Before injury	**Normal ECG**
↓	
Ischemia	**ST depression & T-wave inversion**
↓	
Infarction	**ST depression & T-wave inversion**
↓	
Fibrosis	**ST returns to baseline, but T-wave inversion persists**

Non-ST Elevation Infarction

Here's an ECG of an evolving non-ST elevation MI:

Note the ST depression and T-wave inversion in leads V_2-V_6.



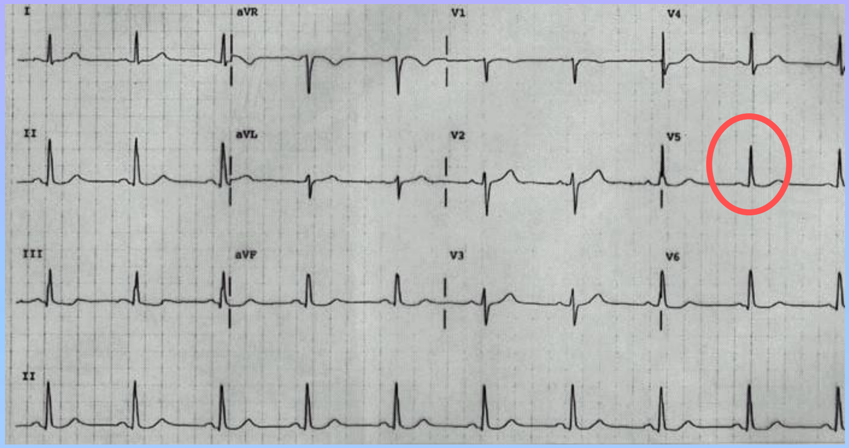
Question:
What area of the heart is infarcting?

Anterolateral

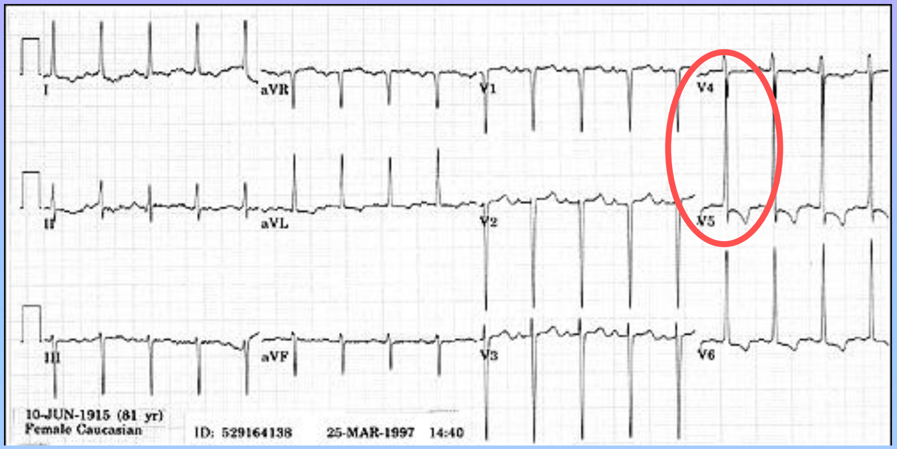
Left Ventricular Hypertrophy

Left Ventricular Hypertrophy

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



Normal



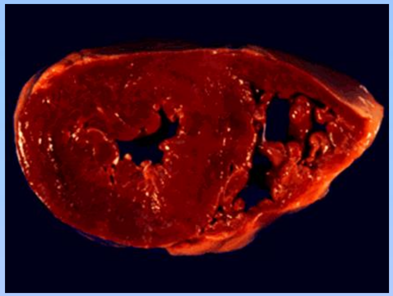
Left Ventricular Hypertrophy

Answer: The QRS complexes are very tall (increased voltage)

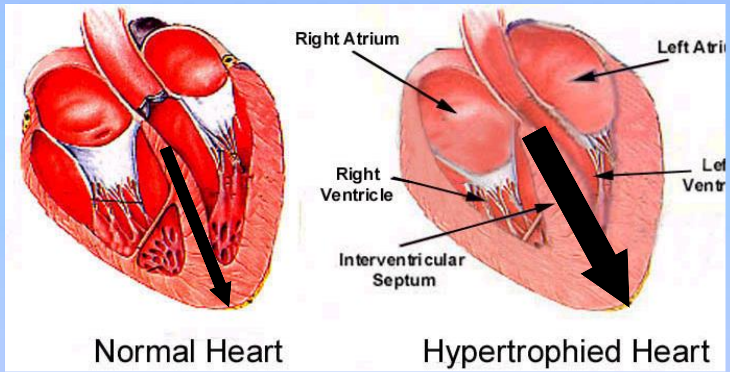
Left Ventricular Hypertrophy

Why is left ventricular hypertrophy characterized by tall QRS complexes?

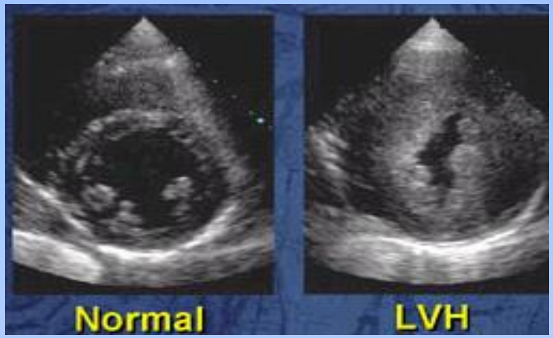
As the heart muscle wall thickens there is an increase in electrical forces moving through the myocardium resulting in increased QRS voltage.



LVH



Increased QRS voltage

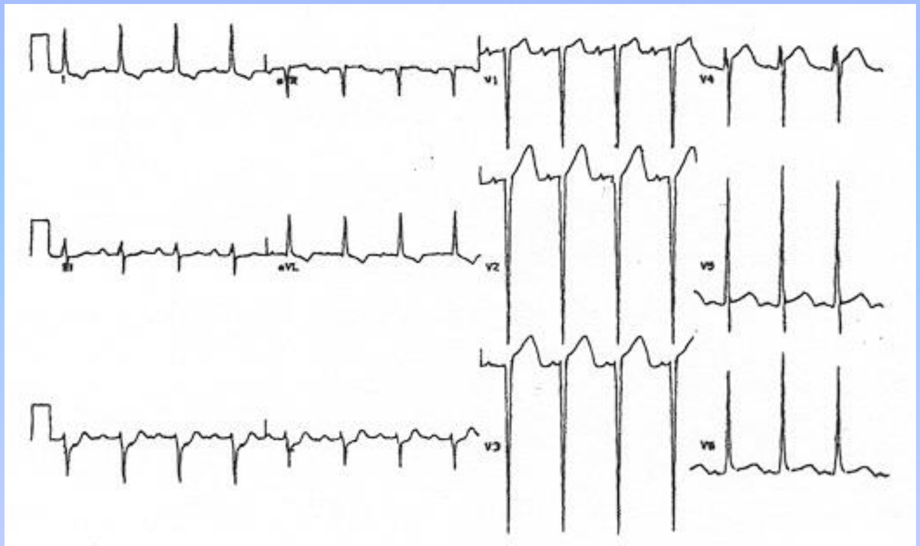


ECHOcardiogram

Left Ventricular Hypertrophy

- Criteria exists to diagnose LVH using a 12-lead ECG.
  - For example:
    - The R wave in V5 or V6 plus the S wave in V1 or V2 exceeds 35 mm.

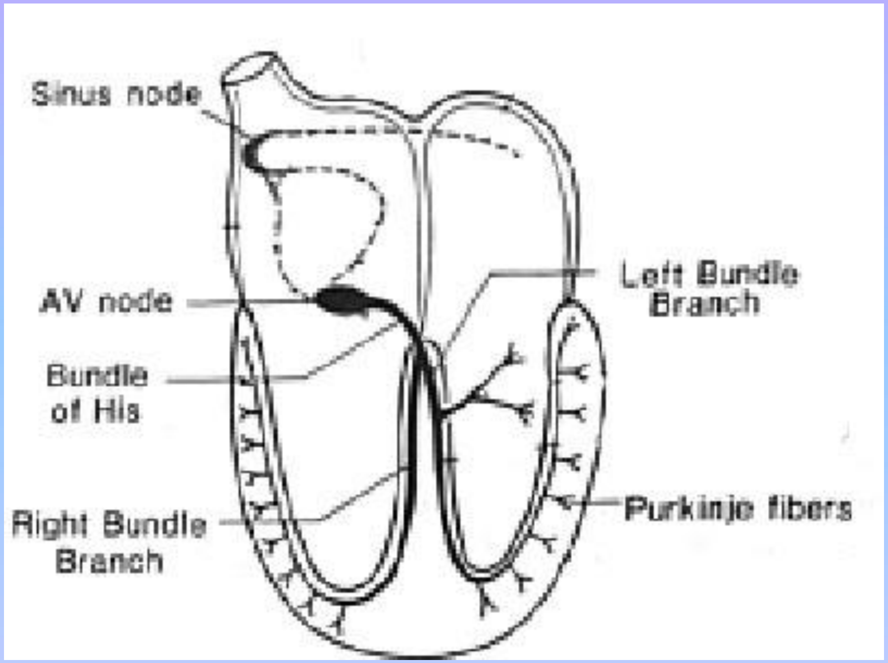
- However, for now, all you need to know is that the QRS voltage increases with LVH.



Bundle Branch Blocks

Bundle Branch Blocks

Turning our attention to bundle branch blocks…



Remember normal impulse conduction is

SA node →

AV node →

Bundle of His →

Bundle Branches →

Purkinje fibers

Normal Impulse Conduction

Sinoatrial node

↓

AV node

↓

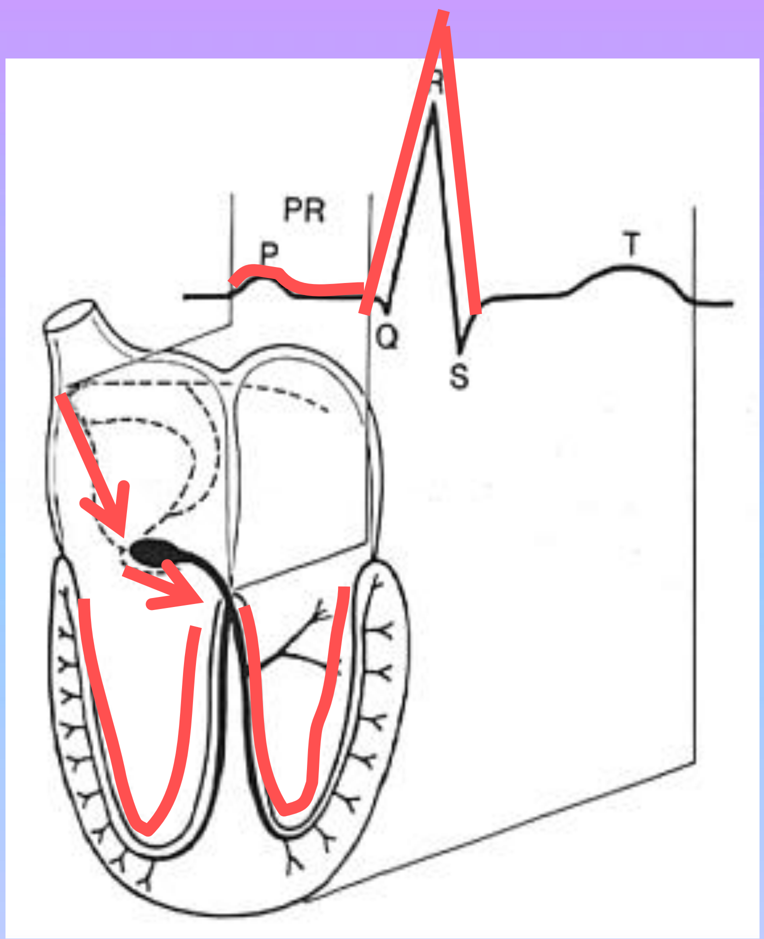
Bundle of His

↓

Bundle Branches

↓

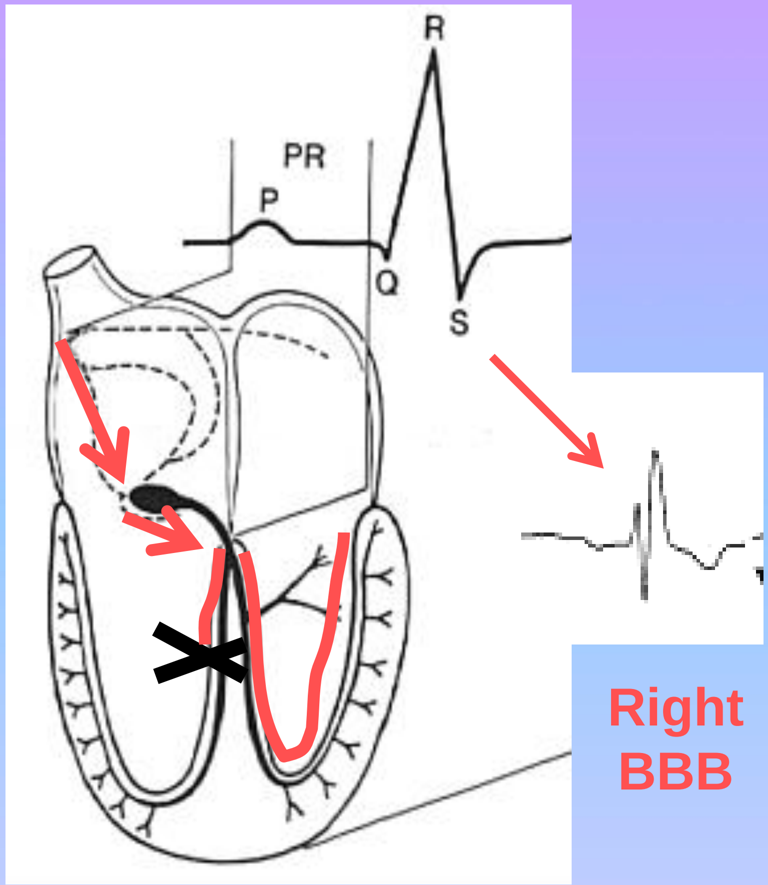
Purkinje fibers



Bundle Branch Blocks

So, depolarization of the Bundle Branches and Purkinje fibers are seen as the QRS complex on the ECG.

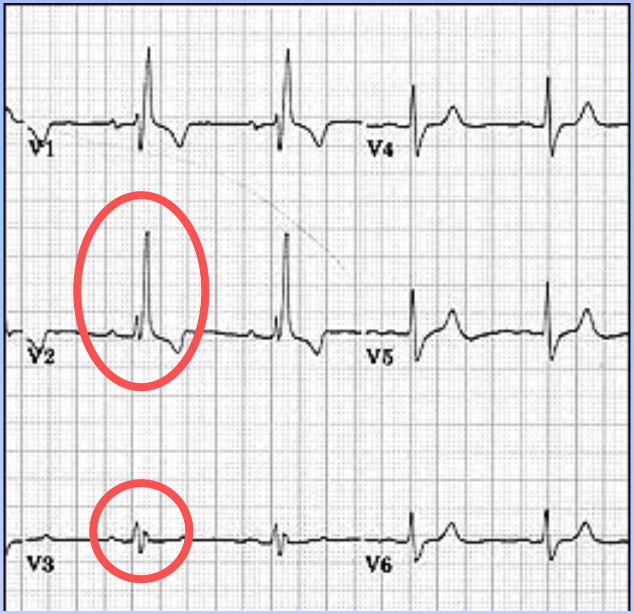
Therefore, a conduction block of the Bundle Branches would be reflected as a change in the QRS complex.



Bundle Branch Blocks

With Bundle Branch Blocks you will see two changes on the ECG.

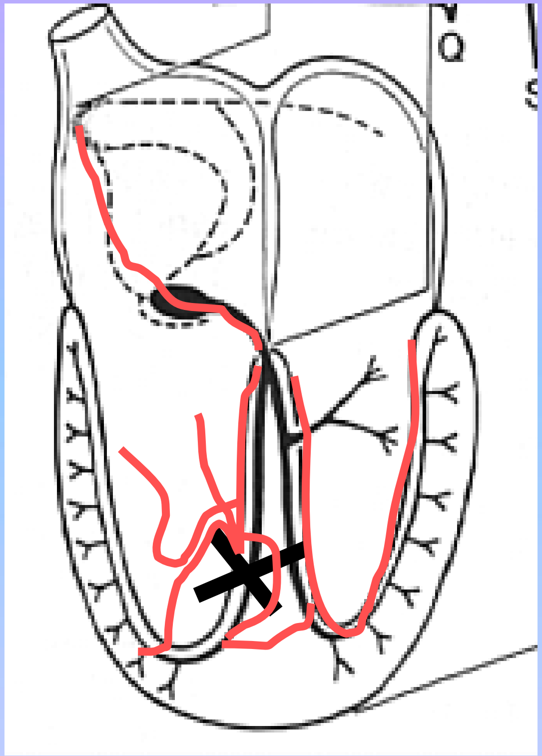
1. **QRS complex widens (> 0.12 sec).**
2. **QRS morphology changes (varies depending on ECG lead, and if it is a right vs. left bundle branch block).**



Bundle Branch Blocks

Why does the QRS complex widen?

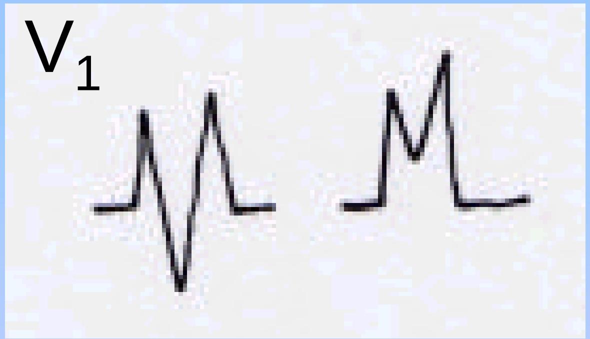
When the conduction pathway is blocked it will take longer for the electrical signal to pass throughout the ventricles.



Right Bundle Branch Blocks

What QRS morphology is characteristic?

For RBBB the wide QRS complex assumes a unique, virtually diagnostic shape in those leads overlying the right ventricle (V_1 and V_2).



"Rabbit Ears"

Left Bundle Branch Blocks

What QRS morphology is characteristic?

For LBBB the wide QRS complex assumes a characteristic change in shape in those leads opposite the left ventricle (right ventricular leads - V_1 and V_2).

Normal

Broad, deep S waves

Reading 12-Lead ECGs

- The 12-Lead ECG contains information that will assist you in making diagnostic and treatment decisions in your clinical practice. In previous modules you learned how to read and interpret parts of the ECG. Now, we will bring all that you have learned together so that you can systematically read and interpret a 12-lead ECG.

- The information will be divided into two modules, VII a and VII b.

Reading 12-Lead ECGs

The best way to read 12-lead ECGs is to develop a step-by-step approach (just as we did for analyzing a rhythm strip). In these modules we present a 6-step approach:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
6. Look for evidence of INFARCTION

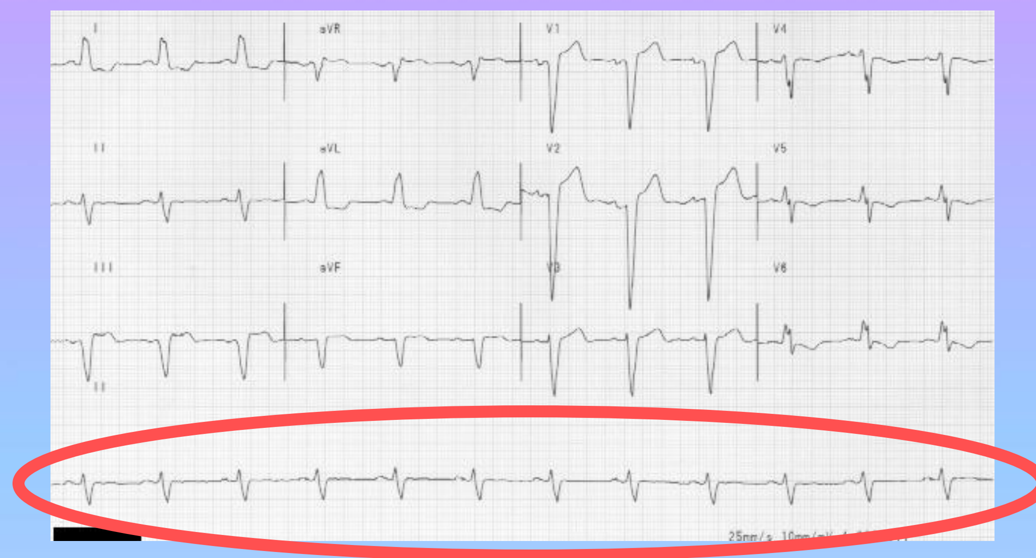
Rate Rhythm Axis Intervals Hypertrophy Infarct

- In Module II you learned how to calculate the rate. If you need a refresher return to that module.

- There is one new thing to keep in mind when determining the rate in a 12-lead ECG…

Rate Rhythm Axis Intervals Hypertrophy Infarct

If you use the rhythm strip portion of the 12-lead ECG the total length of it is always 10 seconds long. So you can count the number of R waves in the rhythm strip and multiply by 6 to determine the beats per minute.



Rate? *12 (R waves) x 6 = 72 bpm*

Rate Rhythm Axis Intervals Hypertrophy Infarct

- In Module II you learned how to systematically analyze a rhythm by looking at the rate, regularity, P waves, PR interval and QRS complexes.
- In Modules III, IV and V you learned how to recognize Normal Sinus Rhythm and the 13 most common rhythm disturbances.
- If you need a refresher return to these modules.

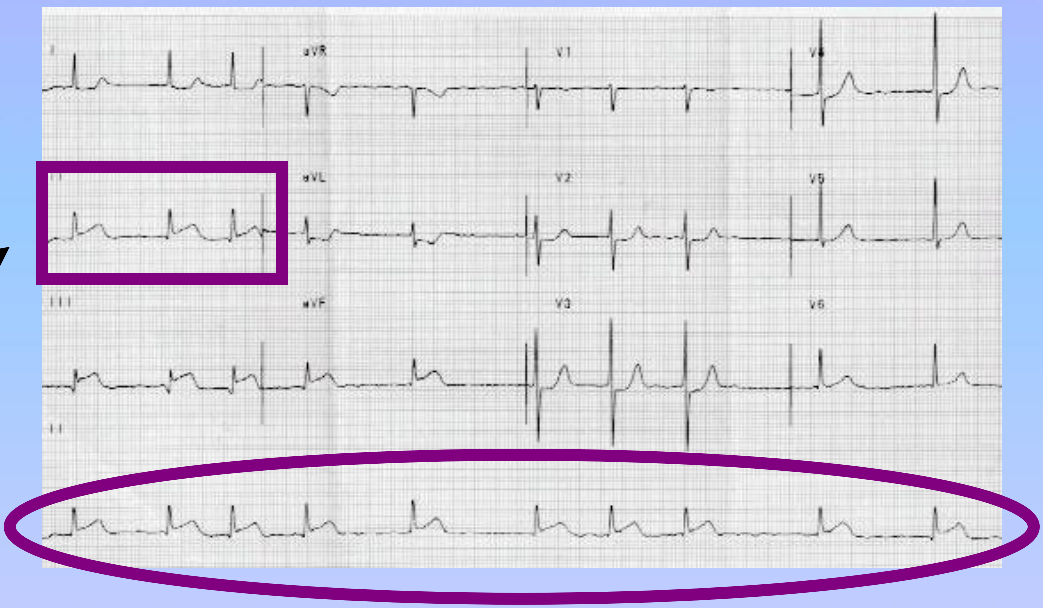
Rate **Rhythm** Axis Intervals Hypertrophy Infarct

Tip: the rhythm strip portion of the 12-lead ECG is a good place to look at when trying to determine the rhythm because the 12 leads only capture a few beats.

1 of 12 leads

Lead II

Rhythm strip

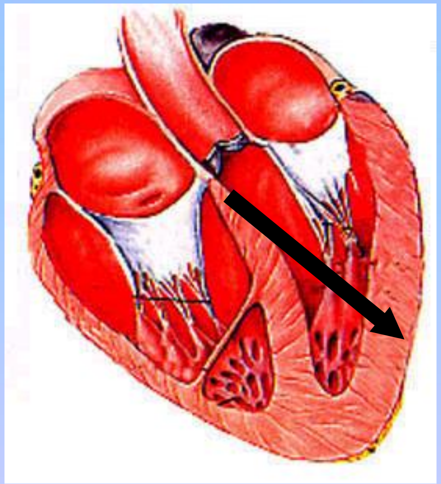


Rhythm?

Atrial fibrillation

Rate Rhythm Axis Intervals Hypertrophy Infarct

Axis refers to the mean QRS axis (or vector) during ventricular depolarization. As you recall when the ventricles depolarize (in a normal heart) the direction of current flows leftward and downward because most of the ventricular mass is in the left ventricle. We like to know the QRS axis because an abnormal axis can suggest disease such as pulmonary hypertension from a pulmonary embolism.



Rate Rhythm **Axis** Intervals Hypertrophy Infarct

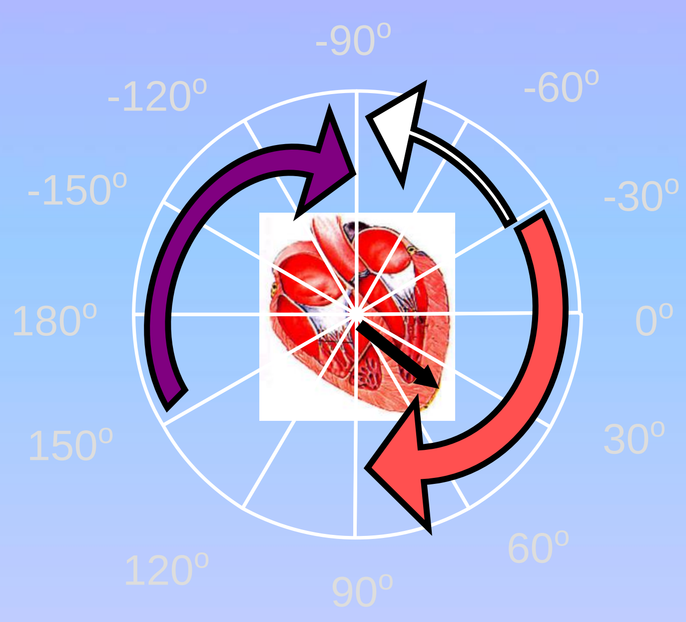
The QRS axis is determined by overlying a circle, in the frontal plane. By convention, the degrees of the circle are as shown.

The normal QRS axis lies between -30^o and $+90^o$.

A QRS axis that falls between -30^o and -90^o is abnormal and called left axis deviation.

A QRS axis that falls between $+90^o$ and $+150^o$ is abnormal and called right axis deviation.

A QRS axis that falls between $+150^o$ and -90^o is abnormal and called superior right axis deviation.



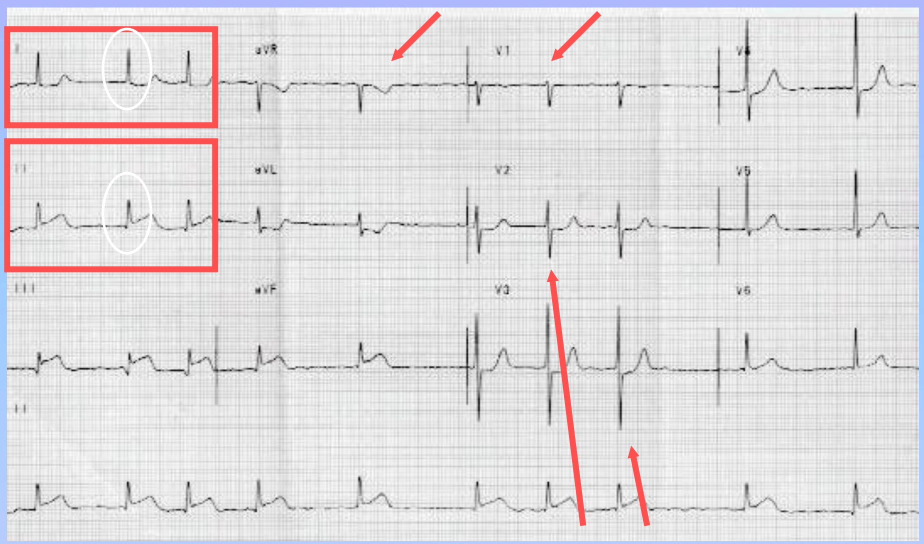
Rate Rhythm Axis Intervals Hypertrophy Infarct

We can quickly determine whether the QRS axis is normal by looking at leads I and II.

If the QRS complex is overall positive (R > Q+S) in leads I and II, the QRS axis is normal.

In this ECG what leads have QRS complexes that are negative? equivocal?

QRS negative (R < Q+S)



QRS equivocal (R = Q+S)

Rate Rhythm **Axis** Intervals Hypertrophy Infarct

How do we know the axis is normal when the QRS complexes are positive in leads I and II?

Rate Rhythm **Axis** Intervals Hypertrophy Infarct

The answer lies in the fact that each frontal lead corresponds to a location on the circle.

Limb leads

I = +0°

II = +60°

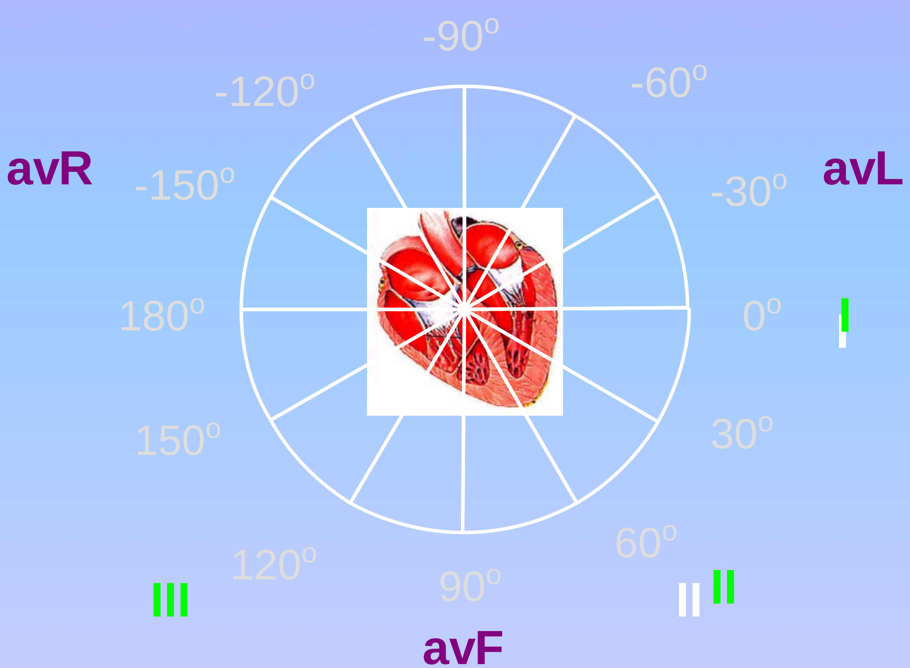
III = +120°

Augmented leads

avL = -30°

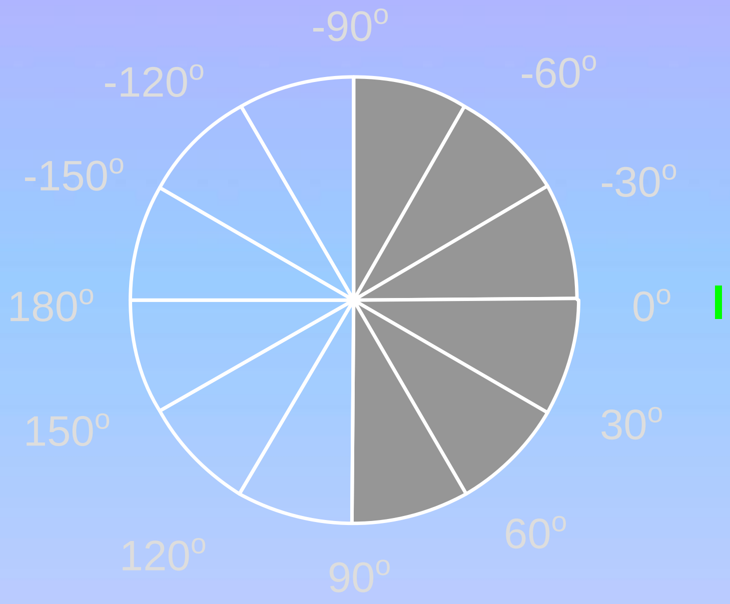
avF = +90°

avR = -150°



Rate Rhythm **Axis** Intervals Hypertrophy Infarct

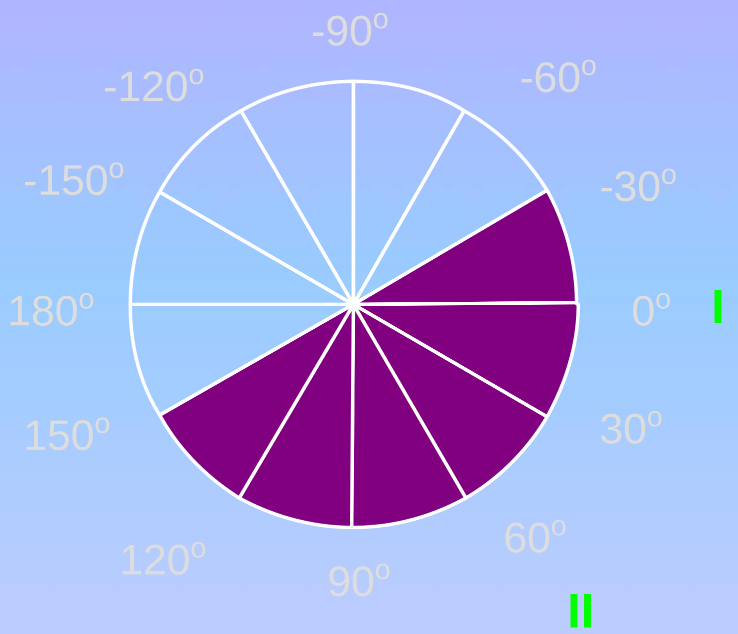
Since lead I is orientated at 0^o a wave of depolarization directed towards it will result in a positive QRS axis. Therefore any mean QRS vector between -90^o and $+90^o$ will be positive.



Rate Rhythm **Axis** Intervals Hypertrophy Infarct

Since lead I is orientated at 0^o a wave of depolarization directed towards it will result in a positive QRS axis. Therefore any mean QRS vector between -90^o and $+90^o$ will be positive.

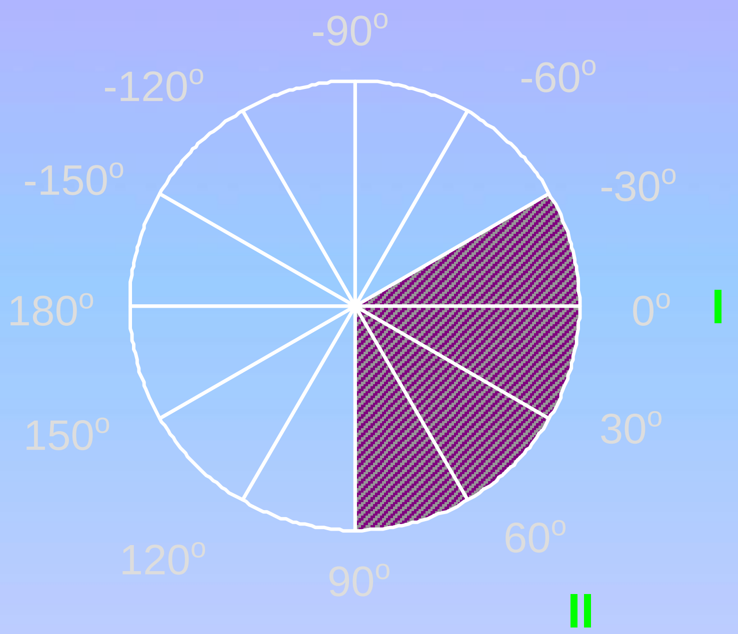
Similarly, since lead II is orientated at 60^o a wave of depolarization directed towards it will result in a positive QRS axis. Therefore any mean QRS vector between -30^o and $+150^o$ will be positive.



Since lead I is orientated at 0^o a wave of depolarization directed towards it will result in a positive QRS axis. Therefore any mean QRS vector between -90^o and +90^o will be positive.

Similarly, since lead II is orientated at 60^o a wave of depolarization directed towards it will result in a positive QRS axis. Therefore any mean QRS vector between -30^o and +150^o will be positive.

Therefore, if the QRS complex is positive in both leads I and II the QRS axis must be between -30^o and 90^o (where leads I and II overlap) and, as a result, the axis must be normal.

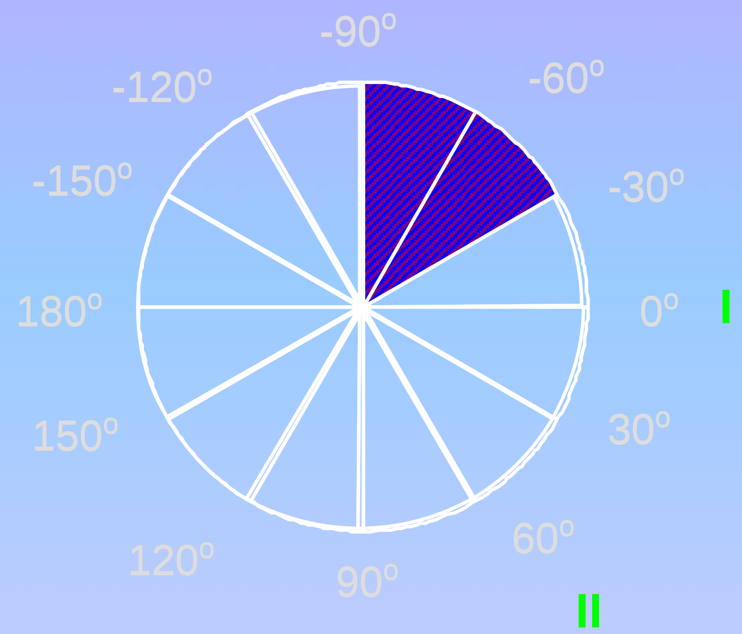


Rate Rhythm **Axis** Intervals Hypertrophy Infarct

Now using what you just learned fill in the following table. For example, if the QRS is positive in lead I and negative in lead II what is the QRS axis? (normal, left, right or right superior axis deviation)

QRS Complexes

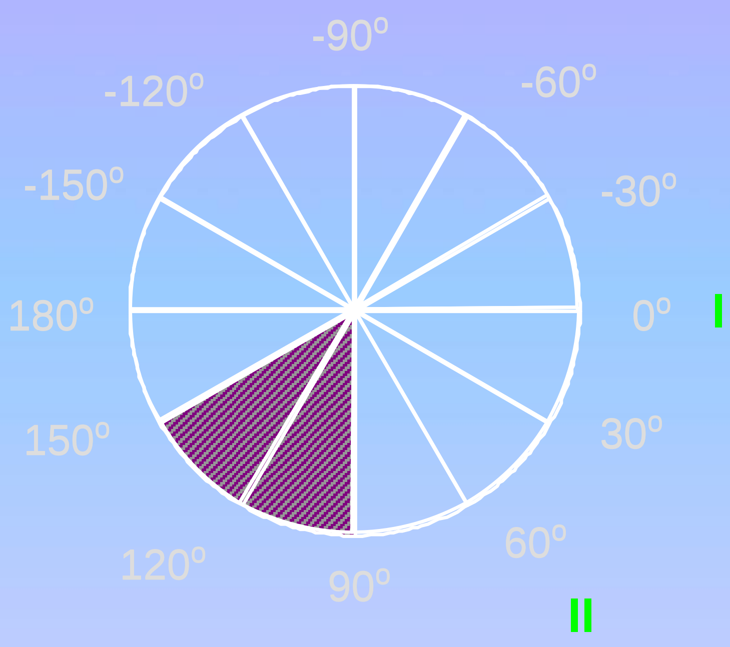
I	II	Axis
+	+	normal
+	-	left axis deviation



Rate Rhythm **Axis** Intervals Hypertrophy Infarct

… if the QRS is negative in lead I and positive in lead II what is the QRS axis? (normal, left, right or right superior axis deviation)

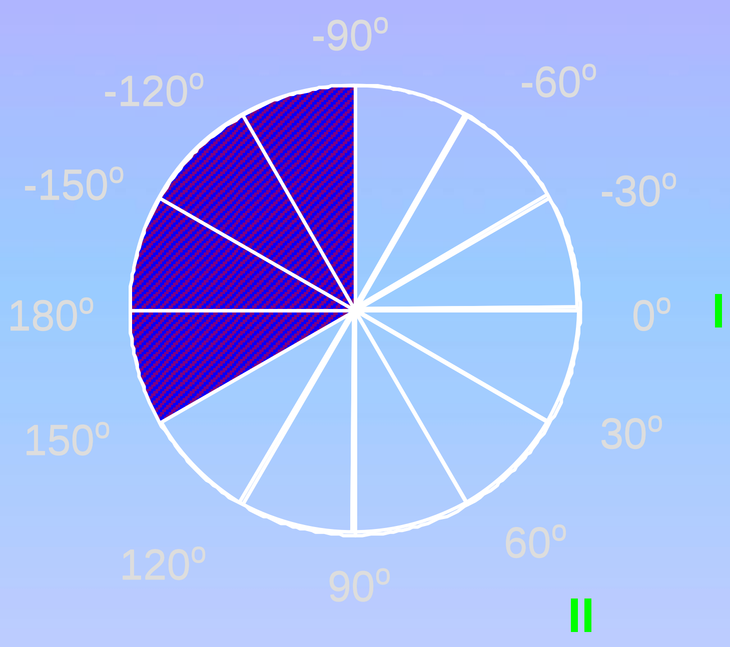
QRS Complexes		
I	II	Axis
+	+	normal
+	-	left axis deviation
-	+	right axis deviation



Rate Rhythm Axis Intervals Hypertrophy Infarct

… if the QRS is negative in lead I and negative in lead II what is the QRS axis? (normal, left, right or right superior axis deviation)

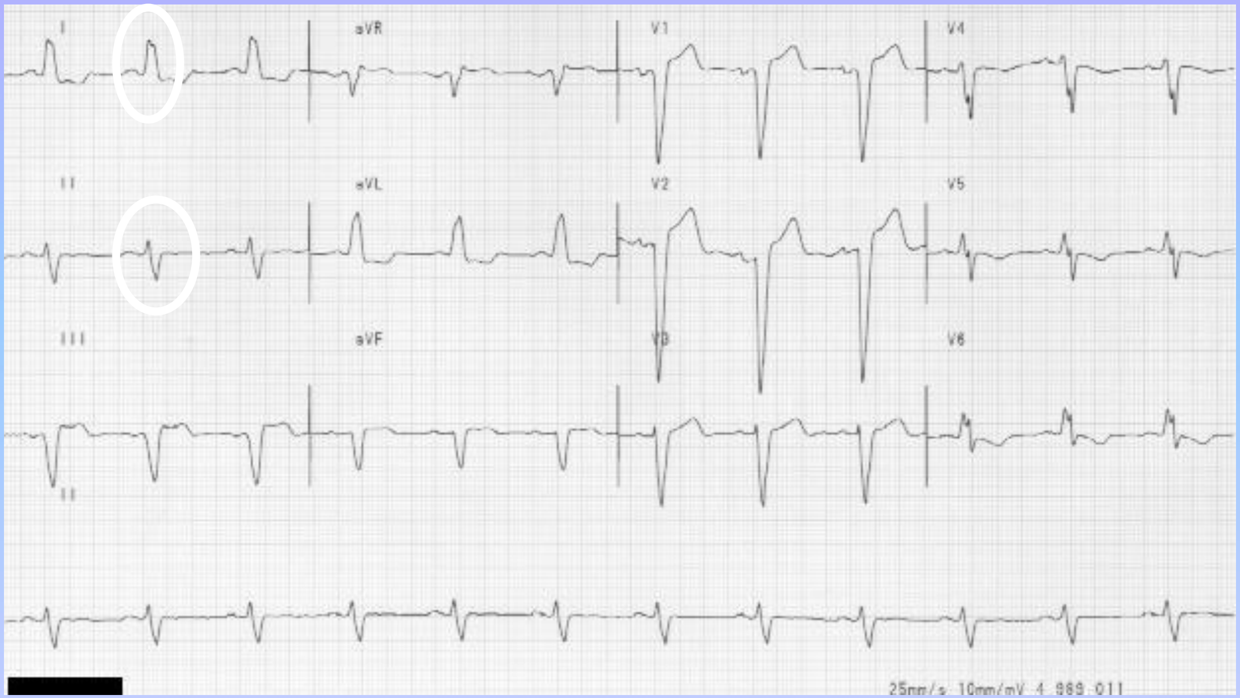
QRS Complexes I	II	Axis
+	+	normal
+	-	left axis deviation
-	+	right axis deviation
-	-	right superior axis deviation



Rate Rhythm Axis Intervals Hypertrophy Infarct

Is the QRS axis normal in this ECG?

No, there is left axis deviation.



The QRS is positive in I and negative in II.

Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize:

- The normal QRS axis falls between -30° and +90° because ventricular depolarization is leftward and downward.
- Left axis deviation occurs when the axis falls between -30° and -90°.
- Right axis deviation occurs when the axis falls between +90° and +150°.
- Right superior axis deviation occurs when the axis falls between between +150° and -90°.
- A quick way to determine the QRS axis is to look at the QRS complexes in leads I and II.

QRS Complexes

I	II	Axis
+	+	normal
+	-	left axis deviation
-	+	right axis deviation
-	-	right superior axis deviation

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize VII a:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
   - Normal
   - Left axis deviation
   - Right axis deviation
   - Right superior axis deviation

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

In VII b we will cover the next 3 steps:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
6. Look for evidence of INFARCTION

Reading 12-Lead ECGs

In Module VII a we introduced a 6 step approach for analyzing a 12-lead ECG and covered the first 3 steps. In this module we will cover the last 3 steps.

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
6. Look for evidence of INFARCTION

Rate Rhythm Axis Intervals Hypertrophy Infarct

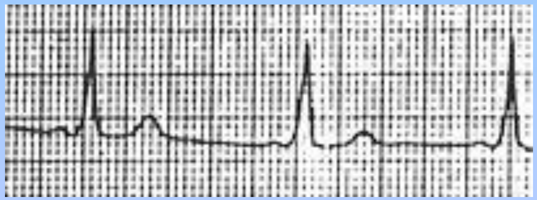
- Intervals refers to the length of the PR and QT intervals and the width of the QRS complexes. You should have already determined the PR and QRS during the “rhythm” step, but if not, do so in this step.

- In the following few slides we’ll review what is a normal and abnormal PR, QRS and QT interval. Also listed are a few common causes of abnormal intervals.

Rate Rhythm Axis Intervals Hypertrophy Infarct

PR interval

< 0.12 s	0.12-0.20 s	> 0.20 s
High catecholamine states Wolff-Parkinson-White	Normal	AV nodal blocks



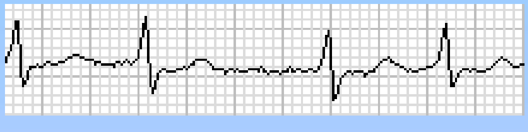
Wolff-Parkinson-White

1st Degree AV Block

Rate Rhythm Axis Intervals Hypertrophy Infarct

QRS complex

$\leq$ 0.10 s	0.10-0.12 s	> 0.12 s
Normal	Incomplete bundle branch block	Bundle branch block PVC Ventricular rhythm



Incomplete bundle branch block

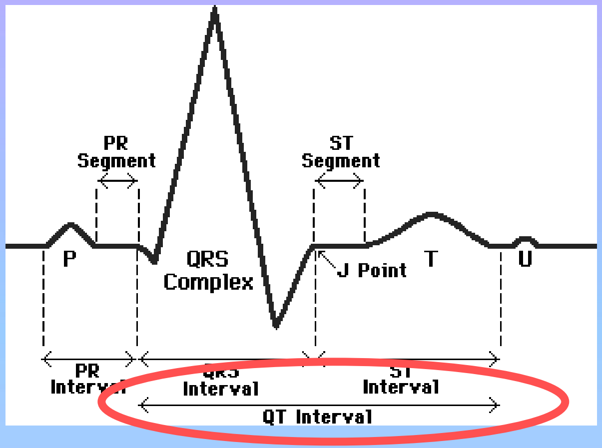
3rd degree AV block with ventricular escape rhythm

Remember: If you have a BBB determine if it is a right or left BBB. If you need a refresher see Module VI.

Rate Rhythm Axis **Intervals** Hypertrophy Infarct

QT interval

The duration of the QT interval is proportionate to the heart rate. The faster the heart beats, the faster the ventricles repolarize so the shorter the QT interval. Therefore what is a “normal” QT varies with the heart rate. For each heart rate you need to calculate an adjusted QT interval, called the “corrected QT” (QTc):

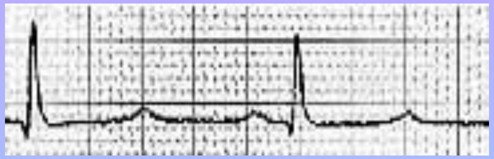


QTc = QT / square root of RR interval

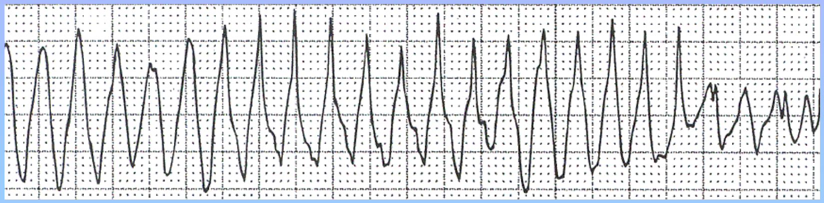
Rate Rhythm Axis Intervals Hypertrophy Infarct

QTc interval

< 0.44 s	> 0.44 s
Normal	Long QT



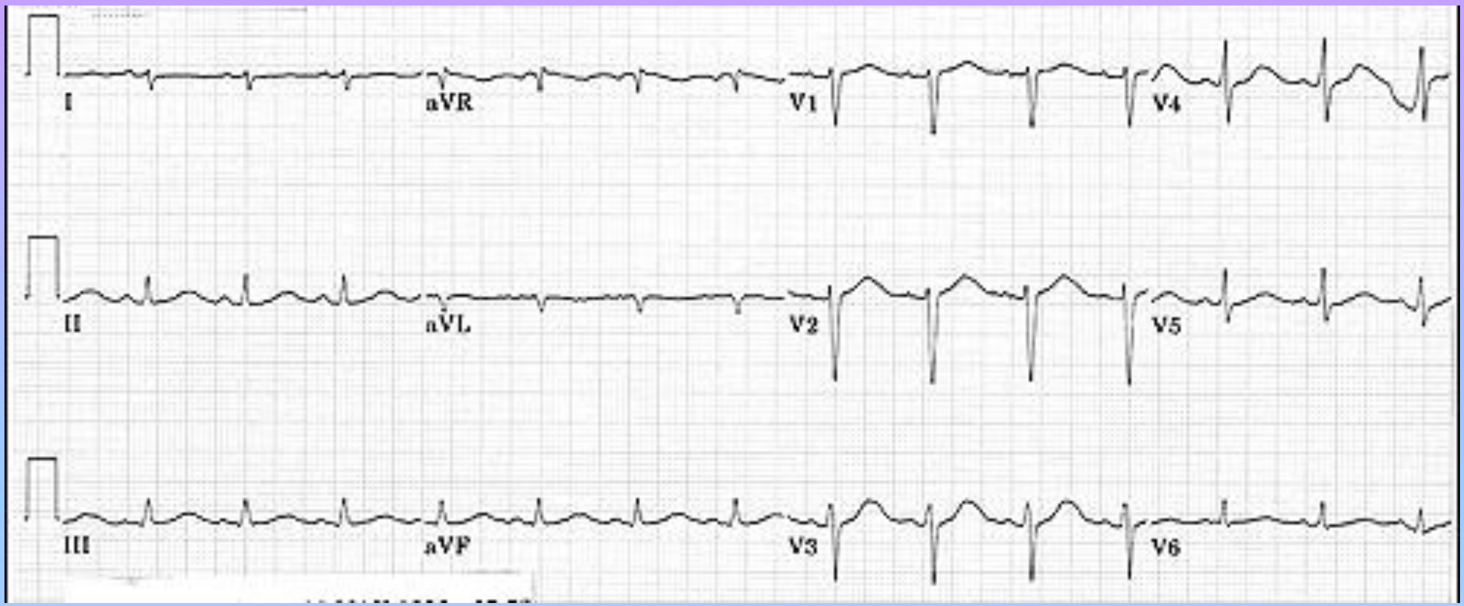
Long QT



Torsades de Pointes

A prolonged QT can be very dangerous. It may predispose an individual to a type of ventricular tachycardia called Torsades de Pointes. Causes include drugs, electrolyte abnormalities, CNS disease, post-MI, and congenital heart disease.

Rate Rhythm Axis Intervals Hypertrophy Infarct



QT = 0.40 s

RR = 0.68 s

Square root of RR = 0.82

QTc = 0.40/0.82 = 0.49 s

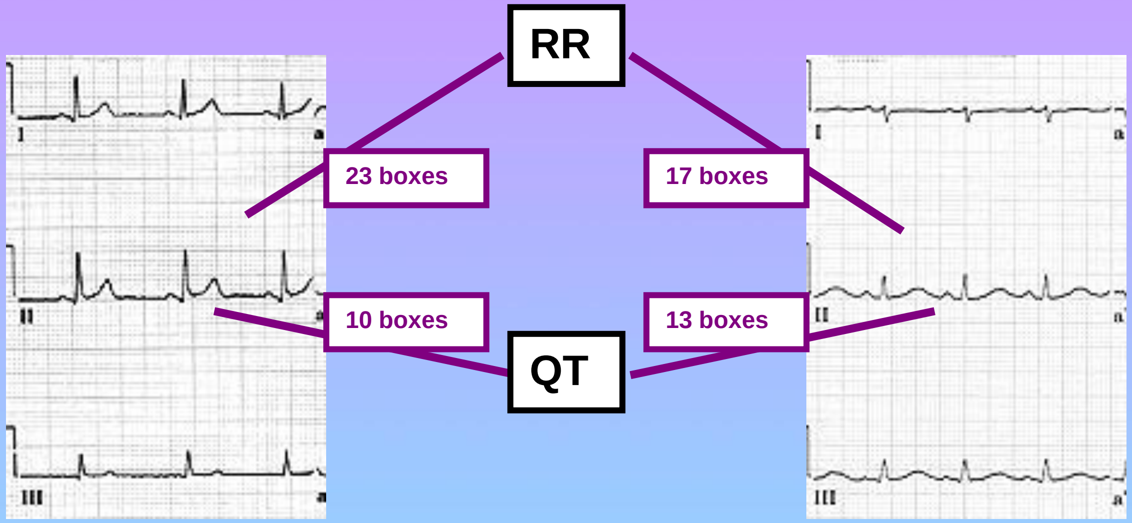
PR interval? *0.16 seconds*

QRS width? *0.08 seconds*

QTc interval? *0.49 seconds*

Interpretation of intervals? *Normal PR and QRS, long QT*

Rate Rhythm Axis Intervals Hypertrophy Infarct



Normal QT Long QT

Tip: Instead of calculating the QTc, a quick way to estimate if the QT interval long is to use the following rule:

A QT > half of the RR interval is probably long.

Rate Rhythm Axis Intervals Hypertrophy Infarct

In this step of the 12-lead ECG analysis, we use the ECG to determine if any of the 4 chambers of the heart are enlarged or hypertrophied. We want to determine if there are any of the following:

- Right atrial enlargement (RAE)
- Left atrial enlargement (LAE)
- Right ventricular hypertrophy (RVH)
- Left ventricular hypertrophy (LVH)

Rate Rhythm Axis Intervals Hypertrophy Infarct

- In Module VI we introduced the concept of left ventricular hypertrophy. As you remember the QRS voltage increases with LVH and is characterized by tall QRS complexes in certain leads. Similarly for right ventricular hypertrophy we look at the QRS complexes for changes in voltage patterns.

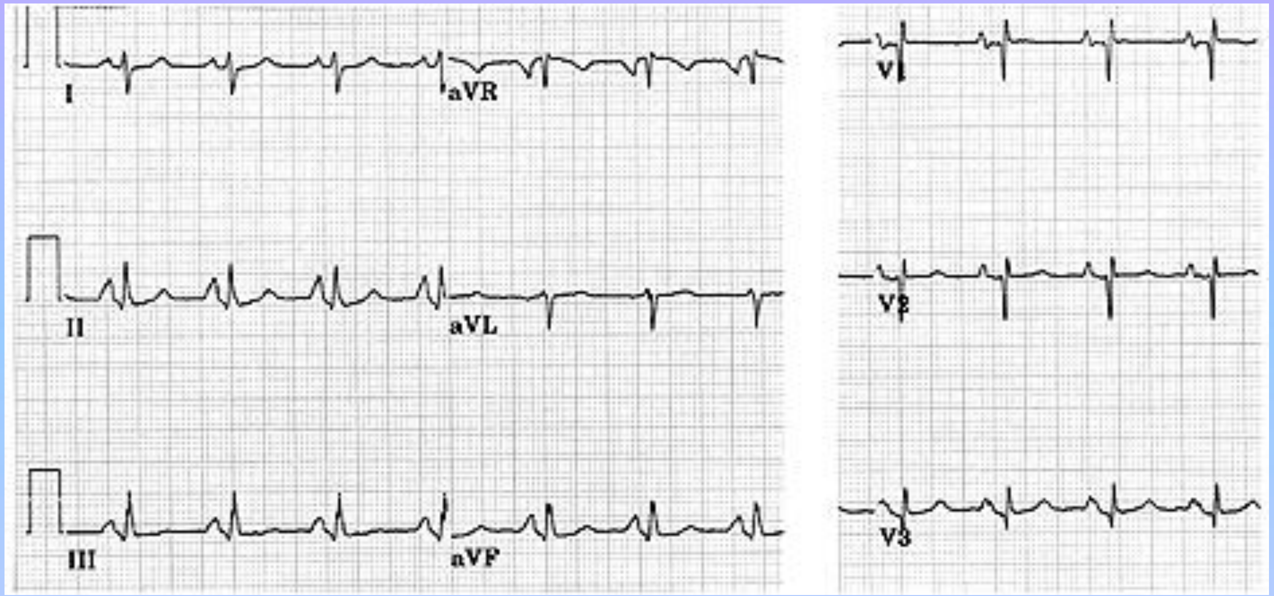
- With right and left atrial enlargement we analyze the P wave (since the P wave represents atrial depolarization). Here we also look for changes in voltage patterns.

- Note: as mentioned in Module VI criteria exists to diagnose LVH, the same goes for RAE, LAE and RVH. In the following slides we will be presenting criteria you can use. However other criteria exists and as a reference you might find it useful to carry a copy of Tom Evans' *ECG Interpretation Cribsheet*.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right atrial enlargement

- Take a look at this ECG. What do you notice about the P waves?

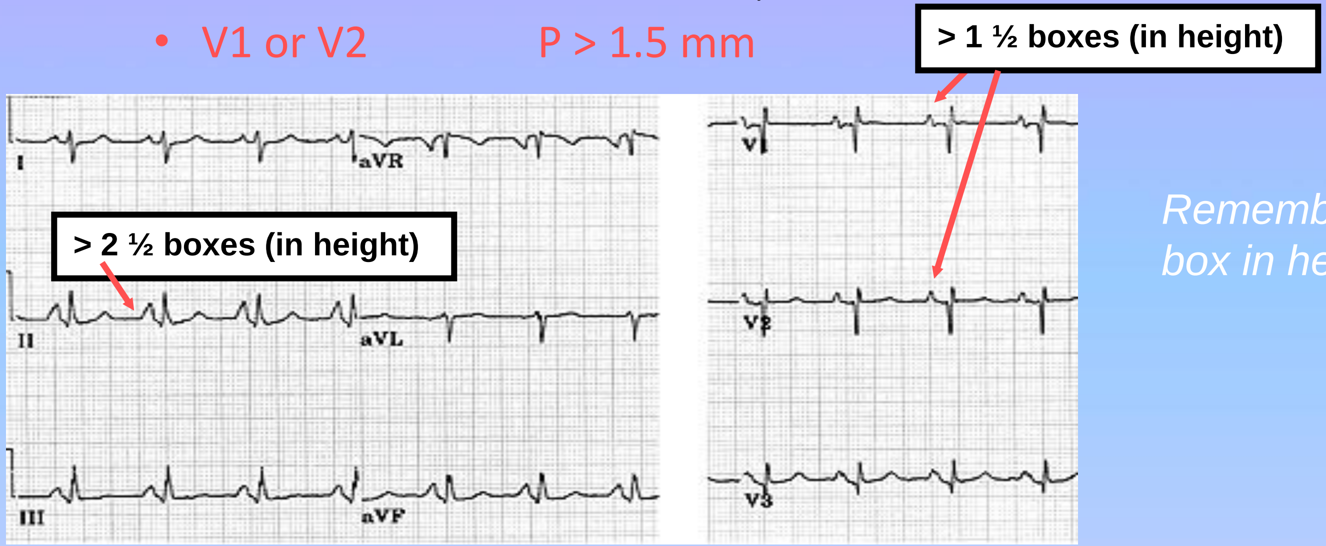


The P waves are tall, especially in leads II, III and avF. Ouch! They would hurt to sit on!!

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right atrial enlargement

- To diagnose RAE you can use the following criteria:
  - II P > 2.5 mm, or
  - V1 or V2 P > 1.5 mm



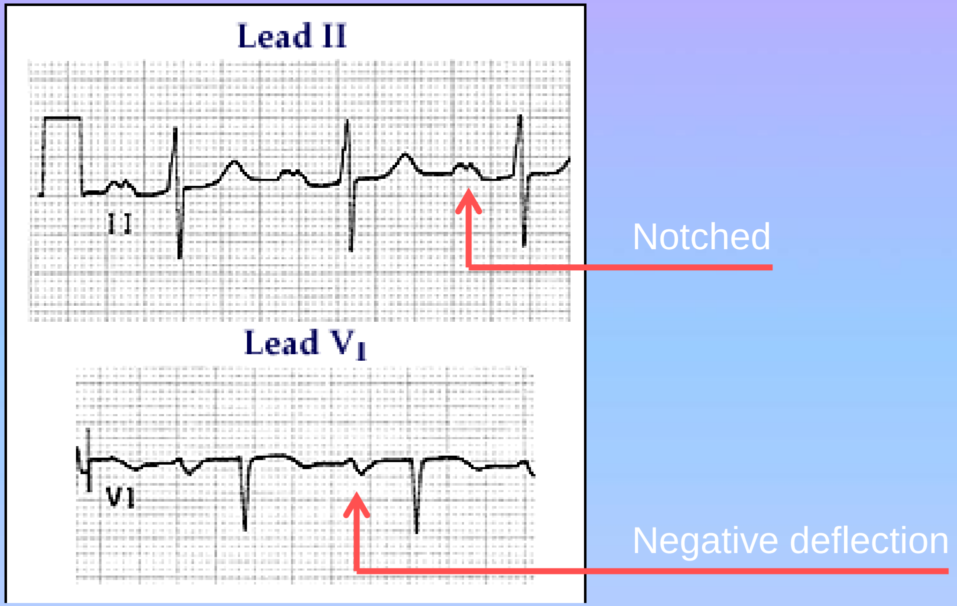
Remember 1 small box in height = 1 mm

A cause of RAE is RVH from pulmonary hypertension.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Left atrial enlargement

- Take a look at this ECG. What do you notice about the P waves?

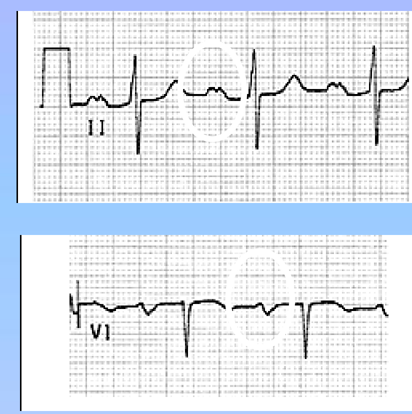


The P waves in lead II are notched and in lead V1 they have a deep and wide negative component.

Left atrial enlargement

- To diagnose LAE you can use the following criteria:
  - II — > 0.04 s (1 box) between notched peaks, or
  - V1 — Neg. deflection > 1 box wide x 1 box deep

Normal



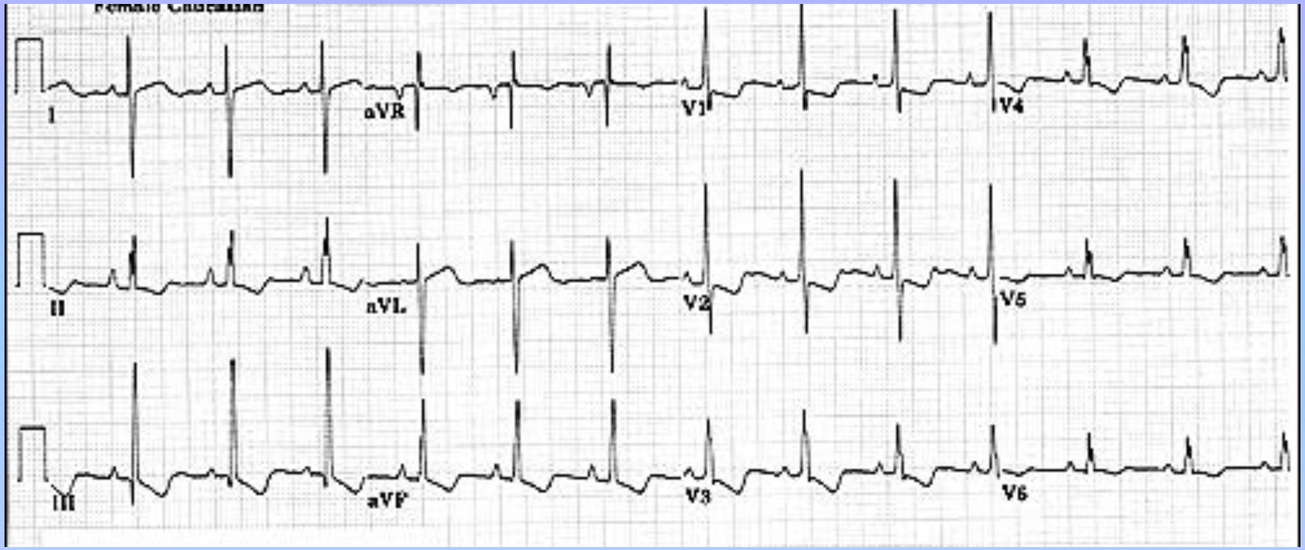
LAE

A common cause of LAE is LVH from hypertension.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right ventricular hypertrophy

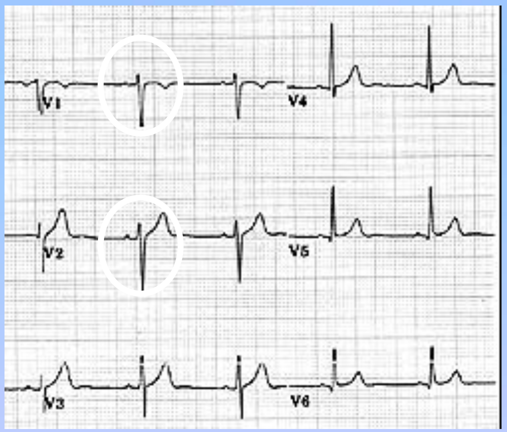
- Take a look at this ECG. What do you notice about the axis and QRS complexes over the right ventricle (V1, V2)?



There is right axis deviation (negative in I, positive in II) and there are tall R waves in V1, V2.

Right ventricular hypertrophy

- Compare the R waves in V1, V2 from a normal ECG and one from a person with RVH.
- Notice the R wave is normally small in V1, V2 because the right ventricle does not have a lot of muscle mass.
- But in the hypertrophied right ventricle the R wave is tall in V1, V2.



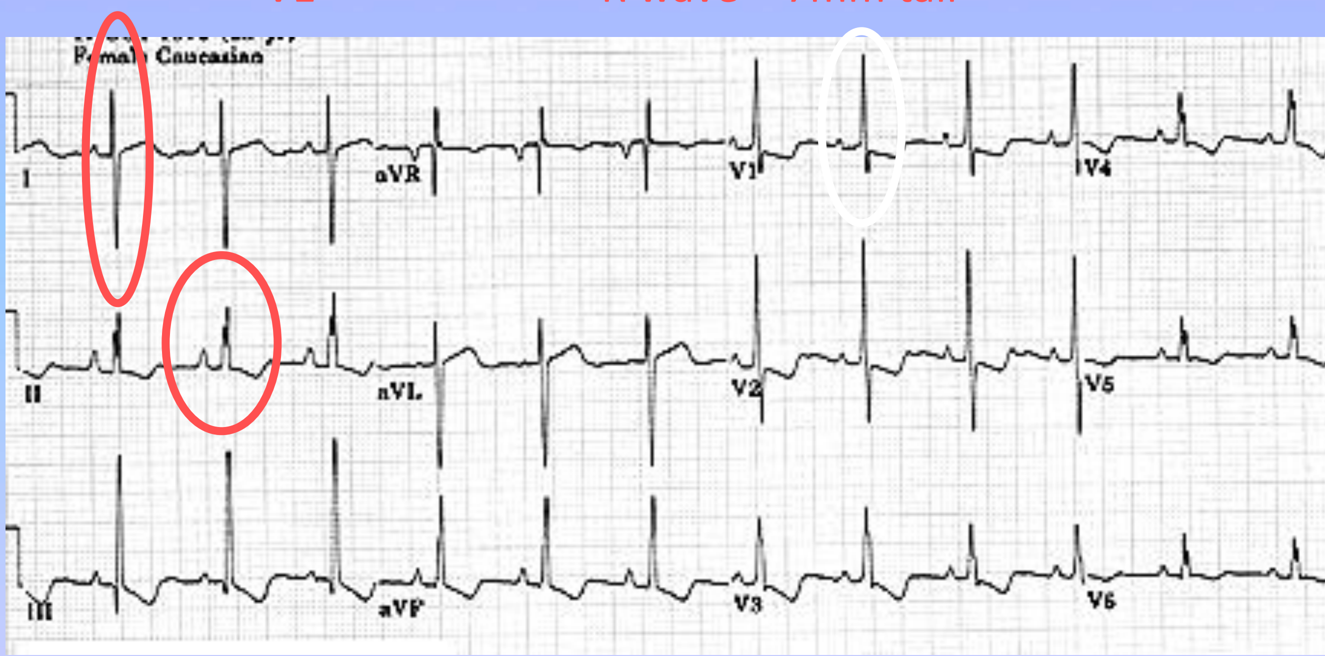
Normal

RVH

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right ventricular hypertrophy

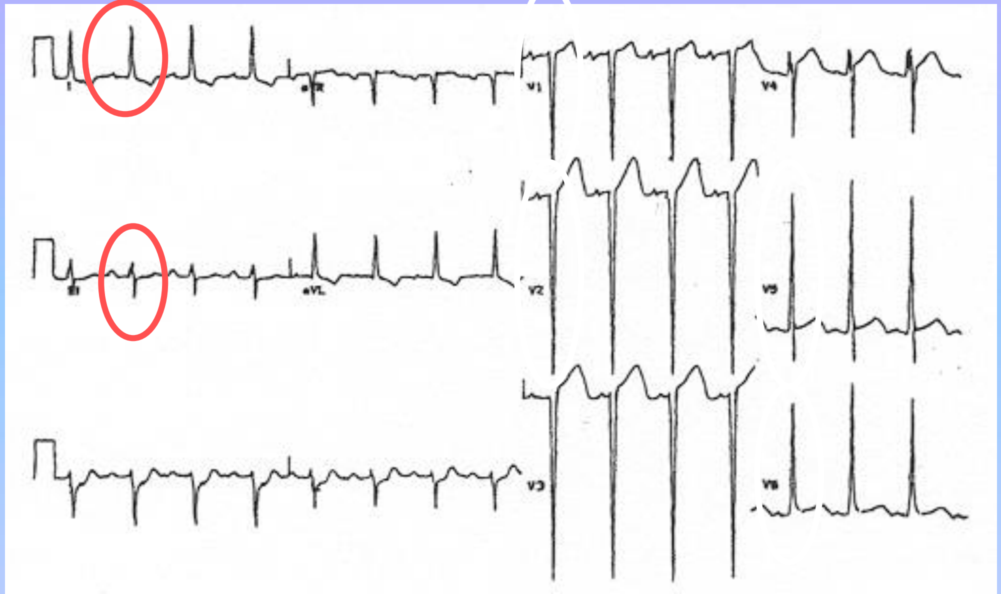
- To diagnose RVH you can use the following criteria:
  - Right axis deviation, and
  - V1 R wave > 7mm tall



A common cause of RVH is left heart failure.

Left ventricular hypertrophy

- Take a look at this ECG. What do you notice about the axis and QRS complexes over the left ventricle (V5, V6) and right ventricle (V1, V2)?



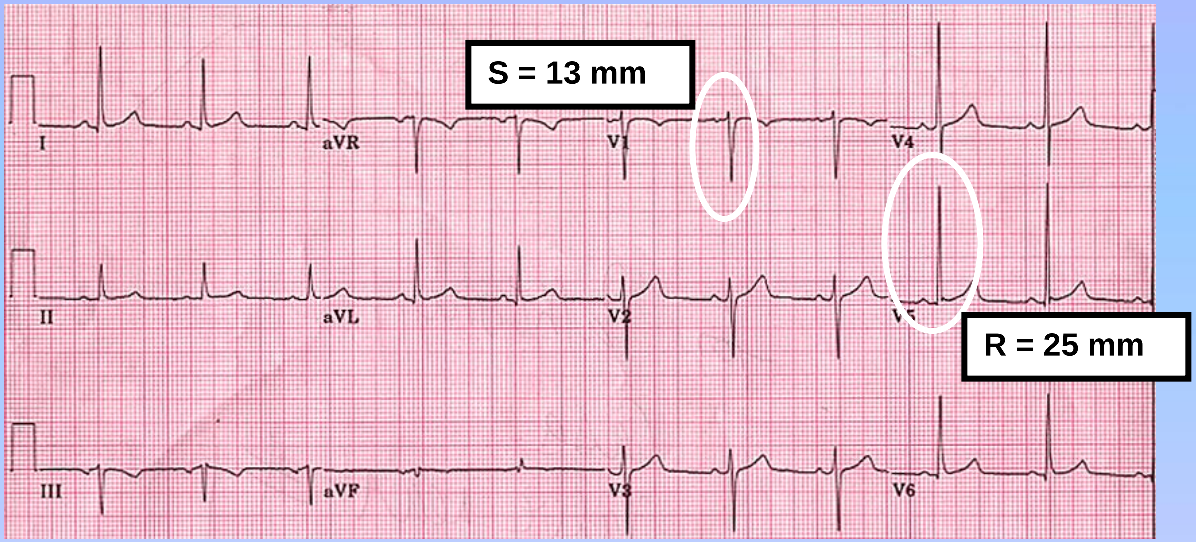
The deep S waves seen in the leads over the right ventricle are created because the heart is depolarizing left, superior and posterior (away from leads V1, V2).

There is left axis deviation (positive in I, negative in II) and there are tall R waves in V5, V6 and deep S waves in V1, V2.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Left ventricular hypertrophy

– To diagnose LVH you can use the following criteria*:
  - R in V5 (or V6) + S in V1 (or V2) > 35 mm, or
  - avL R > 13 mm

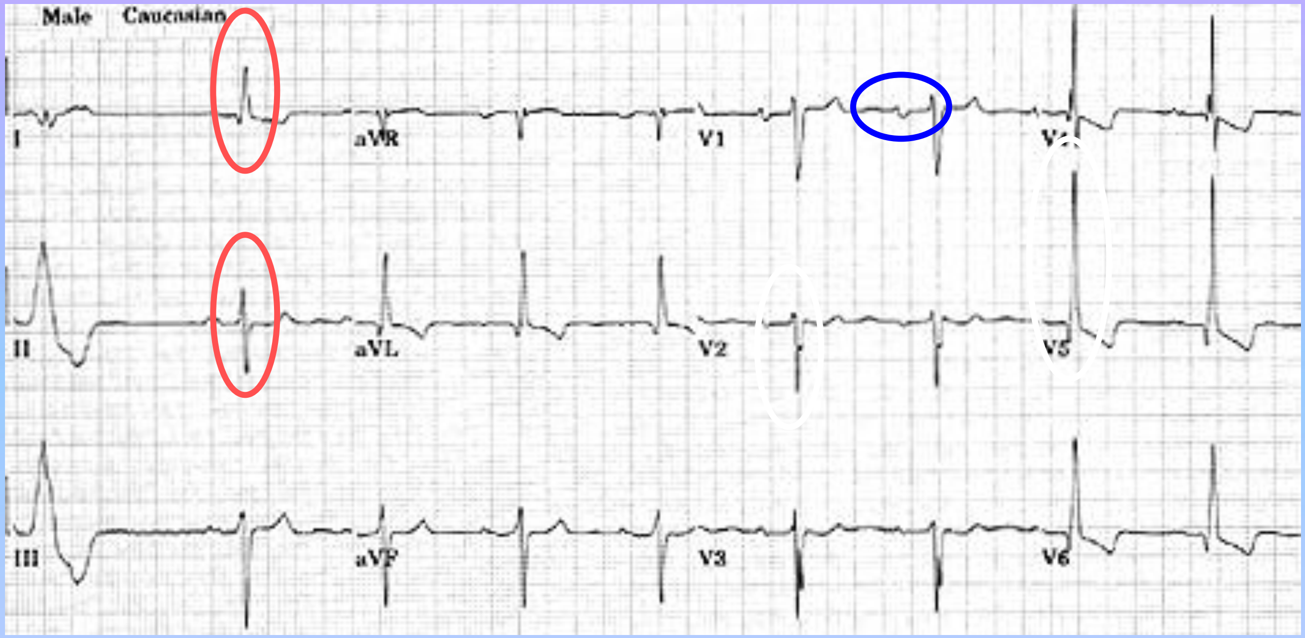


** There are several other criteria for the diagnosis of LVH.*

A common cause of LVH is hypertension.

Rate Rhythm Axis Intervals Hypertrophy Infarct

A 63 yo man has longstanding, uncontrolled hypertension. Is there evidence of heart disease from his hypertension? *(Hint: There a 3 abnormalities.)*



Yes, there is left axis deviation (positive in I, negative in II), left atrial enlargement (> 1 x 1 boxes in V1) and LVH (R in V5 = 27 + S in V2 = 10 → > 35 mm).

Rate Rhythm Axis Intervals Hypertrophy Infarct

- When analyzing a 12-lead ECG for evidence of an infarction you want to look for the following:
  - **Abnormal Q waves**
  - **ST elevation or depression**
  - **Peaked, flat or inverted T waves**

- These topics were covered in Modules V and VI where you learned:
  - **ST elevation (or depression) of 1 mm in 2 or more contiguous leads is consistent with an AMI**
  - **There are ST elevation (Q-wave) and non-ST elevation (non-Q wave) MIs**

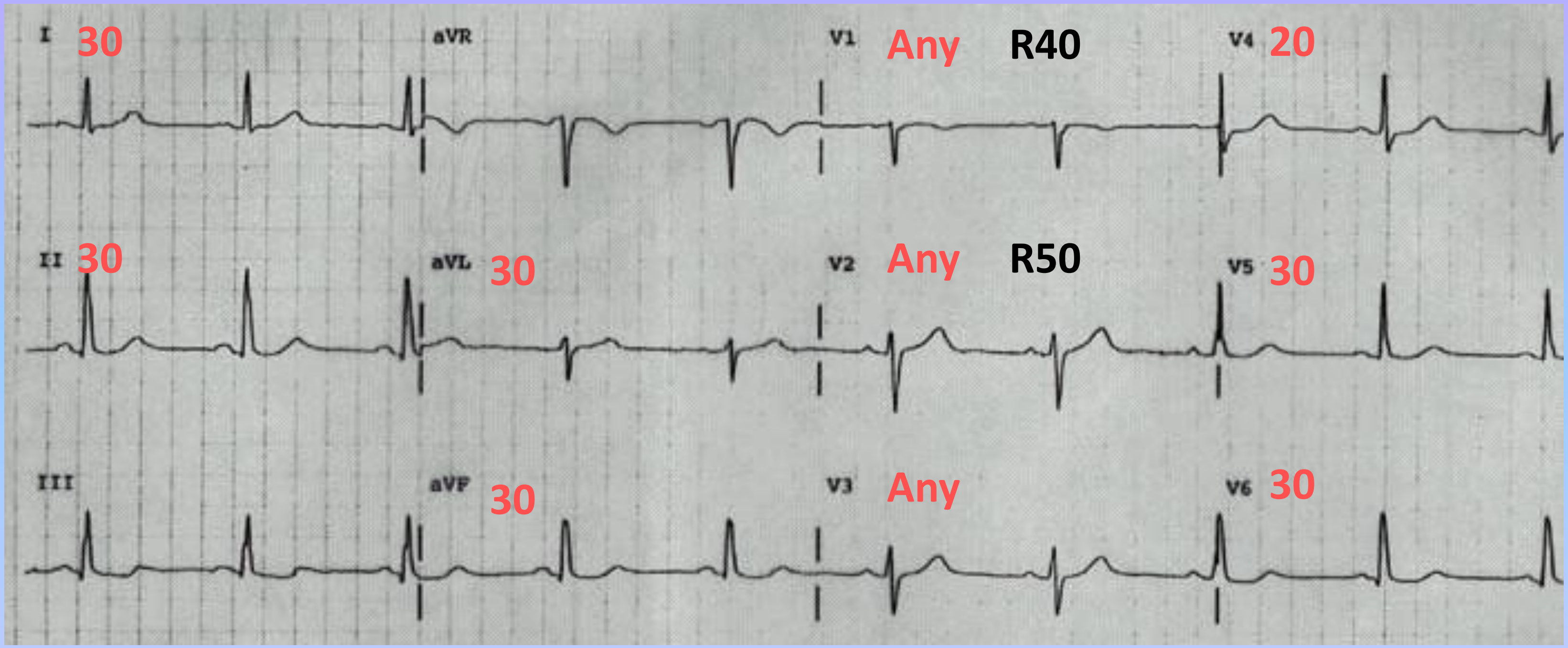
Rate Rhythm Axis Intervals Hypertrophy Infarct

Tip: One way to determine if Q waves (and R waves) are abnormal is by looking at the width and using the following mantra (read red downwards):

Any	Any Q wave in V1
Any	Any Q wave in V2
Any	Any Q wave in V3
20	A Q wave $\geq$ 20 msec in V4 (i.e. 0.02 sec or ½ width of a box)
30	A Q wave $\geq$ 30 msec in V5
30	A Q wave $\geq$ 30 msec in V6
30	A Q wave $\geq$ 30 msec in I
30	A Q wave $\geq$ 30 msec in avL
30	A Q wave $\geq$ 30 msec in II
30	A Q wave $\geq$ 30 msec in avF
R40	A R wave $\geq$ 40 msec in V1
R50	A R wave $\geq$ 50 msec in V2

Rate Rhythm Axis Intervals Hypertrophy Infarct

This mantra corresponds to the ECG in the following way:



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
   – Normal
   – Left axis deviation
   – Right axis deviation
   – Right superior axis deviation

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
   - PR
   - QRS
   - QT

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
   - Right and left atrial enlargement
   - Right and left ventricular hypertrophy

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
6. Look for evidence of INFARCTION
   - Abnormal Q waves
   - ST elevation or depression
   - Peaked, flat or inverted T waves

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

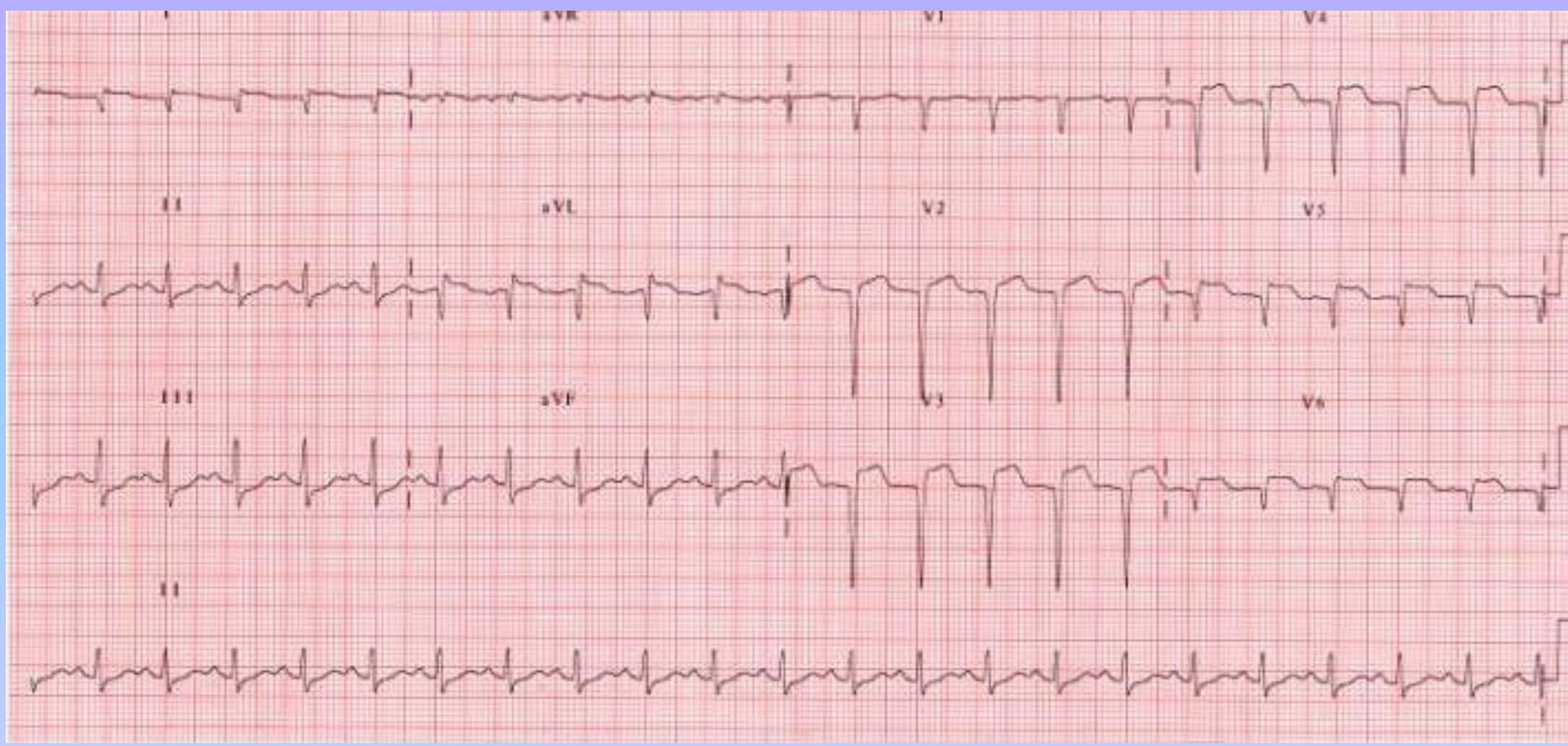
To summarize:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
4. Calculate INTERVALS
5. Assess for HYPERTROPHY
6. Look for evidence of INFARCTION

Now to finish this module lets analyze a 12-lead ECG!

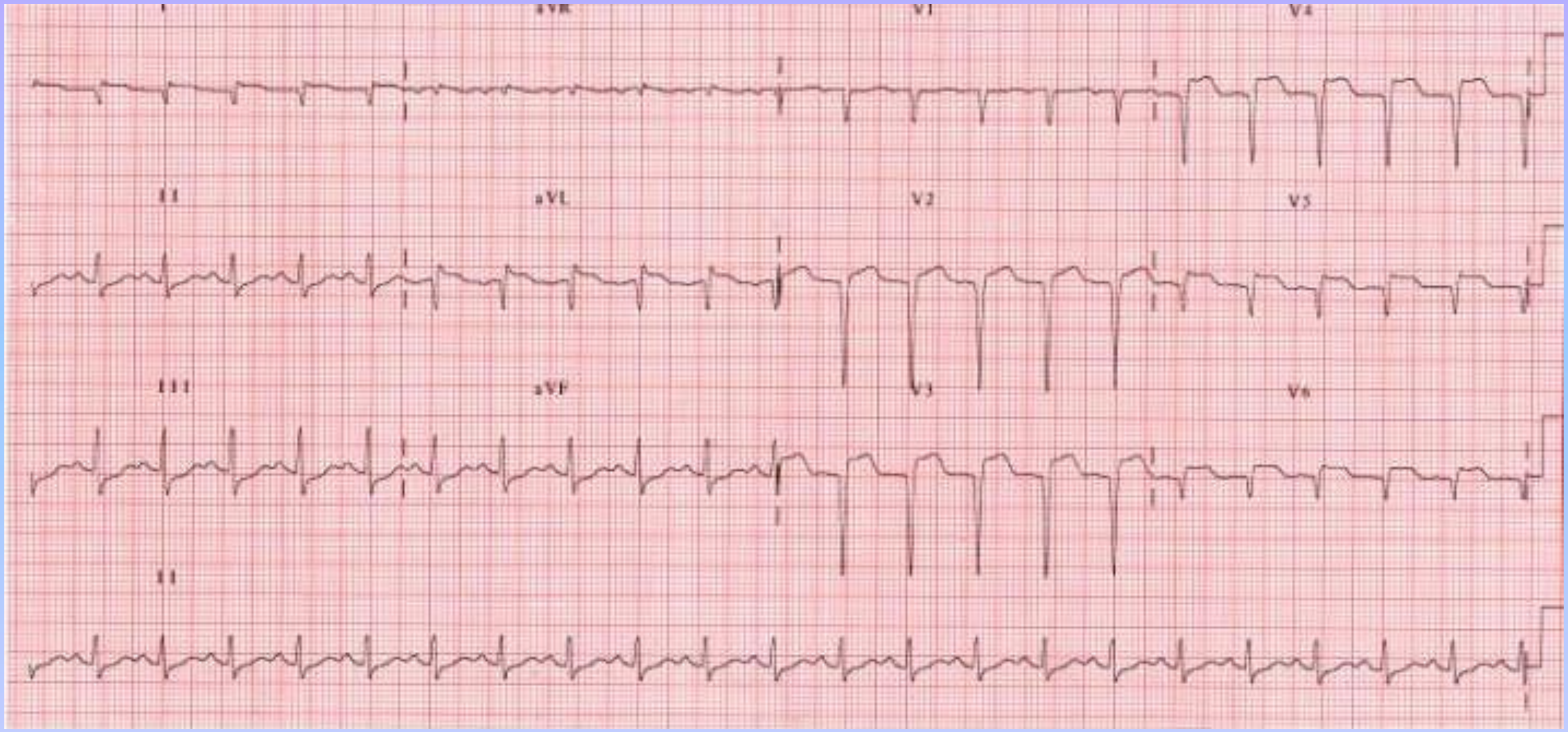
SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

A 16 yo young man ran into a guardrail while riding a motorcycle. In the ED he is comatose and dyspneic. This is his ECG.



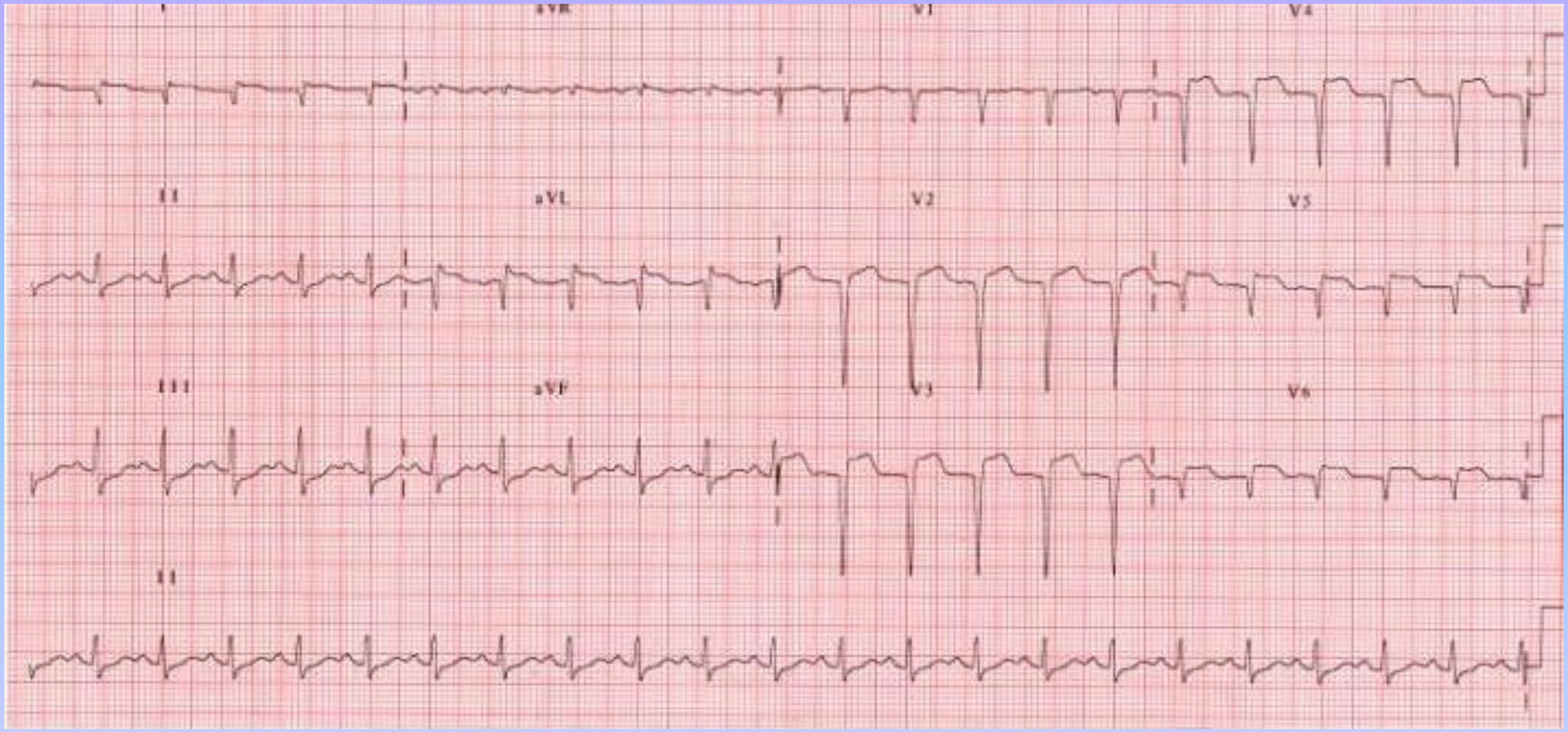
SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

What is the rate? *Approx. 132 bpm (22 R waves x 6)*



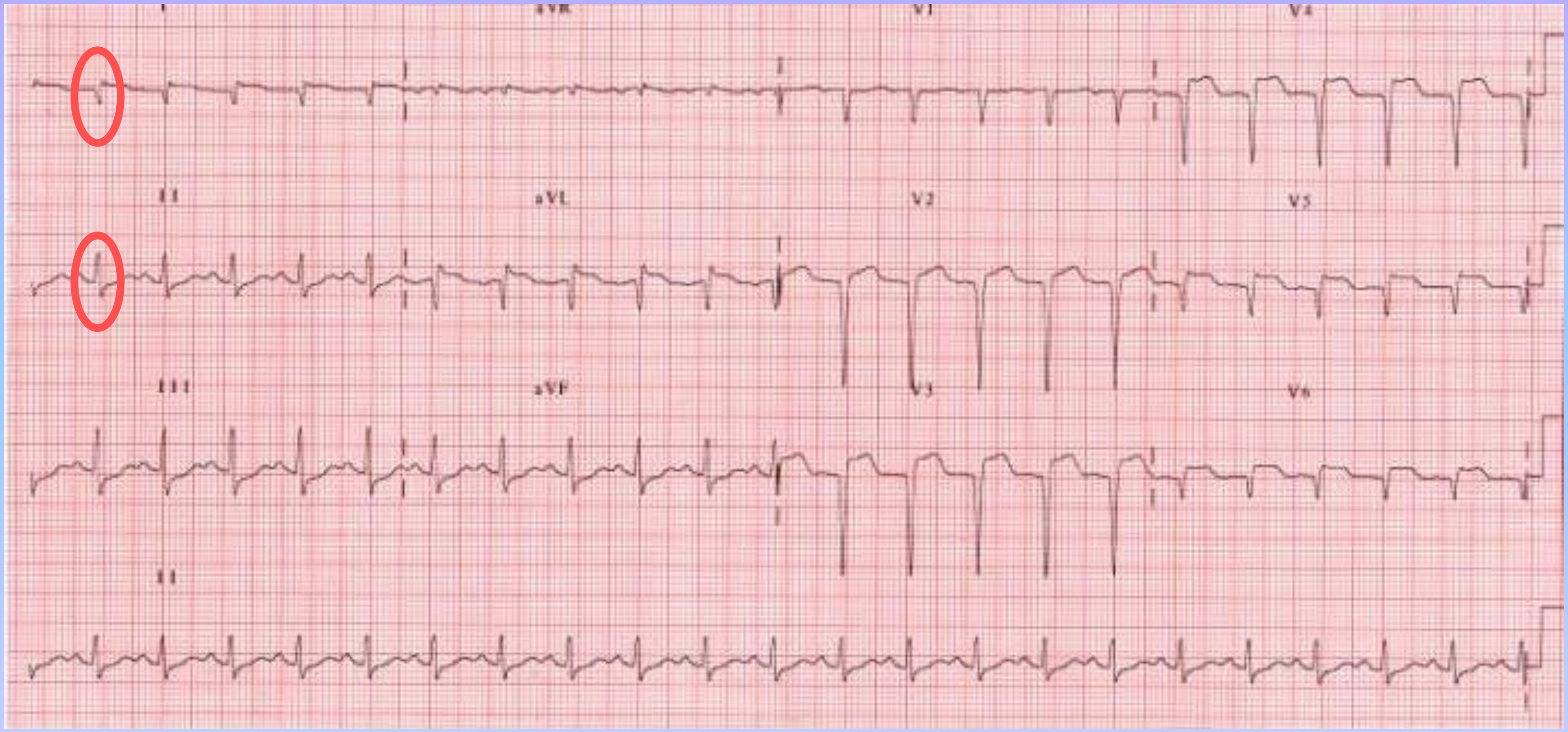
SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

What is the rhythm? *Sinus tachycardia*



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

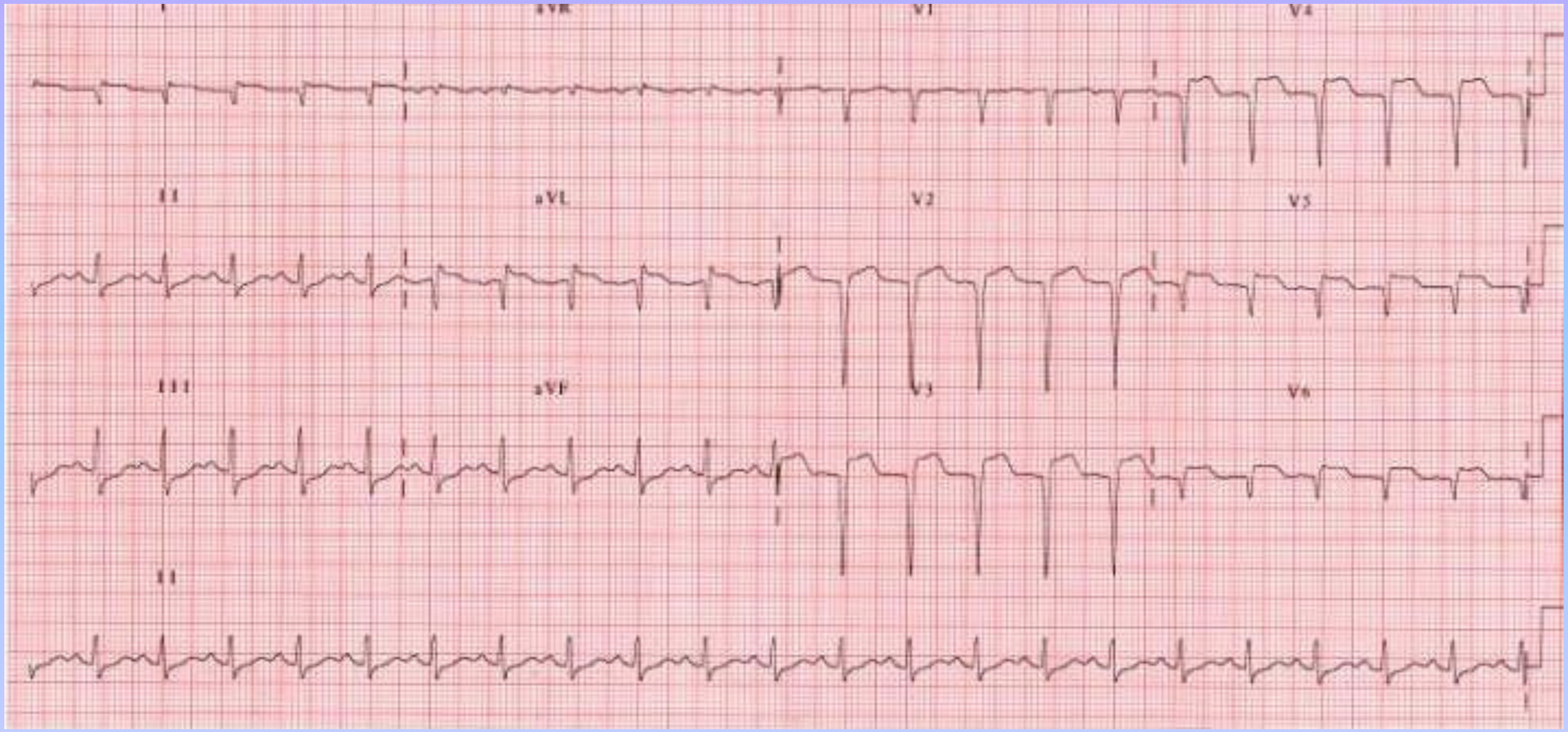
What is the QRS axis? *Right axis deviation* *(- in I, + in II)*



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

What are the PR, QRS and QT intervals?

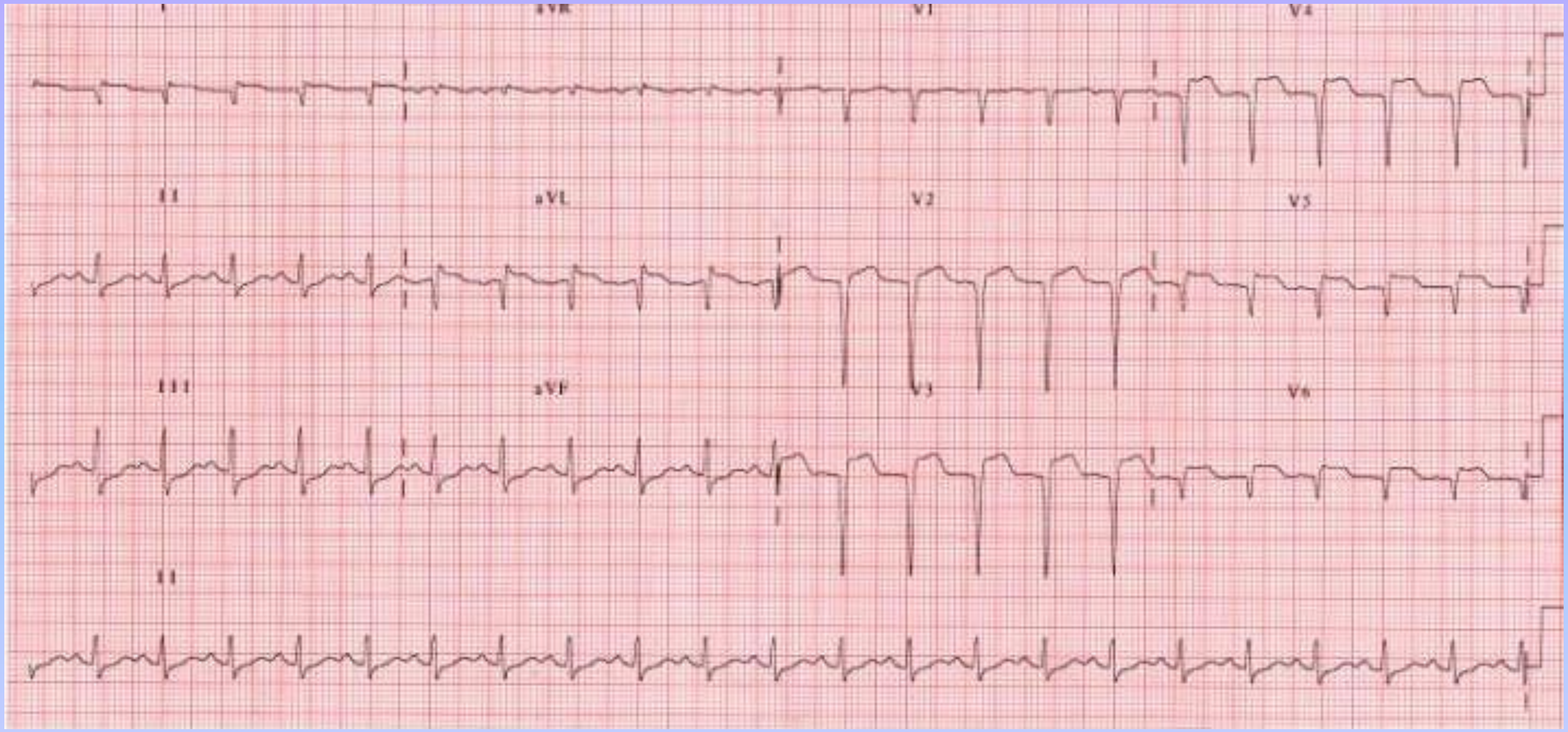
PR = 0.12 s, QRS = 0.08 s, QTc = 0.482 s



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

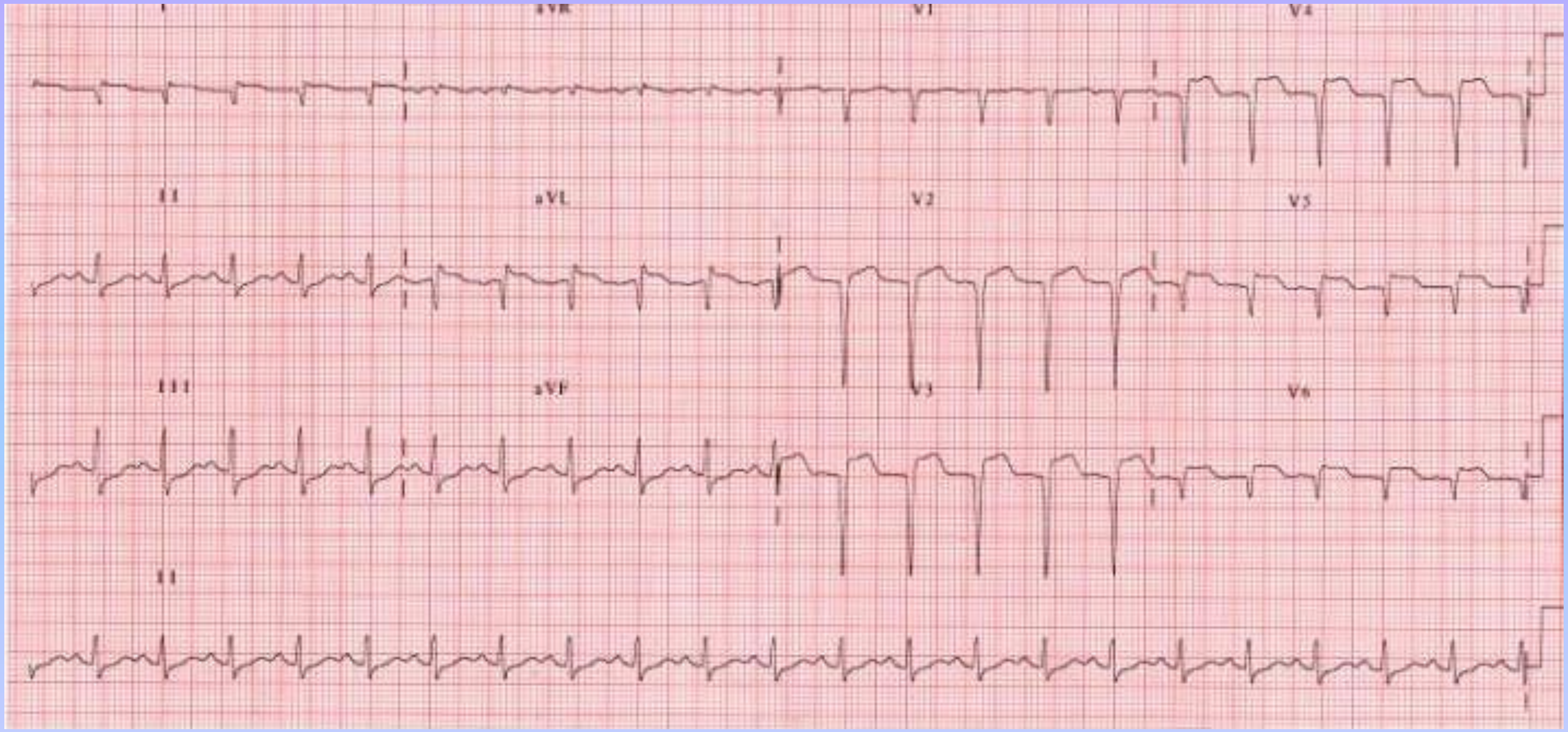
Is there evidence of atrial enlargement?

No (no peaked, notched or negatively deflected P waves)



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

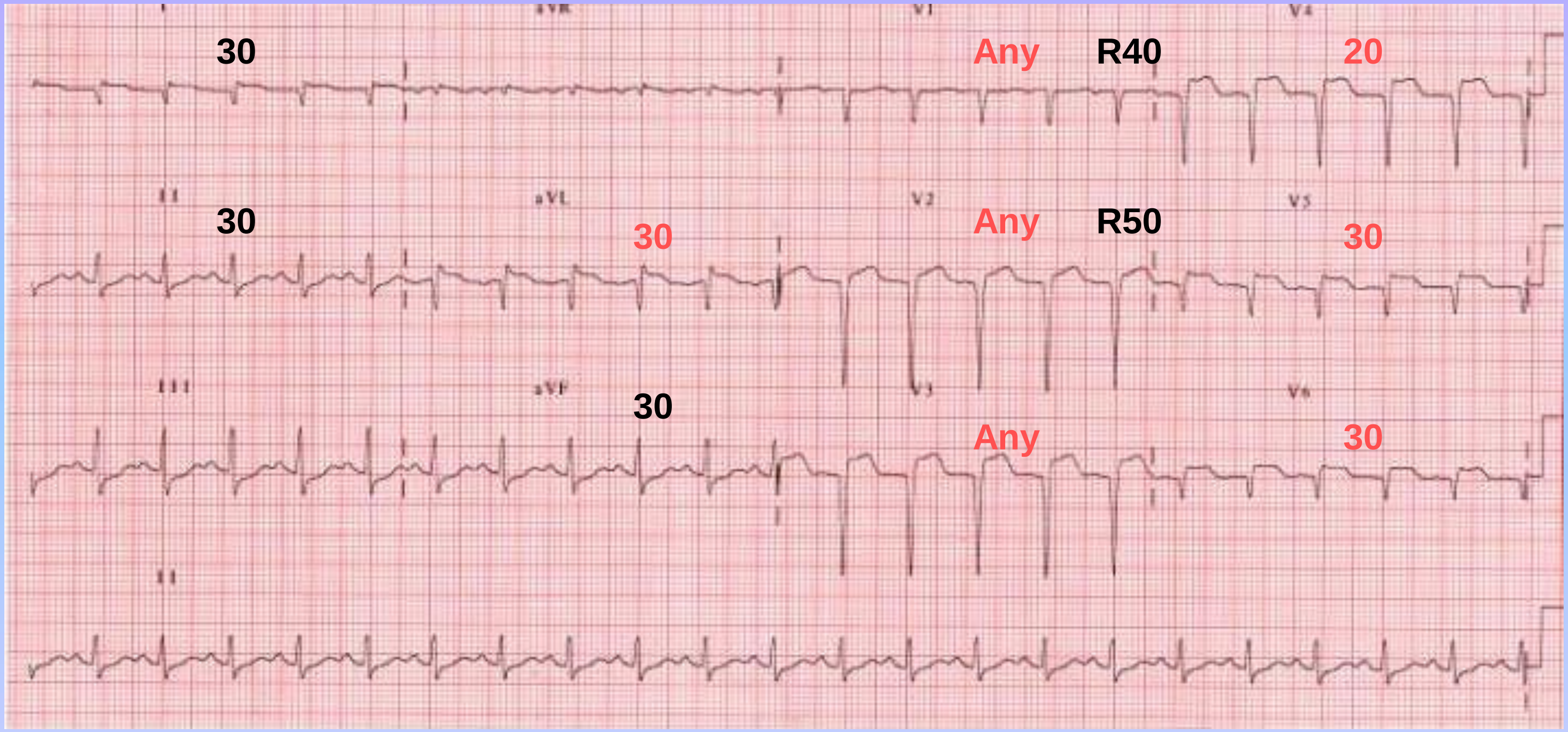
Is there evidence of ventricular hypertrophy? *No (no tall R waves in V1/V2 or V5/V6)*



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

Infarct: Are there abnormal Q waves?

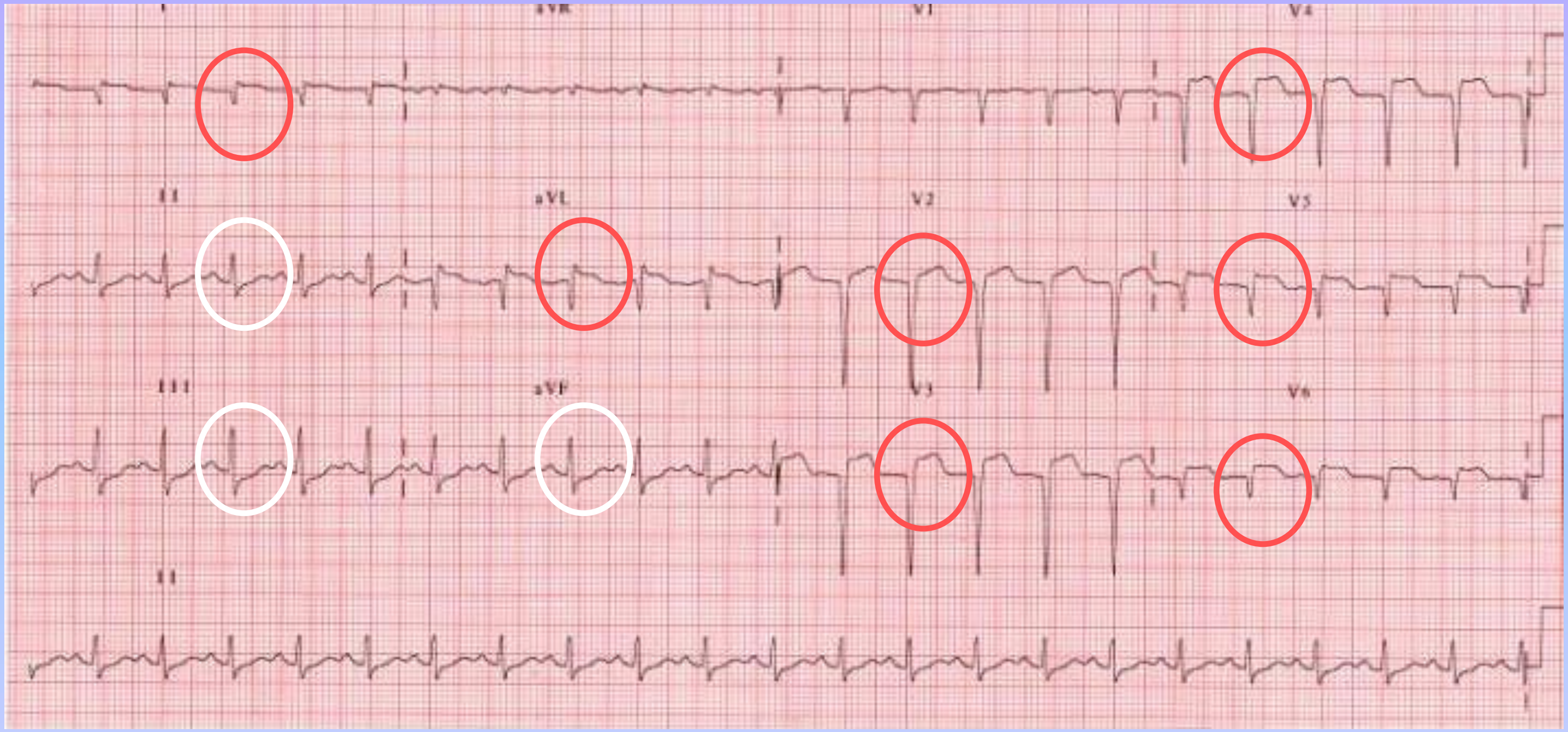
Yes! In leads V1-V6 and I, avL



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

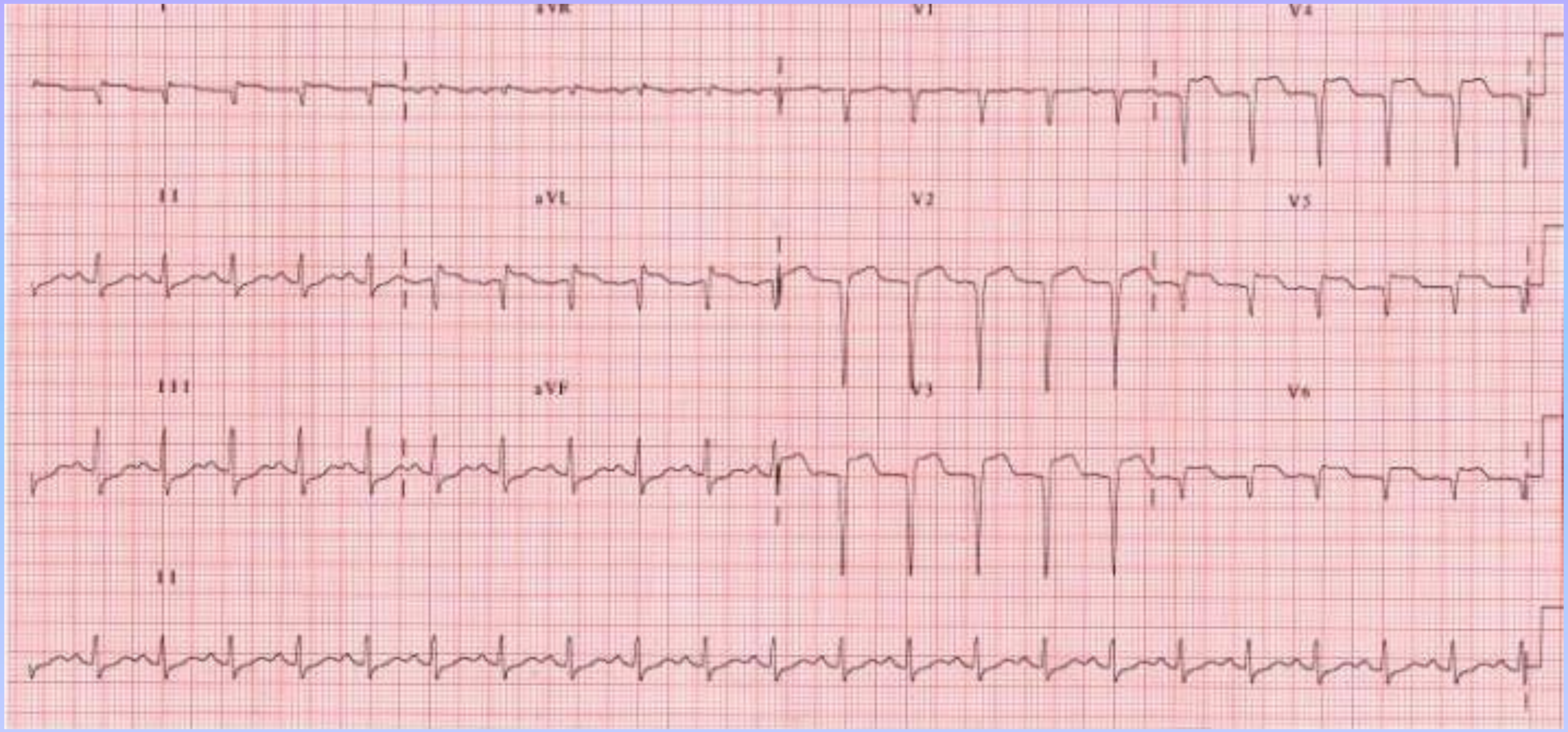
Infarct: Is the ST elevation or depression?

Yes! Elevation in V2-V6, I and avL. Depression in II, III and avF.



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

Infarct: Are there T wave changes? *No*



SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

ECG analysis: *Sinus tachycardia at 132 bpm, right axis deviation, long QT, and evidence of ST elevation infarction in the anterolateral leads (V1-V6, I, avL) with reciprocal changes (the ST depression) in the inferior leads (II, III, avF).*

This young man suffered an acute myocardial infarction after blunt trauma. An echocardiogram showed anteroseptal akinesia in the left ventricle with severely depressed LV function (EF=28%). An angiogram showed total occlusion in the proximal LAD with collaterals from the RCA and LCX.