Basic Interpretation of Electrocardiography

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Division of Cardiology
UTHSCSA

Preliminary Considerations

- The syllabus has all the necessary textual information
- The lectures supply important visual information and most will be completed before the small group sessions
- Design of course is that the examples are to be studied **BEFORE** the small group sessions
- Exam: just read the tracings and answer the questions, open book limited time to 2 hours

Outline

- Description of ECG recording page
- Review of pertinent cardiac physiology
- Identification of waves and intervals
- 3 methods for calculation of rate
- Calculation of QRS electrical axis
- Steps in interpretation
- Diagnosing normal and abnormal findings

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- **Description of ECG recording page**
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Patient Name

01-JUN-2001 04:08:00 UNIVERSITY HOSPITAL-CICU ROUTINE RECORD

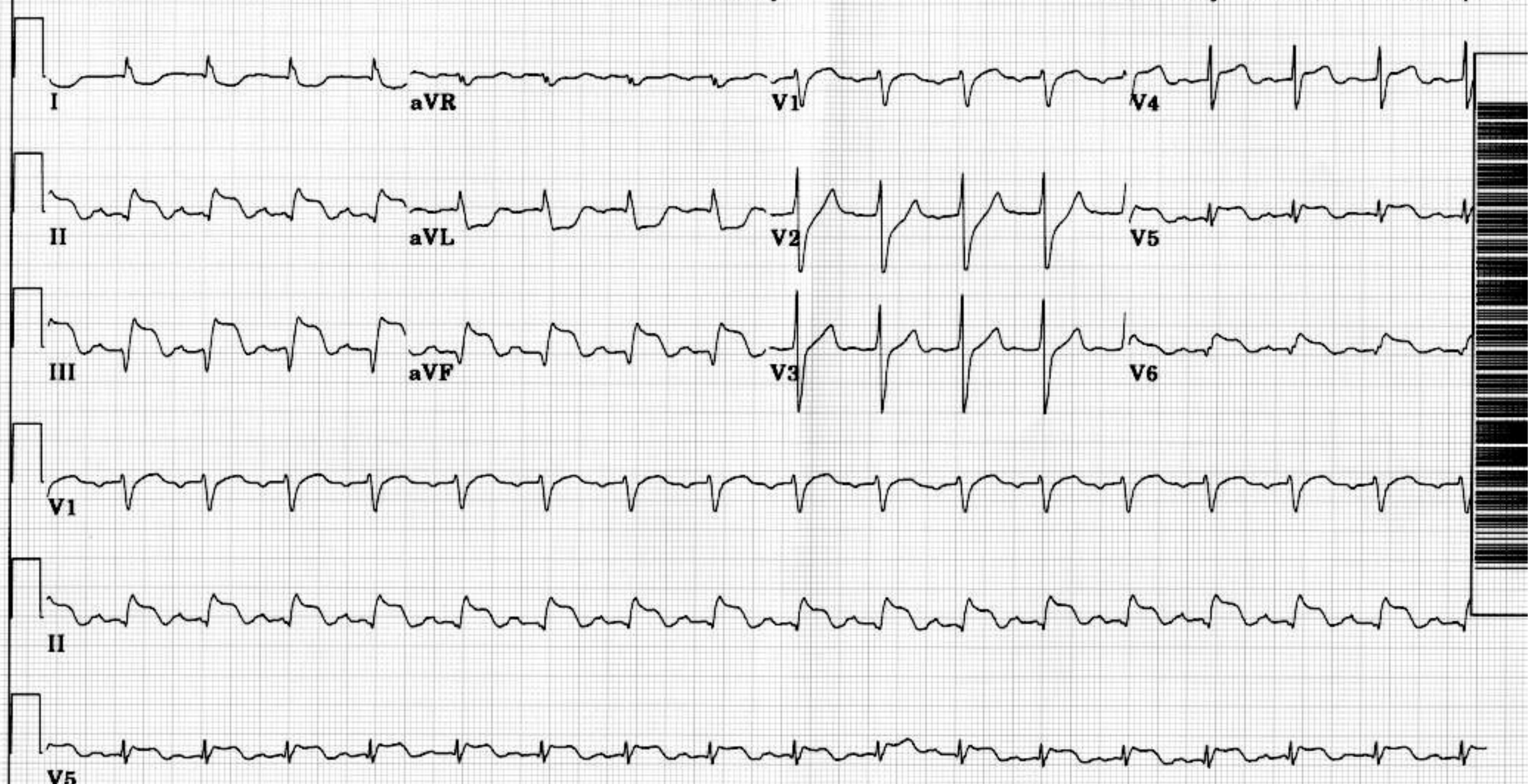
58 yr

Loc:14

Vent. rate	103	BPM
PR interval	208	ms
QRS duration	108	ms
QT/QTc	321/420	ms
P-R-T axes	81 51	117

Sinus tachycardia
Inferior infarct , possibly acute
Lateral injury pattern
** ** ** ** * ACUTE MI * ** ** ** **
Abnormal ECG

Referred by: Confirmed by: F. DWIGHT CHRISMAN, M.D.



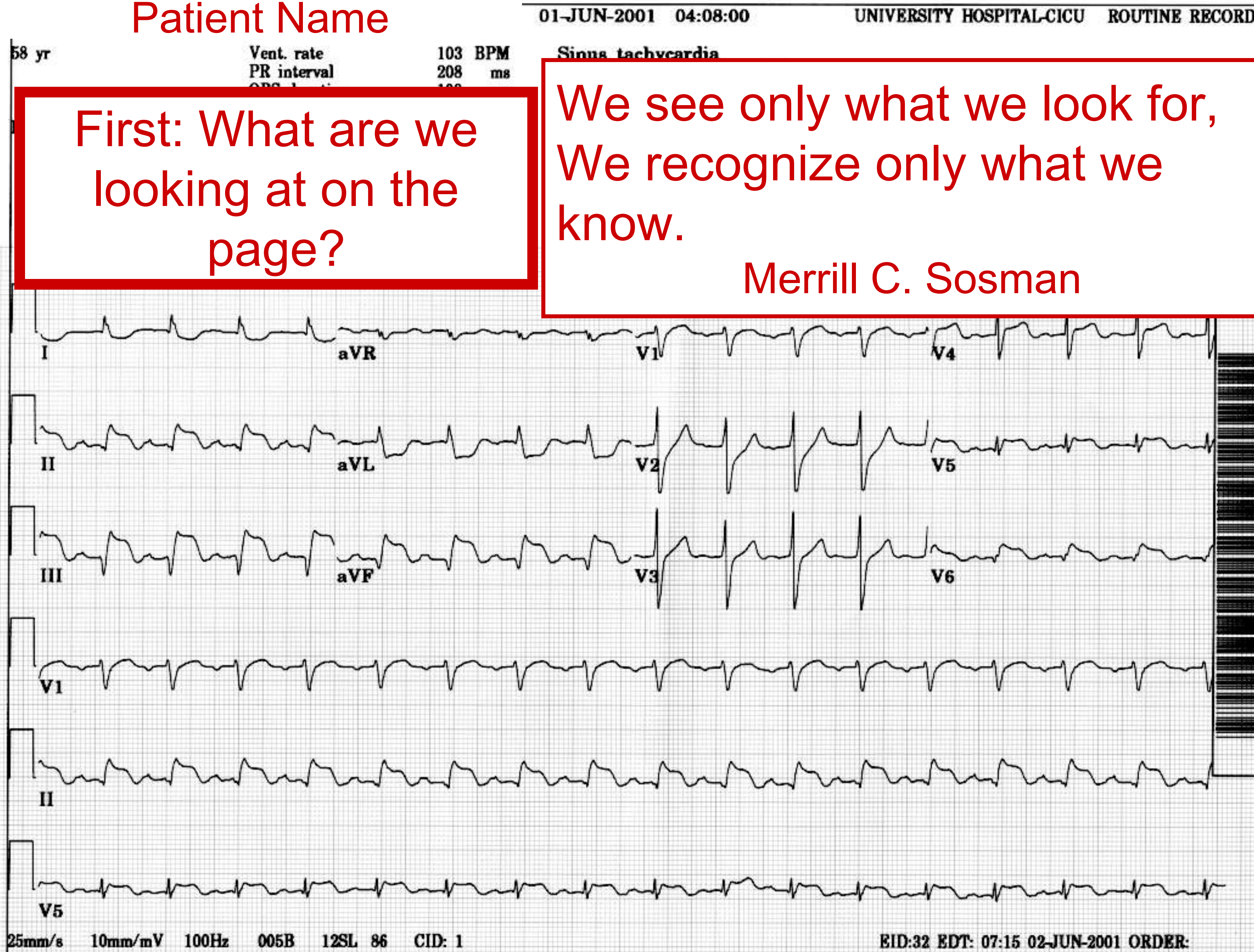
25mm/s 10mm/mV 100Hz 005B 12SL 86 CID: 1 EID:32 EDT: 07:15 02-JUN-2001 ORDER:

Patient Name

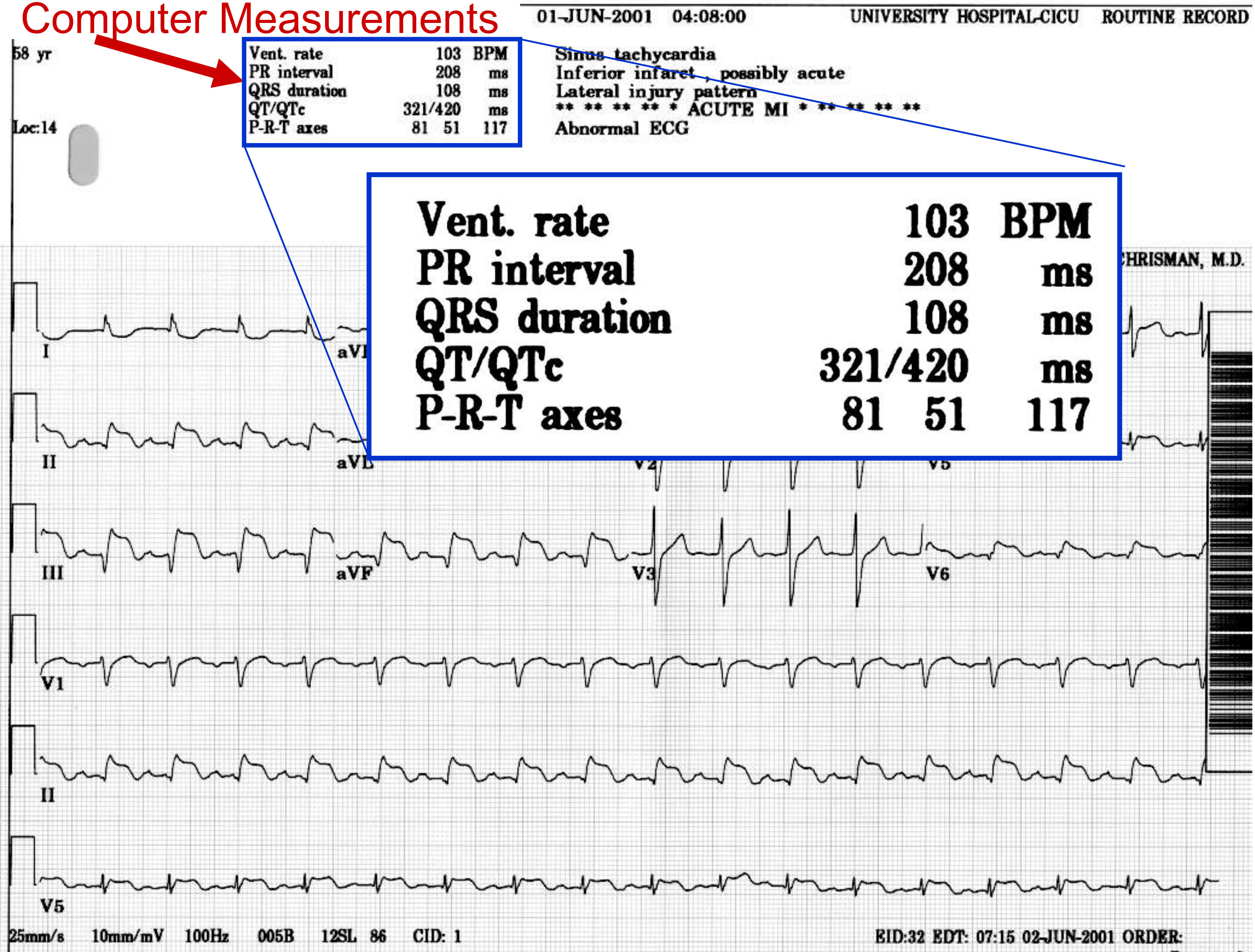
First: What are we looking at on the page?

We see only what we look for,
We recognize only what we know.

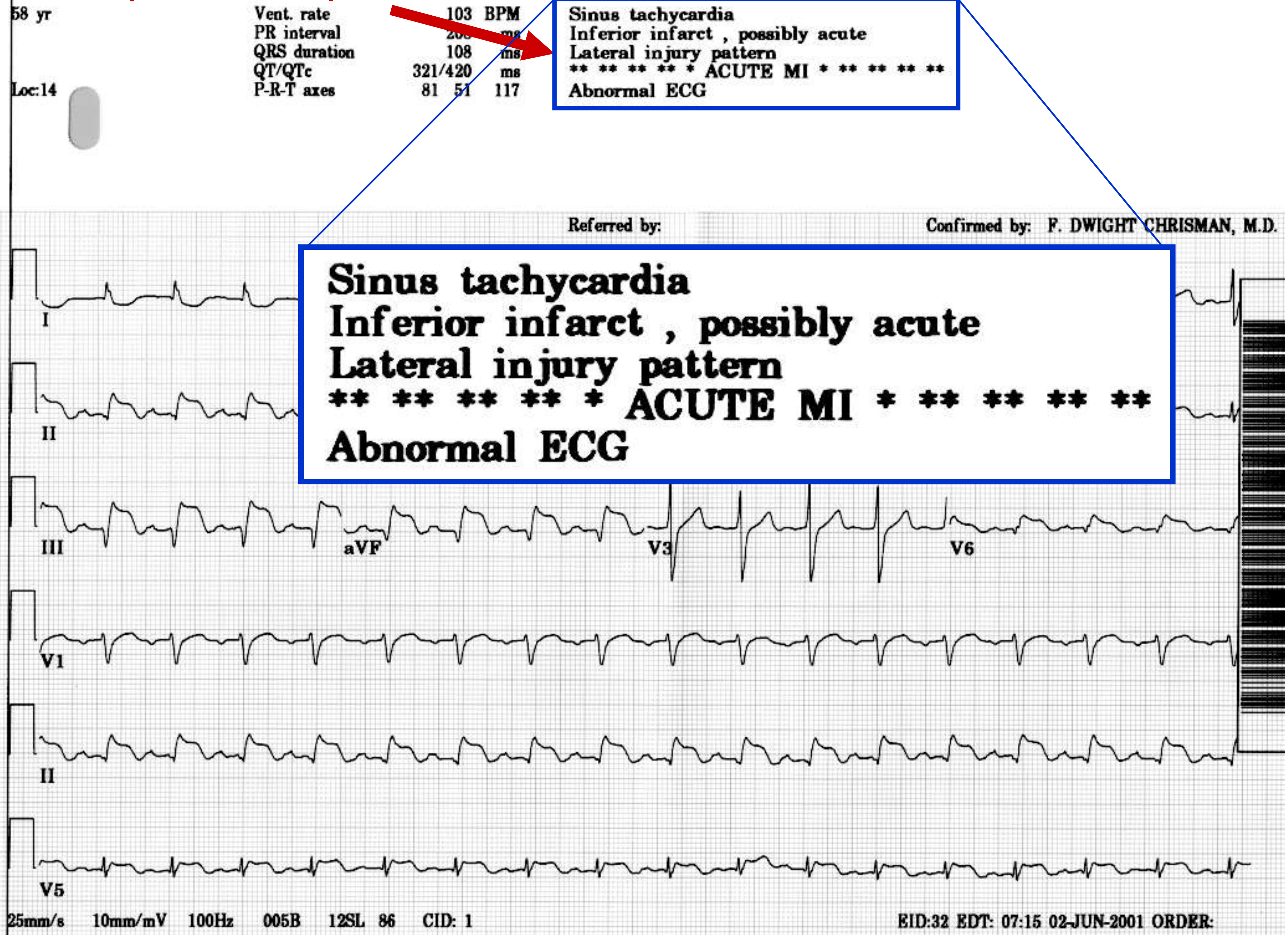
Merrill C. Sosman



Computer Measurements

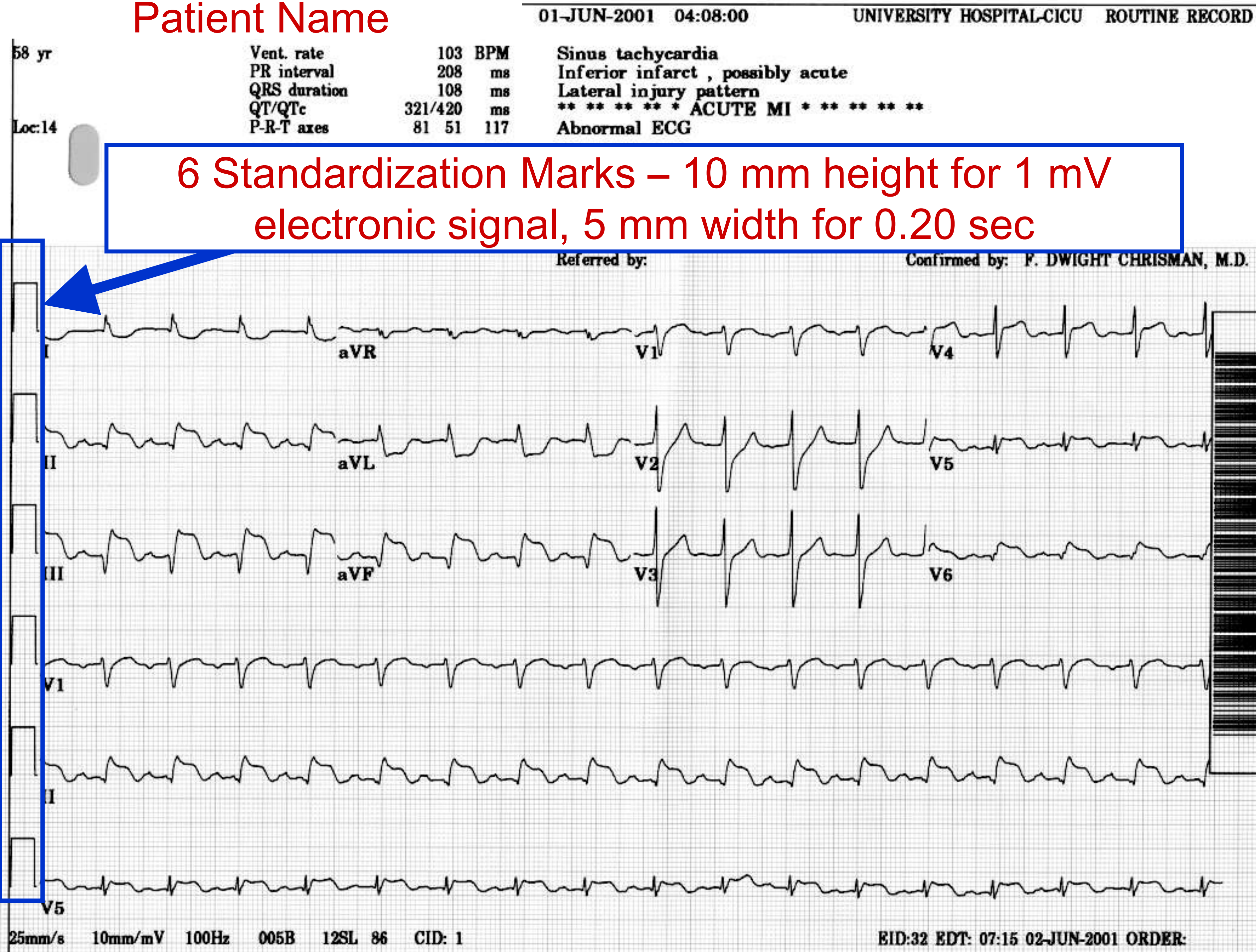


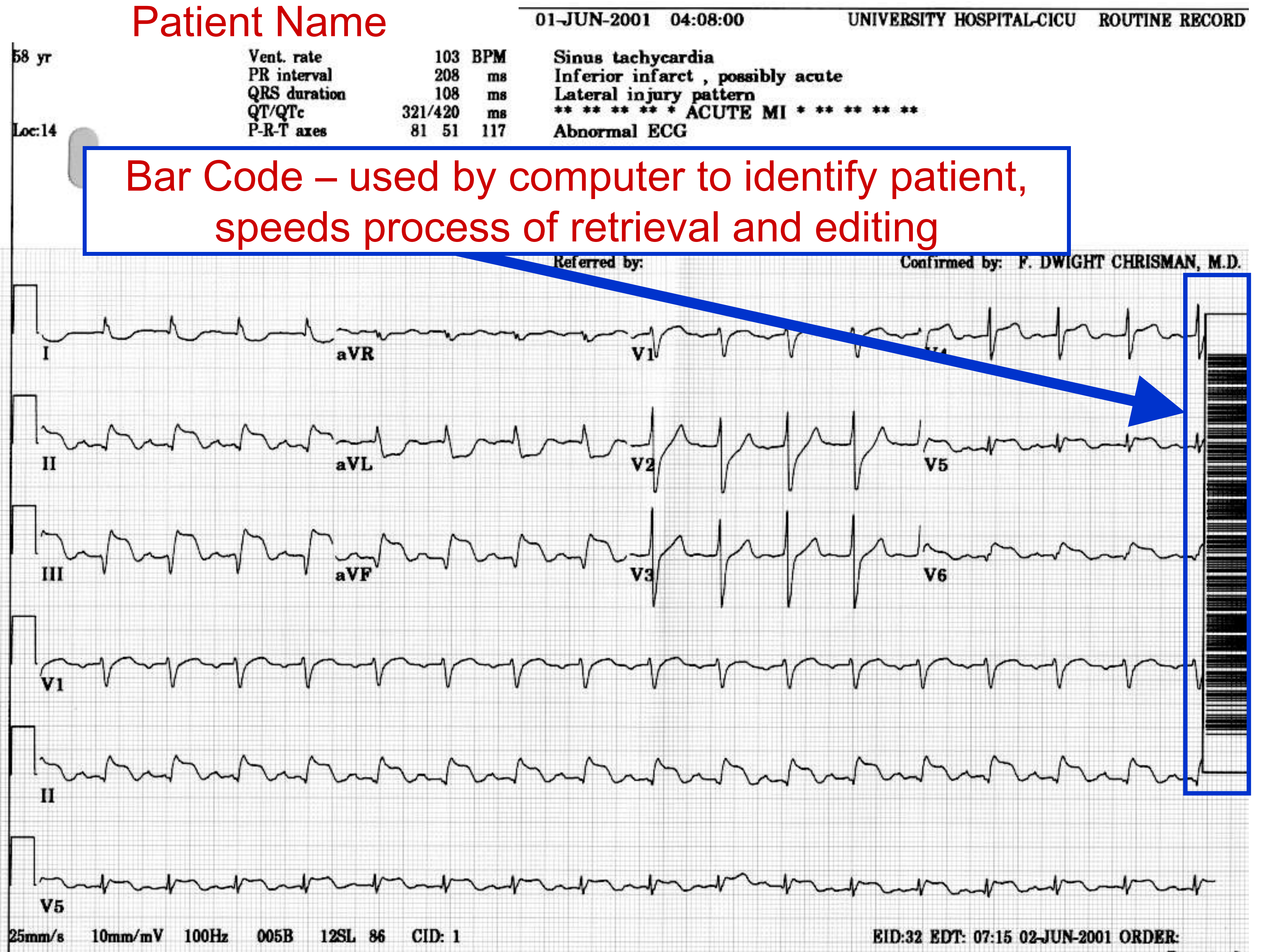
Computer Interpretation



Patient Name

6 Standardization Marks – 10 mm height for 1 mV electronic signal, 5 mm width for 0.20 sec





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P-R-T axes 81 51 117
Sinus tachycardia
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Lateral injury pattern
** ** ** ** * ACUTE MI * ** ** ** **
Abnormal ECG
Bar Code – used by computer to identify patient, speeds process of retrieval and editing
Referred by:
Confirmed by: F. DWIGHT CHRISMAN, M.D.
I
aVR
V1
II
aVL
V2
V5
III
aVF
V3
V6
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II
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Abnormal ECG

Note: Some machines only display 3 or 4

6 lines of ECG signal, simultaneous

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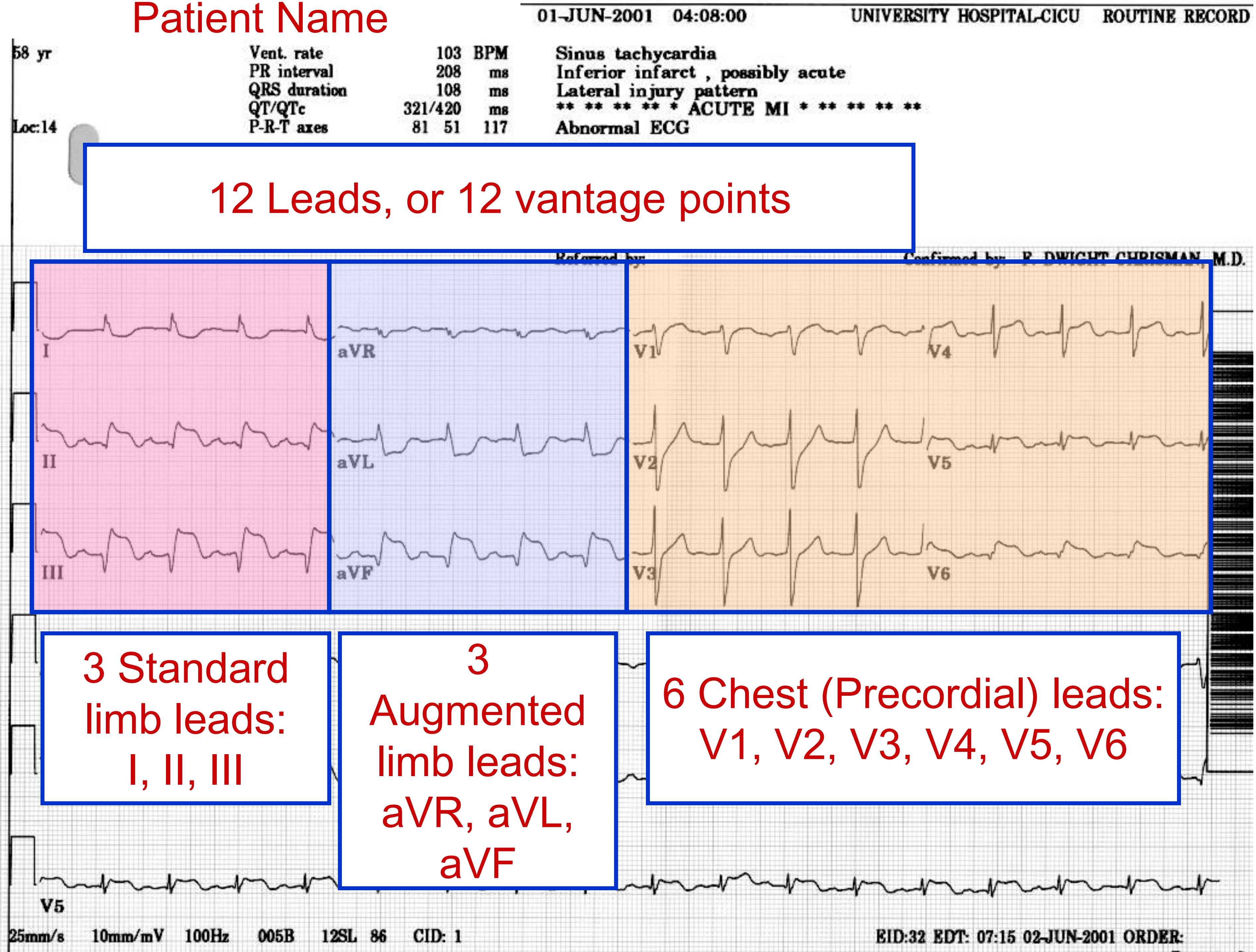
Patient Name

12 Leads, or 12 vantage points



3 Standard limb leads: I, II, III

3 Augmented limb leads: aVR, aVL, aVF

6 Chest (Precordial) leads: V1, V2, V3, V4, V5, V6

Patient Name

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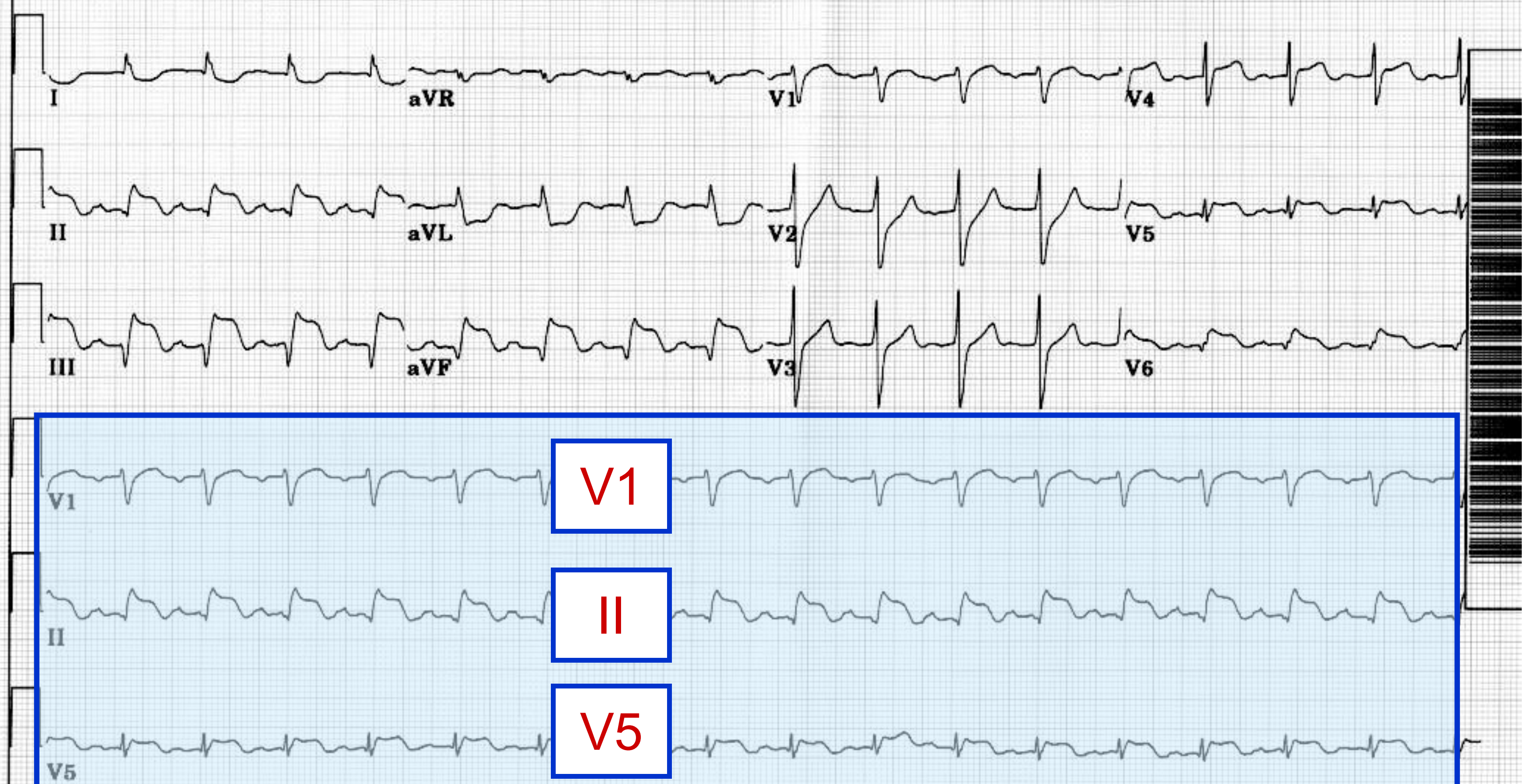
** ** ** ** * ACUTE MI * ** ** ** **
Abnormal ECG

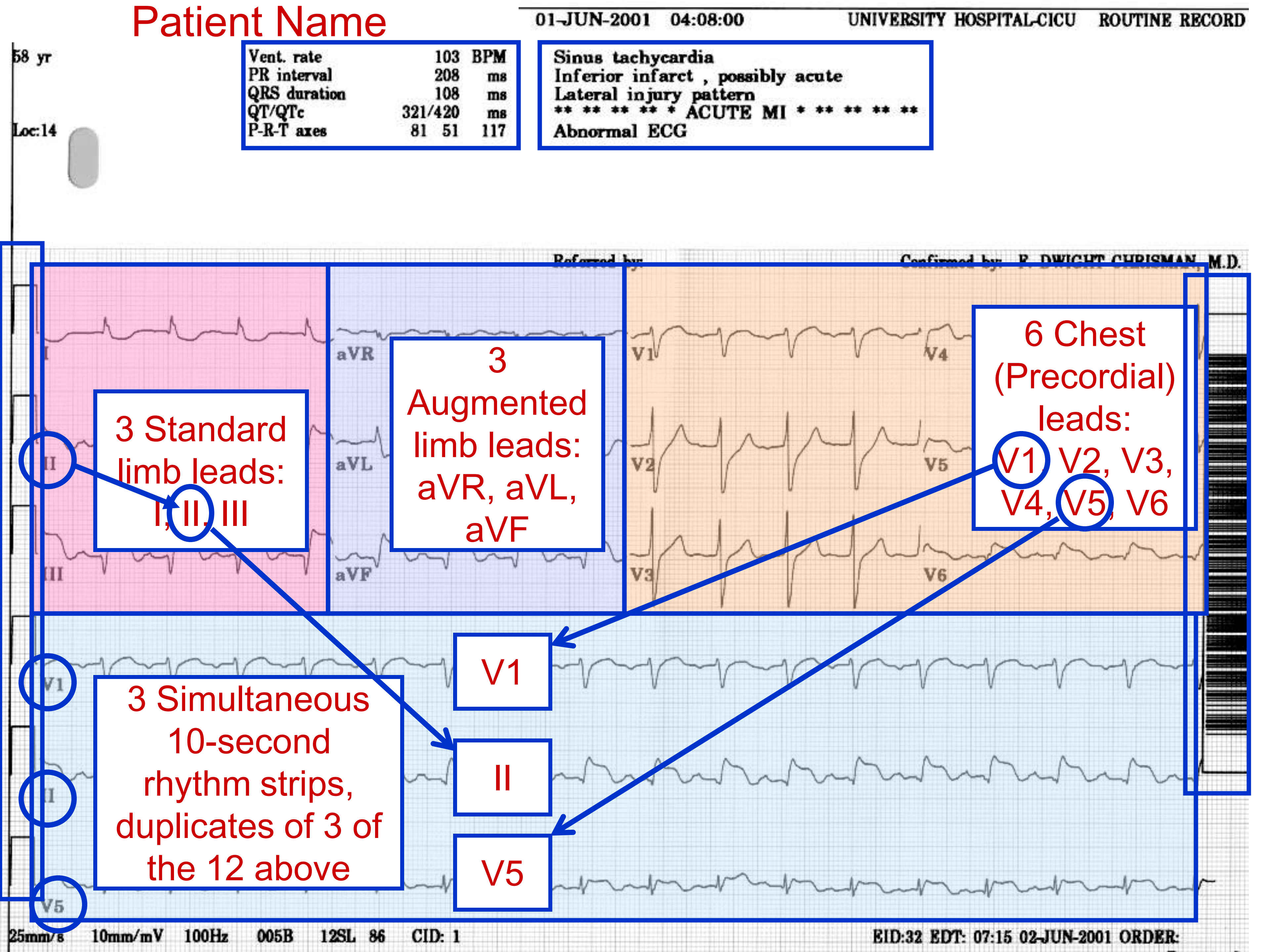
Note: Some machines display 0 or 1

3 Simultaneous 10-second rhythm strips, duplicates of 3 of the 12 above

Referred by: Confirmed by: F. DWIGHT CHRISMAN, M.D.



25mm/s 10mm/mV 100Hz 005B 12SL 86 CID: 1 EID:32 EDT: 07:15 02-JUN-2001 ORDER:



Patient Name
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Abnormal ECG
Referred by:
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I
II
III
aVR
aVL
aVF
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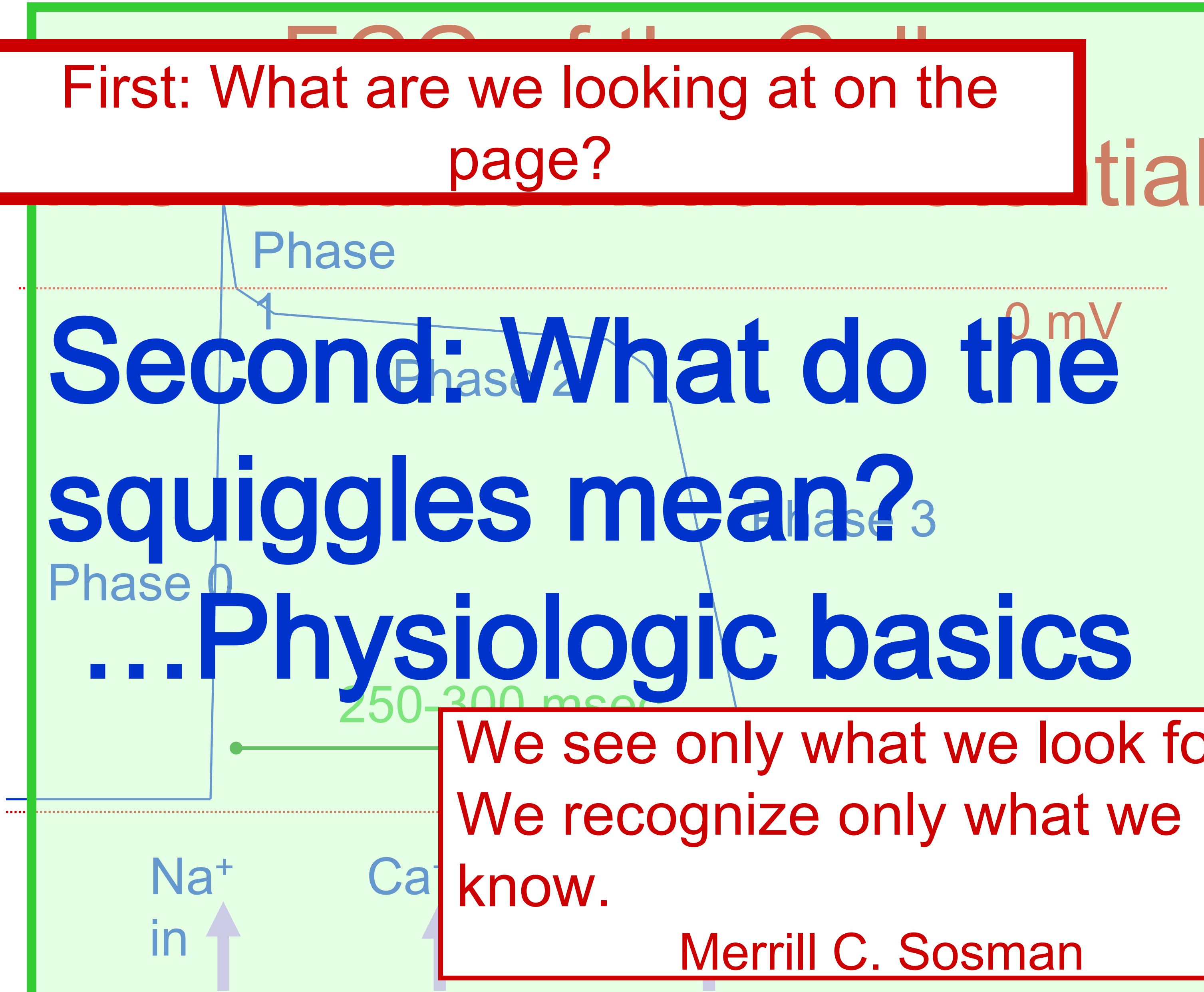
First: What are we looking at on the page?

Second: What do the squiggles mean? …Physiologic basics



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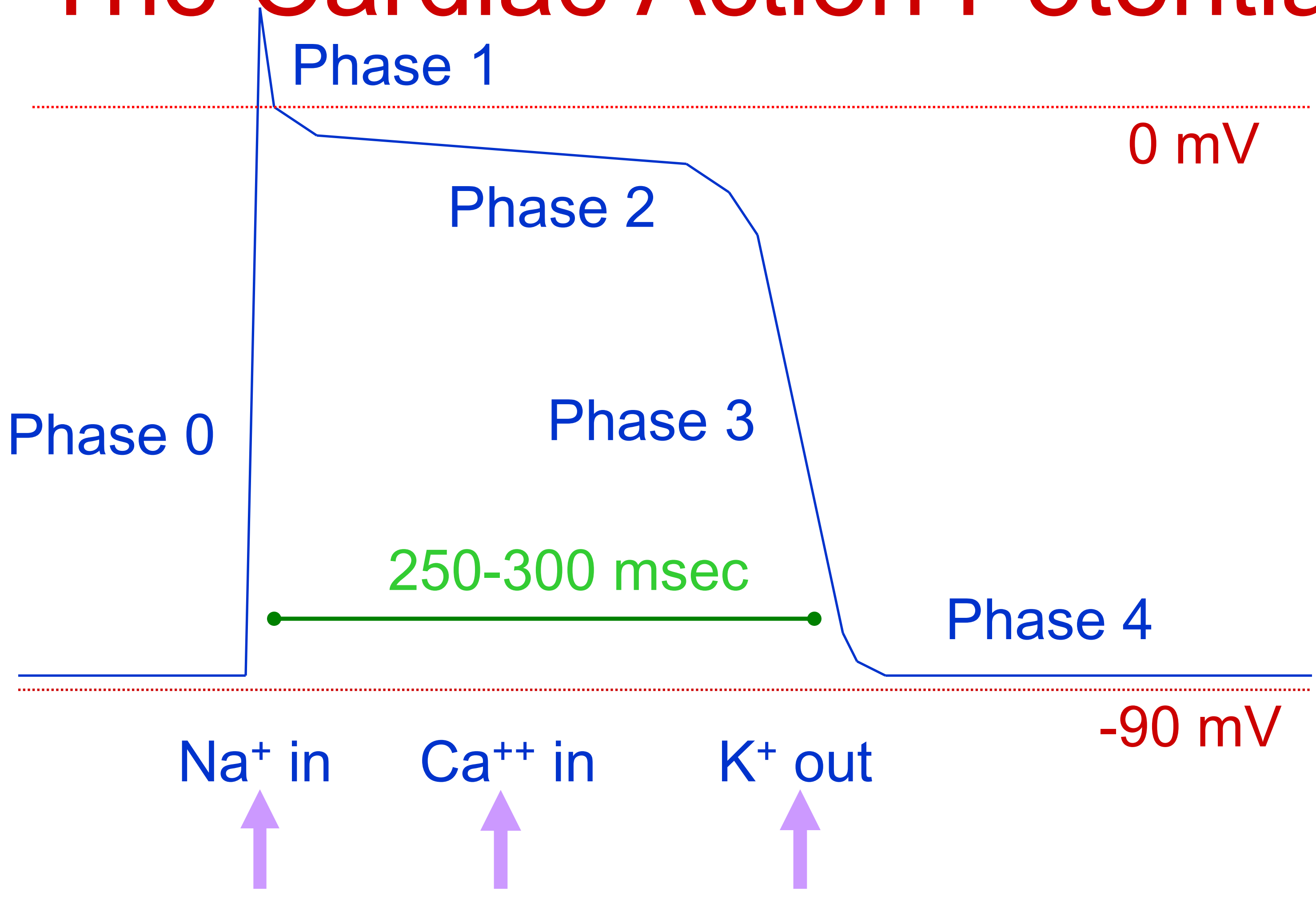
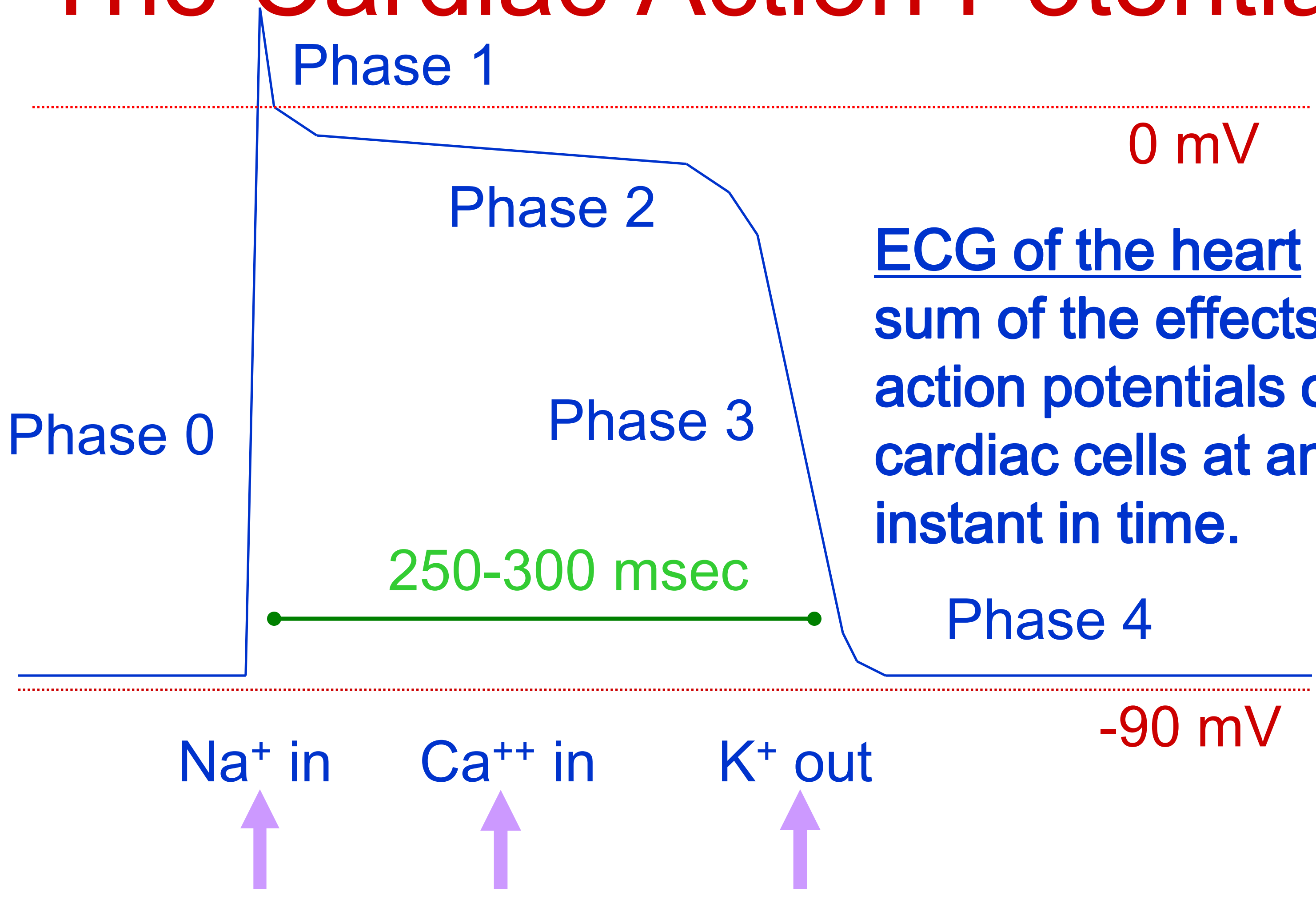
Merrill C. Sosman

ECG of the Cell: The Cardiac Action Potential



ECG of the Cell: The Cardiac Action Potential



<u>ECG of the heart</u> is the sum of the effects of the action potentials of all the cardiac cells at any instant in time.

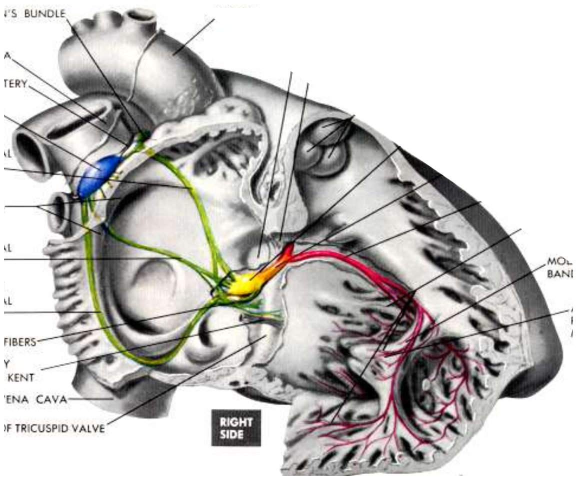
Important Electrical Characteristics

- Automaticity - the characteristic of a tissue with **spontaneous generation** of an action potential (due to phase 4 depolarization)

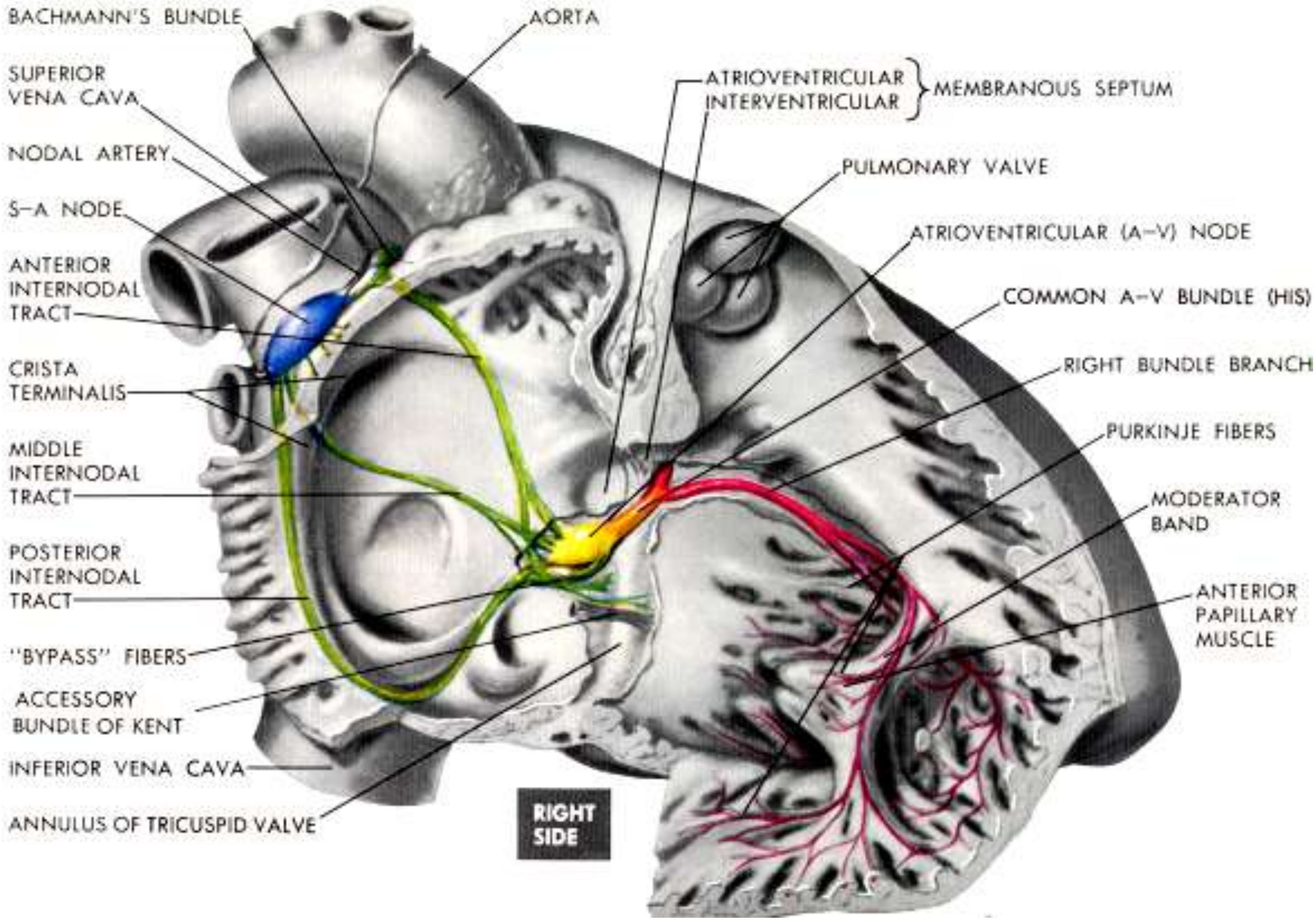
- Conductivity - the characteristic of a tissue with **transmission** of an action potential through a tissue (related mainly to the steepness of phase 0 depolarization)

Cardiac Conduction System

- Sinoatrial Node (Sinus Node, SA node, not seen on the ECG)
  - Normal pacemaker
  - High Right Atrium, near SVC junction
  - Not seen, only inferred, from ECG



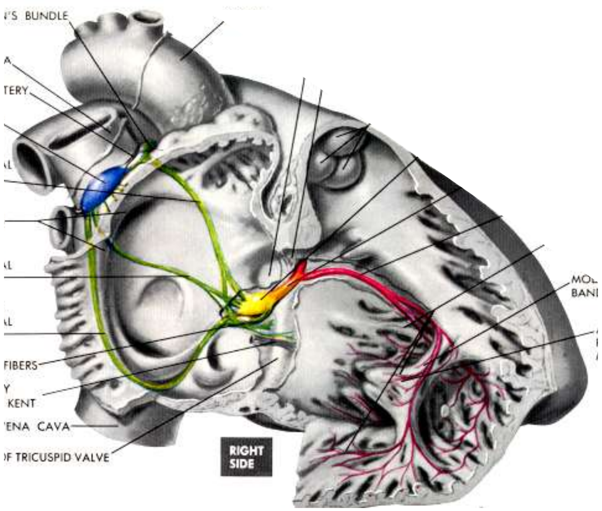
- Atrial muscle (Makes the P wave on the ECG)
- Atrioventricular Node (AV Node, seen as the straight line after the P wave)
  - Slowest conduction velocity in heart
  - Long refractory period
  - Only electrical connection A to V

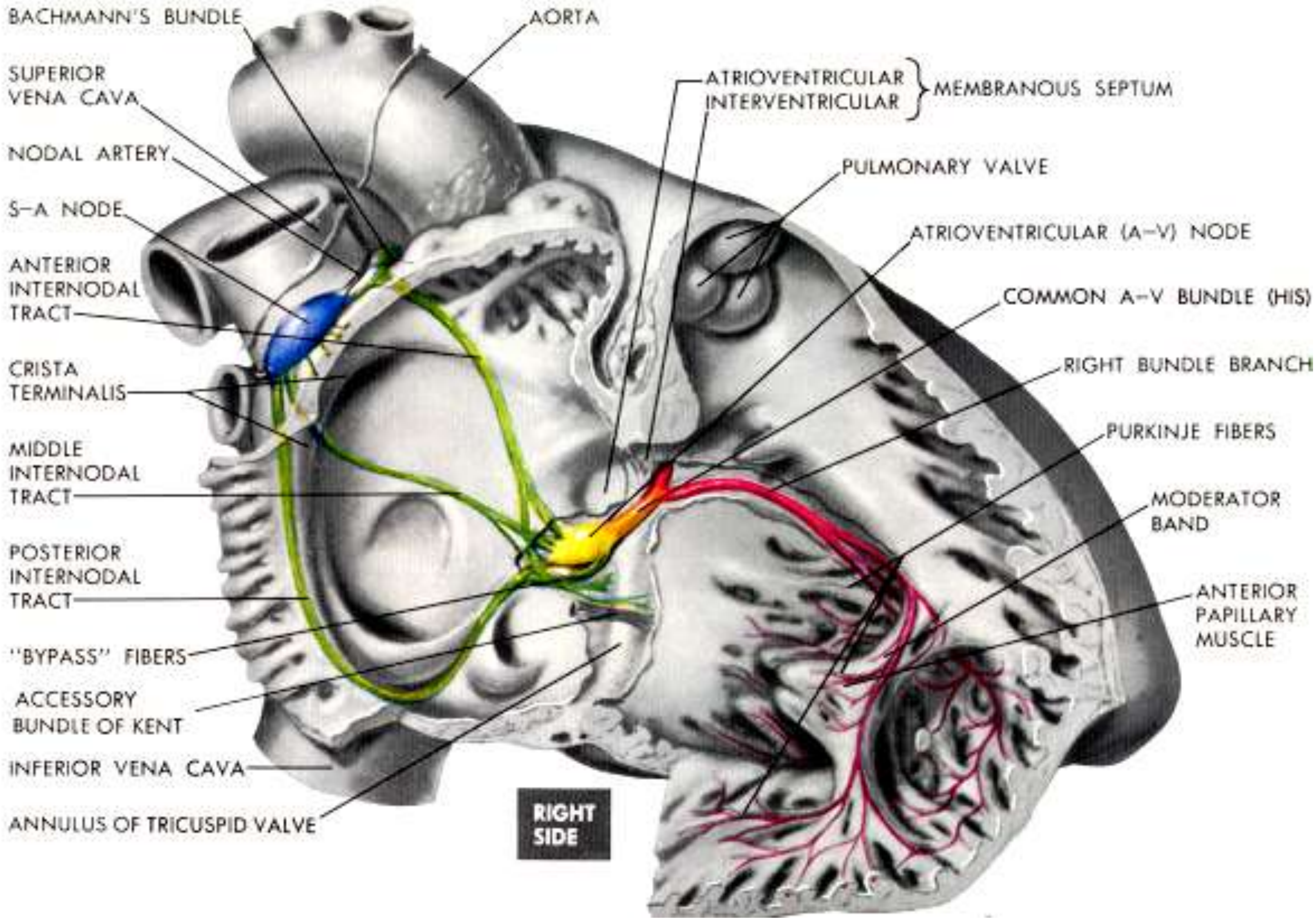


From Netter's Atlas, Volume 5, The Heart 1978

Cardiac Conduction System - 2

- <u>Bundle of His</u> (Common Bundle)
  - Beginning of His-Purkinje system
  - Length about 10 mm
  - Fastest conduction velocity, 1-4 m/sec
- <u>His-Purkinje system</u> (subendocardial)
  - Right Bundle Branch
  - Left Bundle Branch (ant and post fascicles)
- <u>Ventricular myocardium</u> (0.3-0.4 m/sec) makes the QRS complex and the T wave of the ECG





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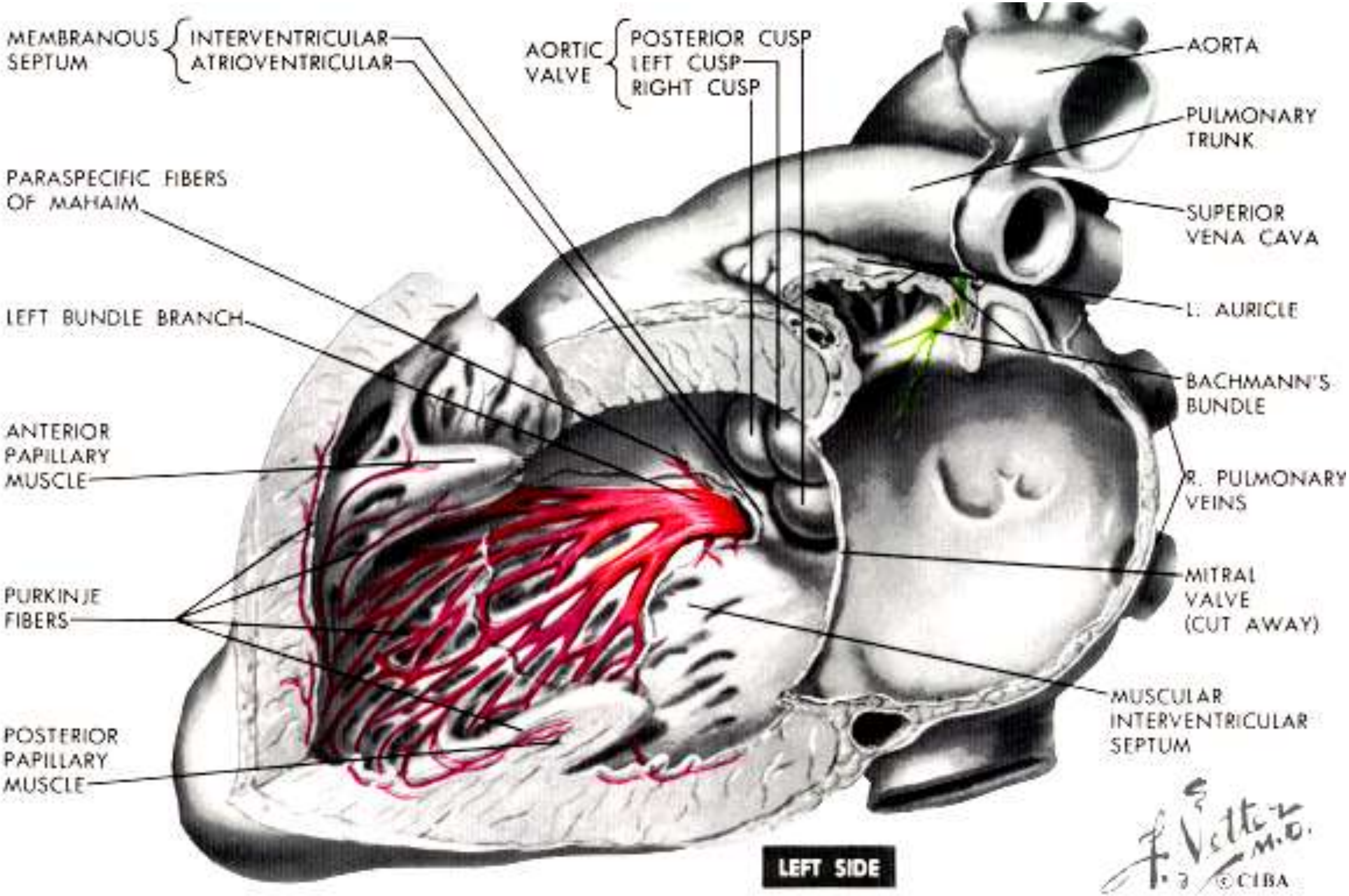
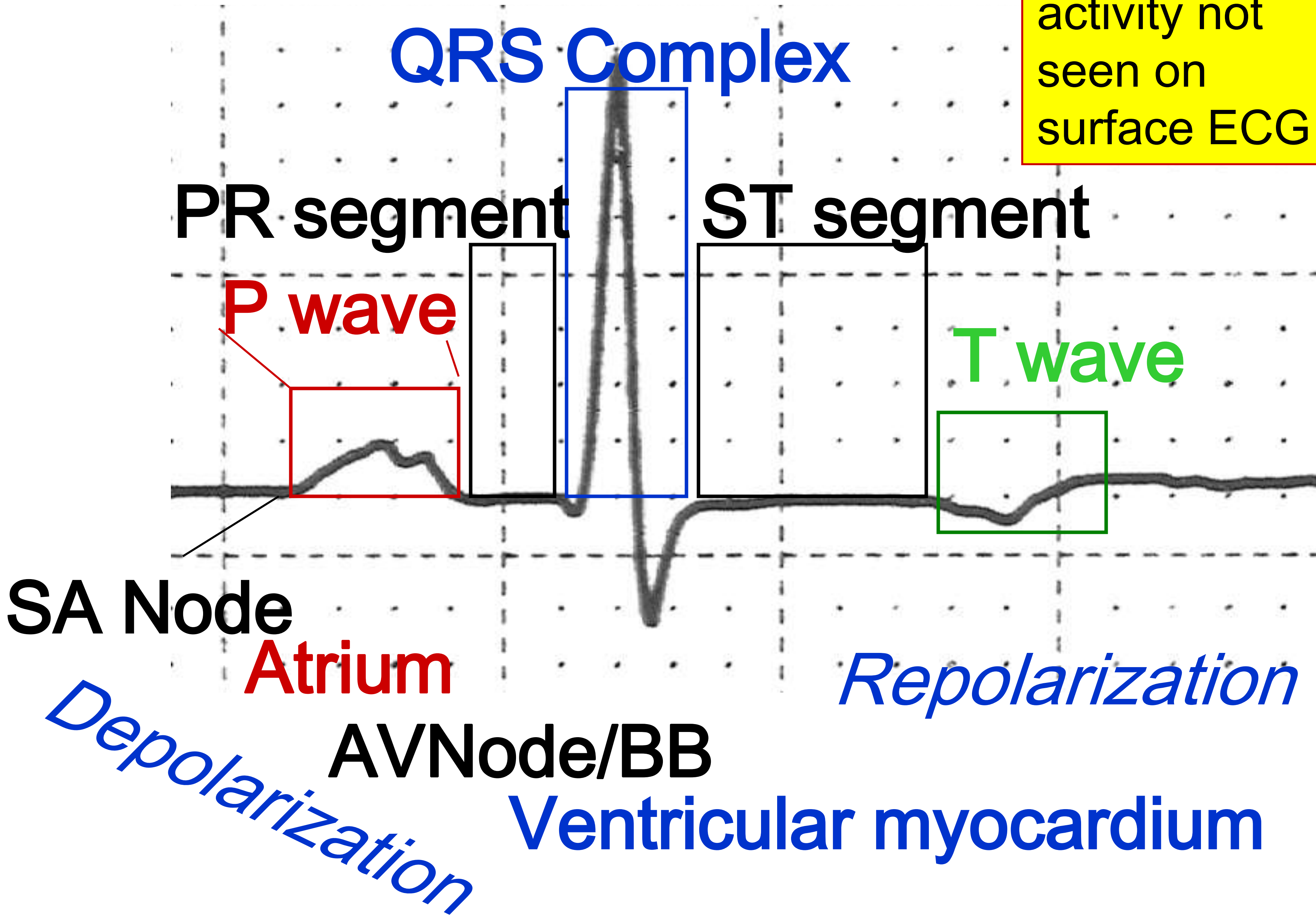


From Netter's Atlas, Volume 5, The Heart 1978

ECG – Anatomy Correlation

Key: Black labels indicate activity not seen on surface ECG



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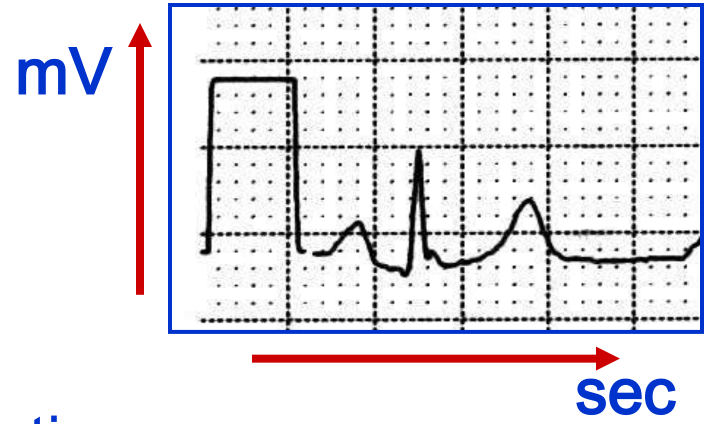
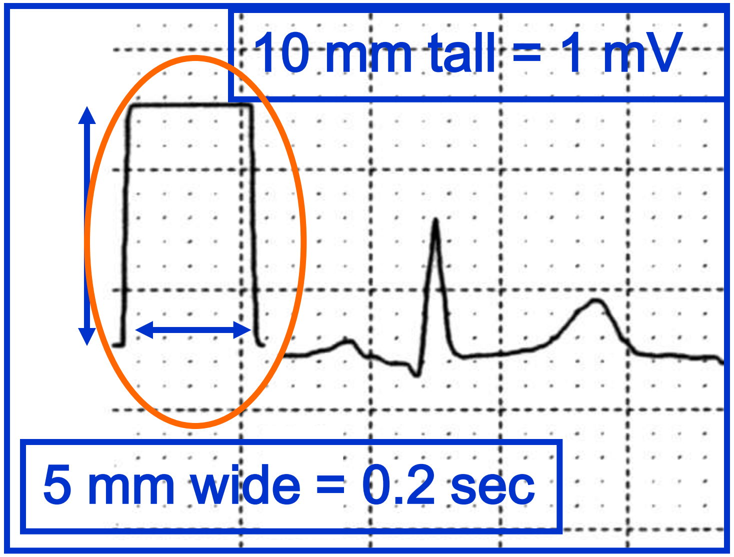
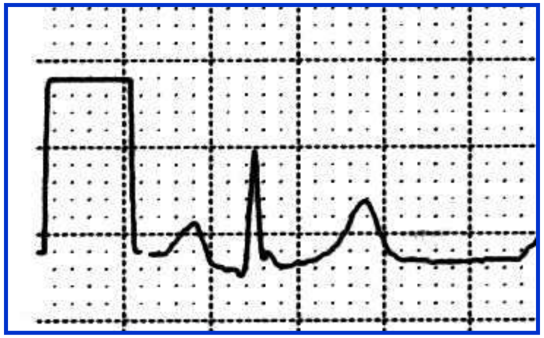
ECG Machine



- Machine creates graph of voltage vs time
- Voltage generated at skin surface (in mV) is the result of the sum of all instantaneous cellular electrical activity.
- <u>Standard Mark</u>: square pulse 1.0 mV amplitude and 0.2 sec duration
- Normal sensitivity is 10 mm/mV,
- Normal paper speed is 25 mm/sec
- ECG paper has a line every mm



Waves of the Cardiac Impulse

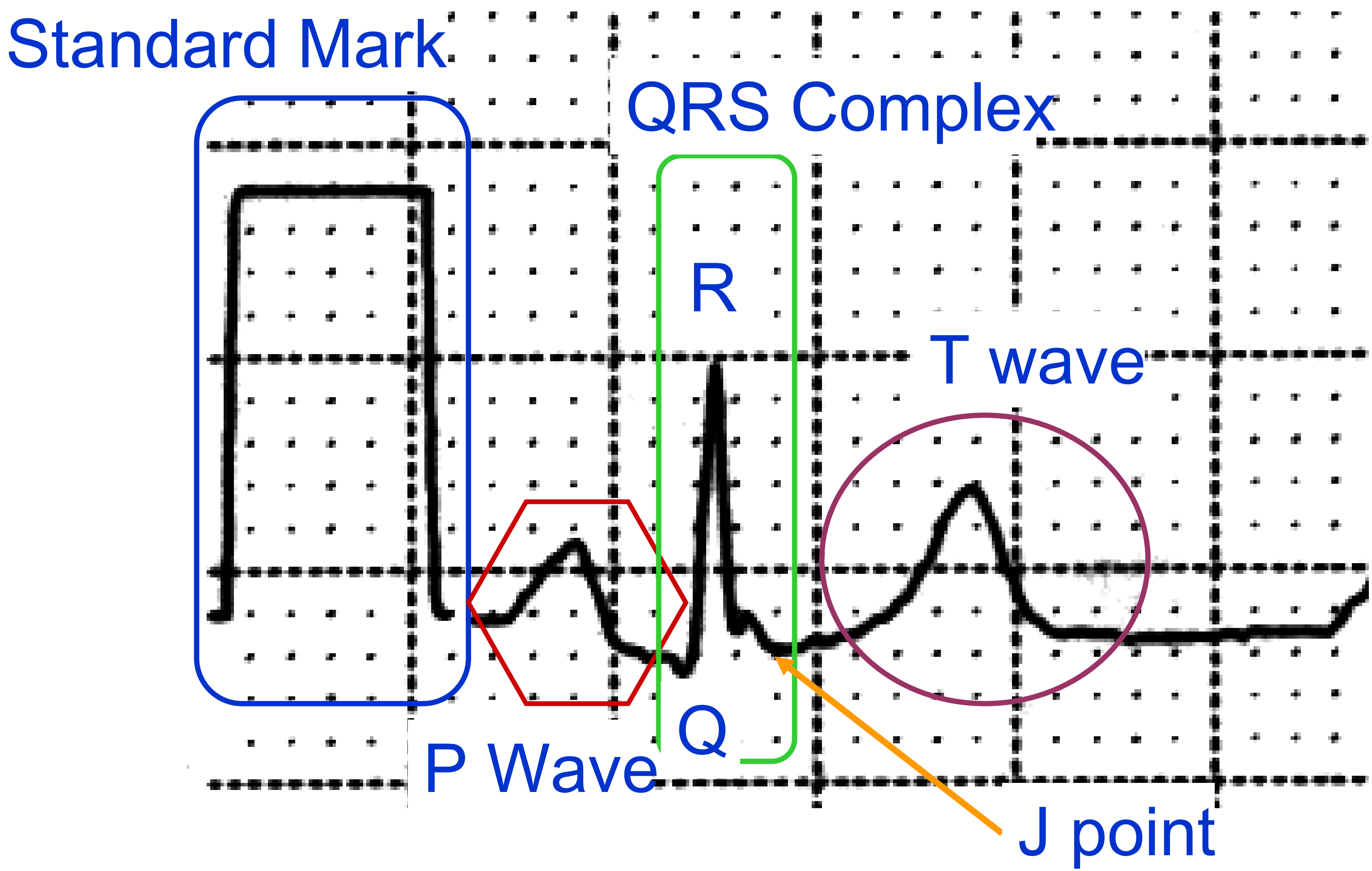


- P wave - atrial depolarization (atrial repolarization is there, but usually is subtle)
- QRS complex - ventricular depolarization
- J point - end of the QRS complex
- T wave - ventricular repolarization
- U wave - more ventricular repolarization (often absent)

Naming the QRS Complex

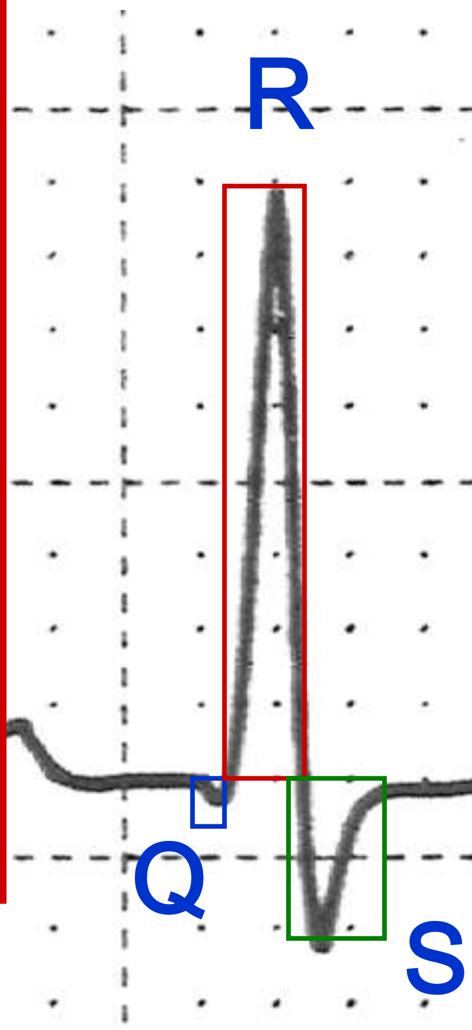
- Name of the QRS complex in a given lead depends on its morphology in that lead
- Morphology is different among different leads
- If there is an initial downward deflection, it is called a Q wave
- If there is no initial downward deflection, there is no Q wave
- The first upward deflection is an R wave
- The first downward deflection after an R wave is an S wave

ECG Waves in Lead II



Naming Waves of the QRS Complex

Waves of the QRS complex are specific to individual leads. So it is proper to say, “pathologic Q waves in II, III, and aVF”.



It is very important to understand the names of the waves properly, so that when someone talks about a

“tall R wave” or a

“wide deep S wave”, or an

“RSR-prime” or a

“pathologic Q wave”, it will be meaningful.

Naming Waves of the QRS Complex

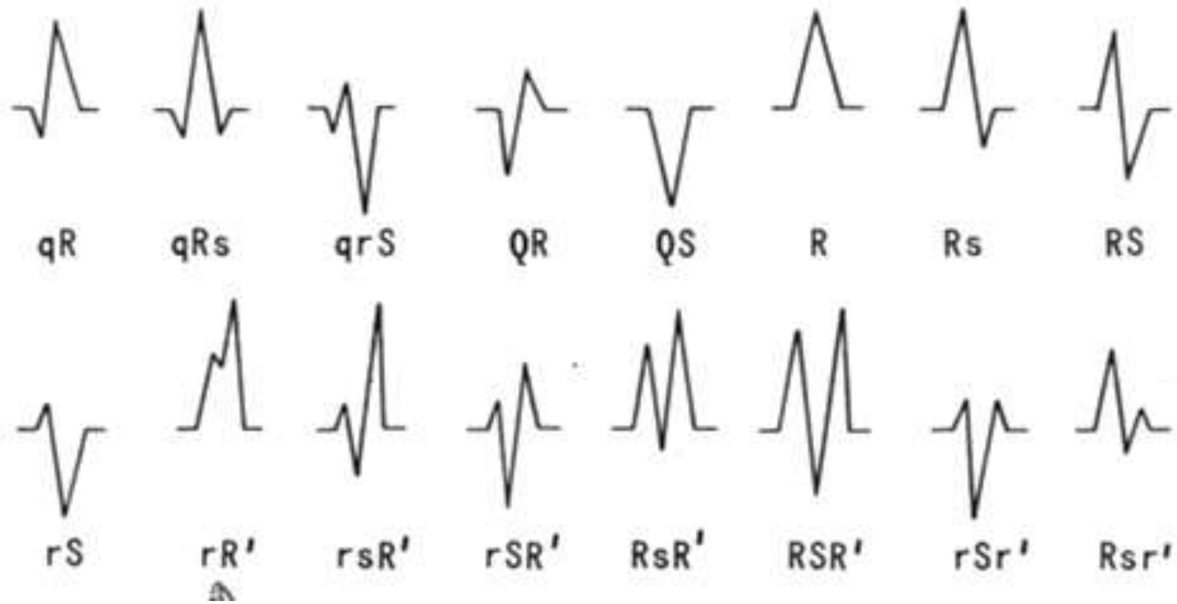
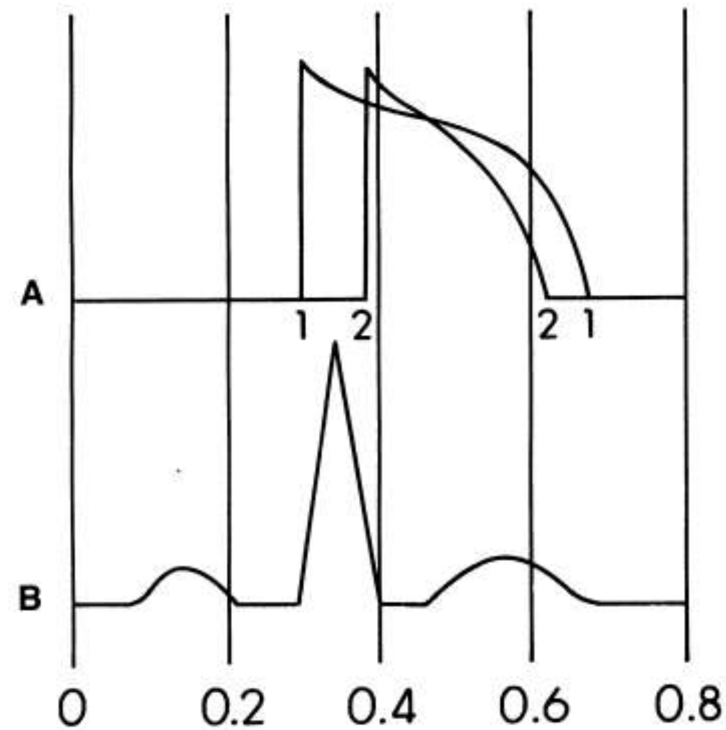


FIG. 5-8 Nomenclature of the various QRS complexes. Capital letters are employed to designate large deflections, and letters in the lower case to indicate small deflections.

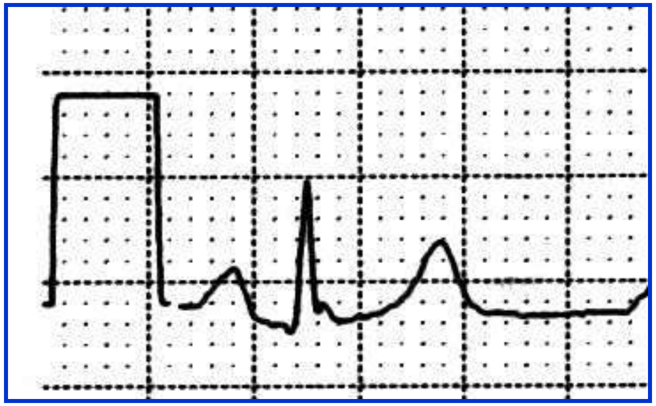
Question: If Depolarization and Repolarization are Opposite in Sign, then Why is the T wave Normally Concordant?

- Answer: Because repolarization of the ventricular endocardium is slower than epicardium, so depolarization and repolarization are opposite in direction and sign



Wagner GS. Marriott's Practical Electrocardiography 1994, p.12

Intervals in the ECG



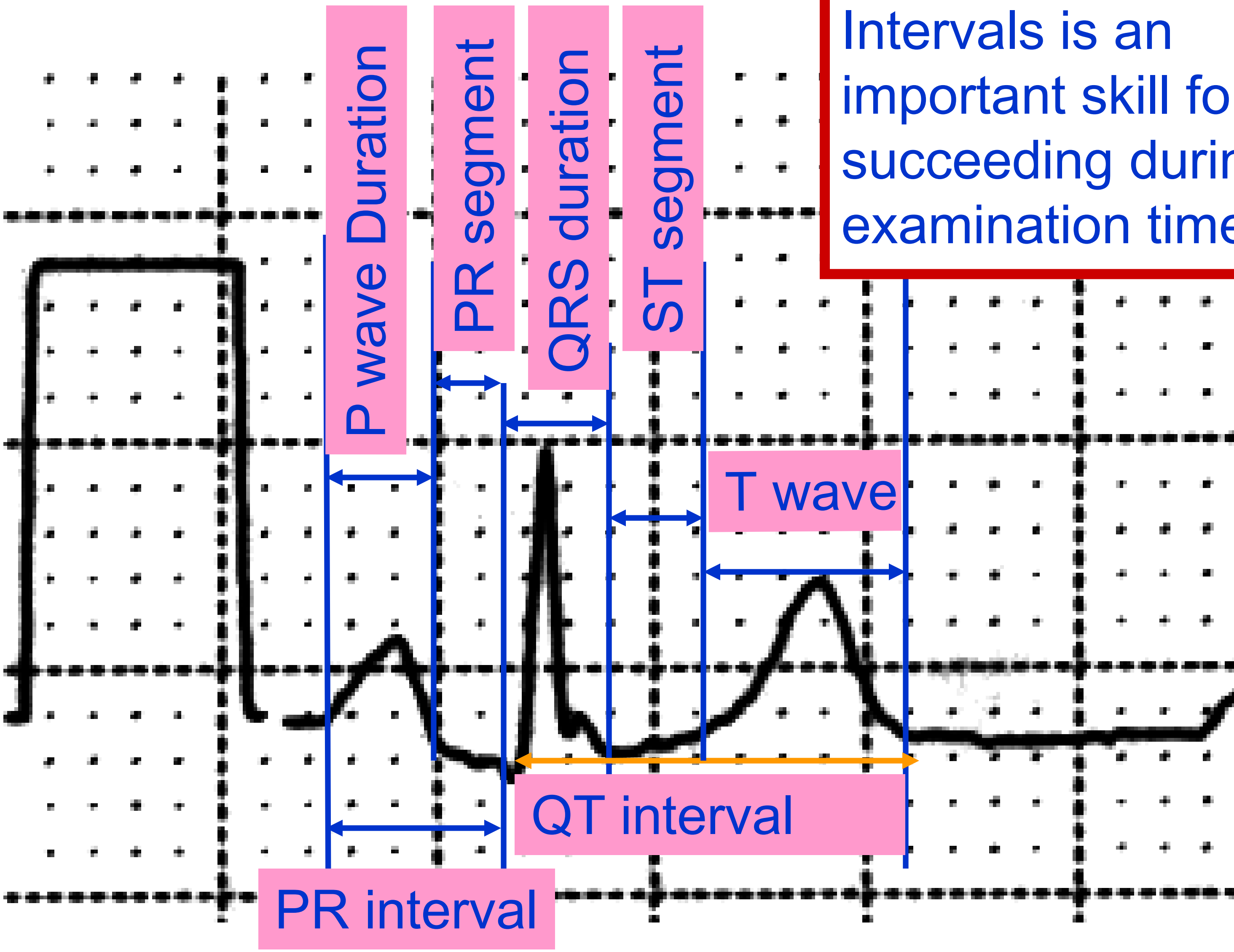
- <u>**P duration**</u> - from beginning to end of P wave (**Normal is 0.06-0.10 sec**)
- <u>**PR interval**</u> - from beginning of P to beginning of QRS (**Normal is 0.12-0.20 sec**)
- <u>**QRS duration**</u> - from beginning of QRS to its end (**Normal is 0.06-0.10 sec**)
- <u>**QT interval**</u> - from beginning of QRS to end of T wave (**Normal varies with heart rate**)

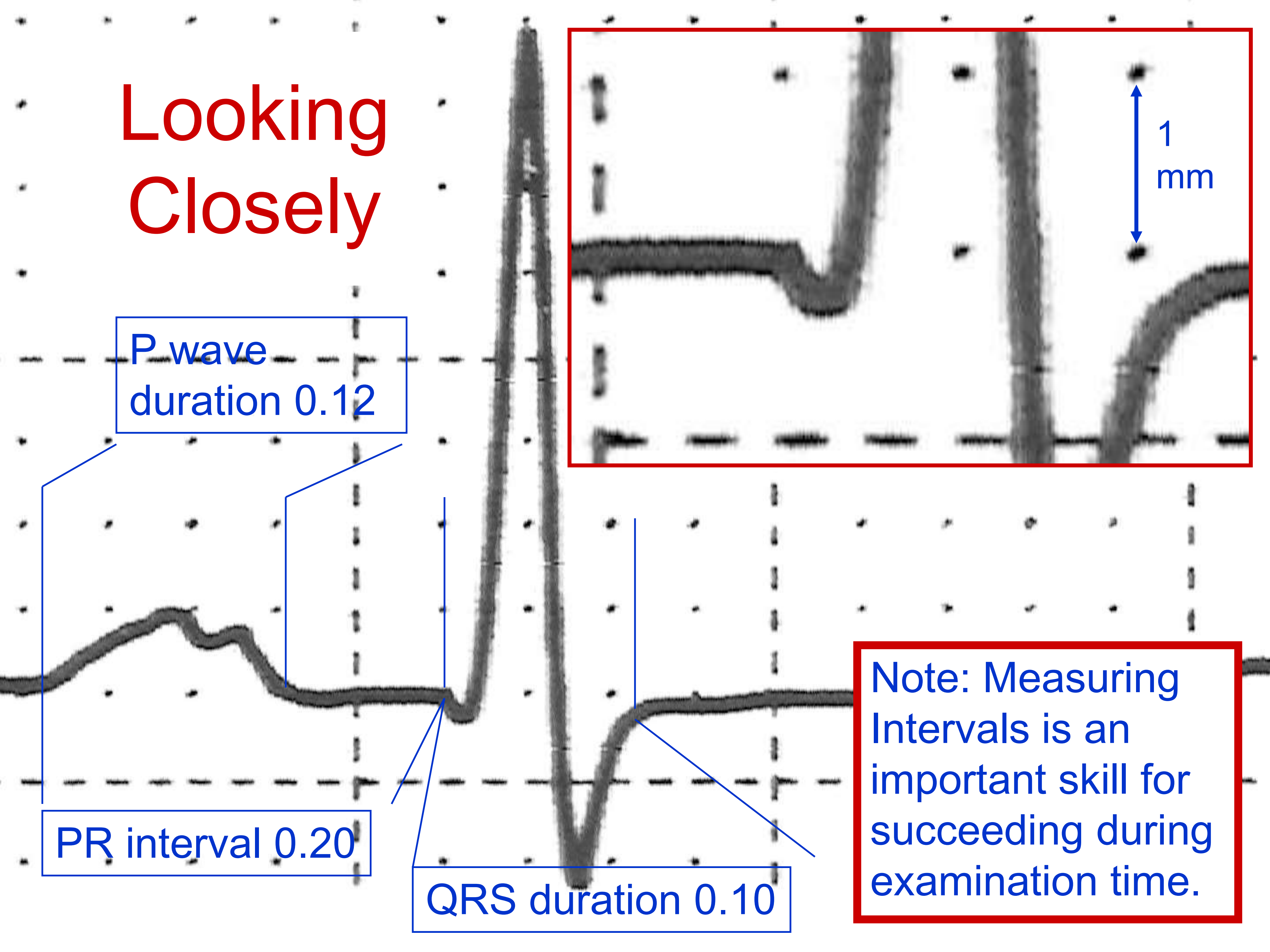
QT Interval

- From beginning of QRS to end of T wave – longest measurement in the 12 leads
- Varies with HR: Bazett's formula is $QT_c = QT/SQRT(R\text{-}R)$
- Normal QT_c is about 0.41 or less
- Significant prolongation is over 0.44 or maybe even over 0.46 sec.

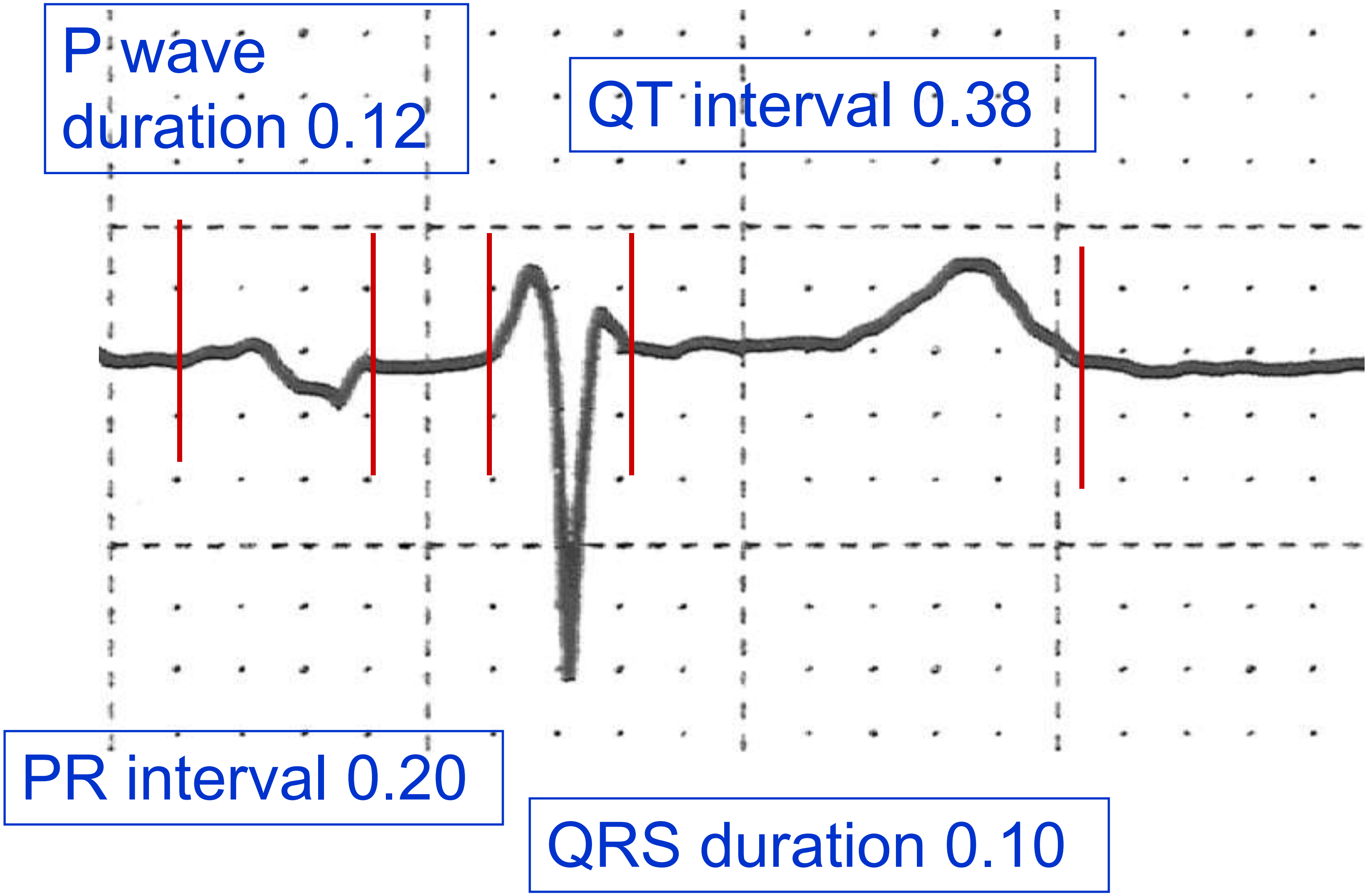
Intervals on the ECG

Note: Measuring Intervals is an important skill for succeeding during examination time.




Looking Closely
1 mm
P wave duration 0.12
PR interval 0.20
QRS duration 0.10
Note: Measuring Intervals is an important skill for succeeding during examination time.

Measuring Intervals



Measuring Intervals

Measure all intervals by choosing the longest interval in the limb leads

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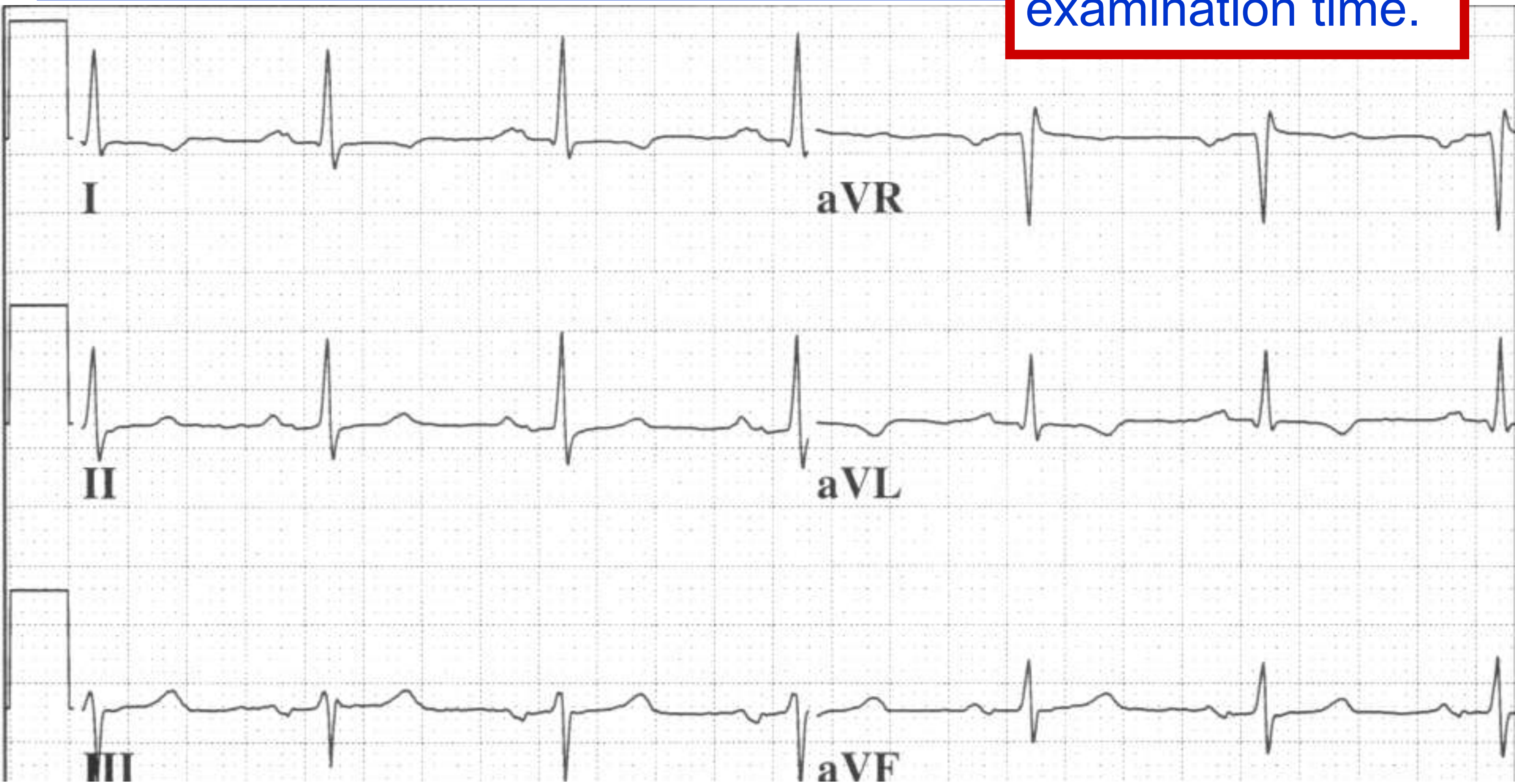
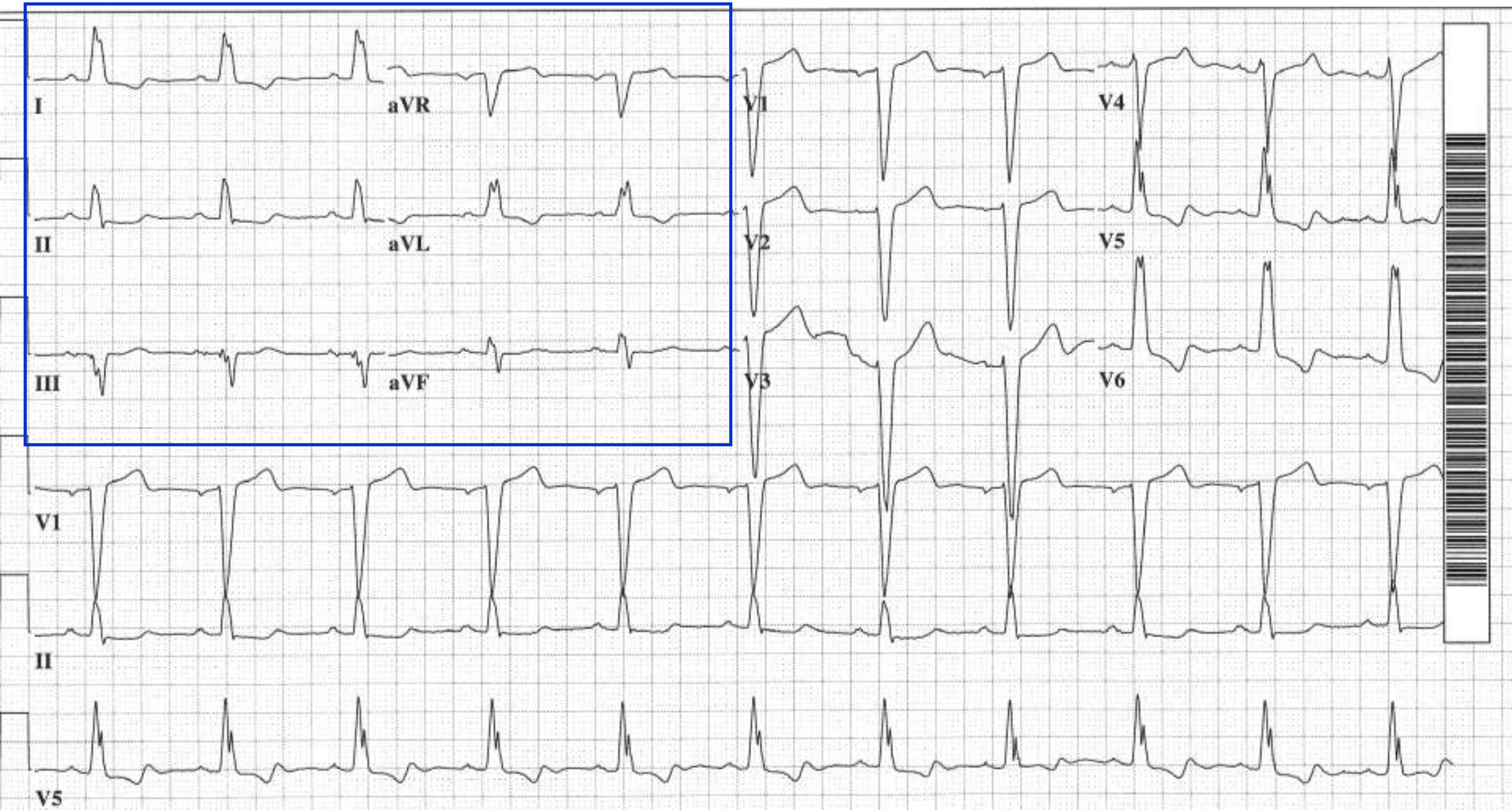


Measuring Intervals - 1

Note: Measuring Intervals is an important skill for succeeding during examination time.

What is the QRS duration?



Measuring Intervals - 1

What is the QRS duration? – **0.12 sec**

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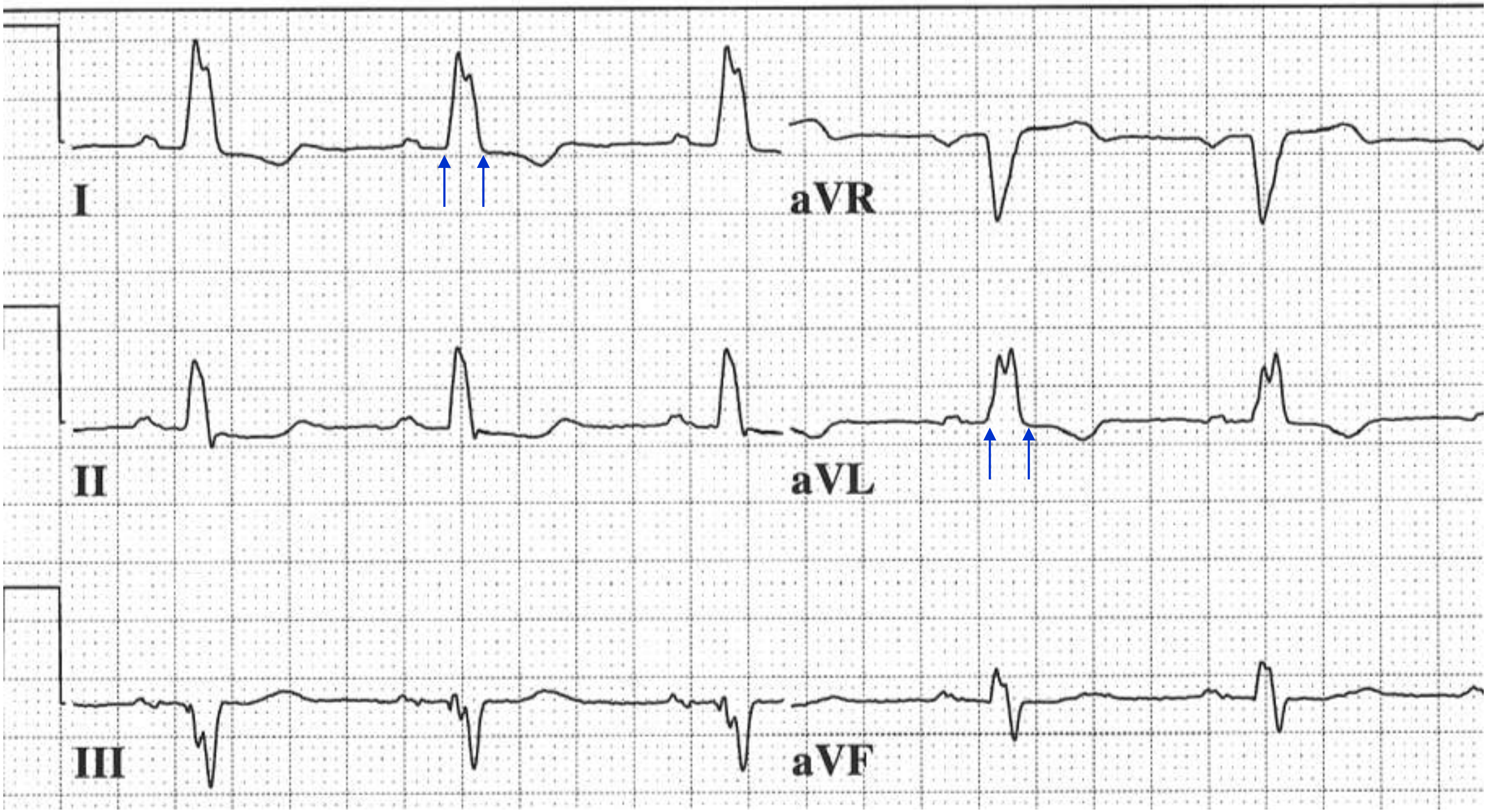

Measuring Intervals - 2

What is the QRS duration?

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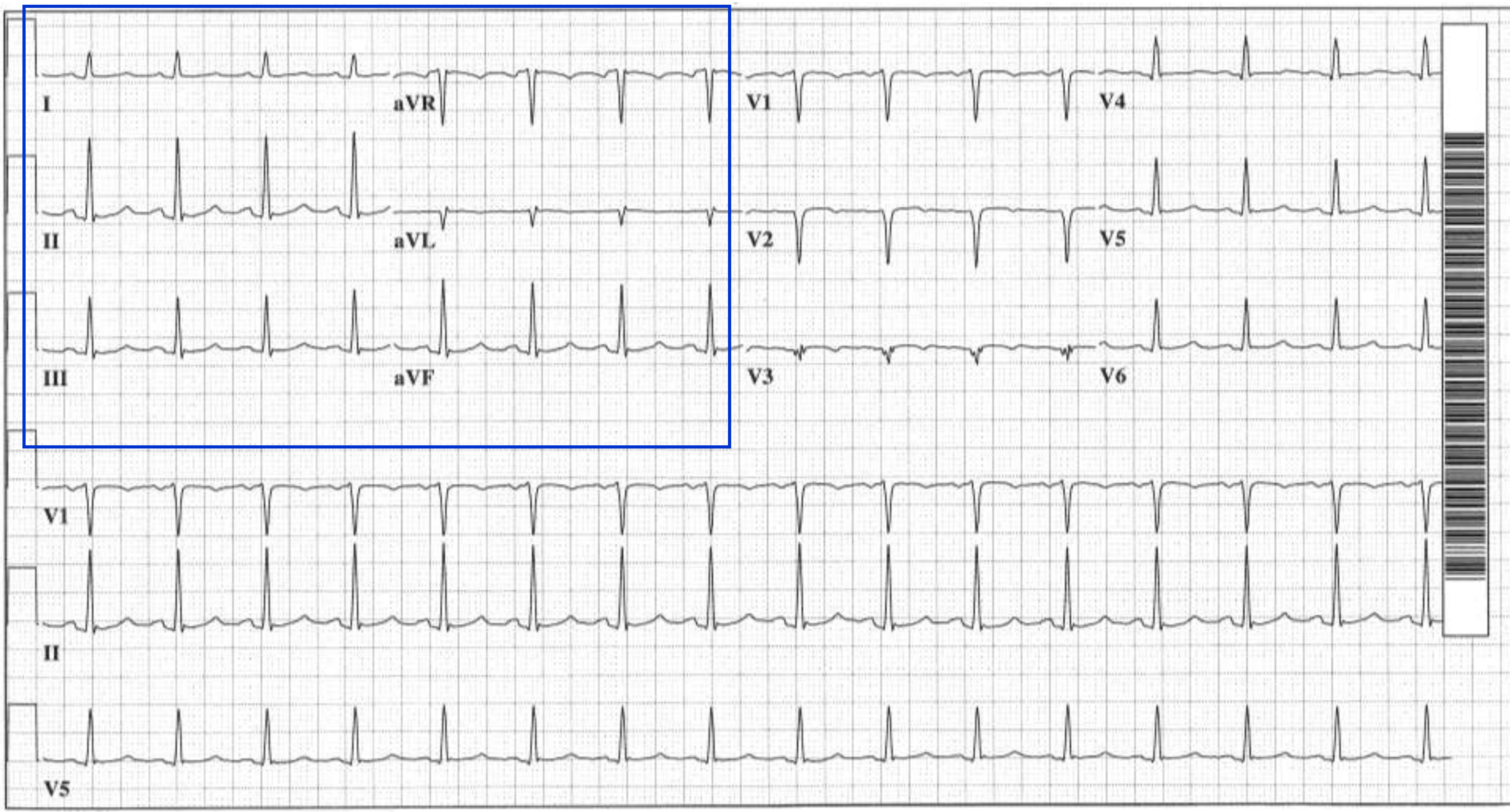

Measuring Intervals - 2

What is the QRS duration? – **0.08 sec**

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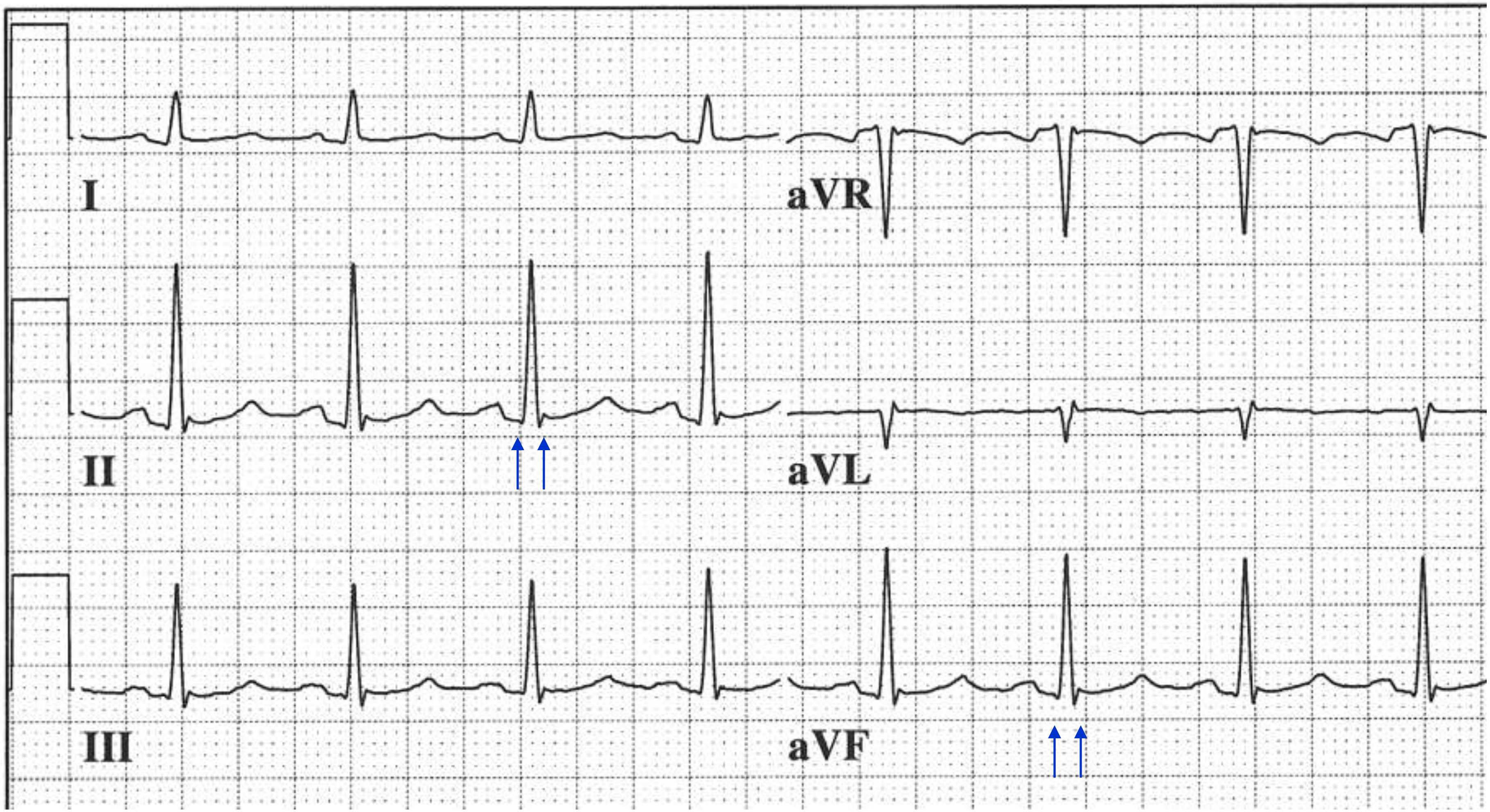

Measuring Intervals - 3

What is the QRS duration?

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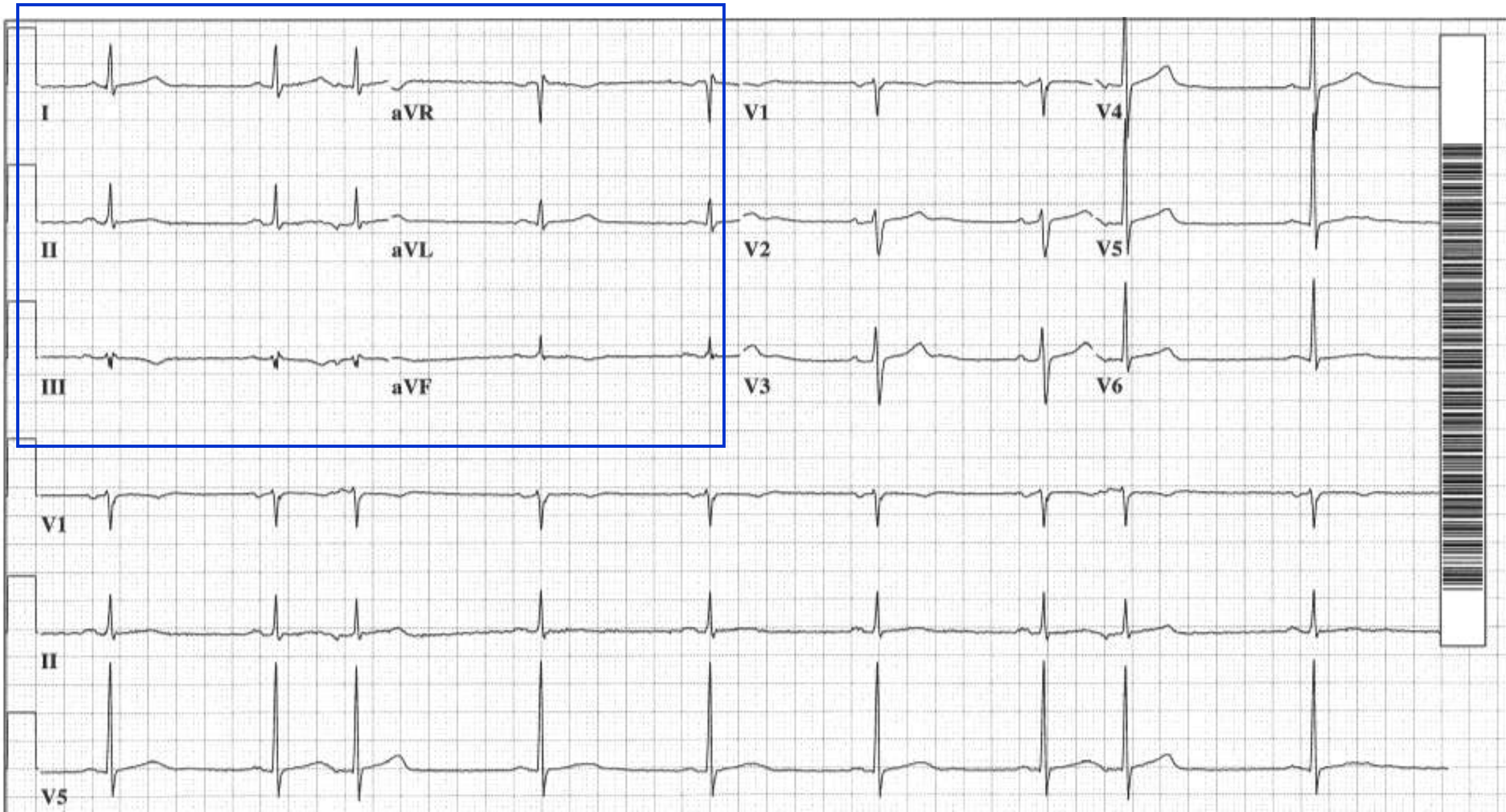

Measuring Intervals - 3

What is the QRS duration? –
0.08 sec

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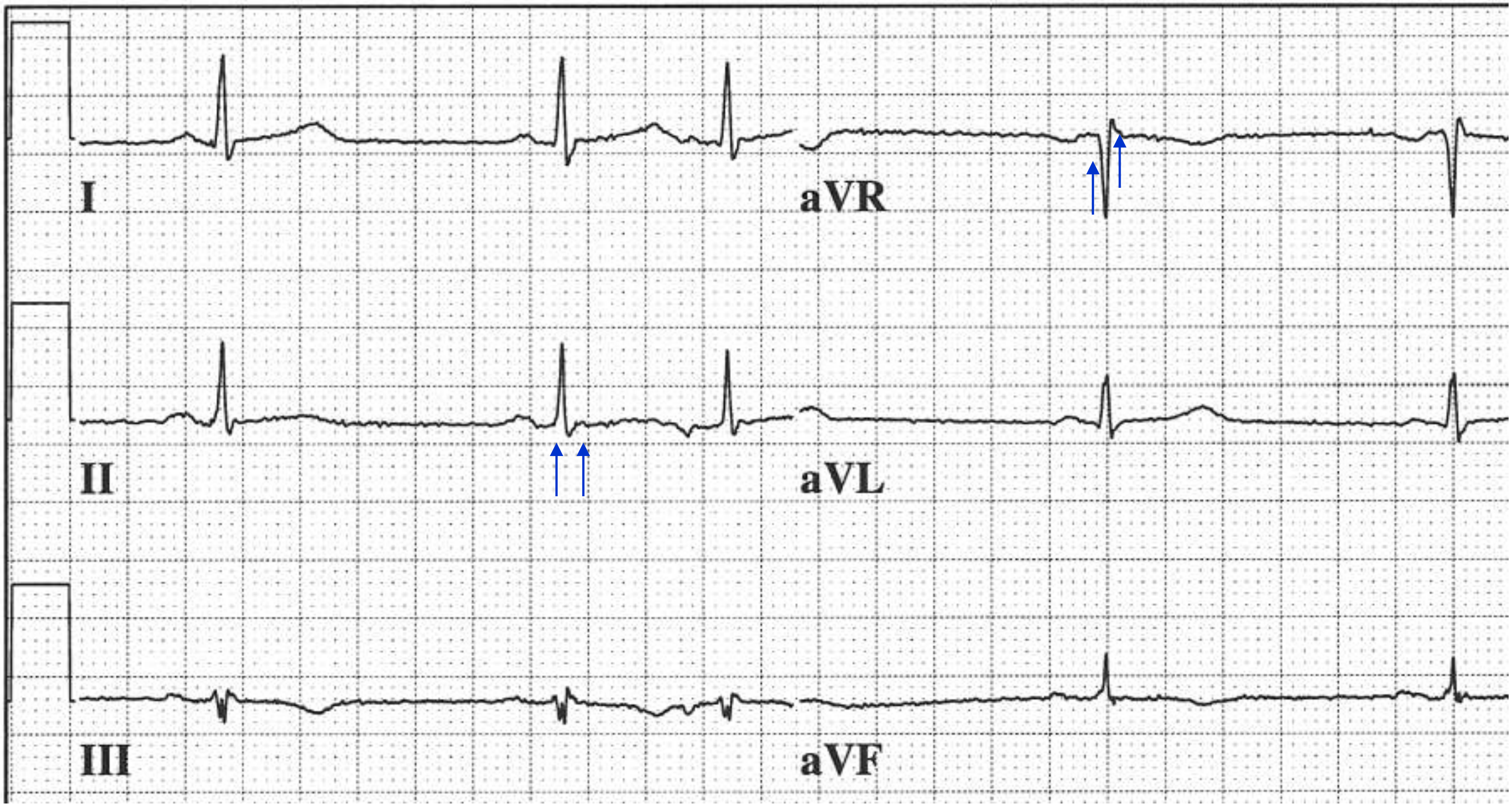

Measuring Intervals - 4

What is the PR interval?

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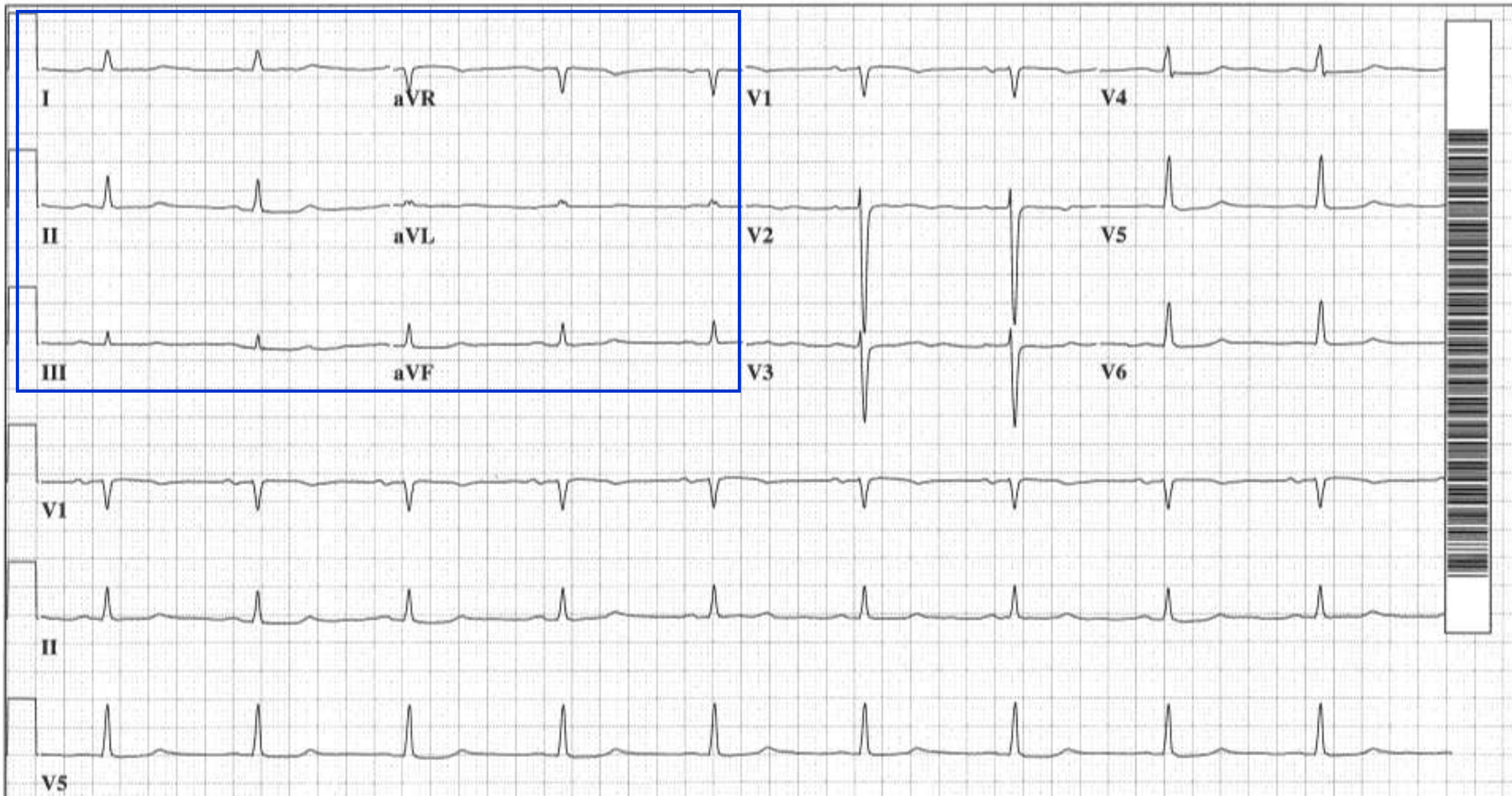
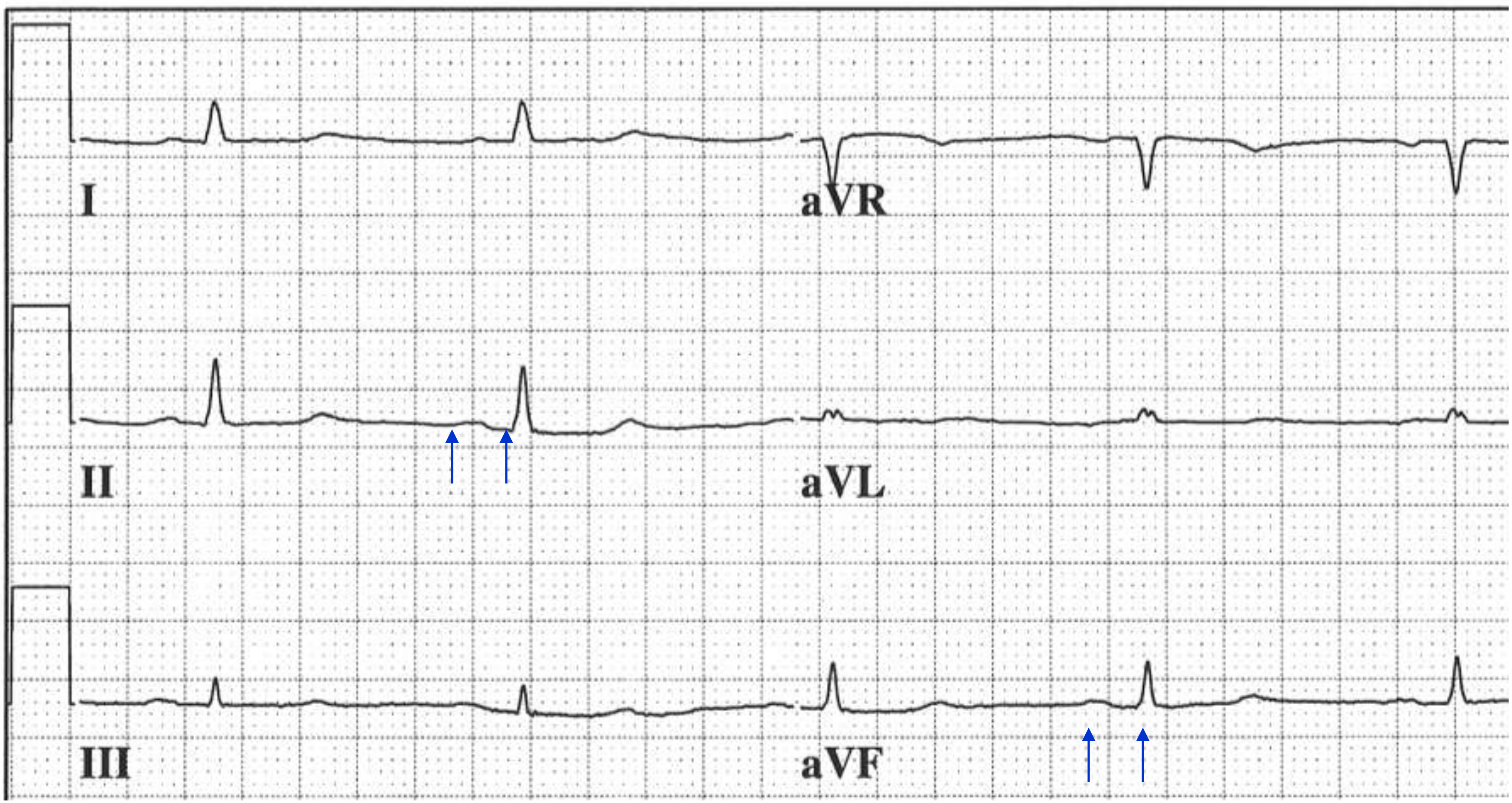


Measuring Intervals - 4

What is the PR interval? –
0.20 sec

Note: Measuring Intervals is an important skill for succeeding during examination time.



Measuring Intervals - 5

What is the QRS duration?

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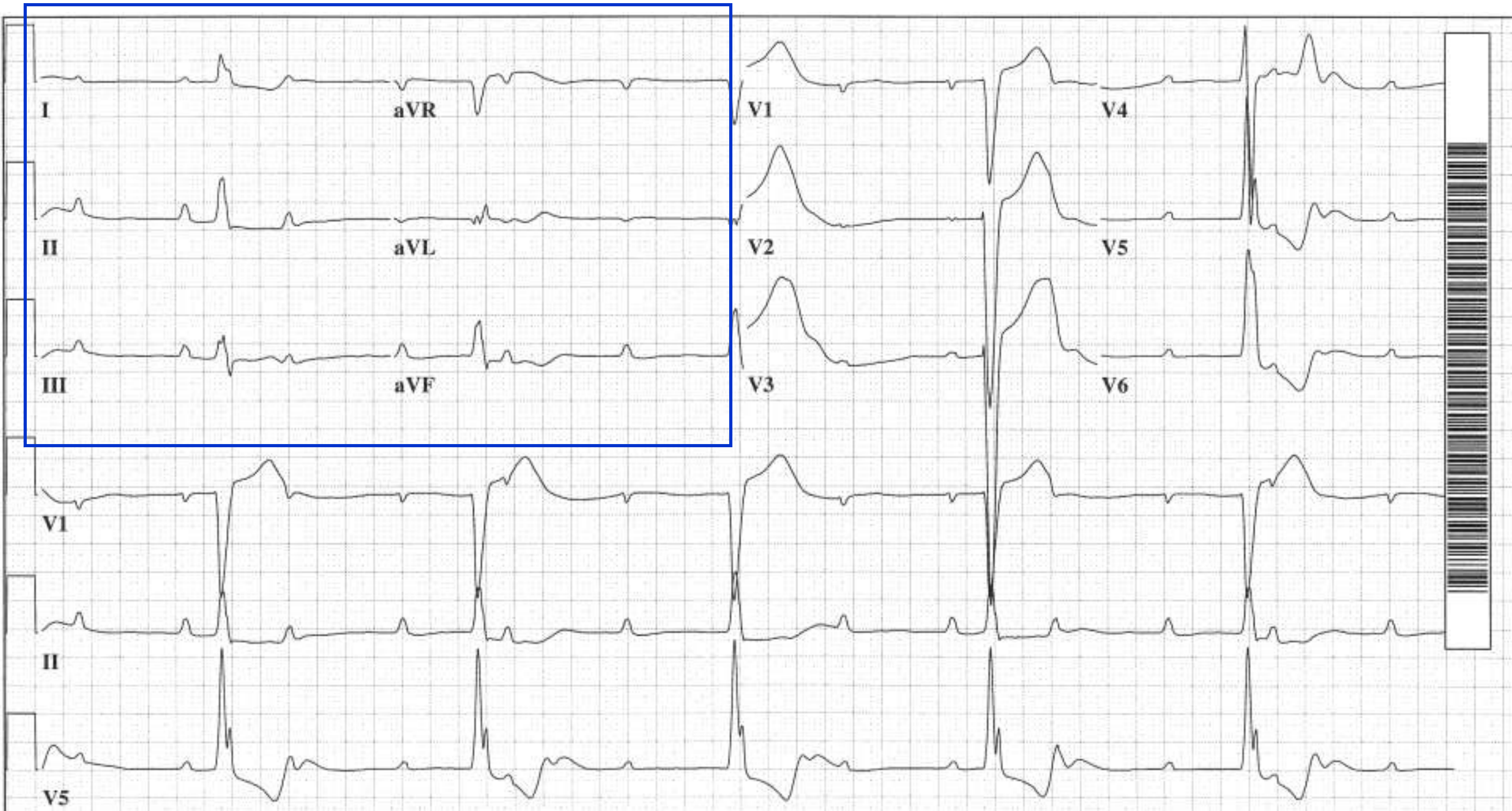
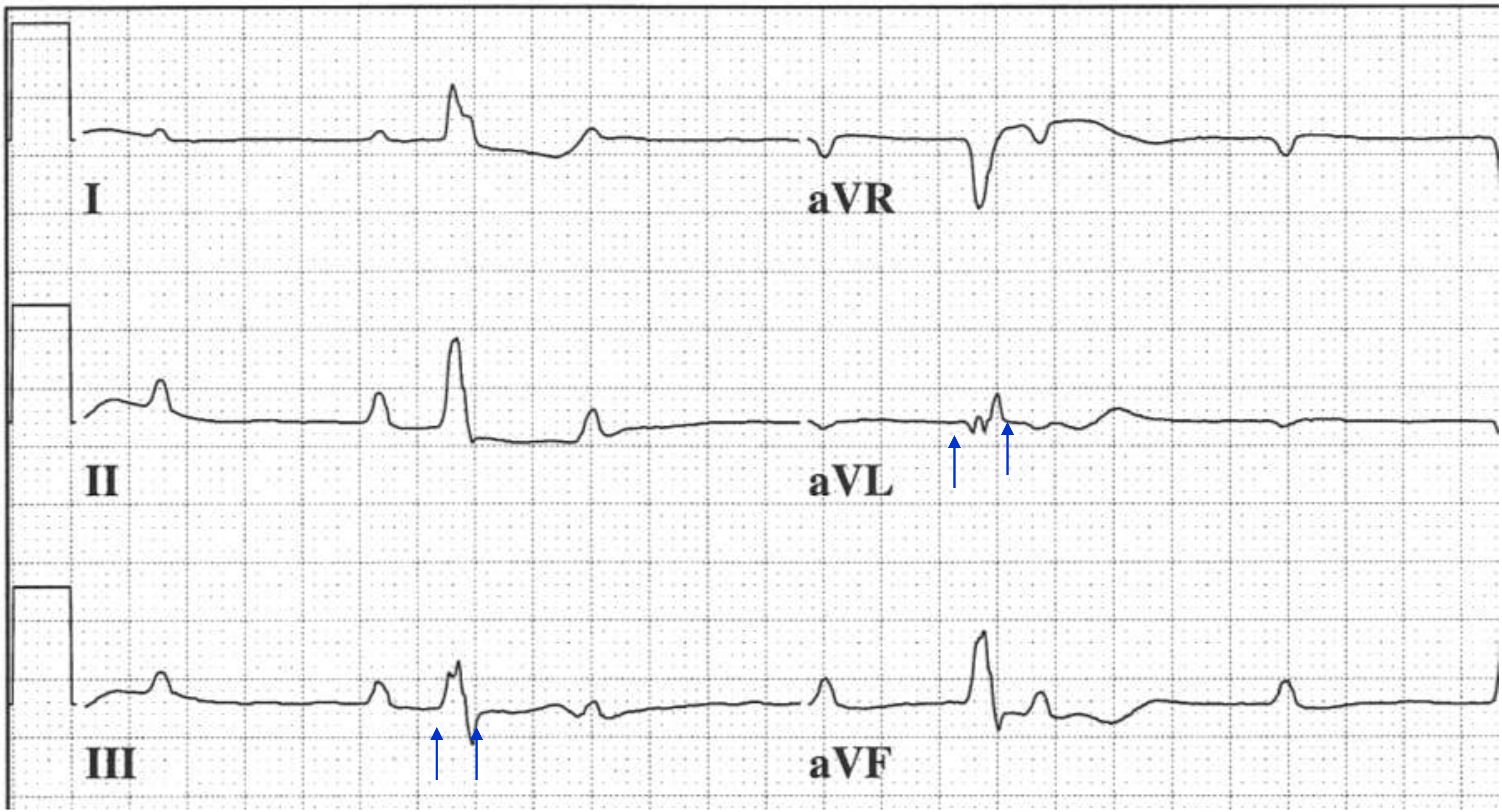


Measuring Intervals - 5

What is the QRS duration? –
0.14 sec

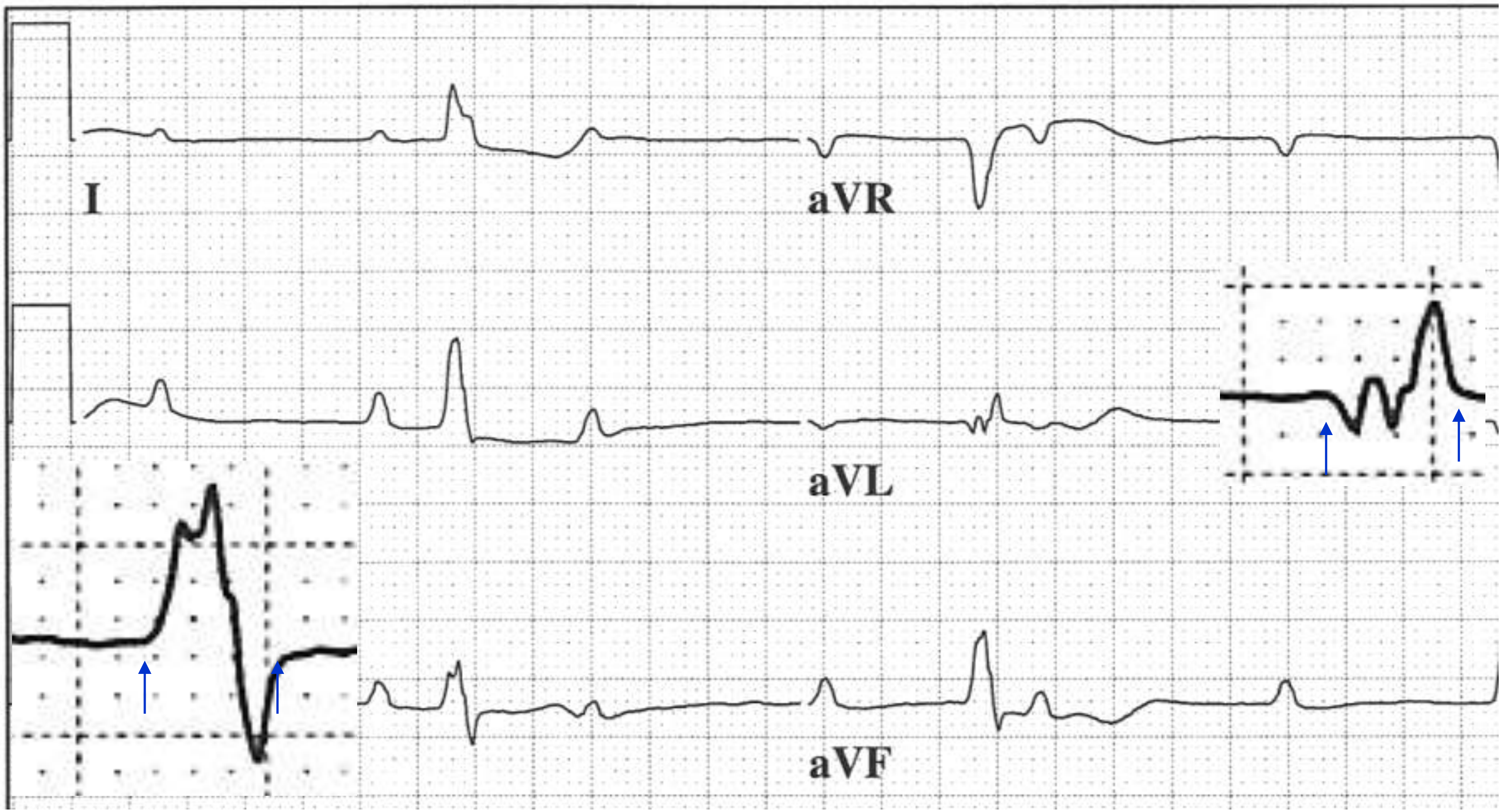
Note: Measuring Intervals is an important skill for succeeding during examination time.



Measuring Intervals - 5

What is the QRS duration? – **0.14 sec**

Note: Measuring Intervals is an important skill for succeeding during examination time.



Measuring Intervals - 6

What is the QRS duration? – **0.08 sec**

Note: Measuring Intervals is an important skill for succeeding during examination time.

Measuring Intervals - 7

What is the QRS duration? – **0.08 sec**

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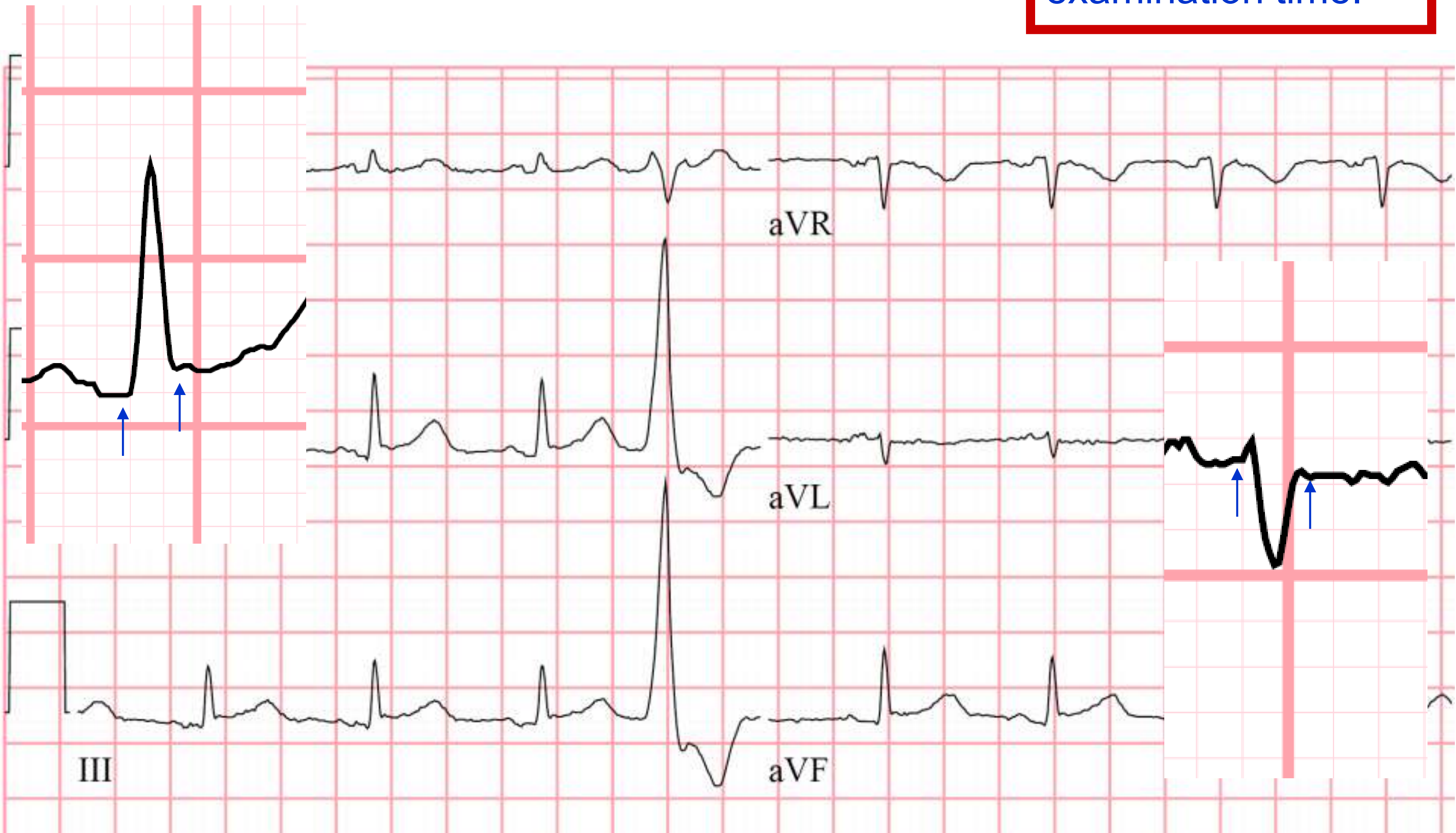

Measuring Intervals - 8

What is the PR interval?

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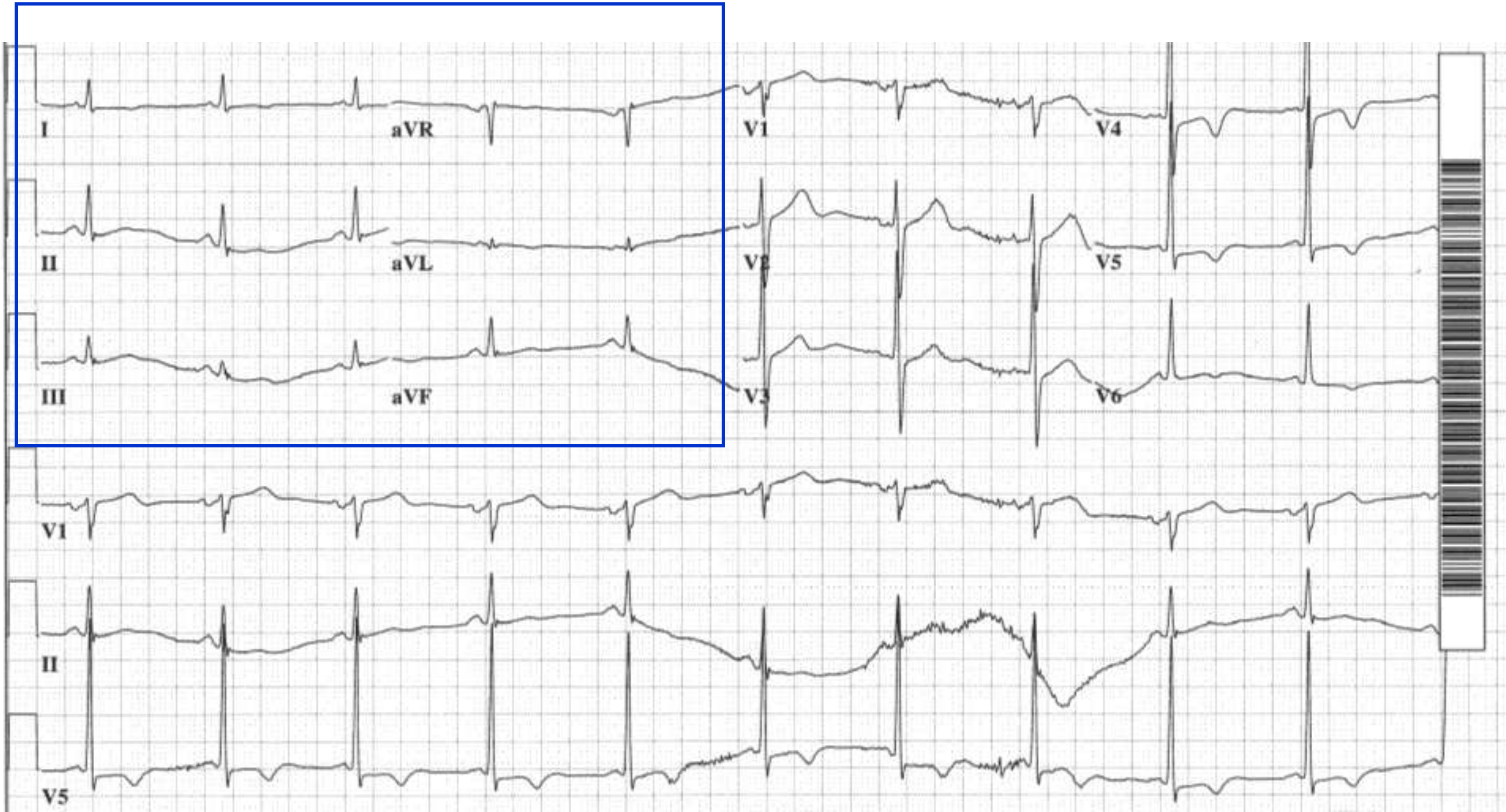
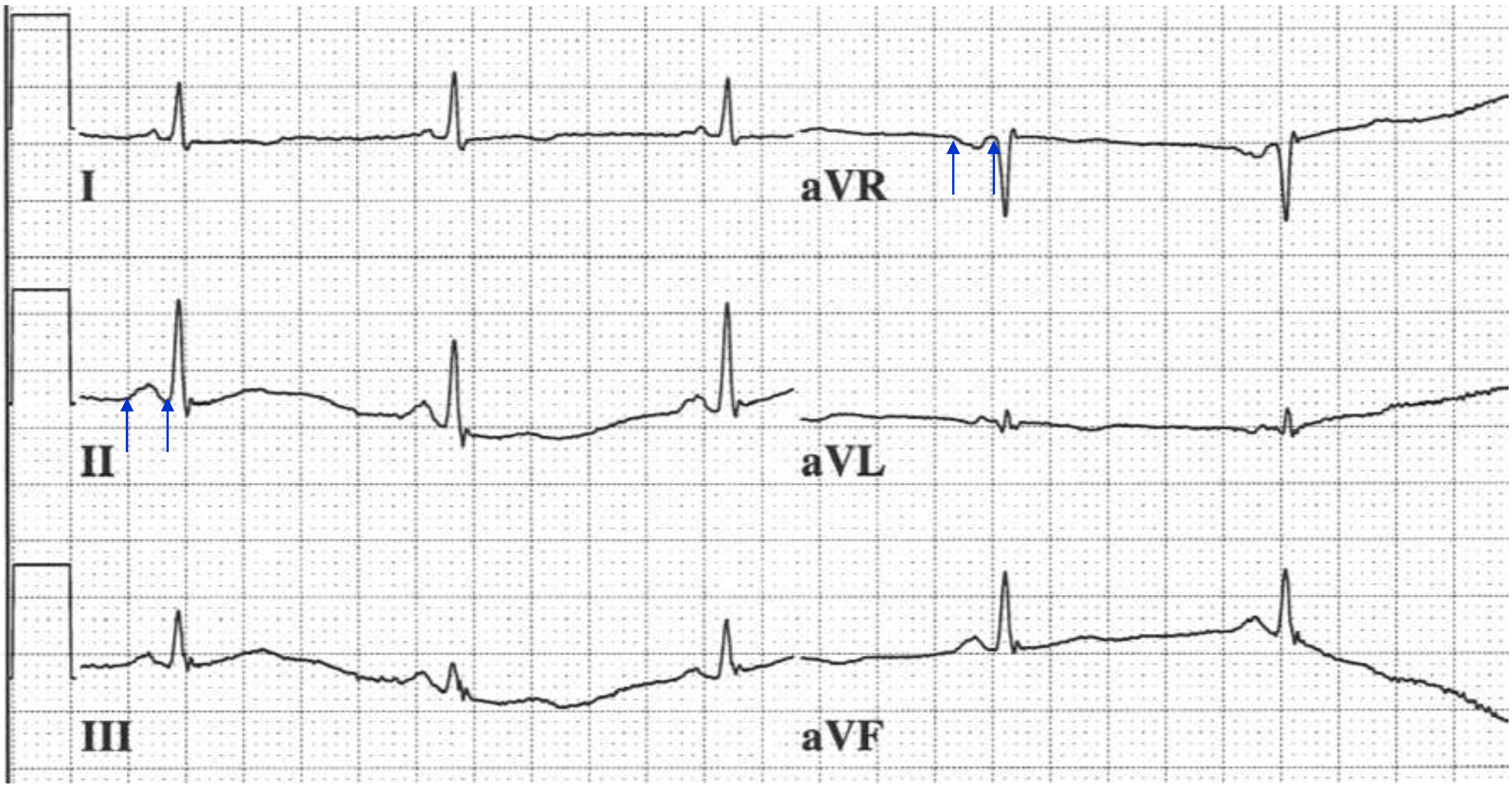


Measuring Intervals - 8

What is the PR interval? – **0.14 sec**

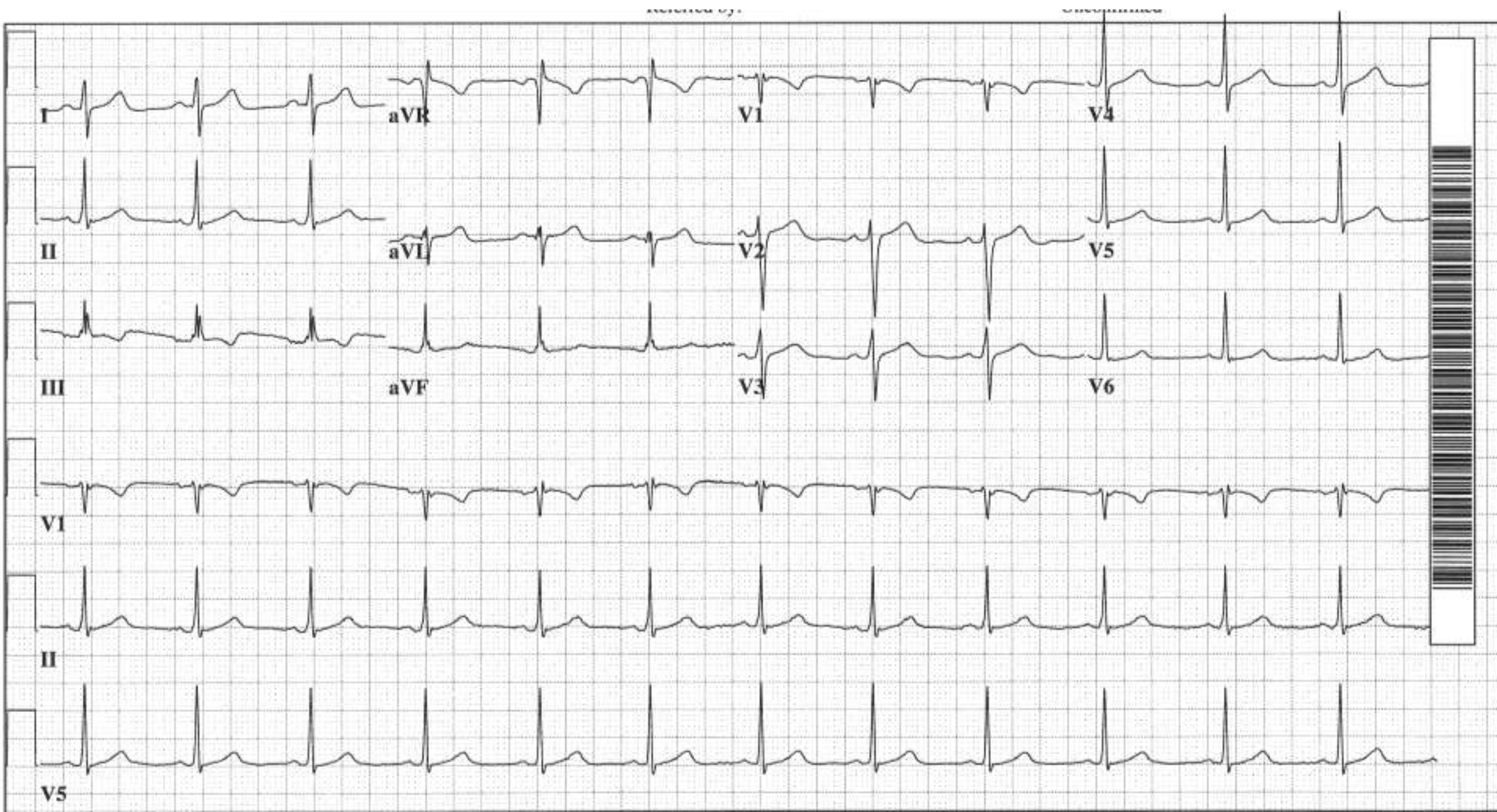
Note: Measuring Intervals is an important skill for succeeding during examination time.



Measuring Intervals - 9

What is the PR interval?

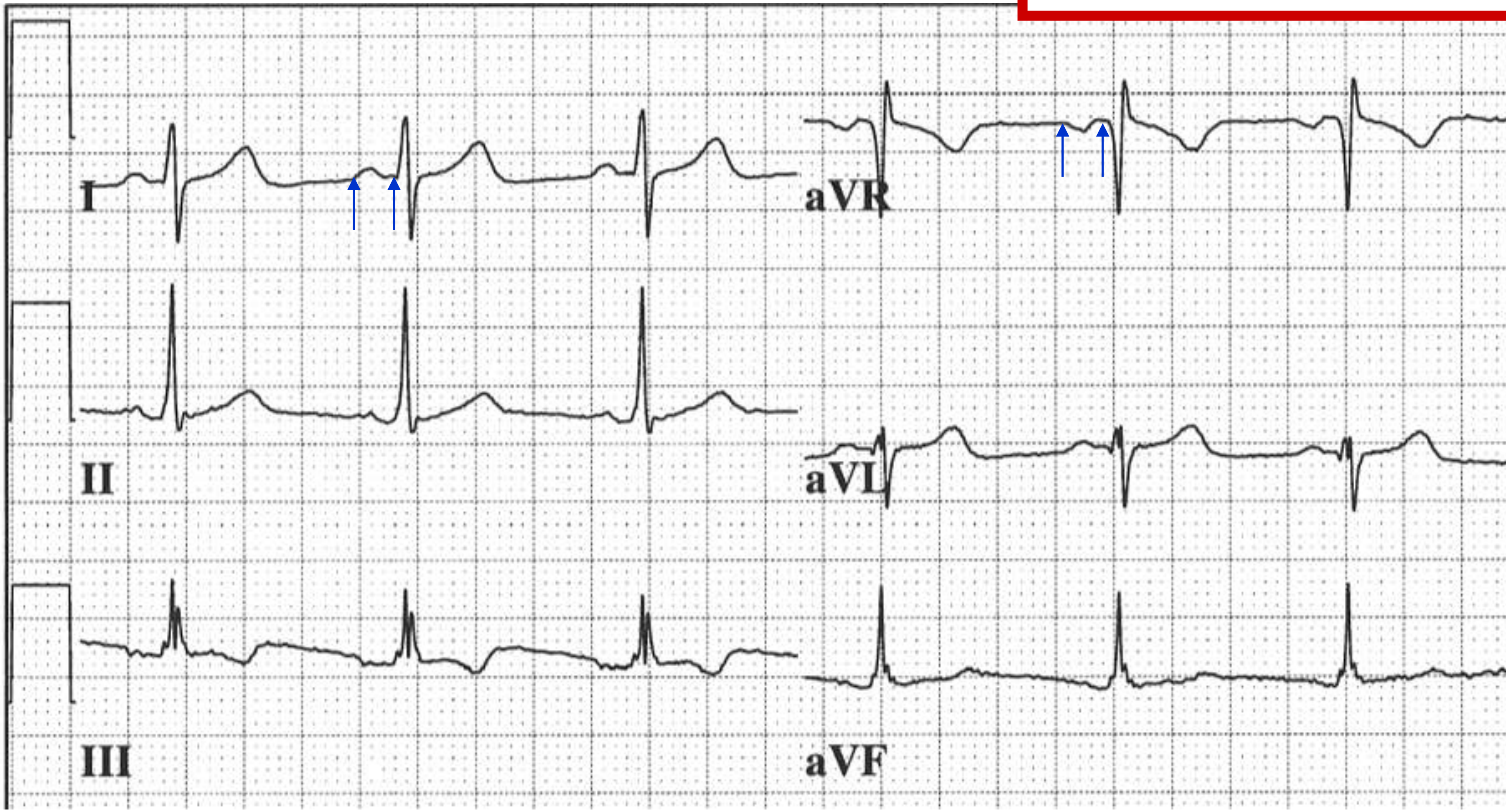
Note: Measuring Intervals is an important skill for succeeding during examination time.



Measuring Intervals - 9

What is the PR interval? – **0.14 sec**

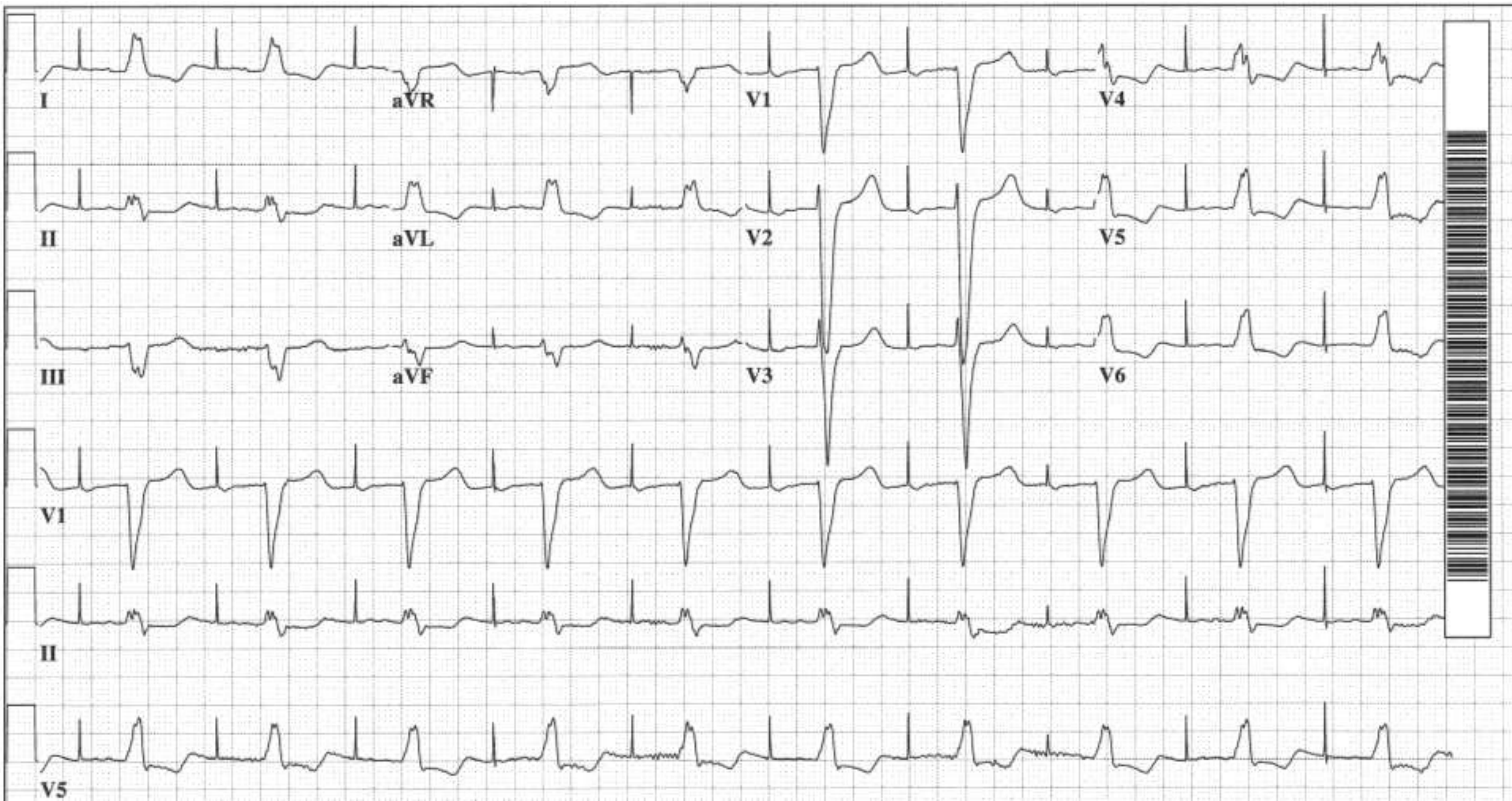
Note: Measuring Intervals is an important skill for succeeding during examination time.



Measuring Intervals - 10

What is the QRS duration?

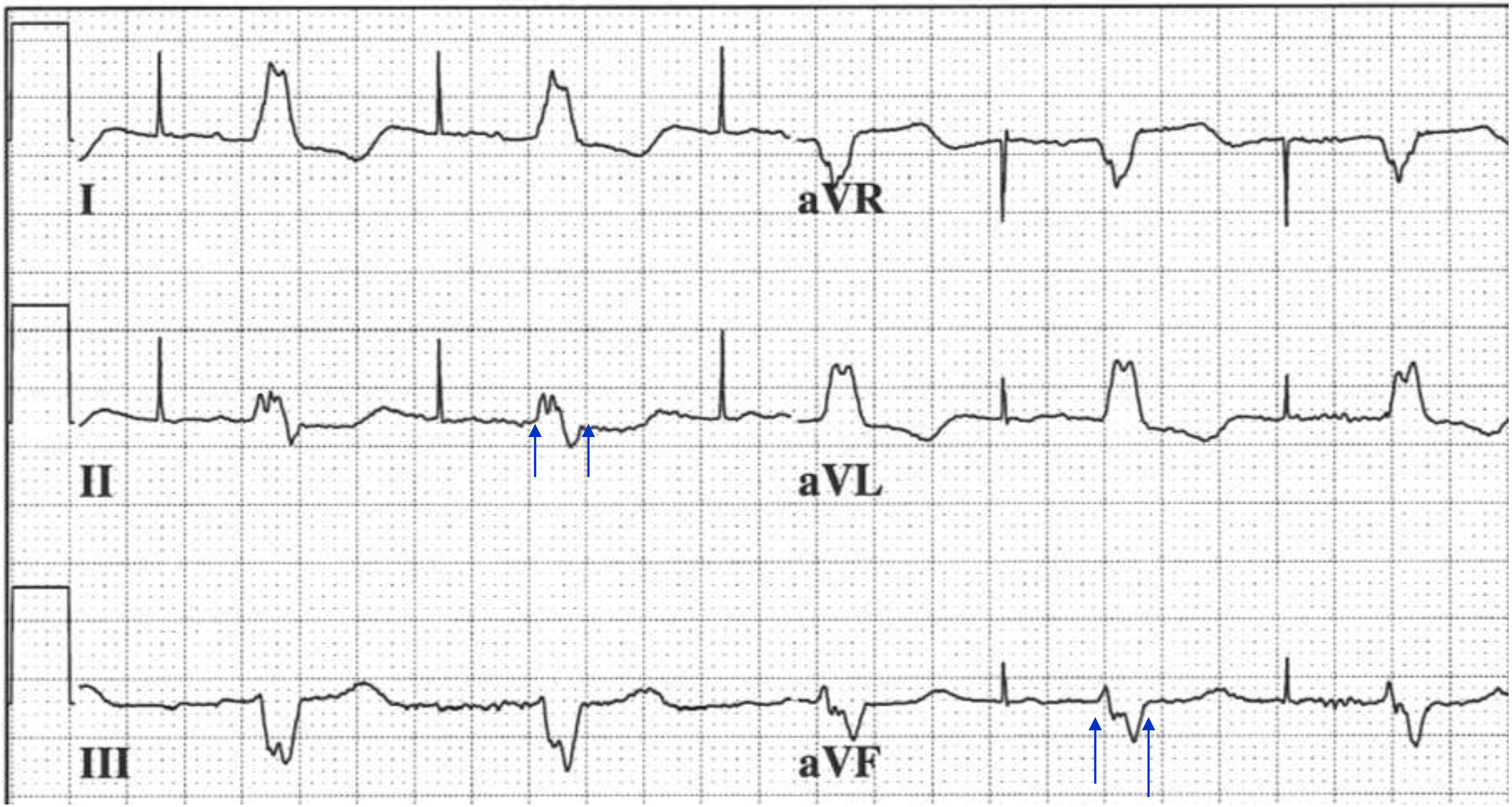
Note: Measuring Intervals is an important skill for succeeding during examination time.

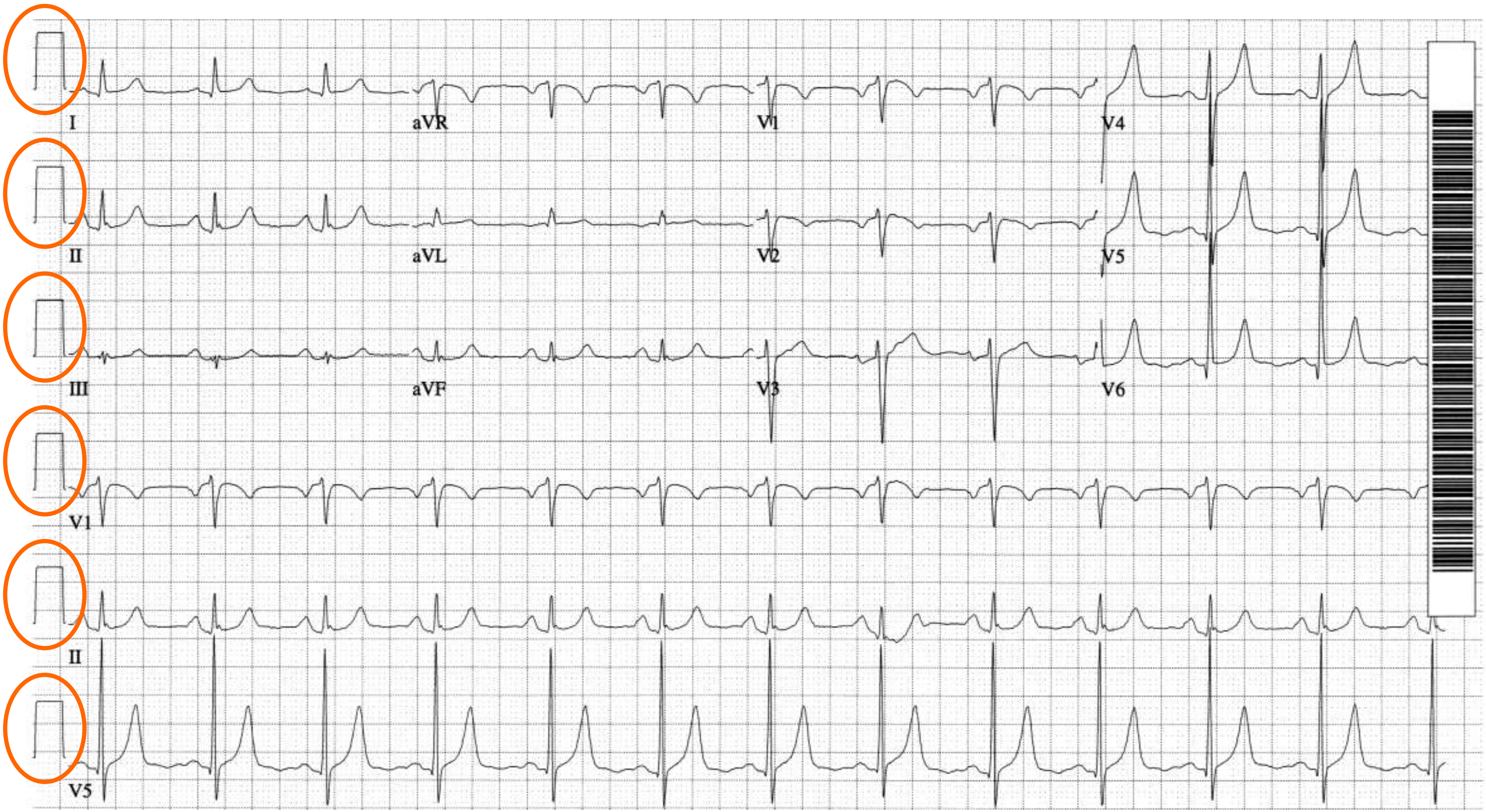


Measuring Intervals - 10

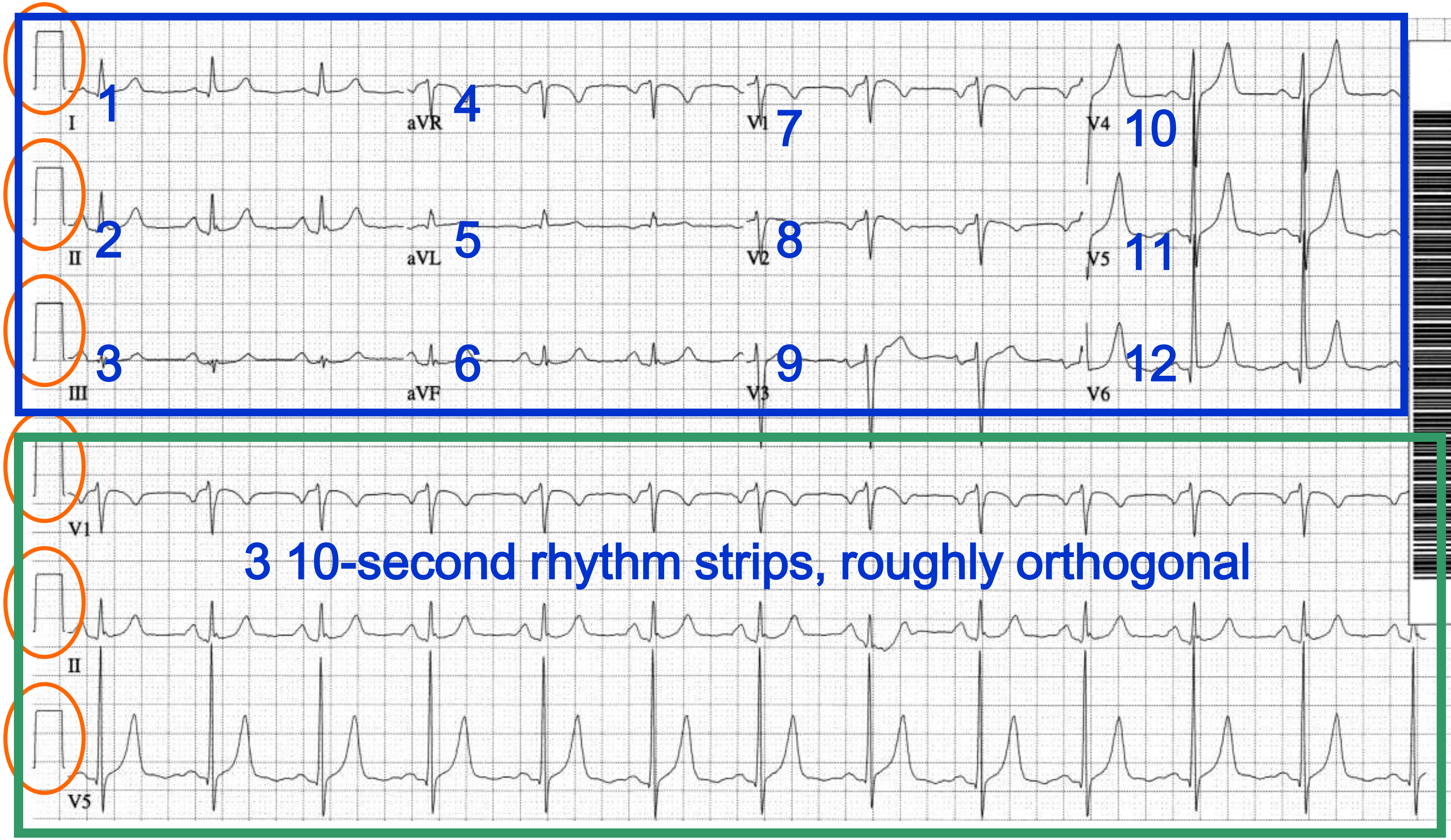
What is the QRS duration? – **0.16 sec**

Note: Measuring Intervals is an important skill for succeeding during examination time.



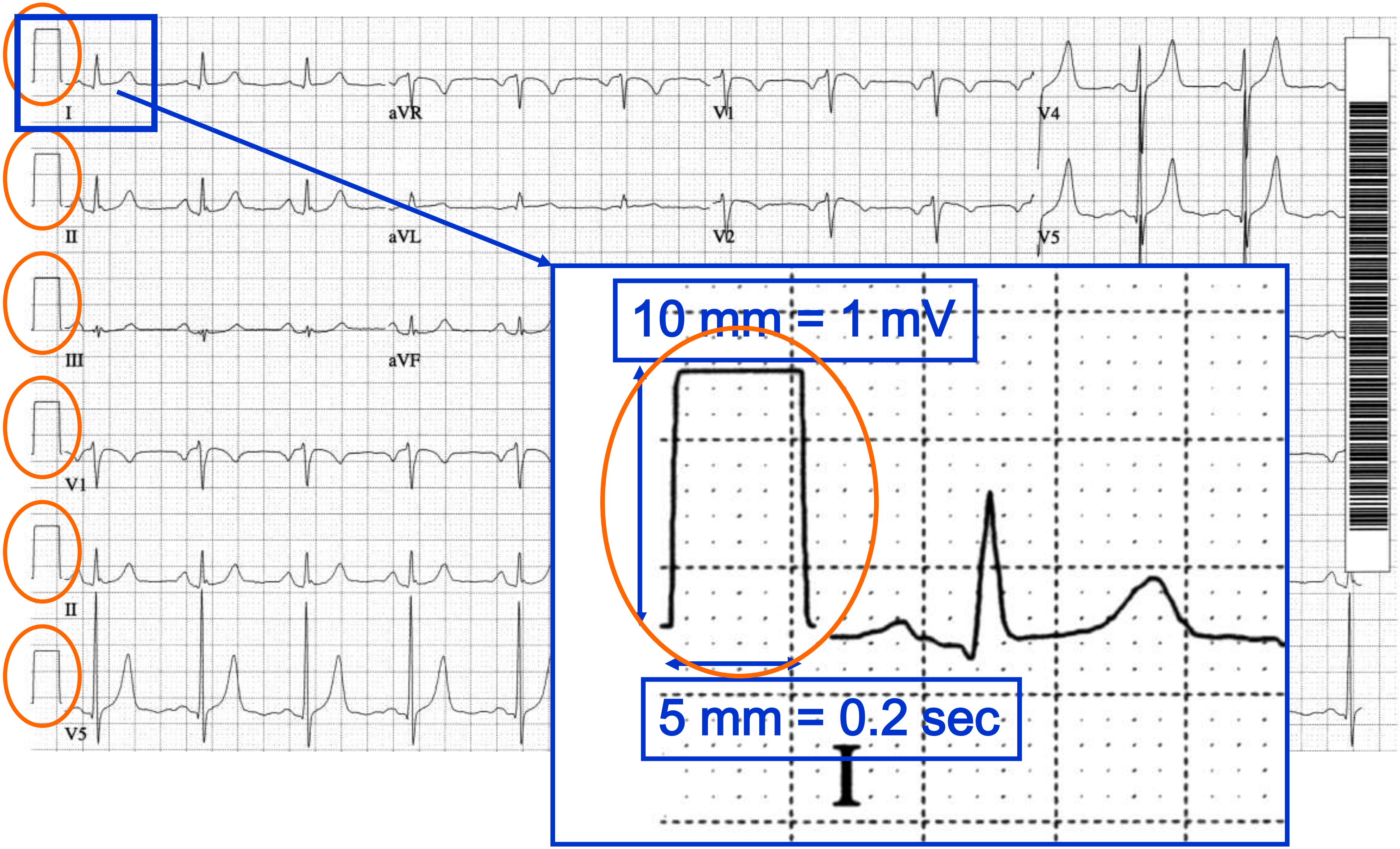


The 12-Lead ECG



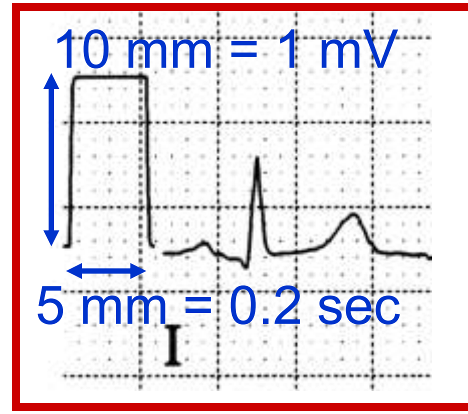
The 12-Lead ECG

This is the usual display format, but many other display formats also exist, so check the labels and standardization marks

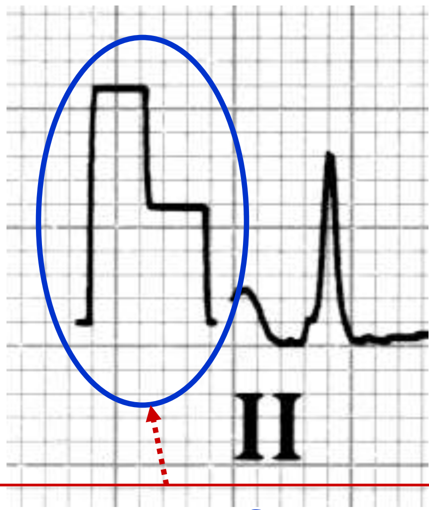


Normal Standard and Paper Speed

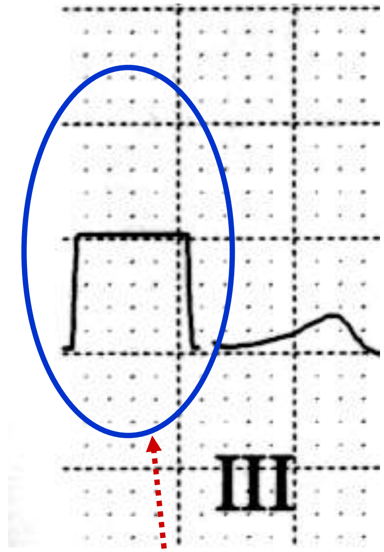
Different Standard Marks



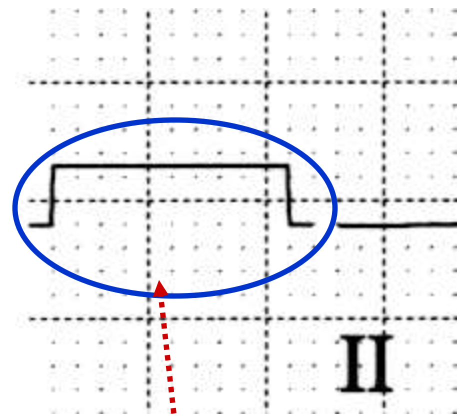
Each marker is 0.1 mV tall and 0.2 sec wide



Limb leads full std
Chest leads half std
Normal speed



Limb leads half std
Chest leads half std
Normal speed



Limb leads qtr std
Chest leads qtr std
Double speed

Outline

- Description of ECG recording page
- Review of pertinent cardiac physiology
- Identification of waves and intervals
- **3 methods for calculation of rate**
- Calculation of QRS electrical axis
- Steps in interpretation
- Diagnosing normal and abnormal findings

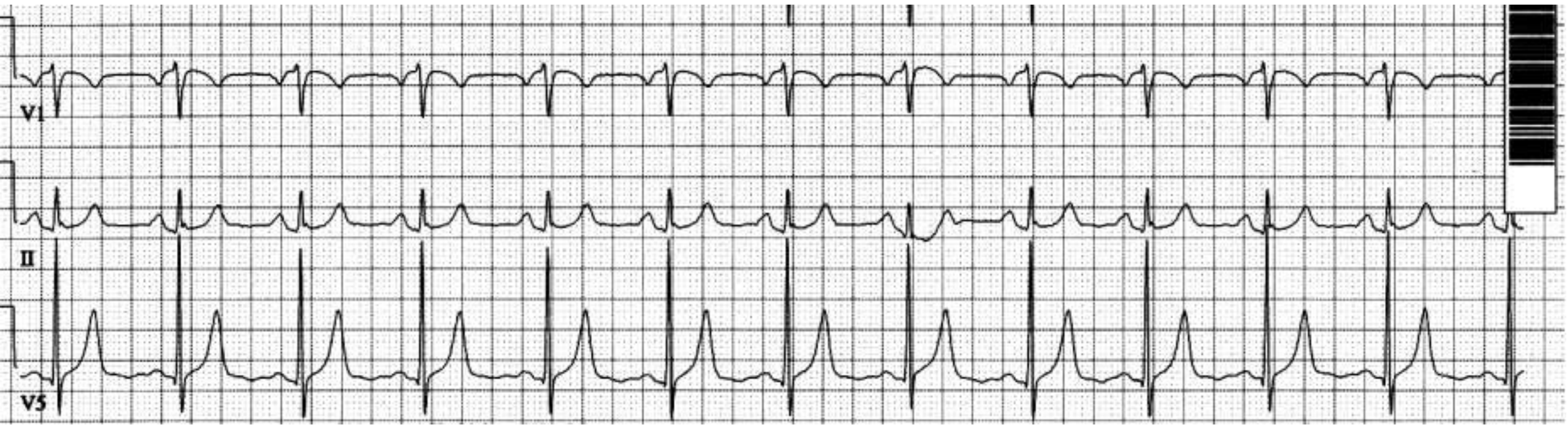
Calculation of Rate

- Method 1 ("Six-second rule" – useful for regular or irregular rhythms) - measure the waves of interest over 6 seconds and multiply by 10
- Method 2 (requires regular rhythm) - measure distance in mm between 2 waves of interest, and divide 1500 by that distance

25 mm/sec*60 sec/min = 1500 mm/min
(Mm/min ÷ millimeters/beat = beat/min)

Calculation of Rate: Method 1

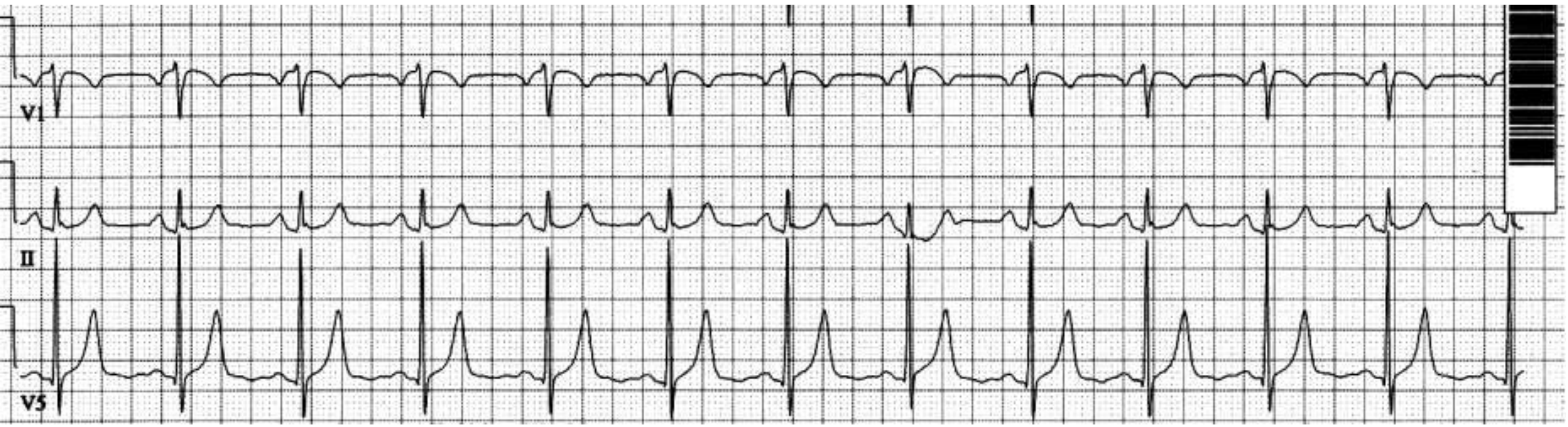
Six second rule:
6 seconds: 8 beats * 10 = 80 bpm



Corollary to six second rule is Ten second rule:
10 seconds: 13 beats * 6 = 78 bpm

Note: Using the ten second rule is an important skill for succeeding during examination time.

Calculation of Rate: Method 2

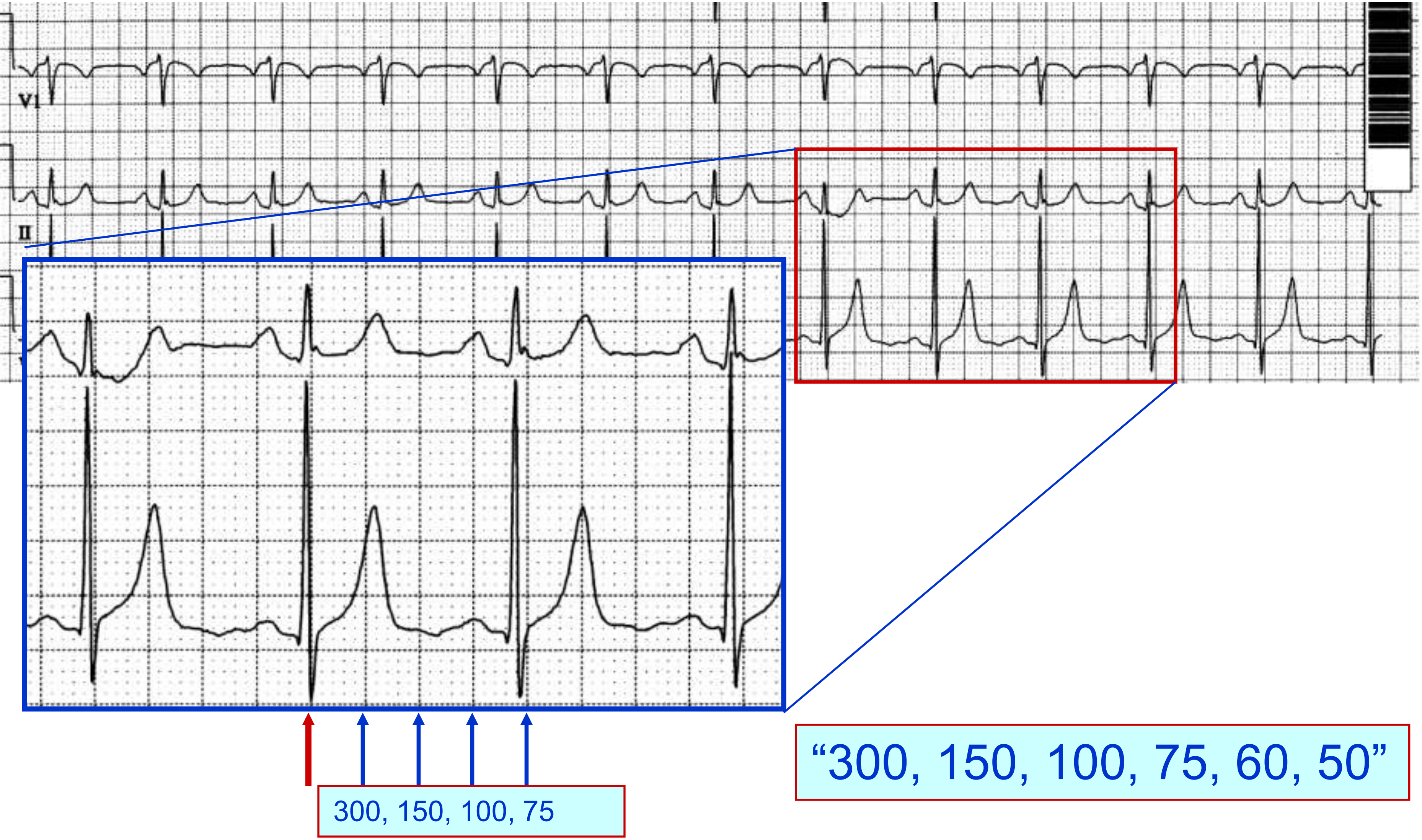


(Requires regular rhythm)
R-R interval is 20 mm.
1500/20 = 75 bpm

Calculation of Rate - 2

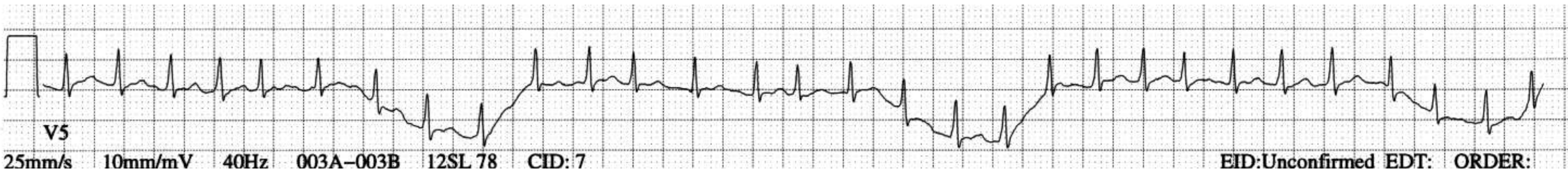
- Method 3 - requires regular rhythm
  - Find wave beginning near a dark 5mm marker
  - Count subsequent 5-mm markers until the next wave of interest
  - Count, “300, 150, 100, 75, 60, 50”
  - When you pass the next wave of interest, you have bracketed the rate between 2 numbers
  - Interpolate between the bracketed numbers

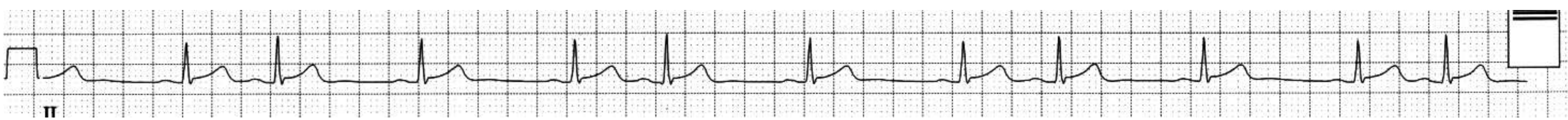
Calculation of Rate: Method 3

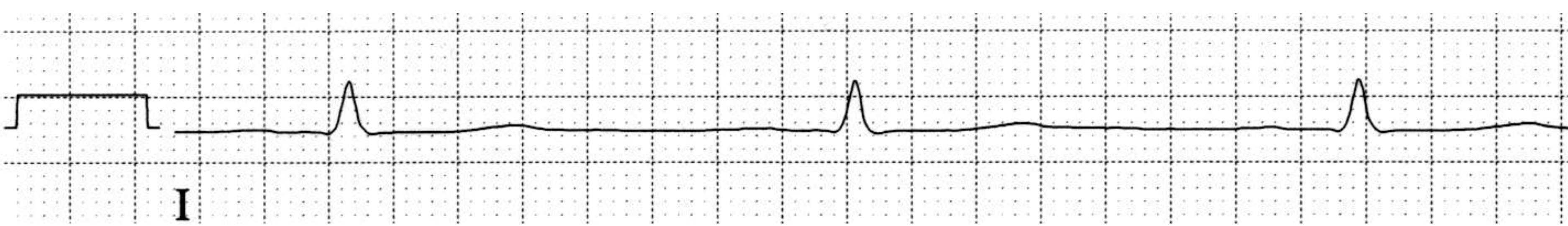


"300, 150, 100, 75, 60, 50"

Calculation of Rate: Examples







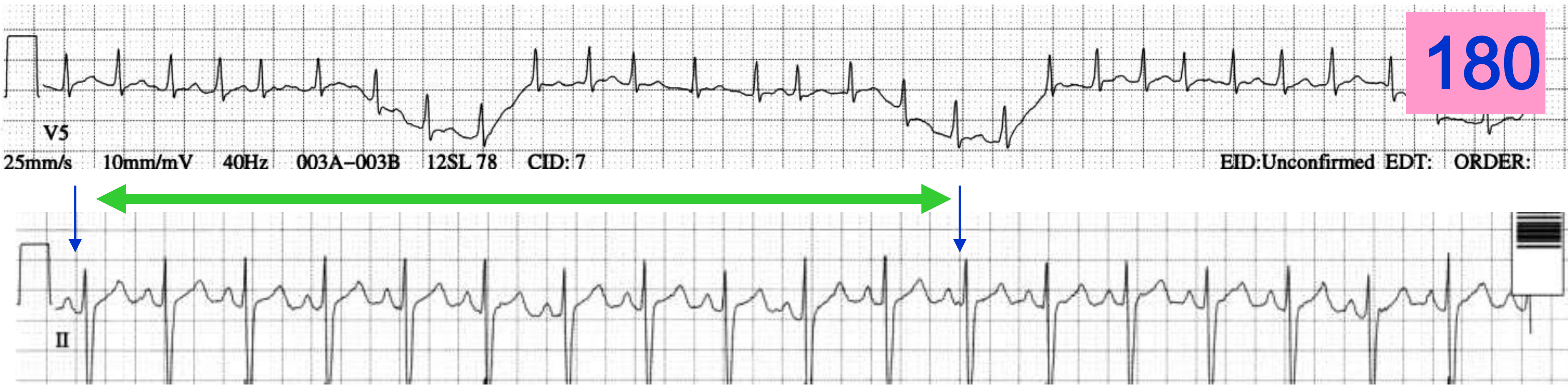
Calculation of Rate: Example 1

<u>Method 1: 6 second rule</u> – since 5 large blocks is one second, count 6 seconds or 30 large blocks (what a pain!), and then count the beats (18) and multiply by 10 (rate 180 bpm), Ouila! Cannot use methods 2 or 3 for irregular rhythm such as this.

<u>Corollary, 10 second rule</u> – if you have a full 10 second strip, then just count all the beats and multiply by 6. (30*6 = 180)

This method is <u>good for any example</u> that is at least 6 seconds long.

Calculation of Rate: Example 2



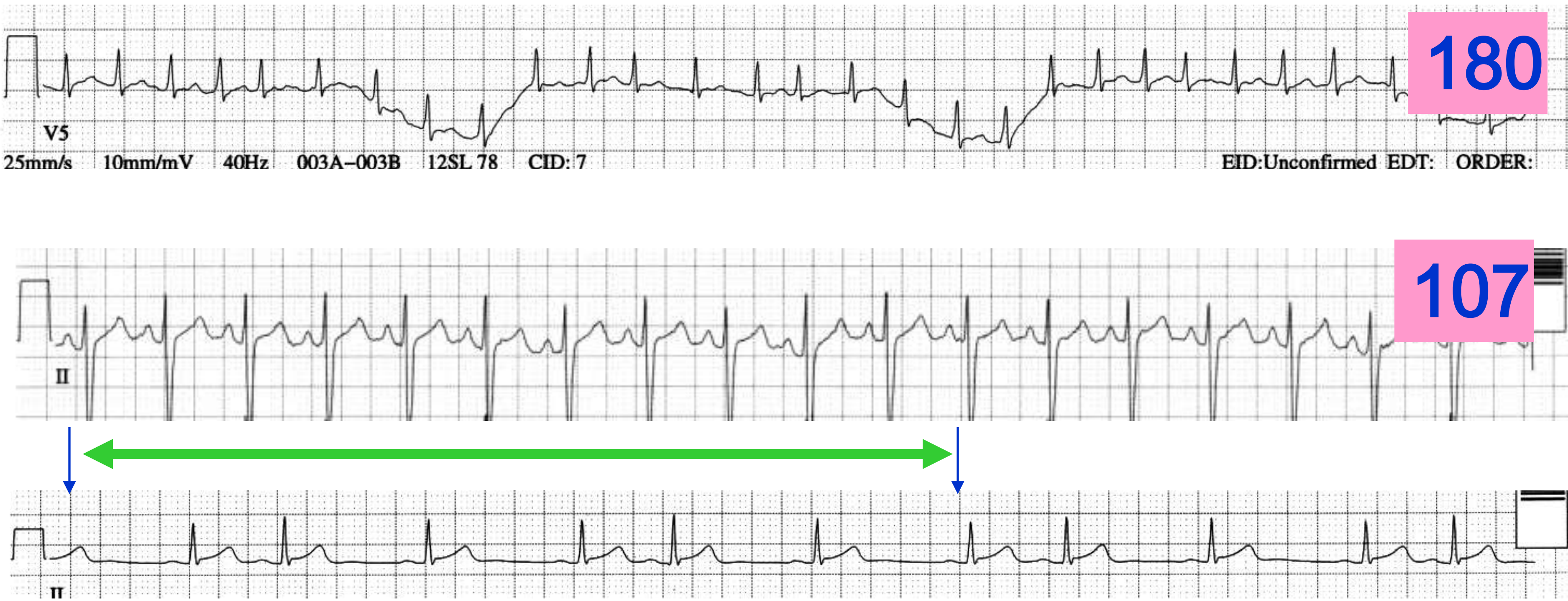
Method 1: 6 second rule: 11*10=110. 10 second rule: 18*6=108

Method 2: 1500/R-R interval: 1500/14=107

Method 3: “300, 150, 100. So, between 150 and 100, closer to 100, so guess about 110.

Method 2 and 3 apply ONLY because the intervals are <u>regular</u>

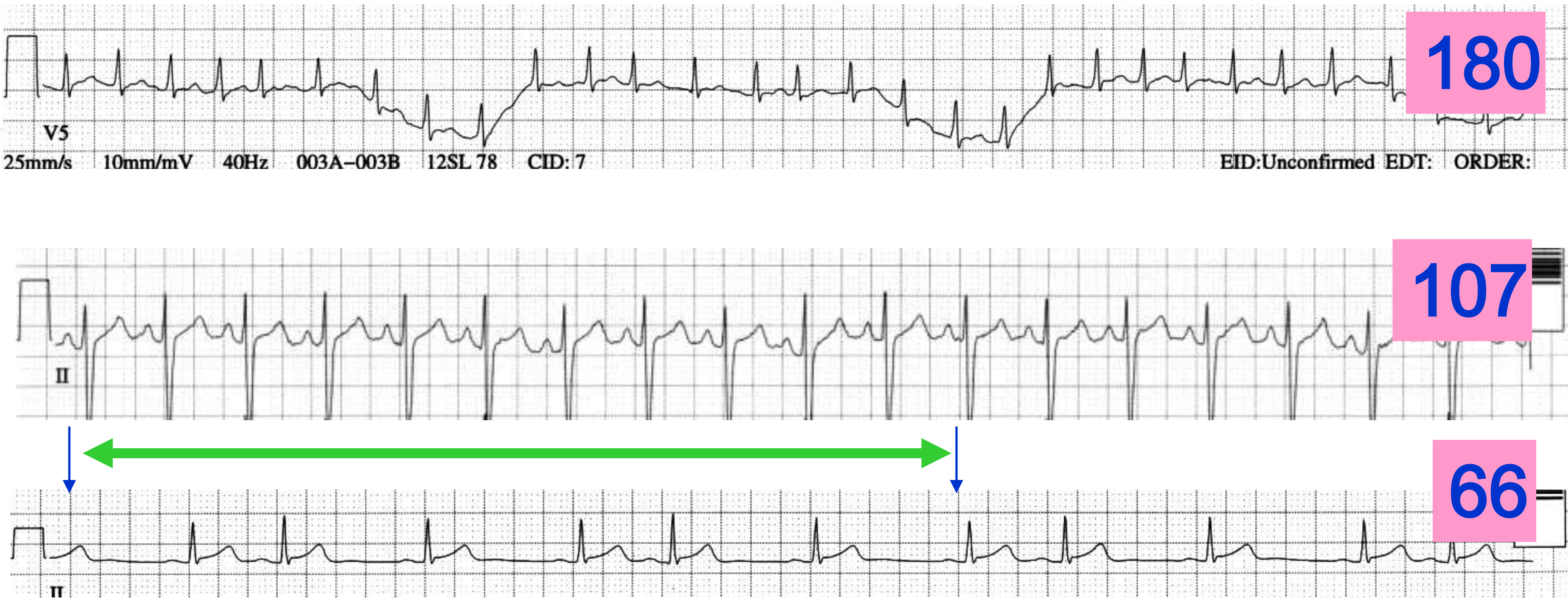
Calculation of Rate: Example 3



Method 1: 6 second rule 6*10=60. 10 second rule 11*6=66.

Method 2 and 3 cannot be used, because the interval is irregular.

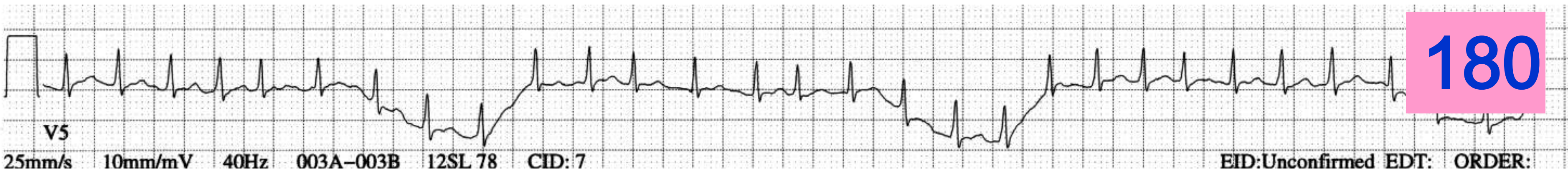
Calculation of Rate: Example 3

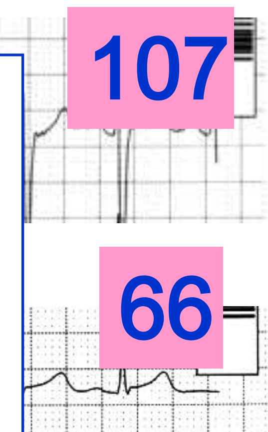


Method 1: 6 second rule 6*10=60. 10 second rule 11*6=66.

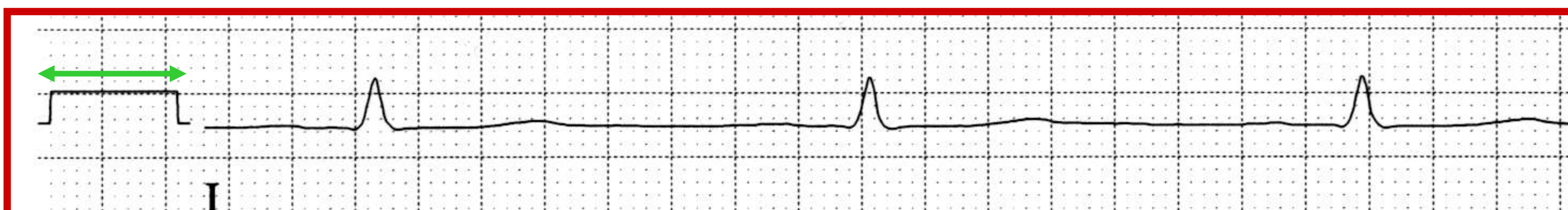
Method 2 and 3 cannot be used, because the interval is irregular.

Calculation of Rate: Example 4

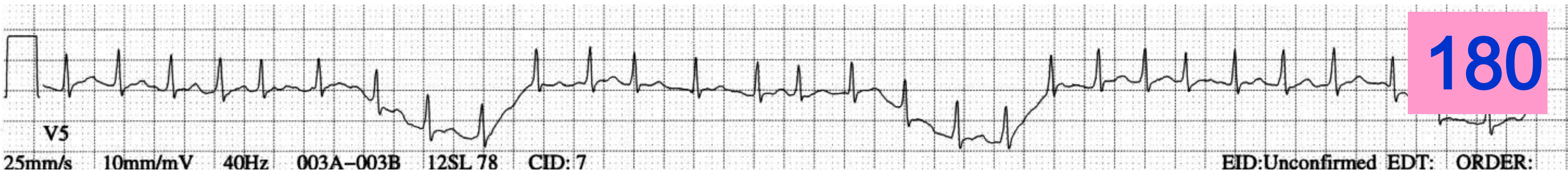




The last example is more challenging, it is tricky. First, look at the Standard mark, that is the key to interpreting any strip, because it explains the display speed and display voltage.

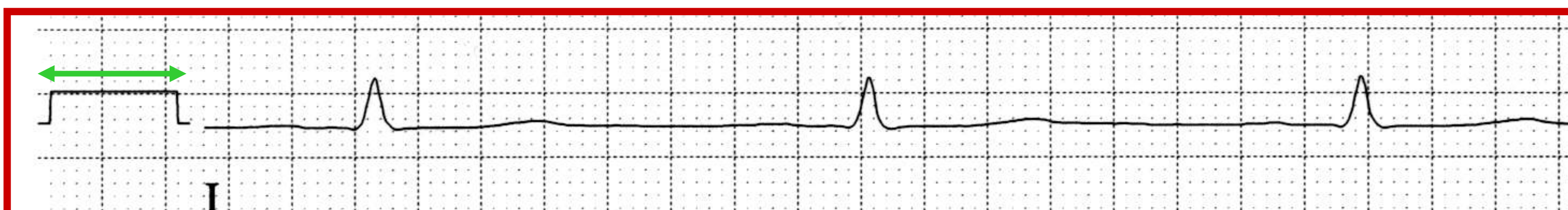


Calculation of Rate: Example 4

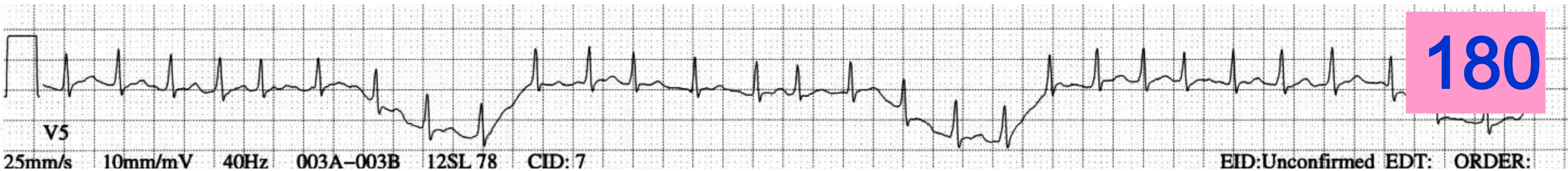


In this unusual example, the standard mark is 10 mm wide. That means the paper speed is 50 mm/sec or 3000 mm/min. That changes all the rules. The rate is twice what you'd normally calculate.

The rate is about 76, using Method 3 and counting by 2-block units.



Calculation of Rate: Example 4



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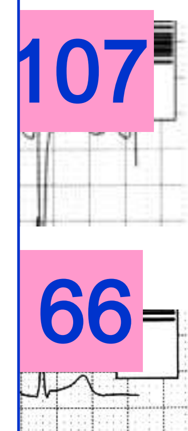
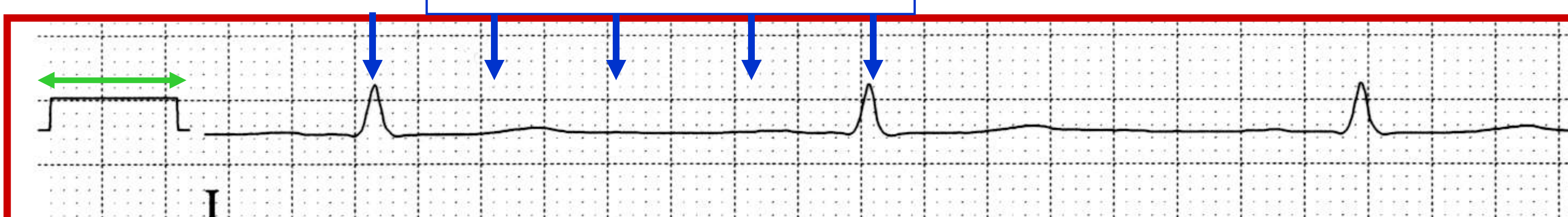
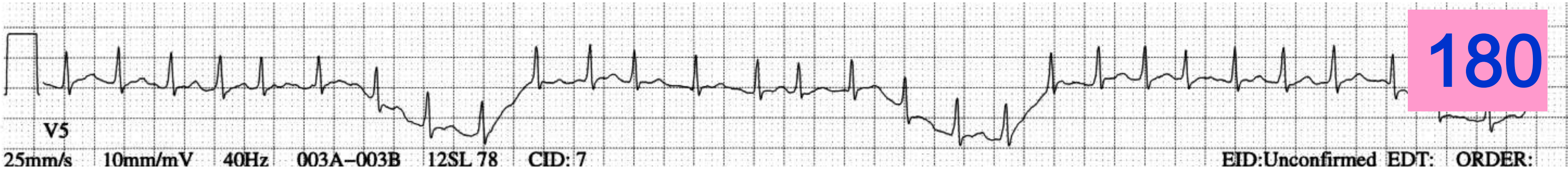
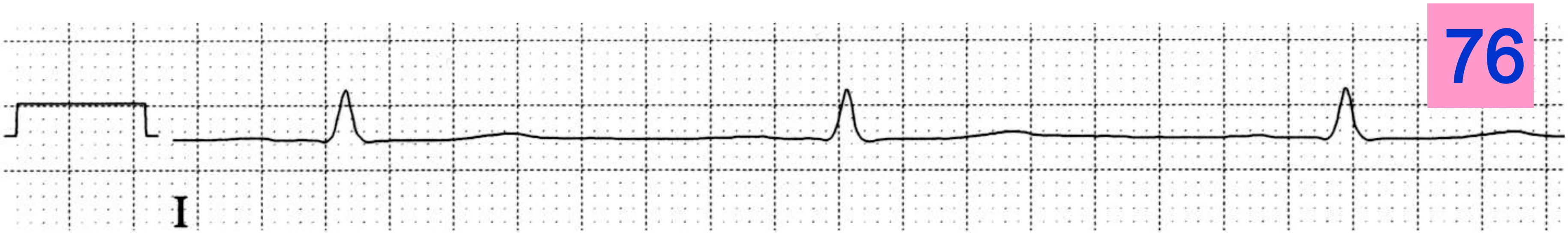


300, 150, 100, 75



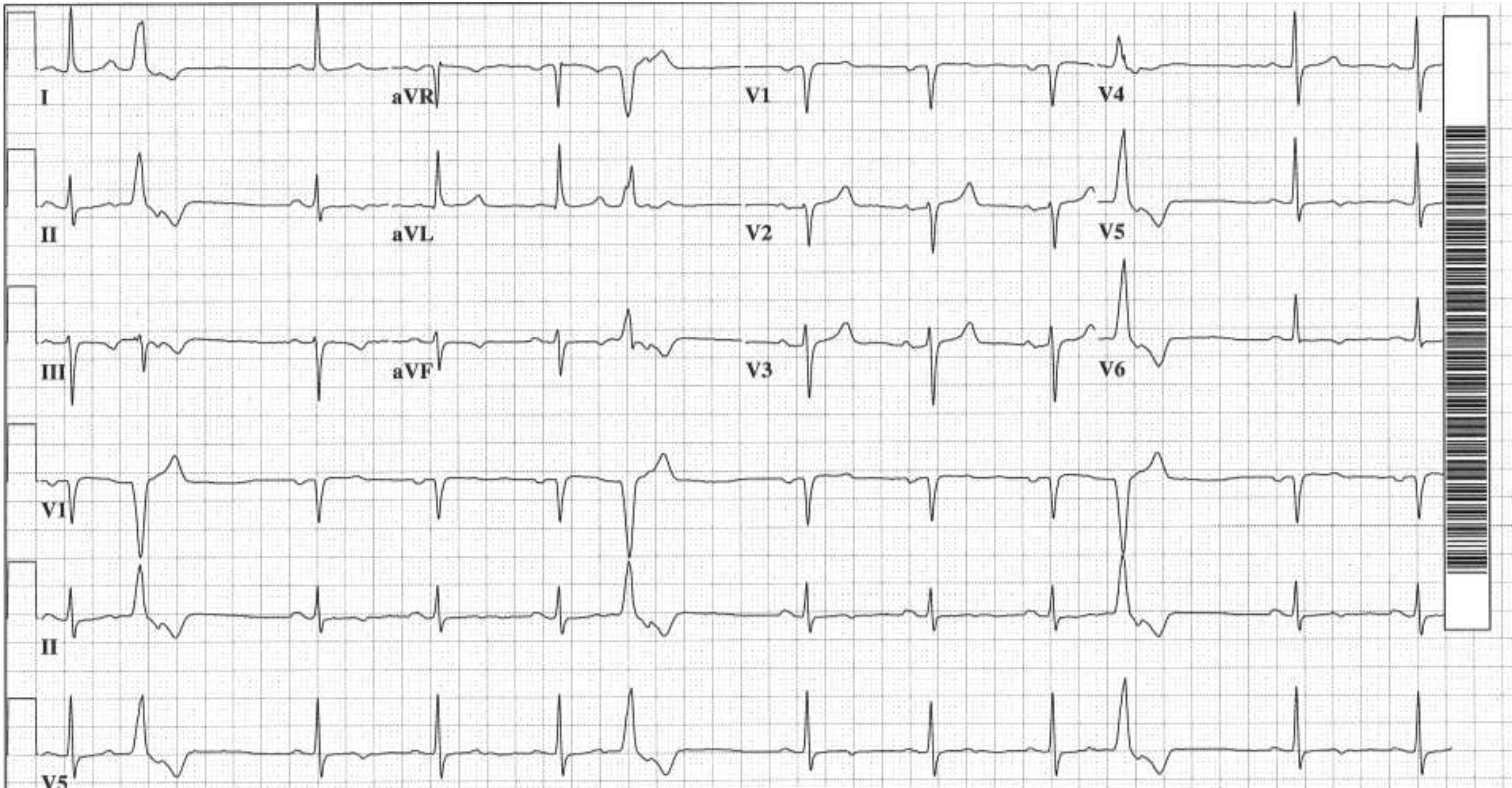
Calculation of Rate: Example 4



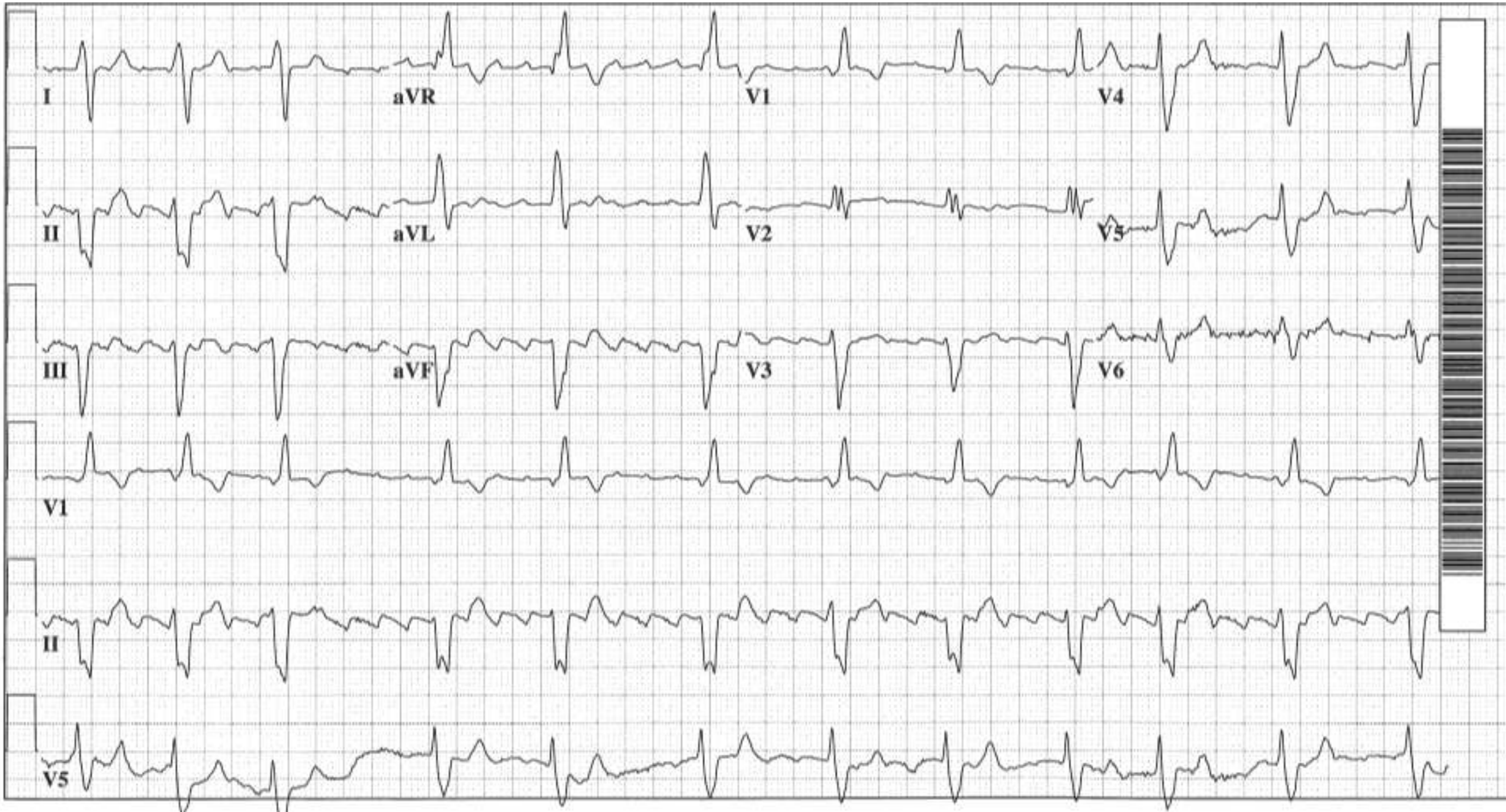


What is the rate? - 1

12*6 = 72

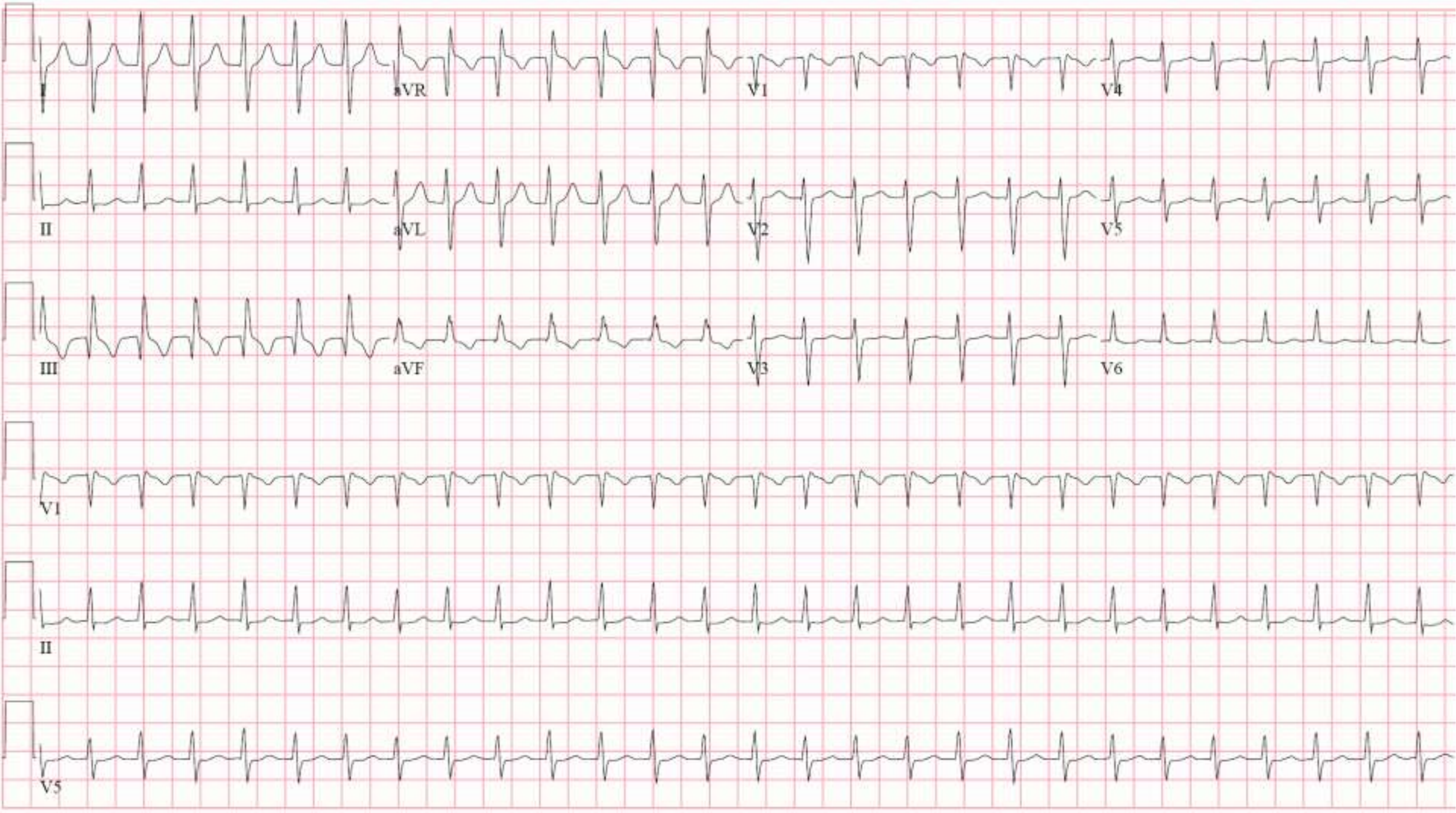


What is the rate? - 2 12*6 = 72

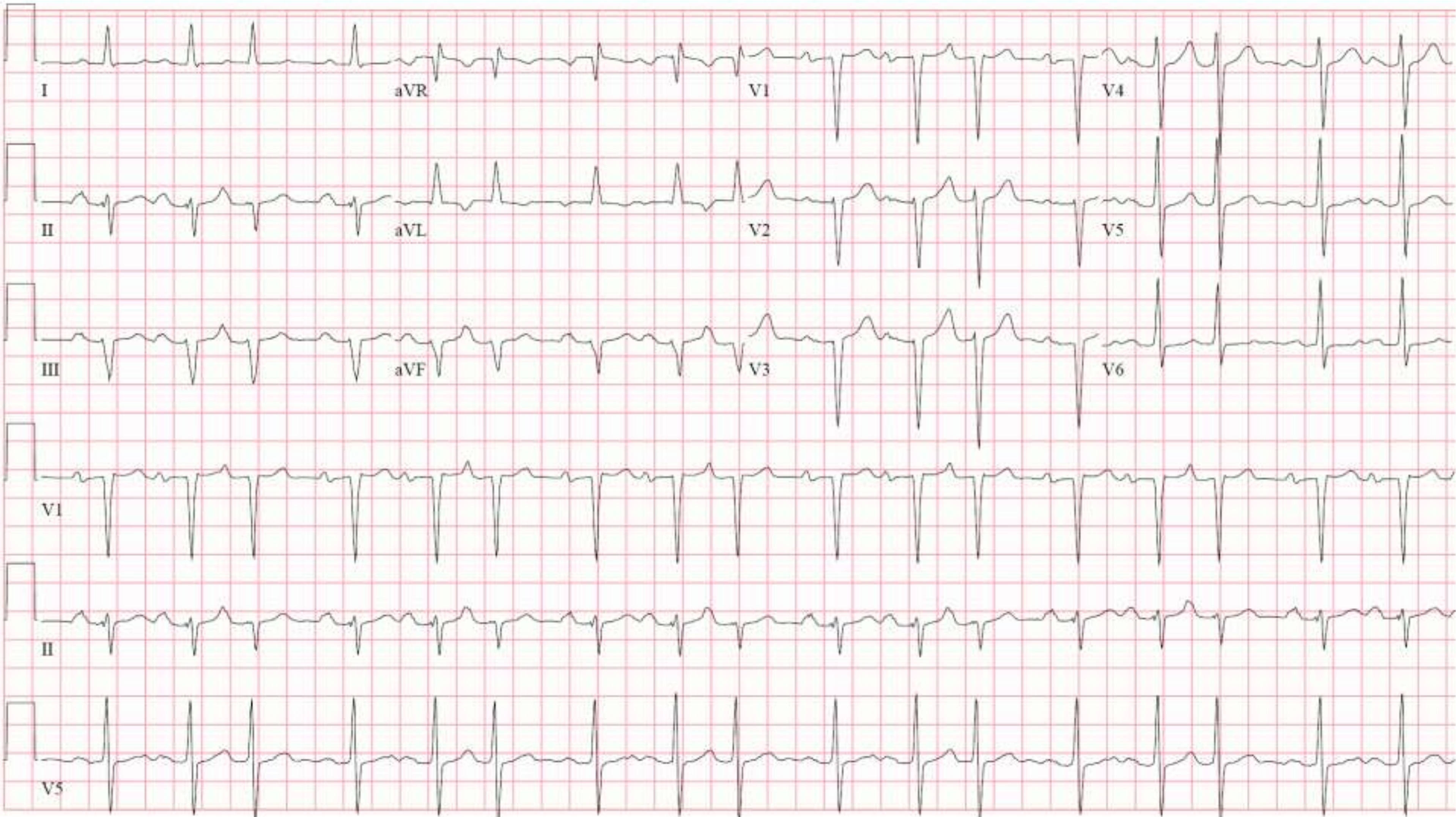


What is the rate? - 3 30*6 = 180

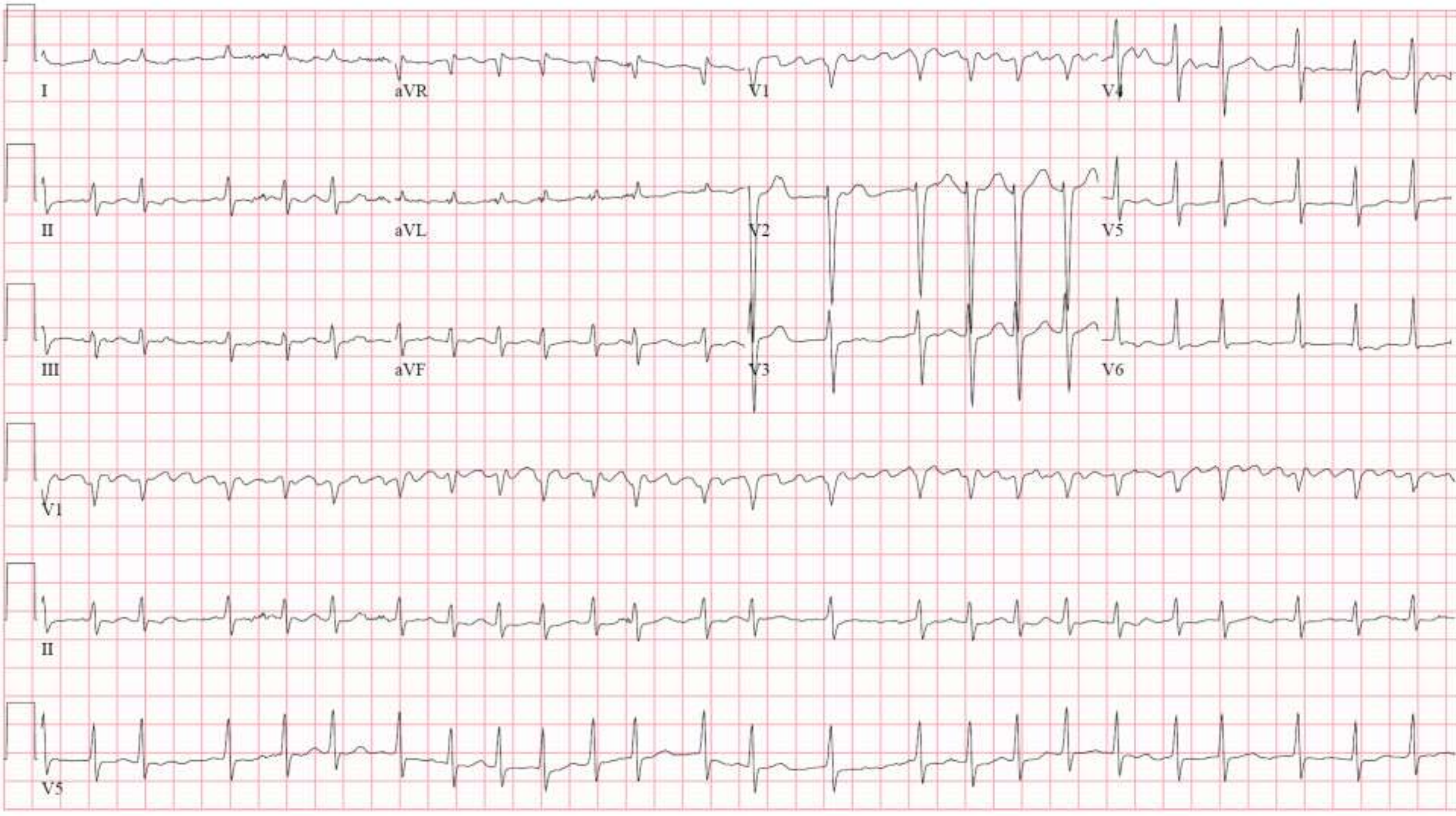
What is the rate? - 4 28*6 = 168



What is the rate? - 5 17*6 = 102



What is the rate? - 6 24*6 = 144



Outline

Note: Accurate assessment of the QRS axis is an important skill for succeeding during examination time.

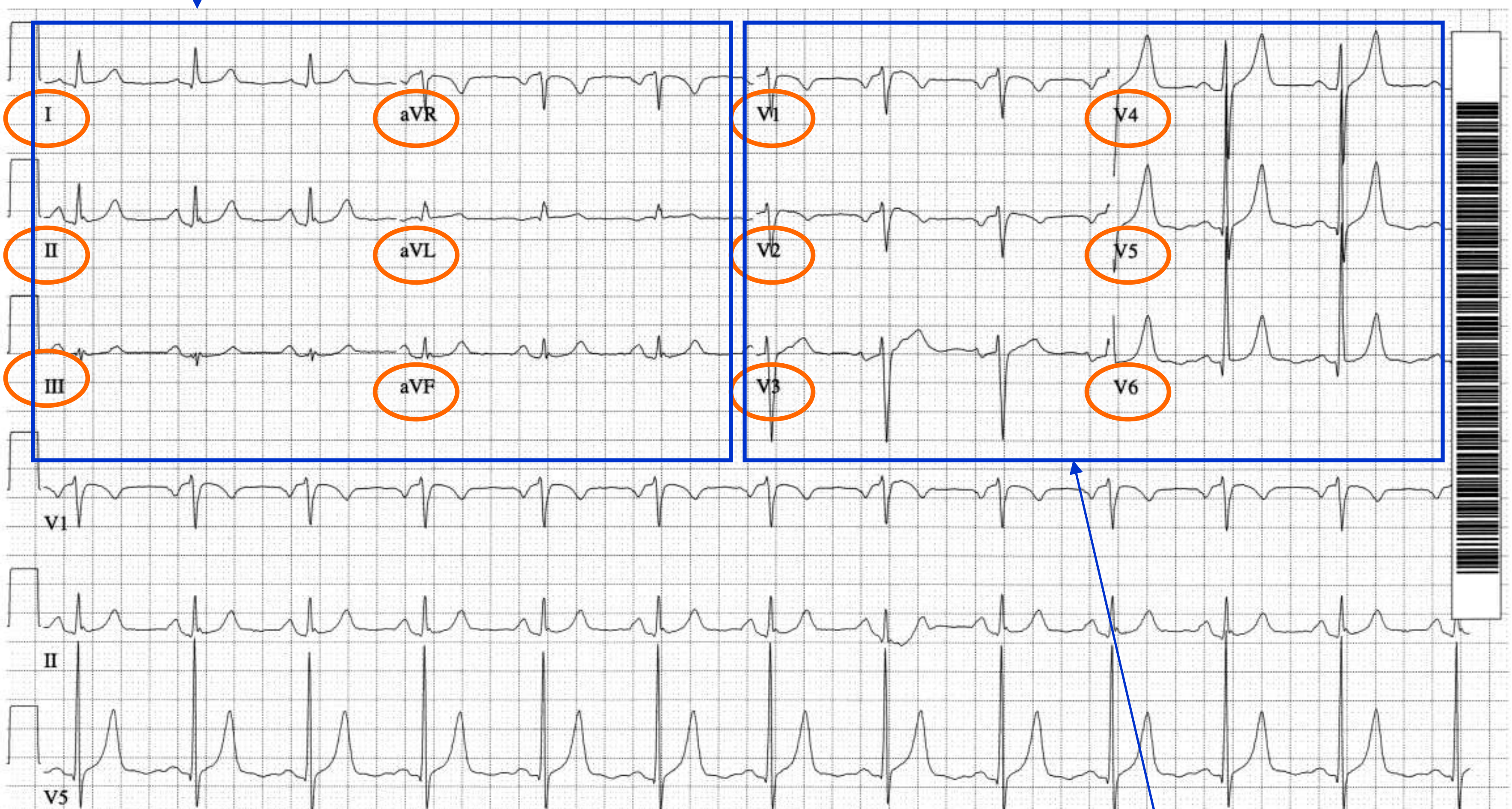
- Description of ECG recording page
- Review of pertinent cardiac physiology
- Identification of waves and intervals
- 3 methods for calculation of rate
- **Calculation of QRS electrical axis**
- Steps in interpretation
- Diagnosing normal and abnormal findings

Twelve ECG Leads

- **Basic Principle**: Each lead records a voltage in one dimension, between 2 points on body surface
- Terminology: Frontal plane
  - 3 standard limb leads
  - 3 augmented (unipolar) limb leads
- Terminology: Transverse (horizontal) plane: 6 unipolar chest leads

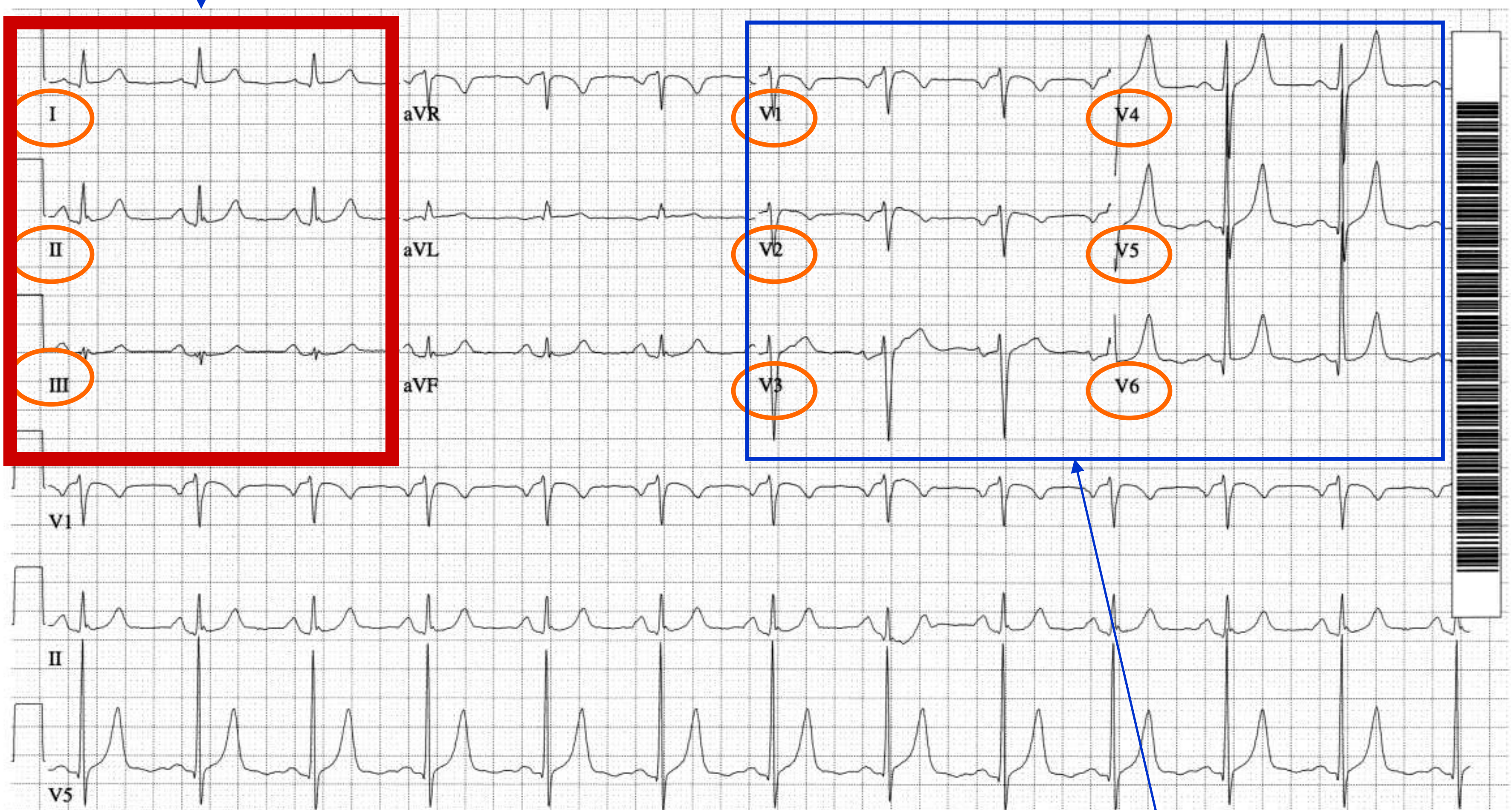
Twelve Leads

Frontal Plane (from limb leads)



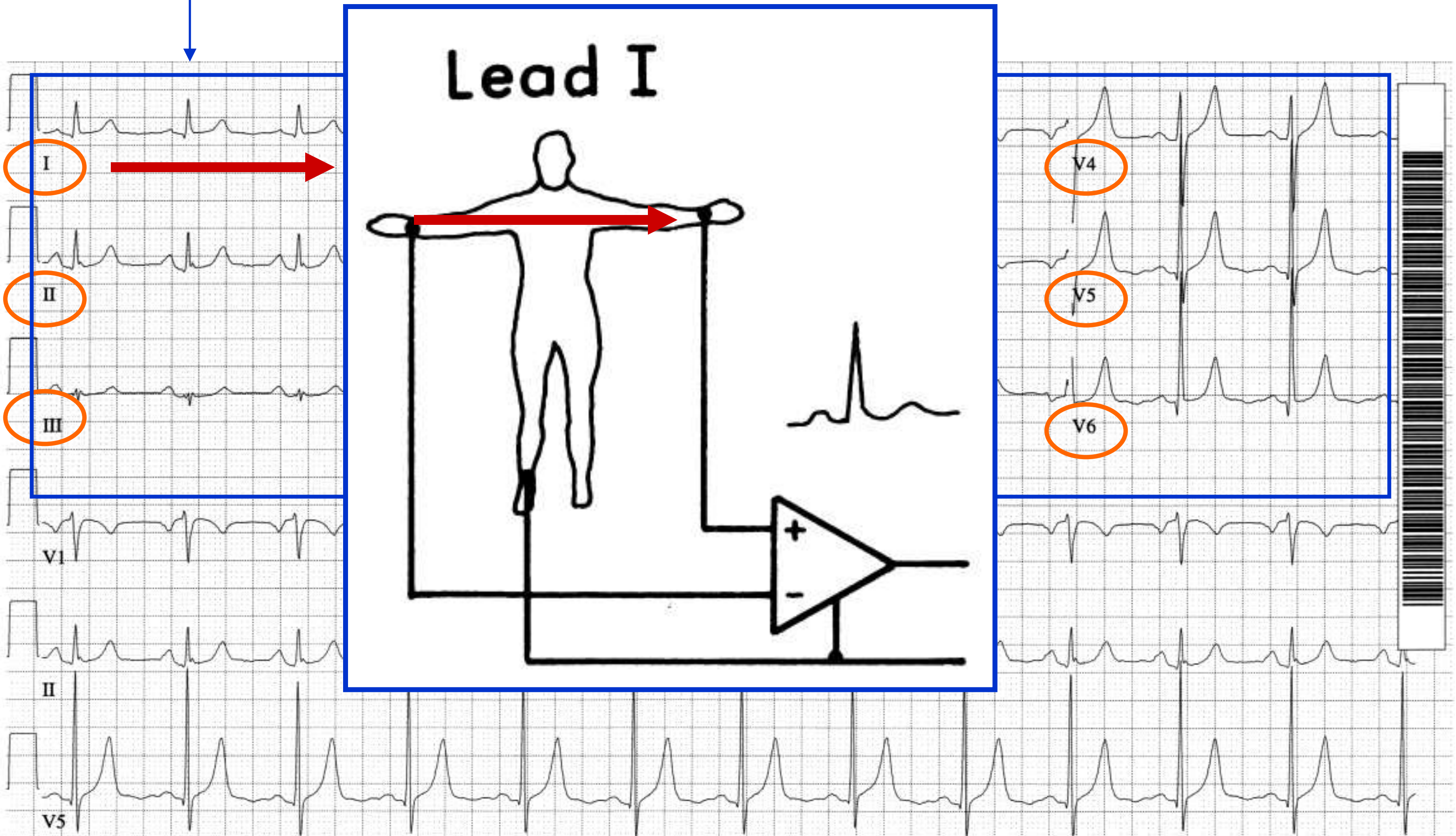
Horizontal (transverse) Plane (from chest leads)

The Standard Leads



Standard leads I, II, III

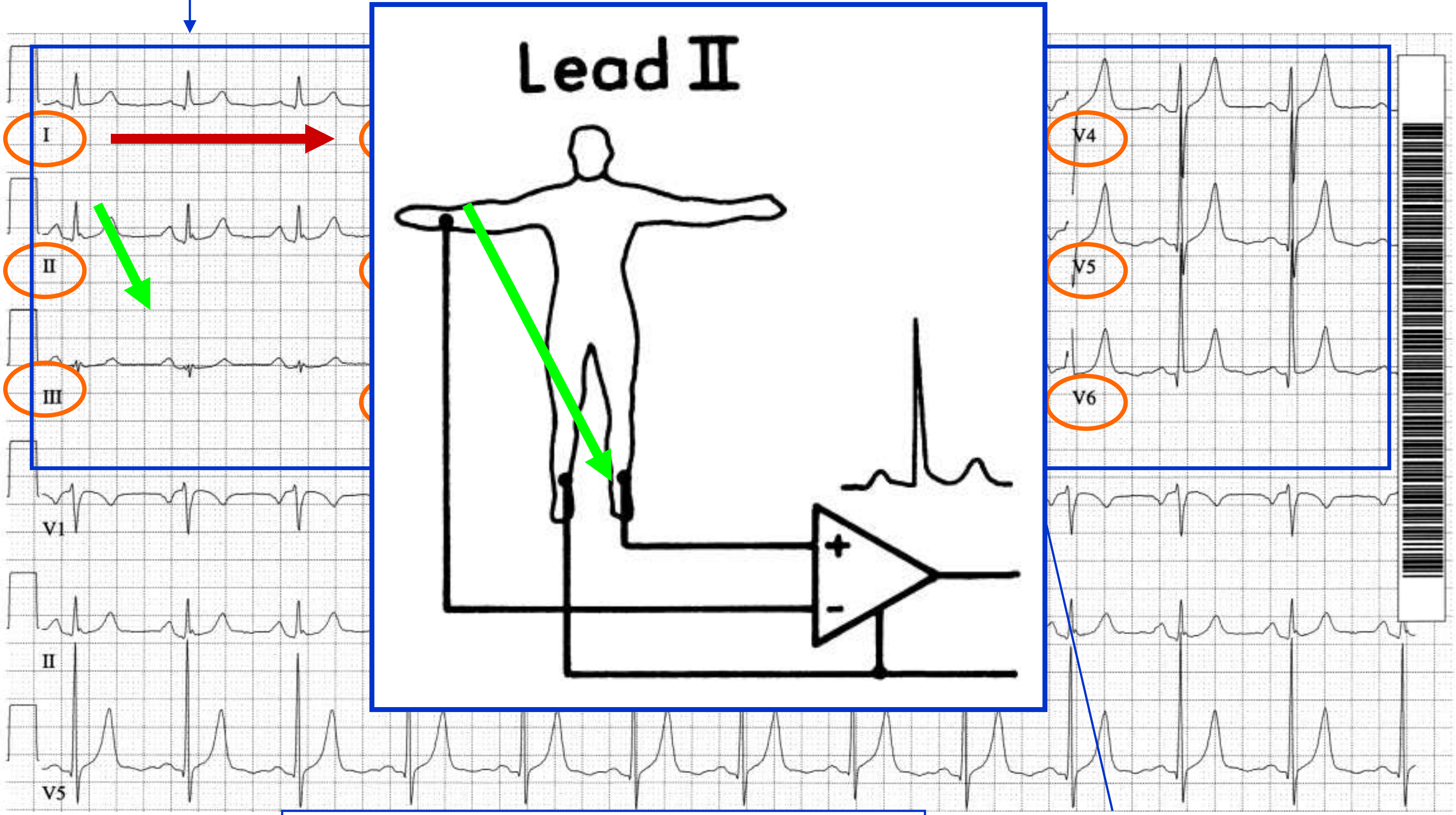
Twelve Leads



From Marriott, 1994, p. 21

Standard leads I, II, III

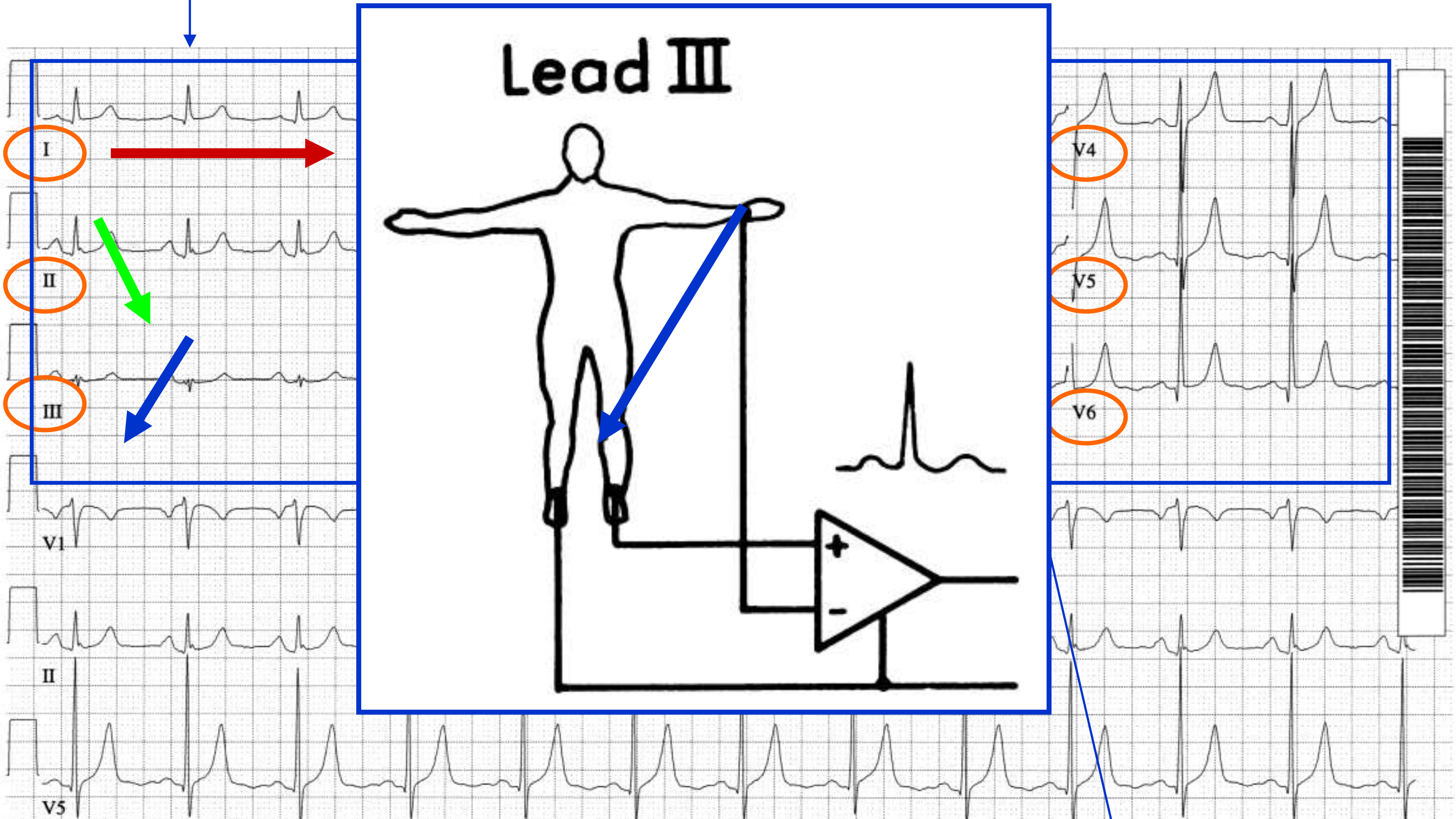
Twelve Leads



From Marriott, 1994, p. 21

Standard leads I, II, III

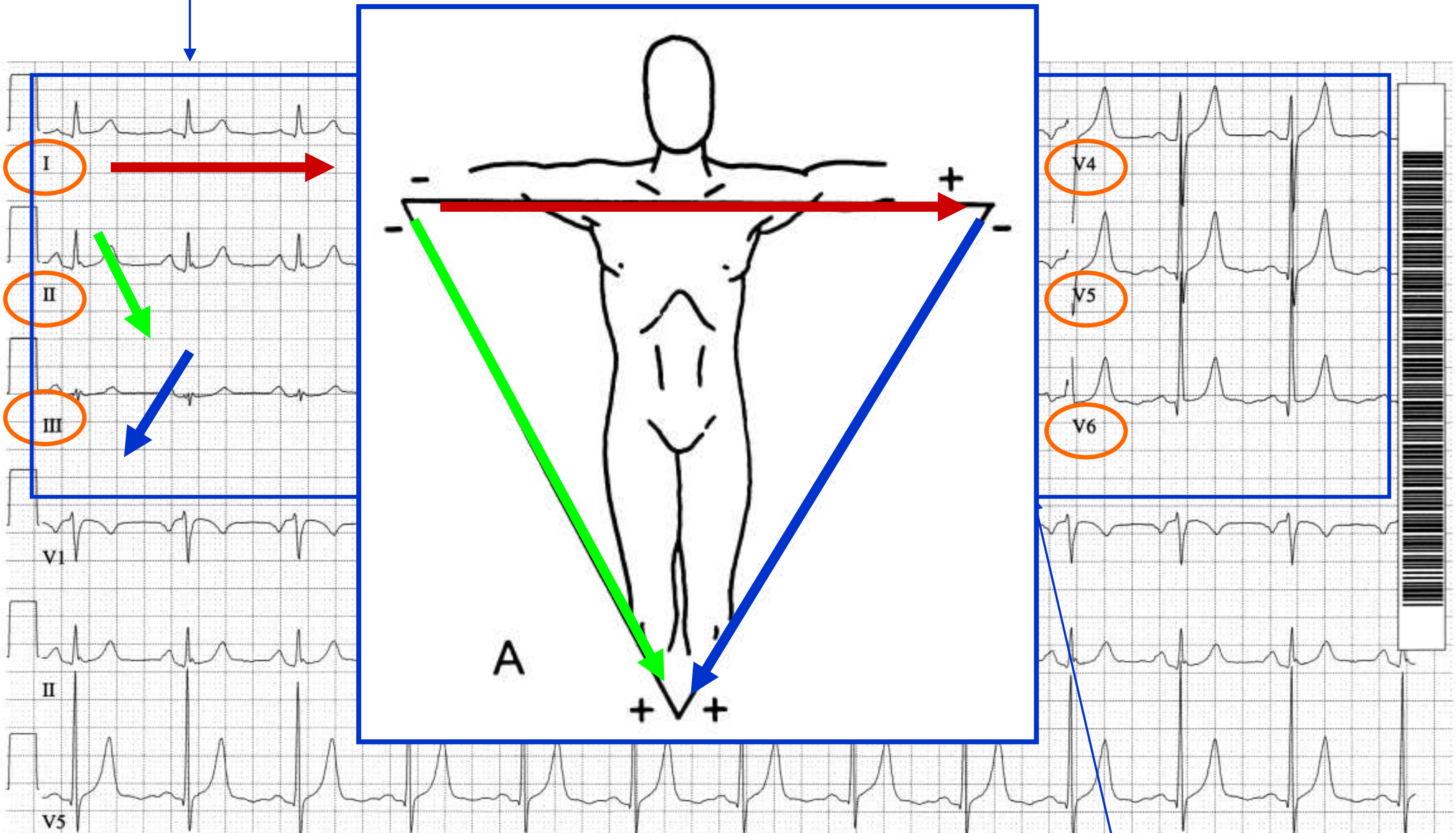
Twelve Leads



From Marriott, 1994, p. 21

Standard leads I, II, III

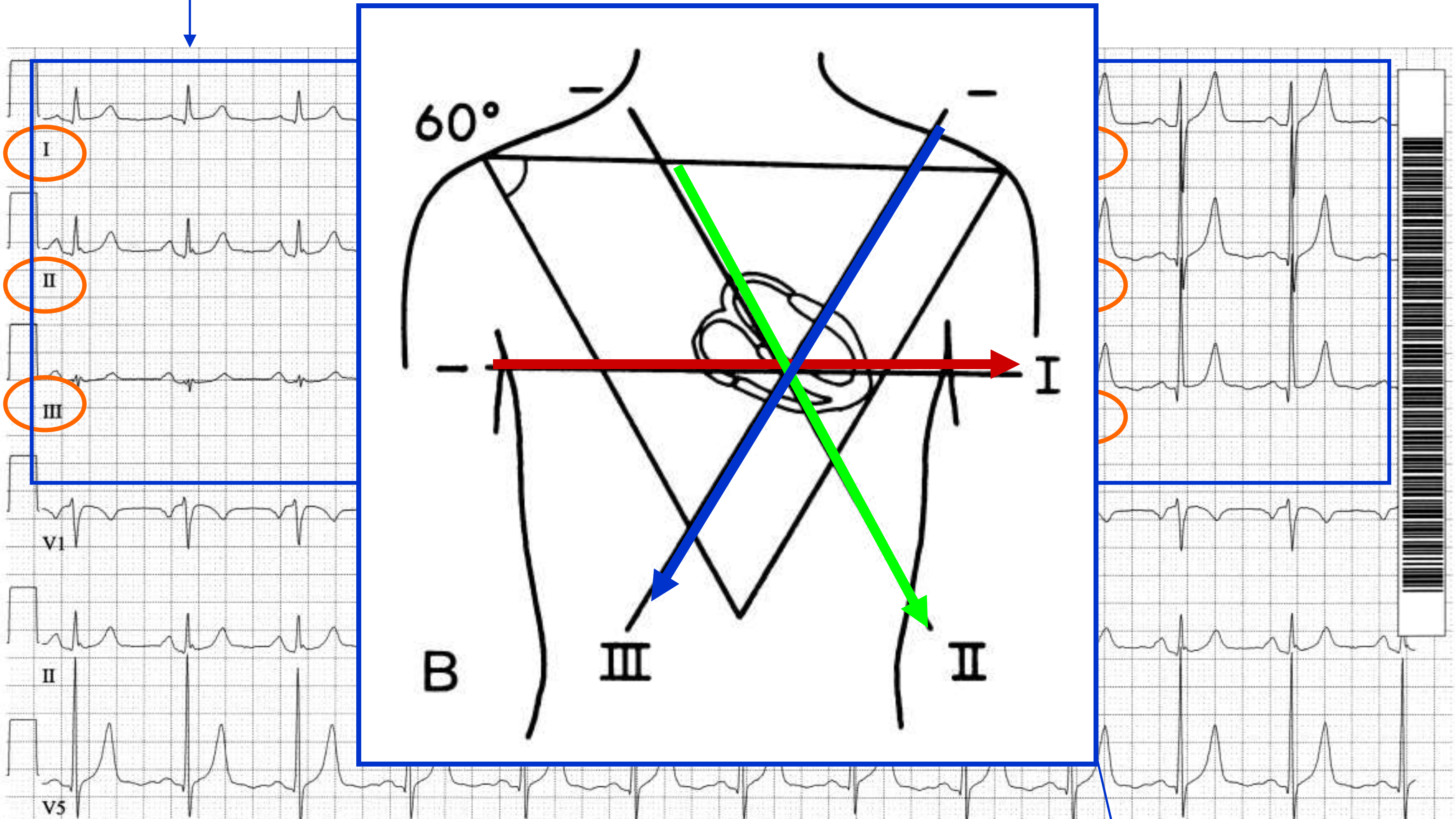
Twelve Leads



From Marriott, 1994, p. 22

Standard leads I, II, III

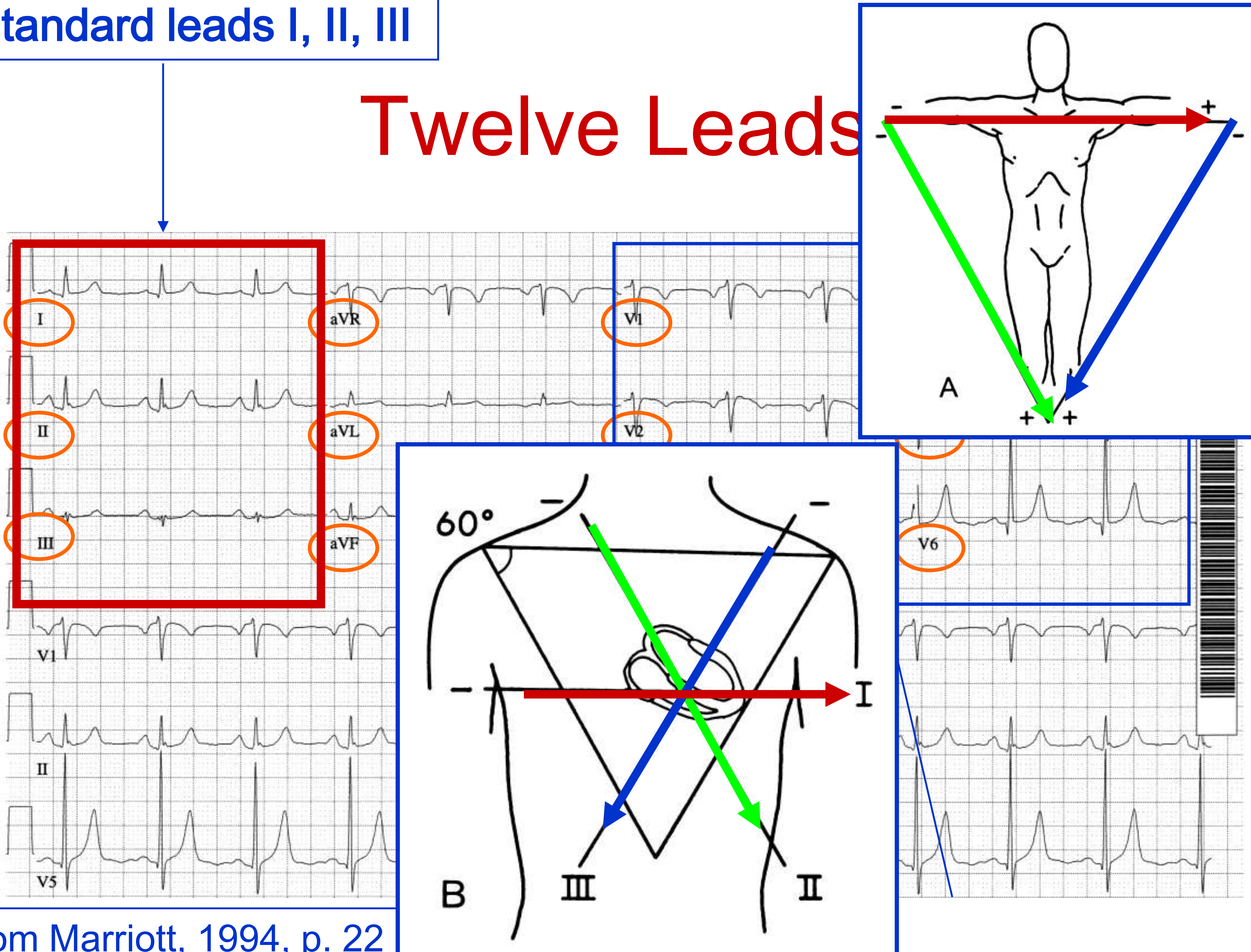
Twelve Leads



From Marriott, 1994, p. 22

Twelve Leads

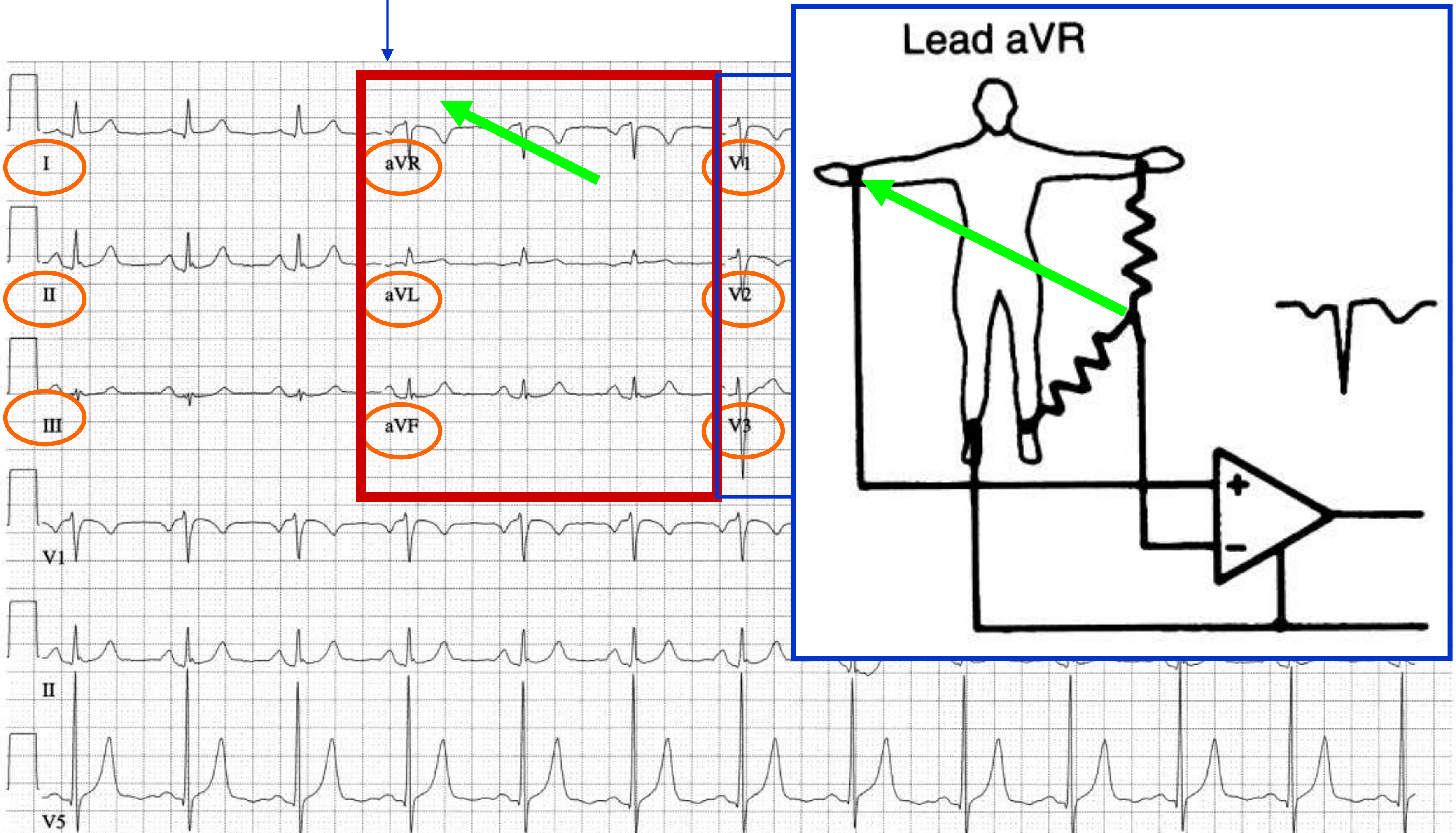
Standard leads I, II, III



From Marriott, 1994, p. 22

Augmented Leads

Augmented Leads aVR, aVL, aVF .
V refers to the unipolar type of lead



From Marriott, 1994, p. 22

Augmented Leads

Augmented Leads aVR, aVL, aVF .
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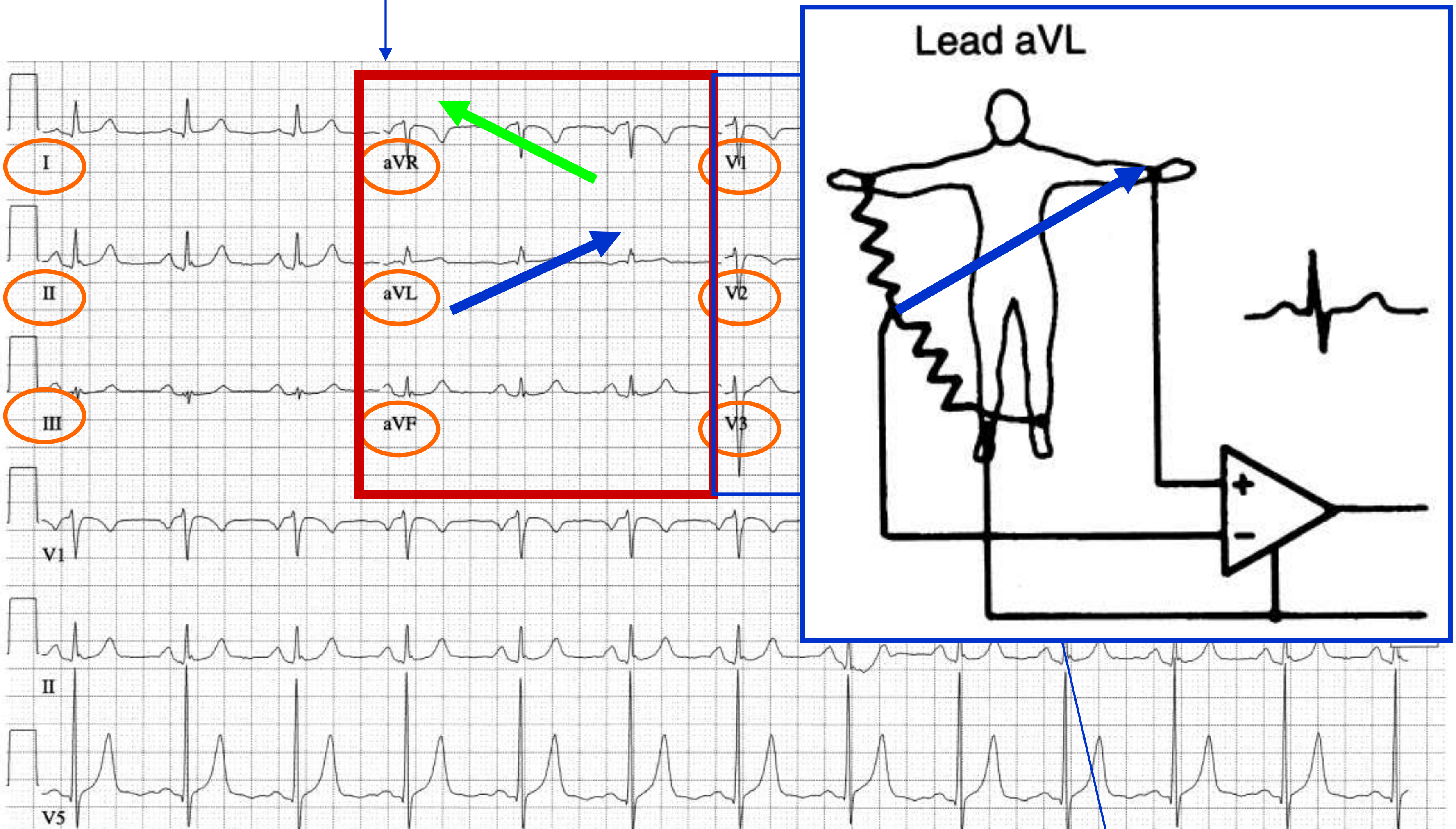

From Marriott, 1994, p. 22

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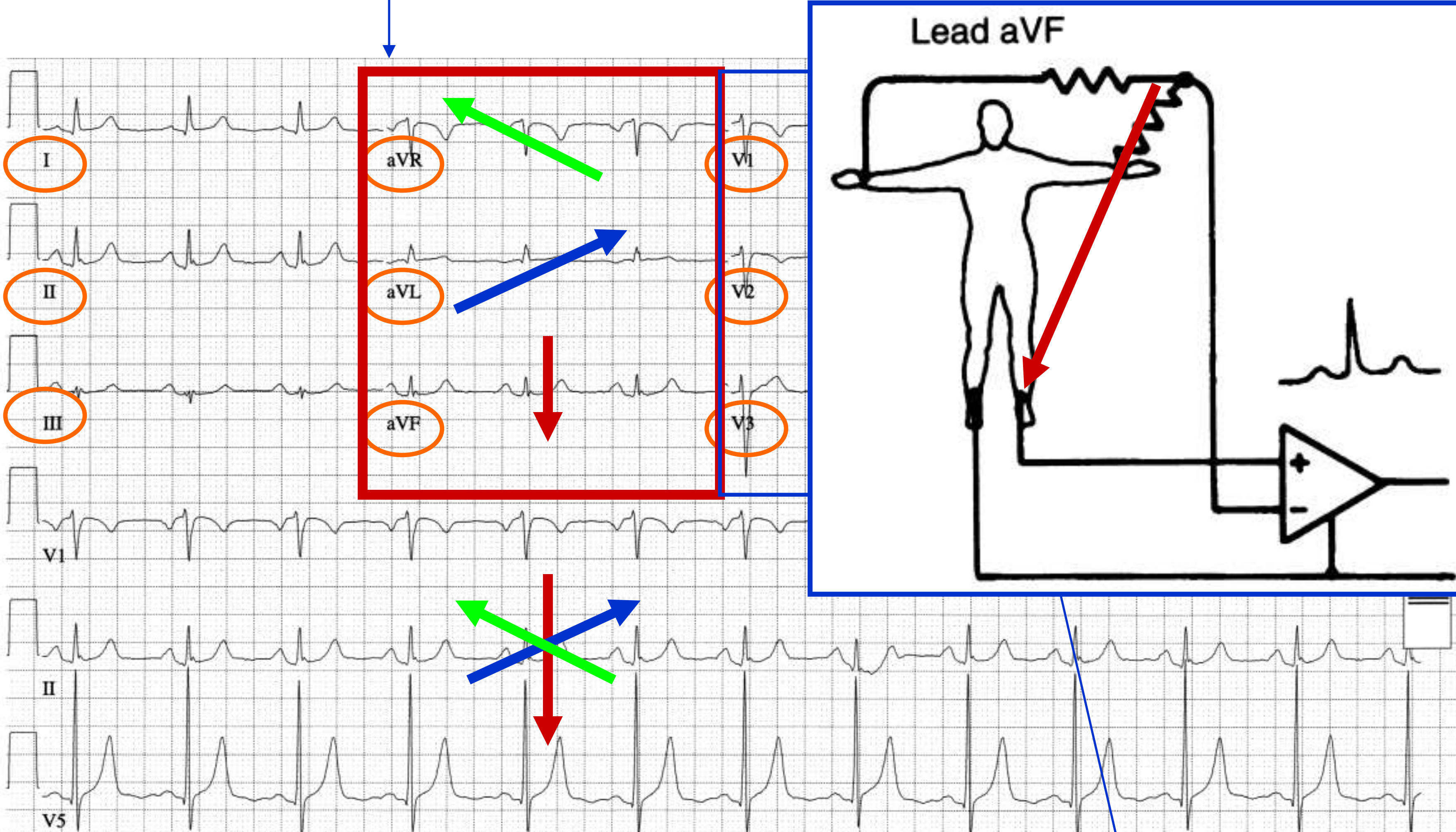
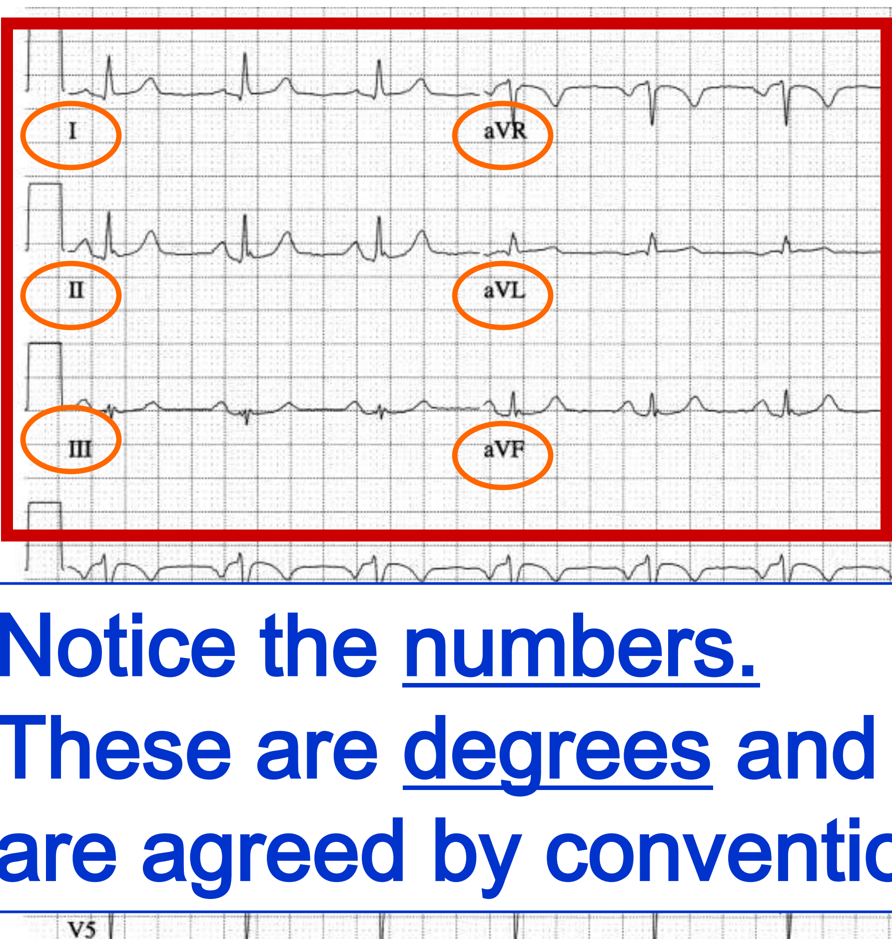
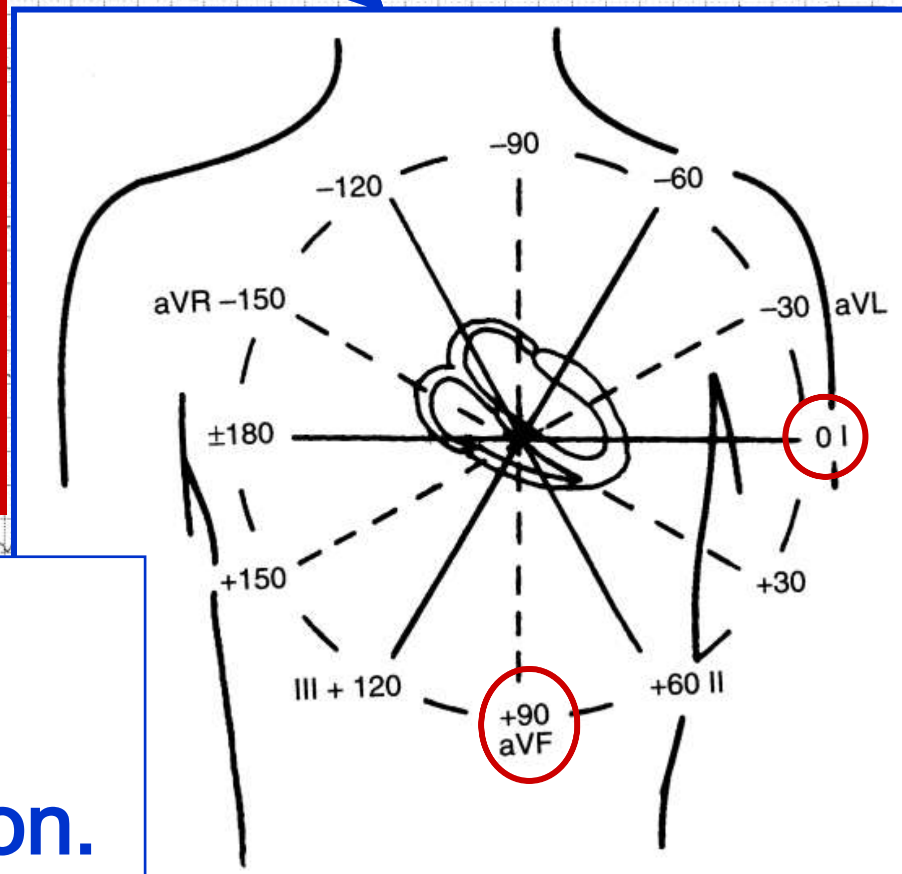


From Marriott, 1994, p. 22

6 Limb Leads – Frontal Plane

6 Limb leads, 3 standard and 3 augmented. Standard leads have solid lines, aV leads have dashed lines in the diagram

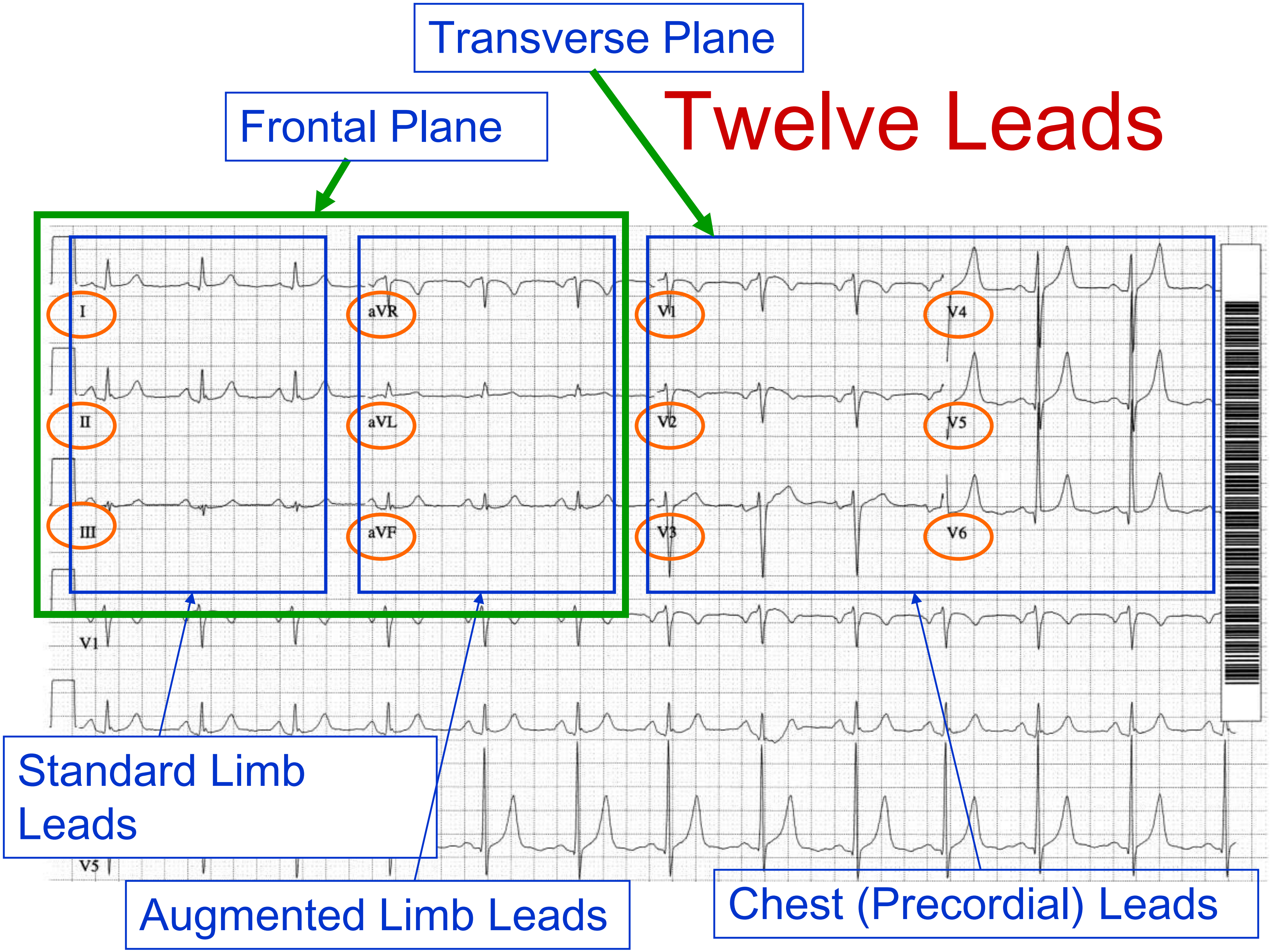




Notice the numbers.
These are degrees and are agreed by convention.

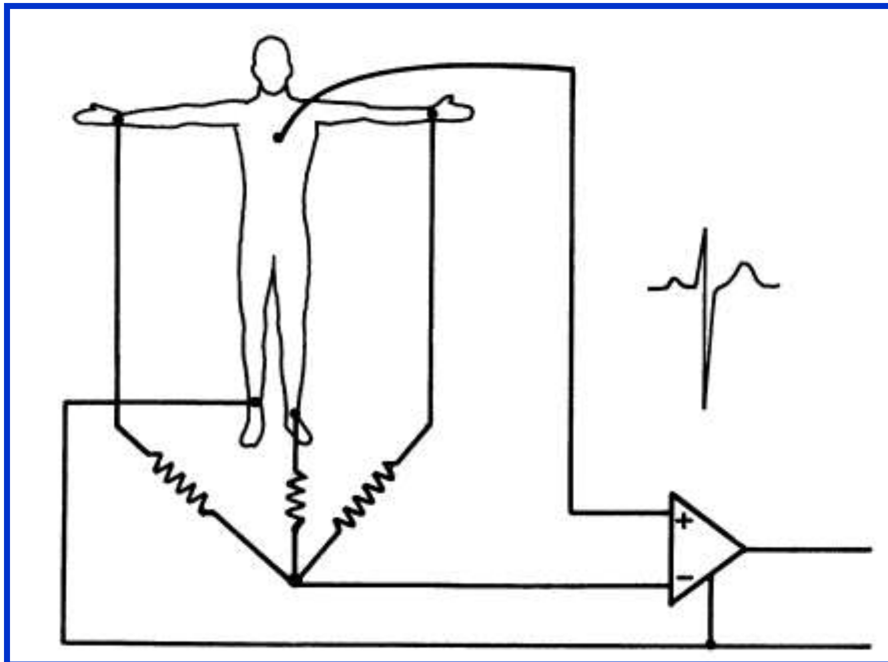
From Marriott, 1994, p. 23

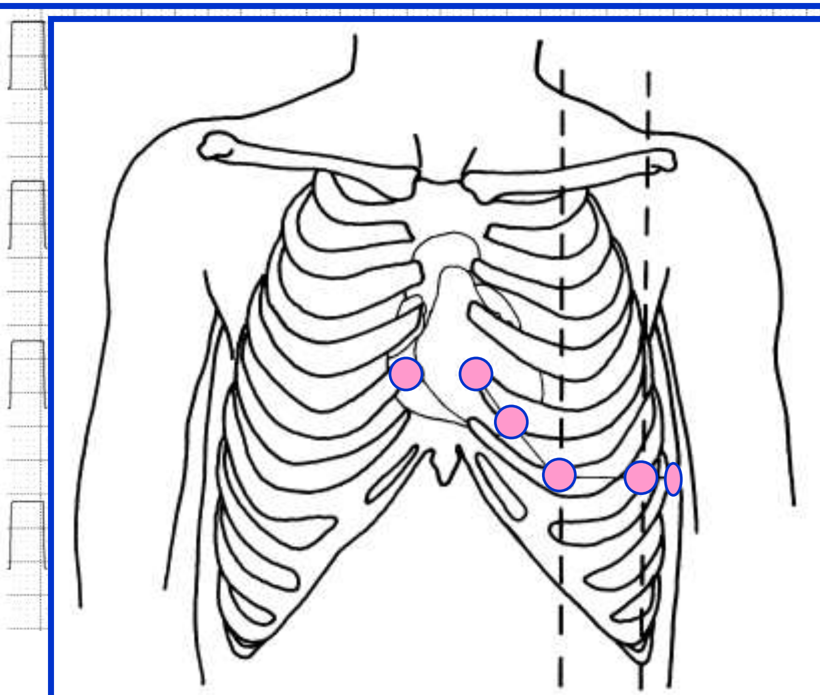
Twelve Leads

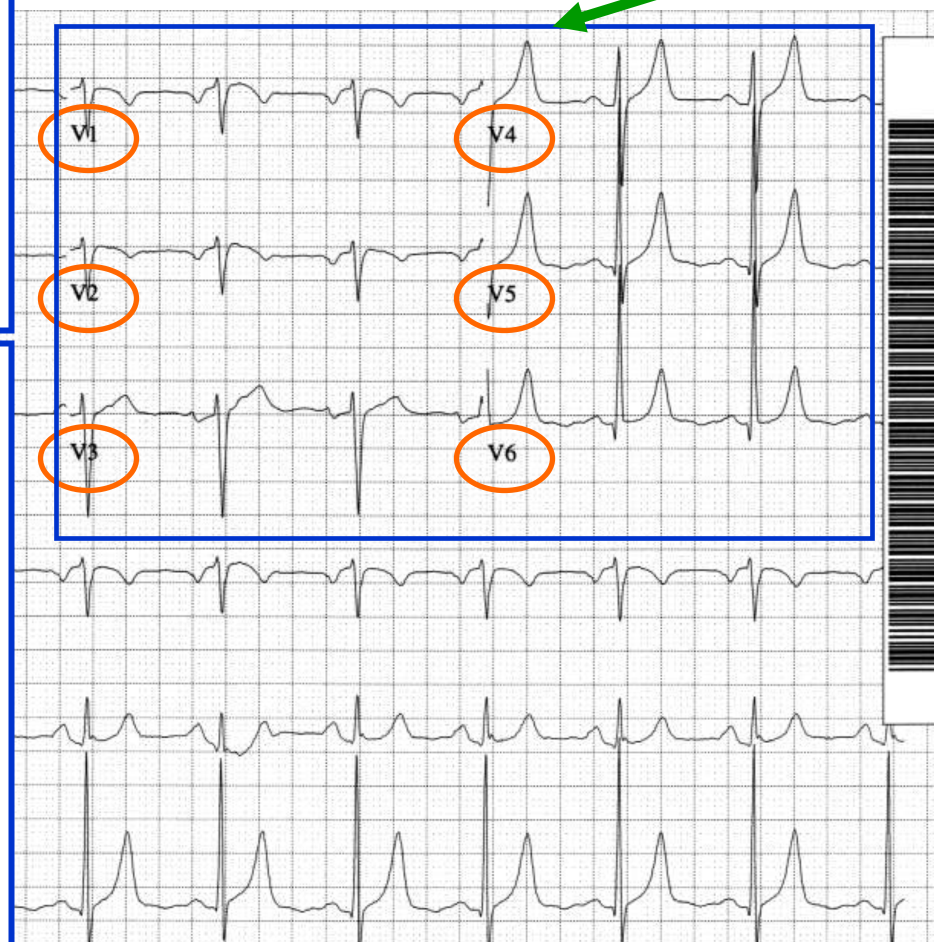


Precordial Leads

Transverse Plane





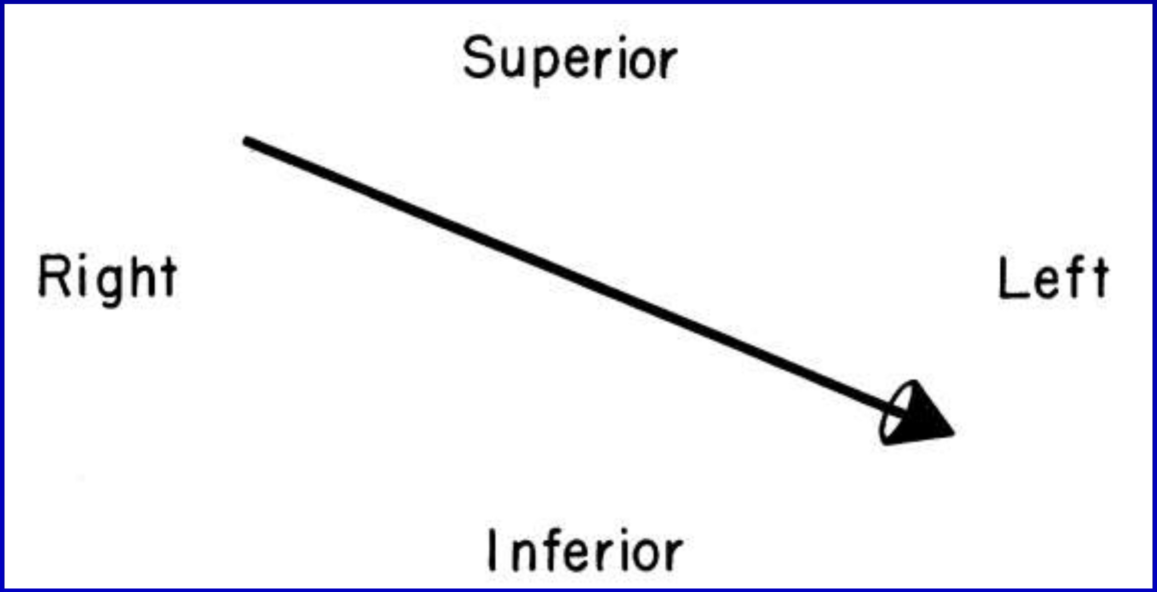


From Marriott, 1994, p. 24

Background: Measuring the Axis - 1

- The cardiac cell depolarizes and repolarizes in a wave across the heart – first atrium, then ventricle
- The dipole created by the wave of depolarization and repolarization is varying in amplitude and direction in 3-dimensional space and time
- But each ECG lead only sees one dimension
  - Direction (toward, away) and amplitude
- The frontal plane leads see two dimensions
- The chest plane leads see two dimensions
- So all twelve leads have 3-D information

The Vector Concept



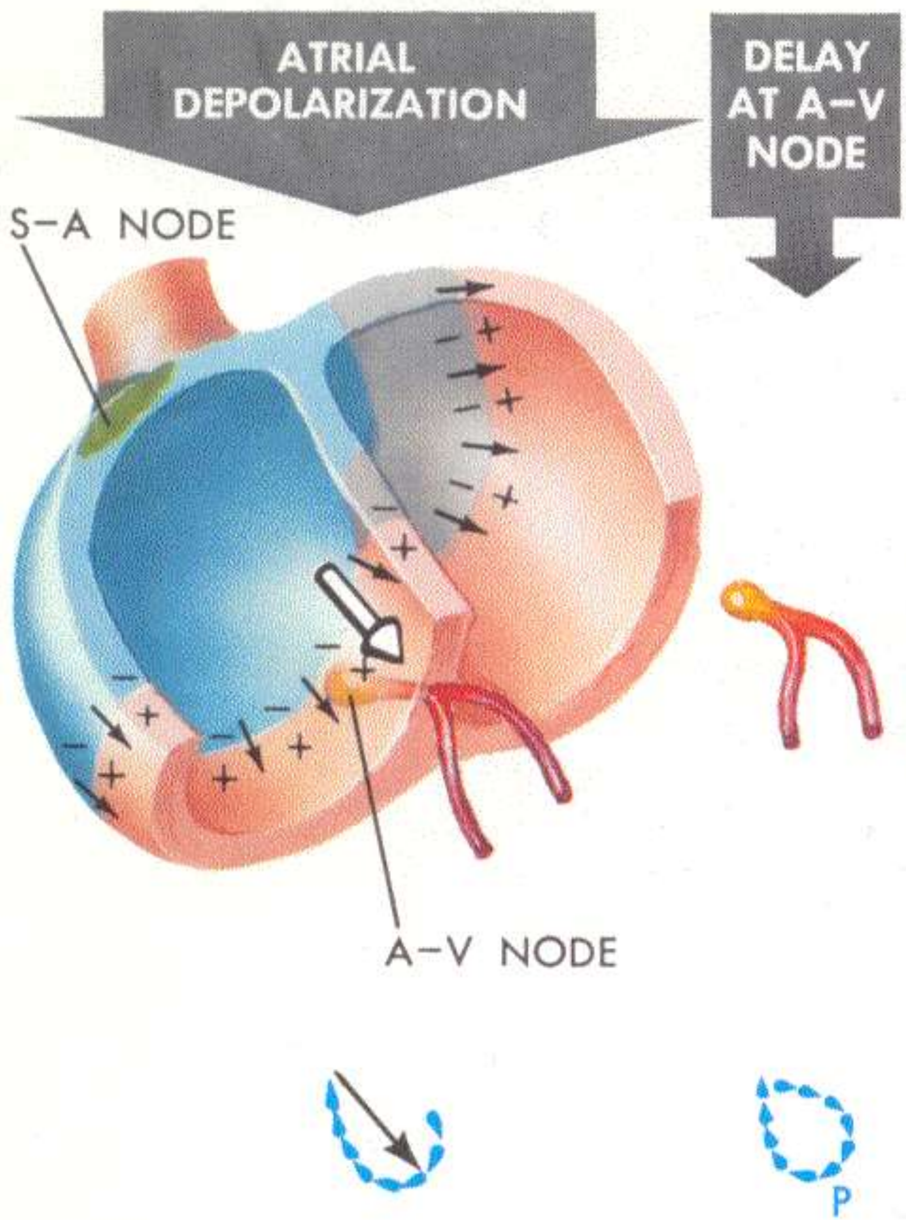
Frontal Plane

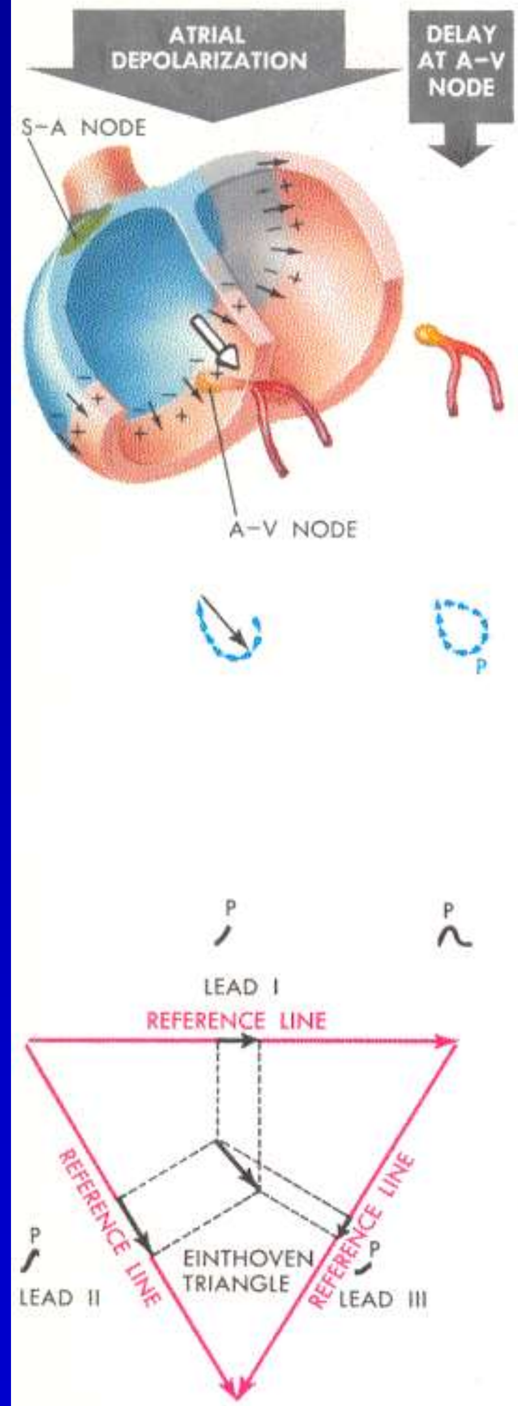
- Magnitude
- Direction

The direction of the arrow is the direction of depolarization

Chou TC et al. Clinical Vectorcardiography, 2nd ed, 1974

Atrial Activation

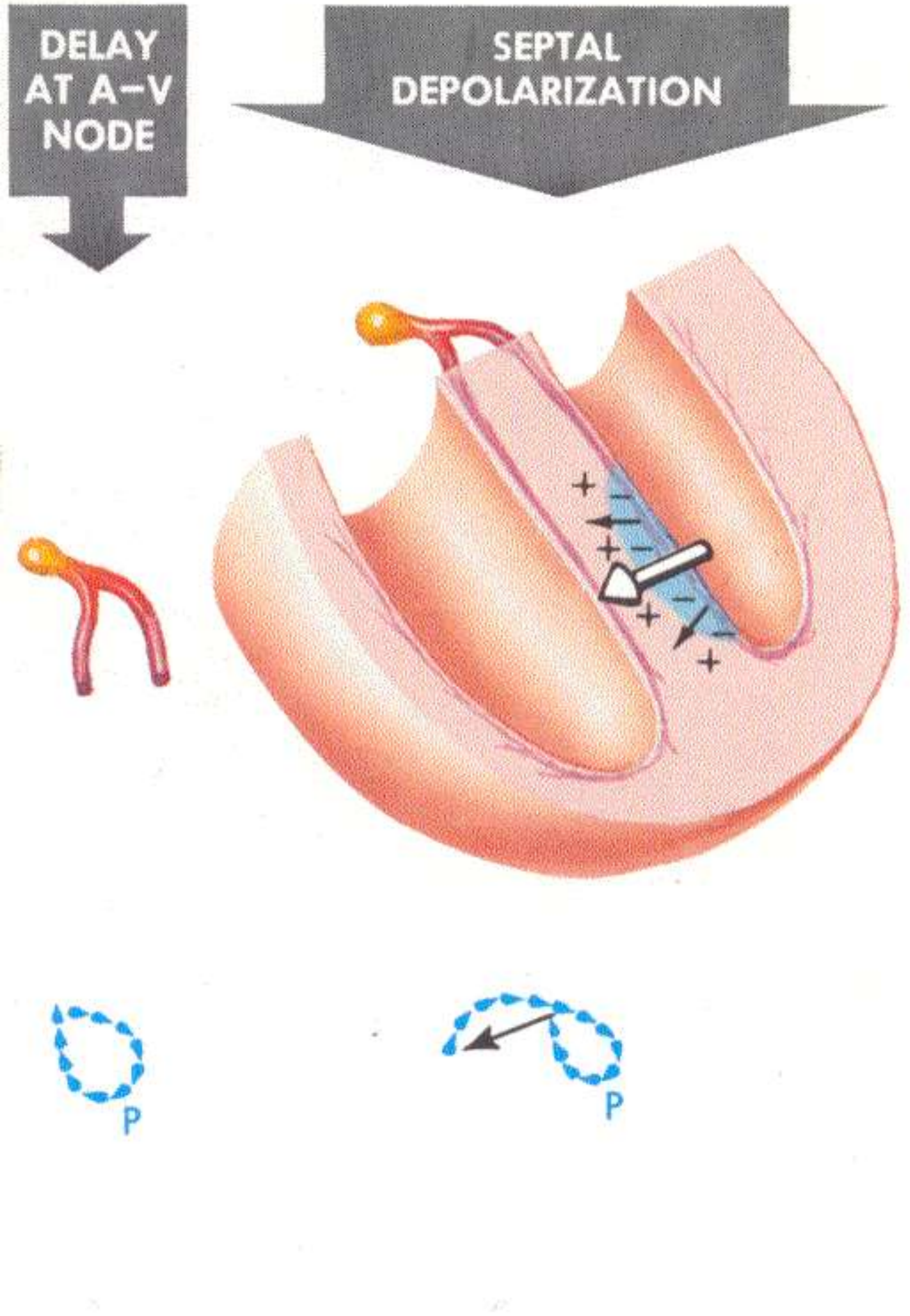


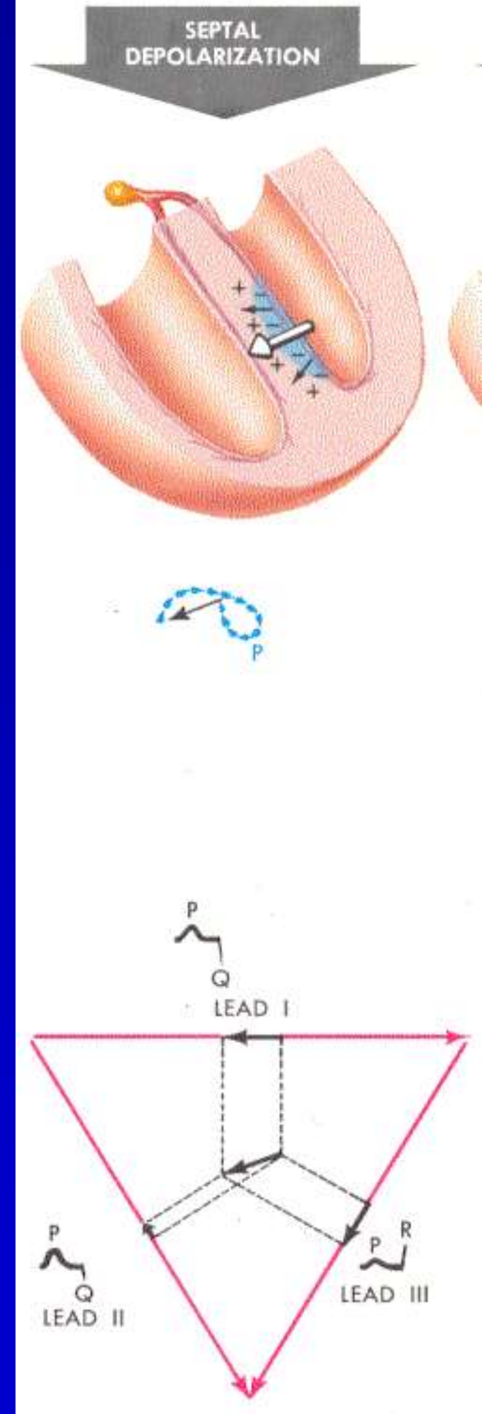


Netter

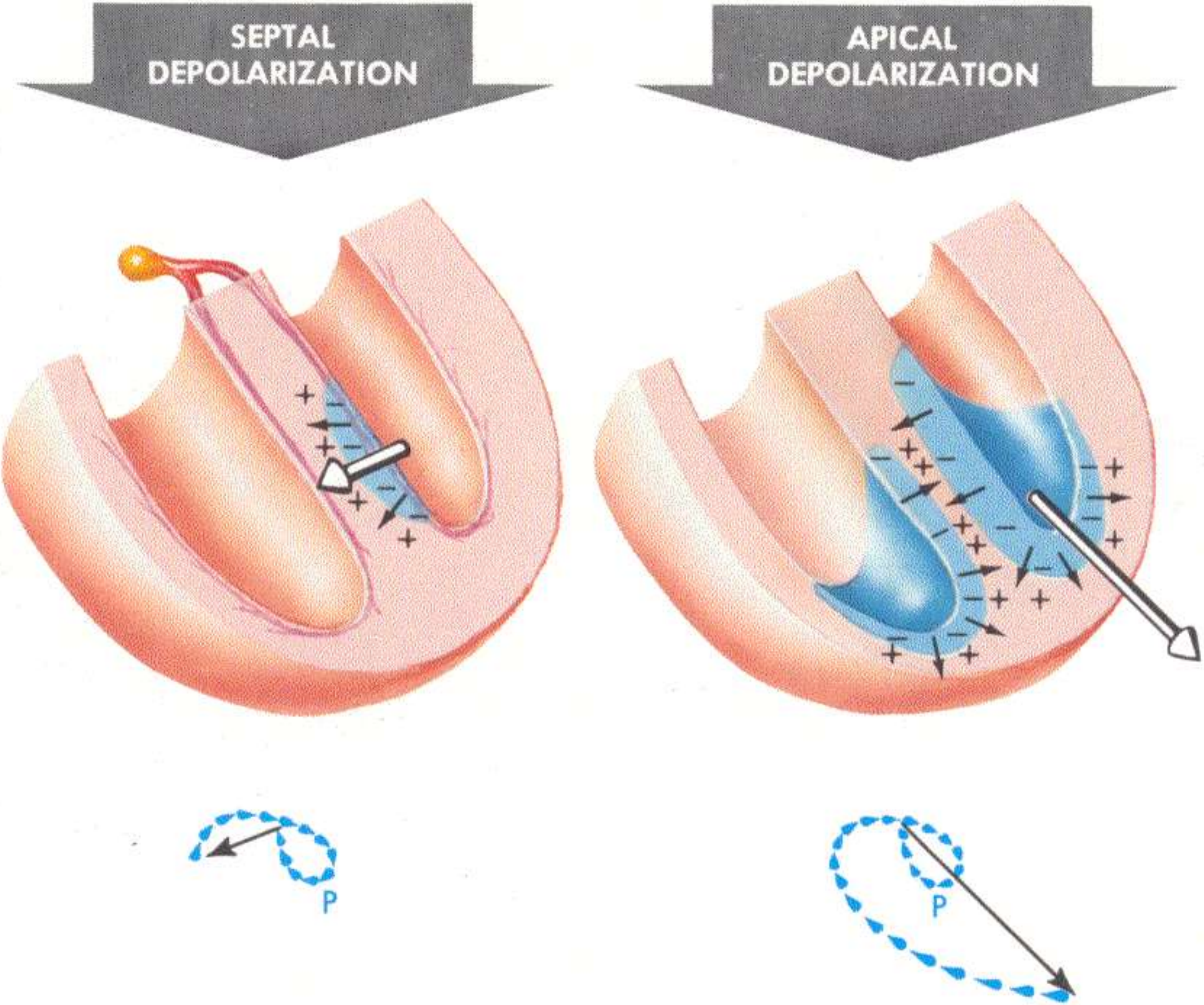
Sequence of Activation

Netter





Ventricular Activation



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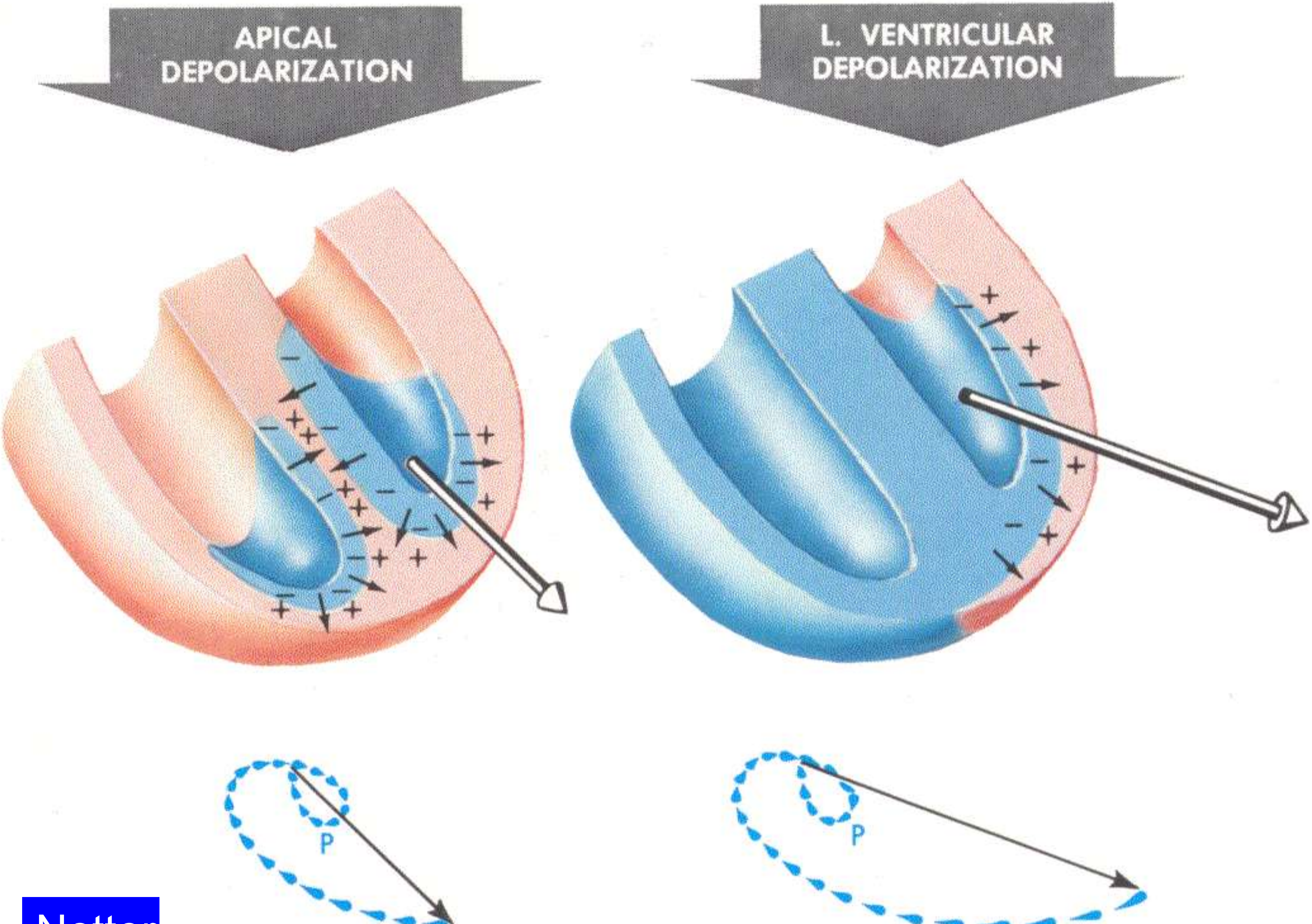

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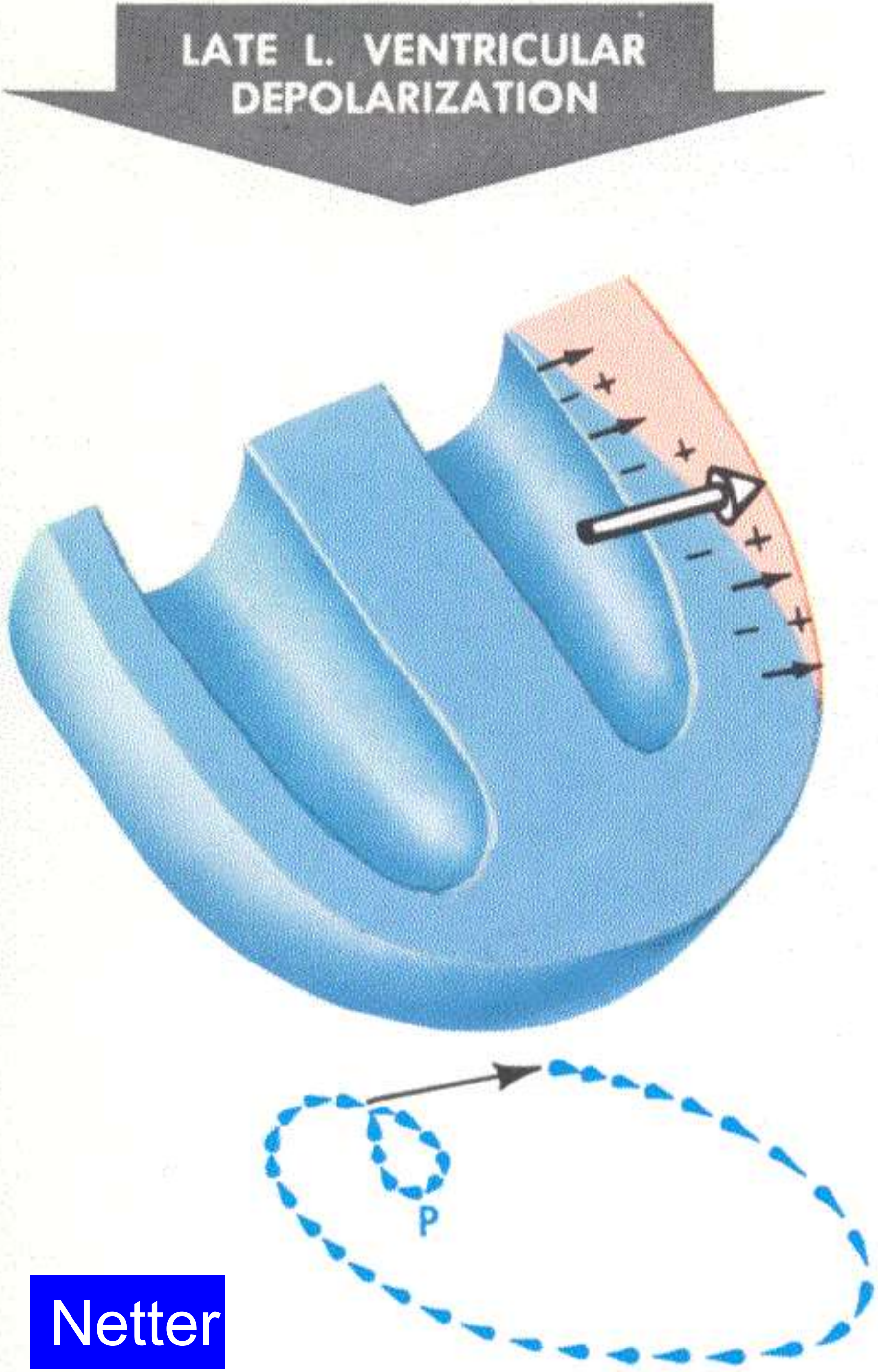
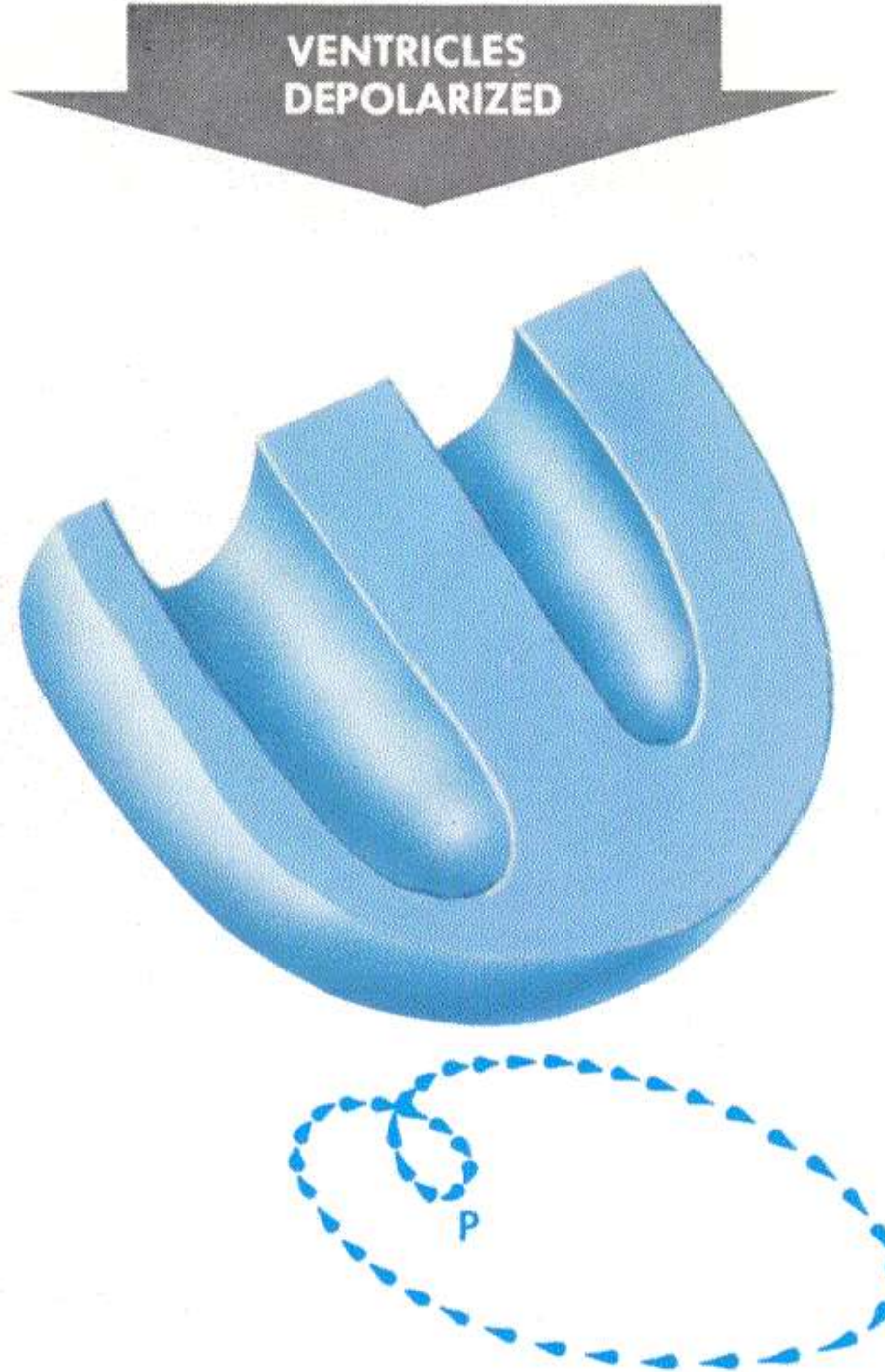
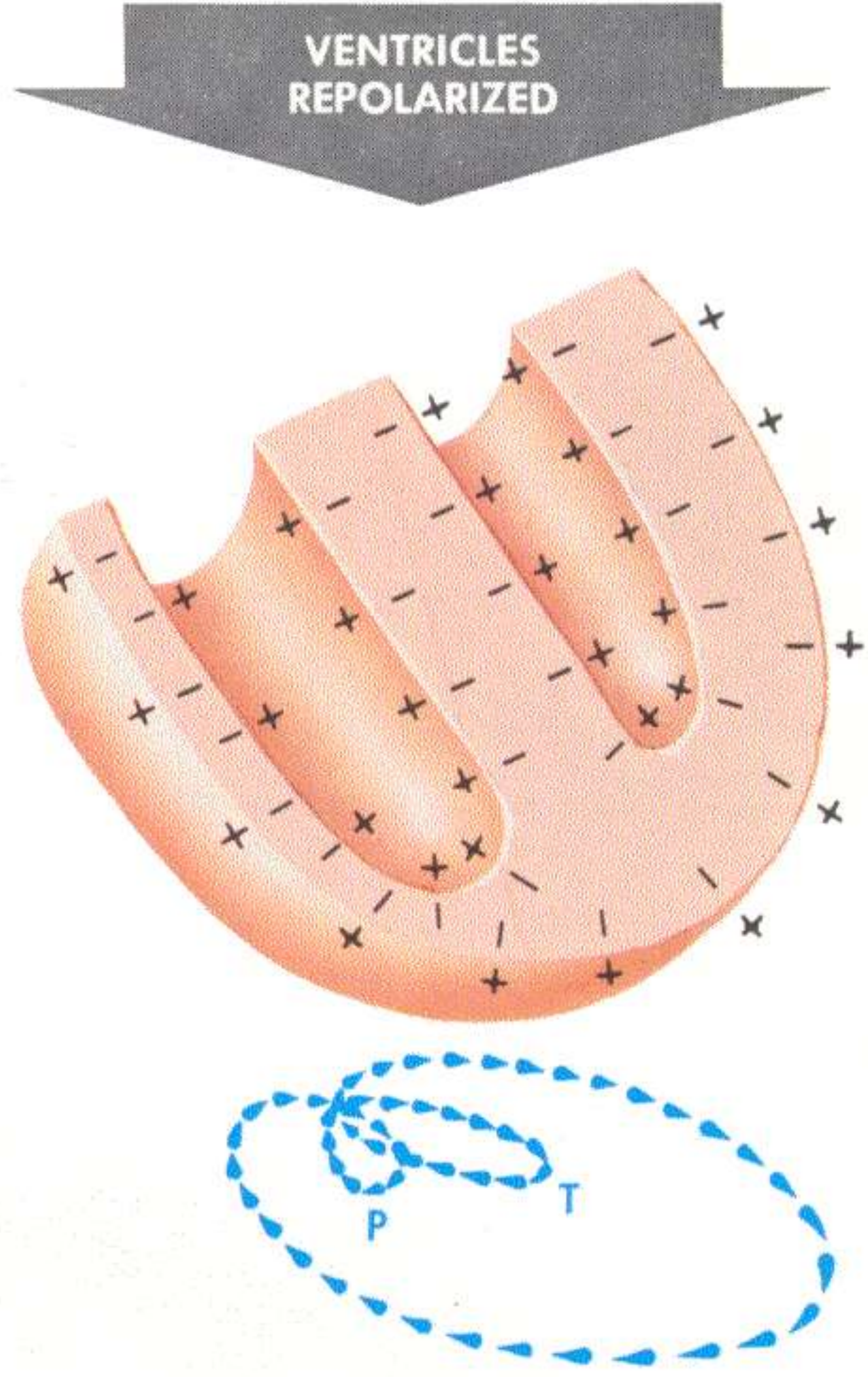

LATE L. VENTRICULAR DEPOLARIZATION
P


VENTRICLES DEPOLARIZED
P

Netter



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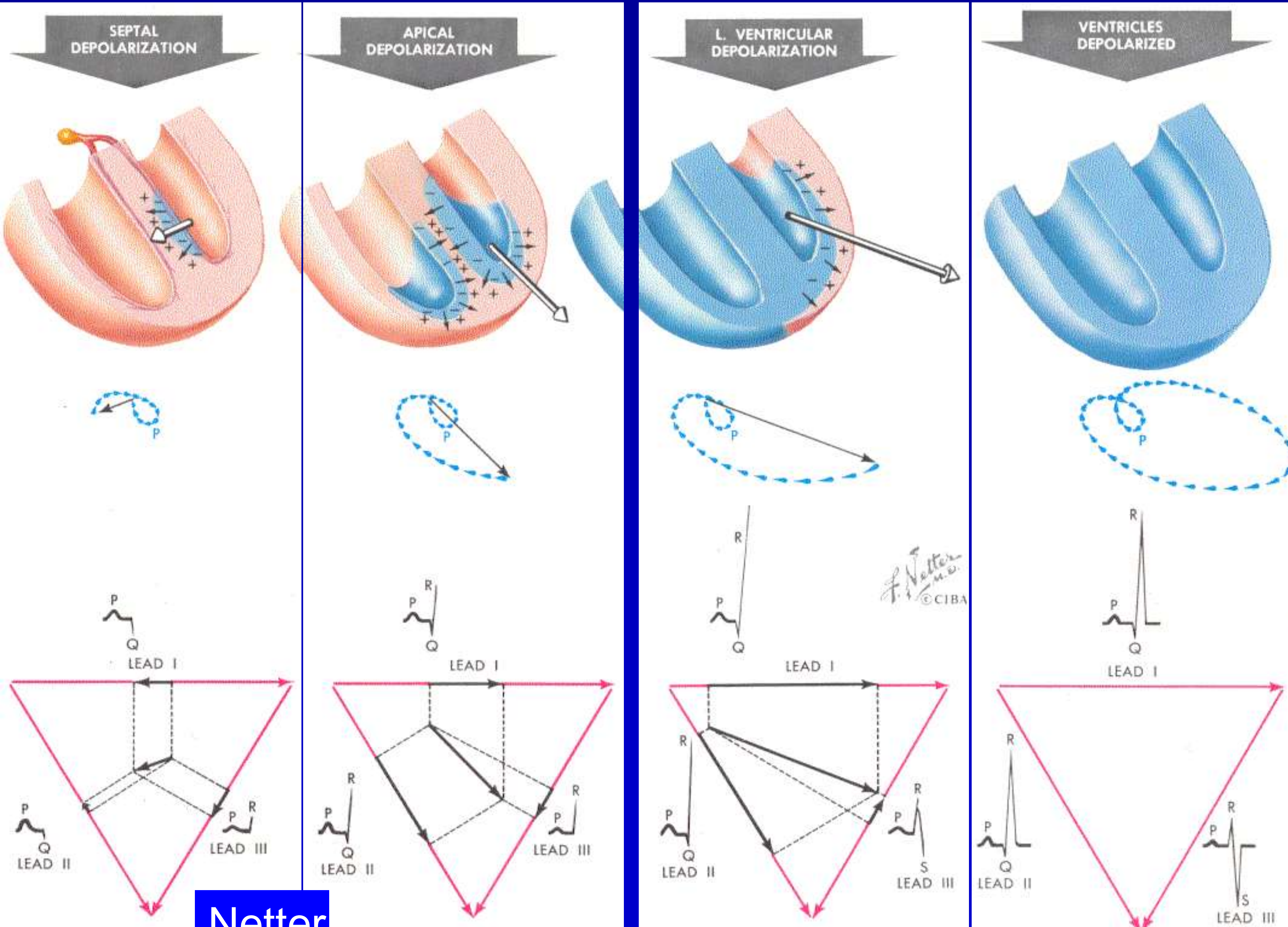
SEPTAL DEPOLARIZATION
APICAL DEPOLARIZATION
L. VENTRICULAR DEPOLARIZATION
VENTRICLES DEPOLARIZED
P
R
Q
S
LEAD I
LEAD II
LEAD III
F. Netter M.D.
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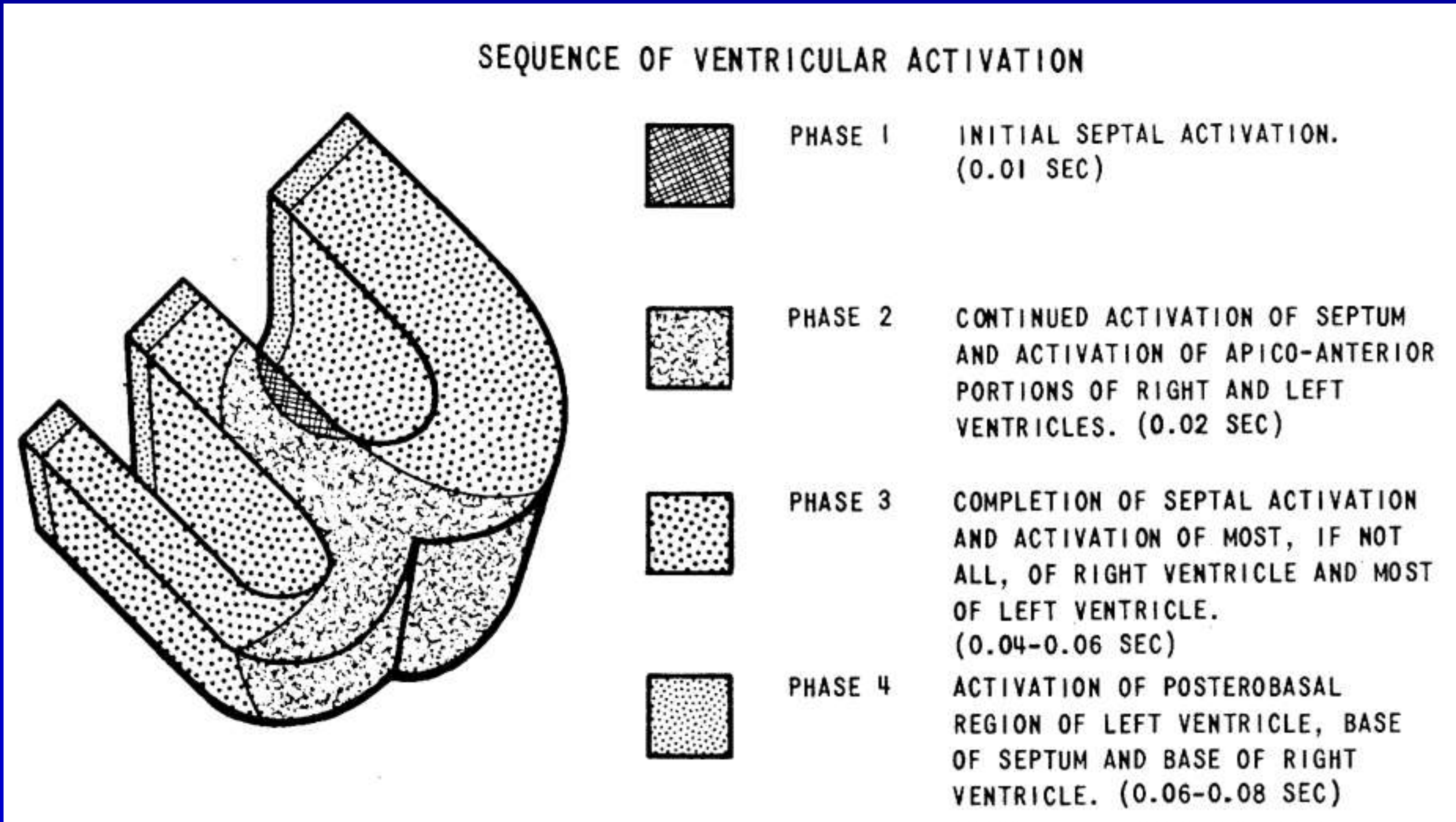
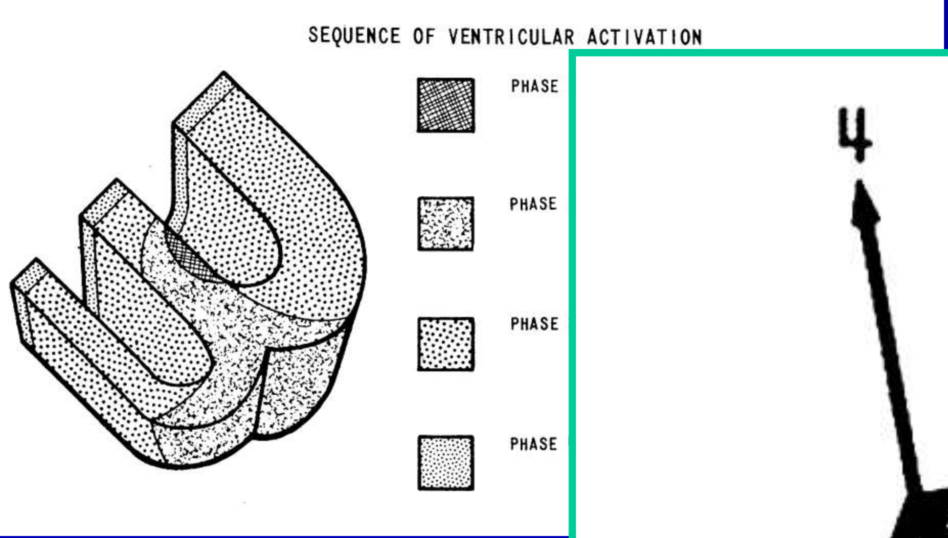
Netter

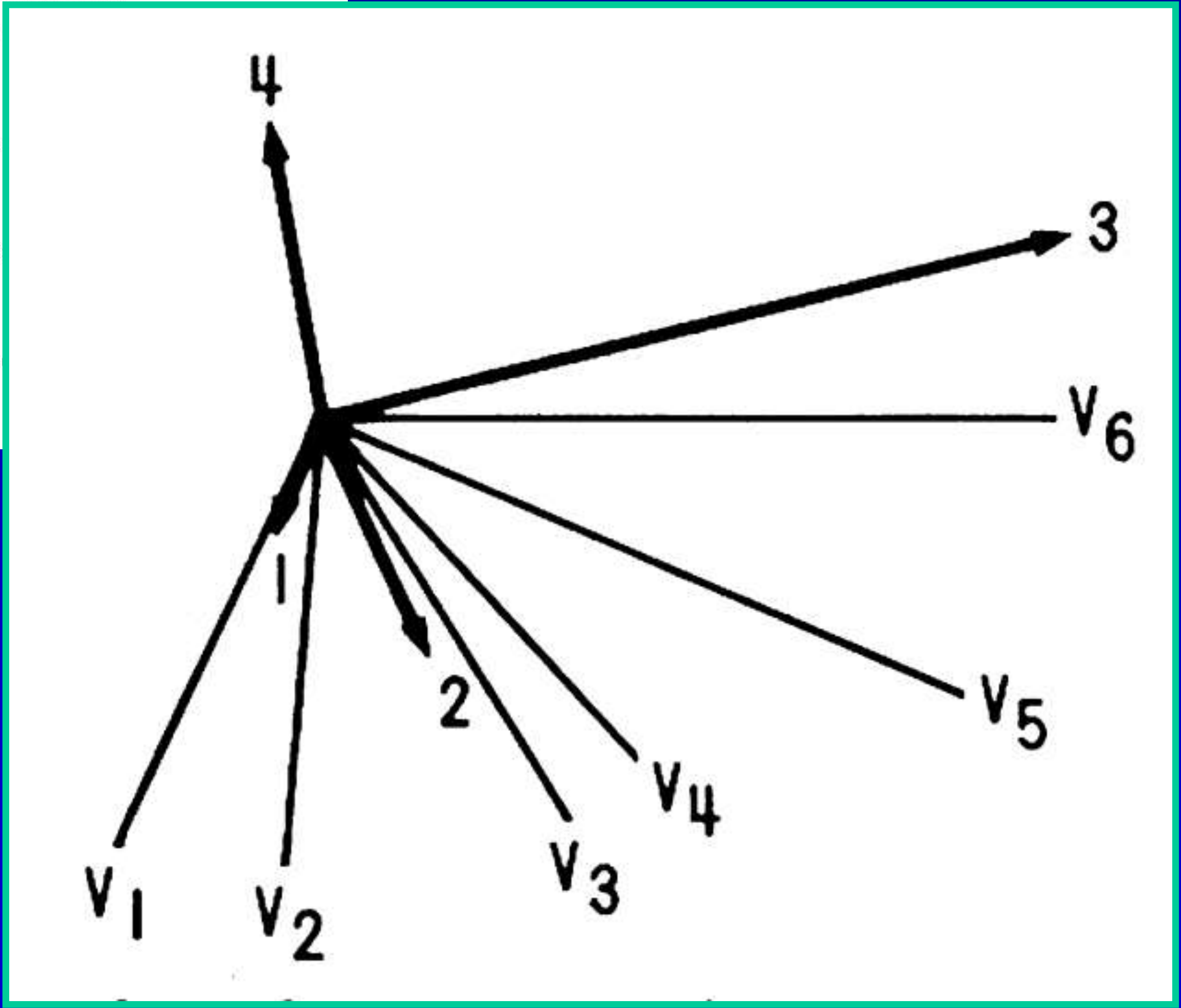
Sequence of Ventricular Activation



Friedman HH, 1971

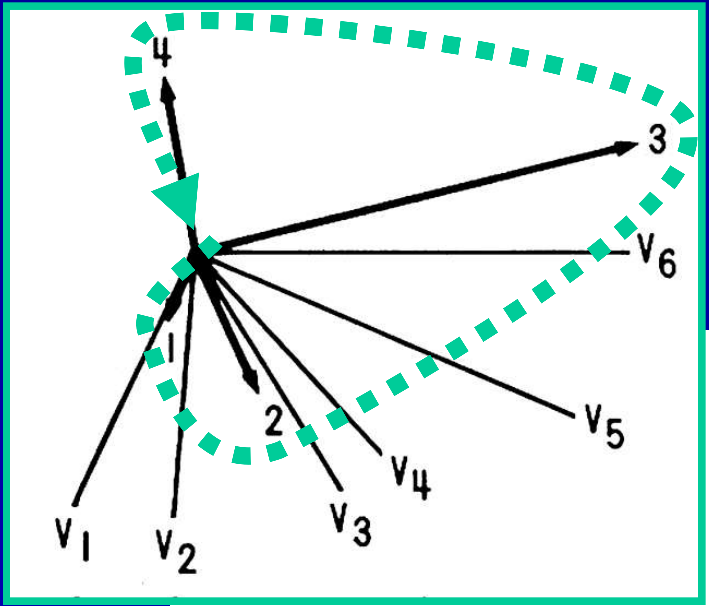
Sequence of Ventricular Activation

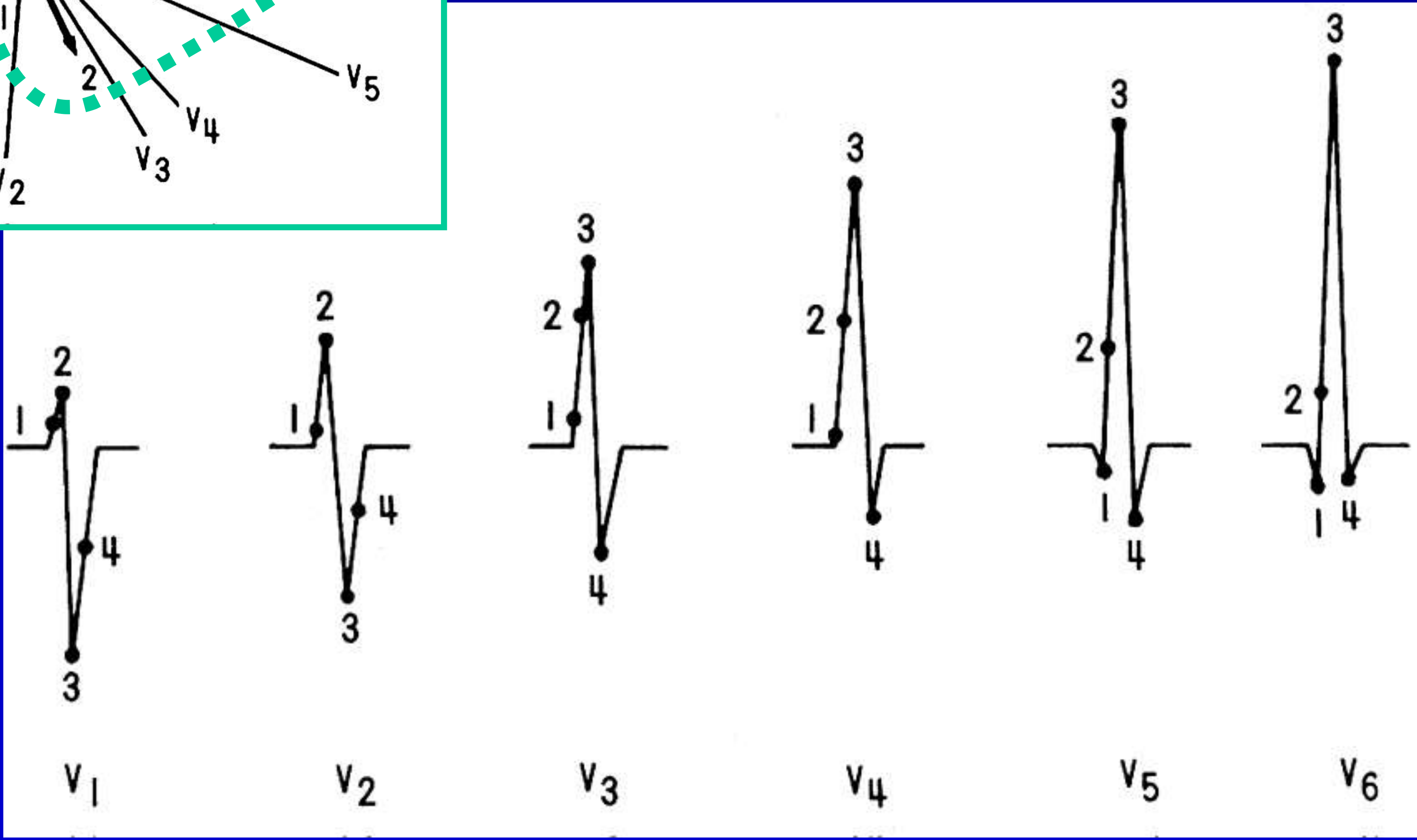




Friedman HH, 1971

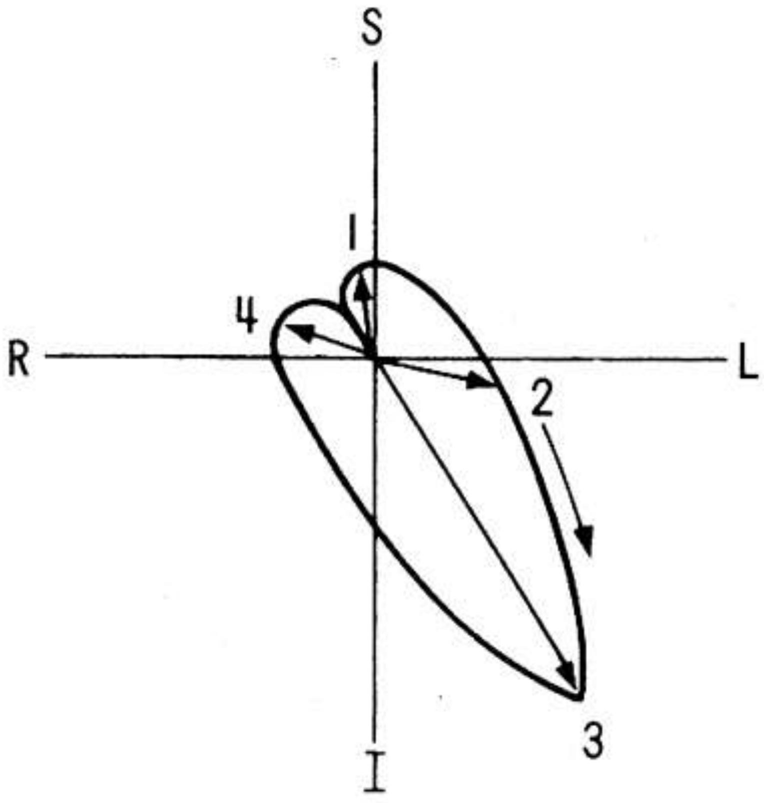
Sequence of Ventricular Activation



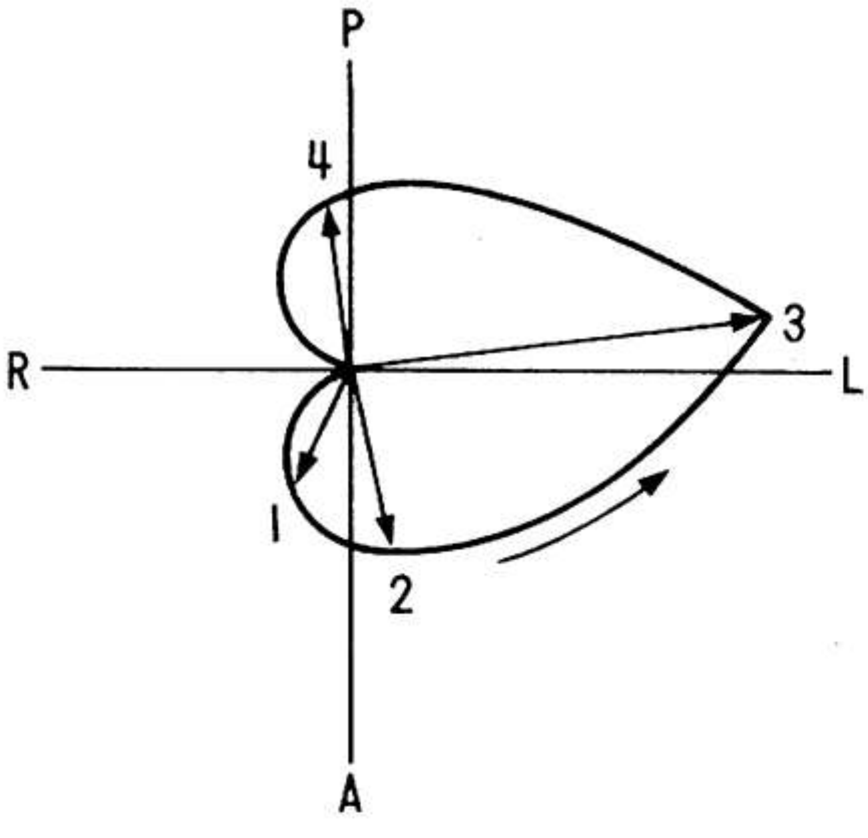


Friedman HH, 1971

Sequence of Activation

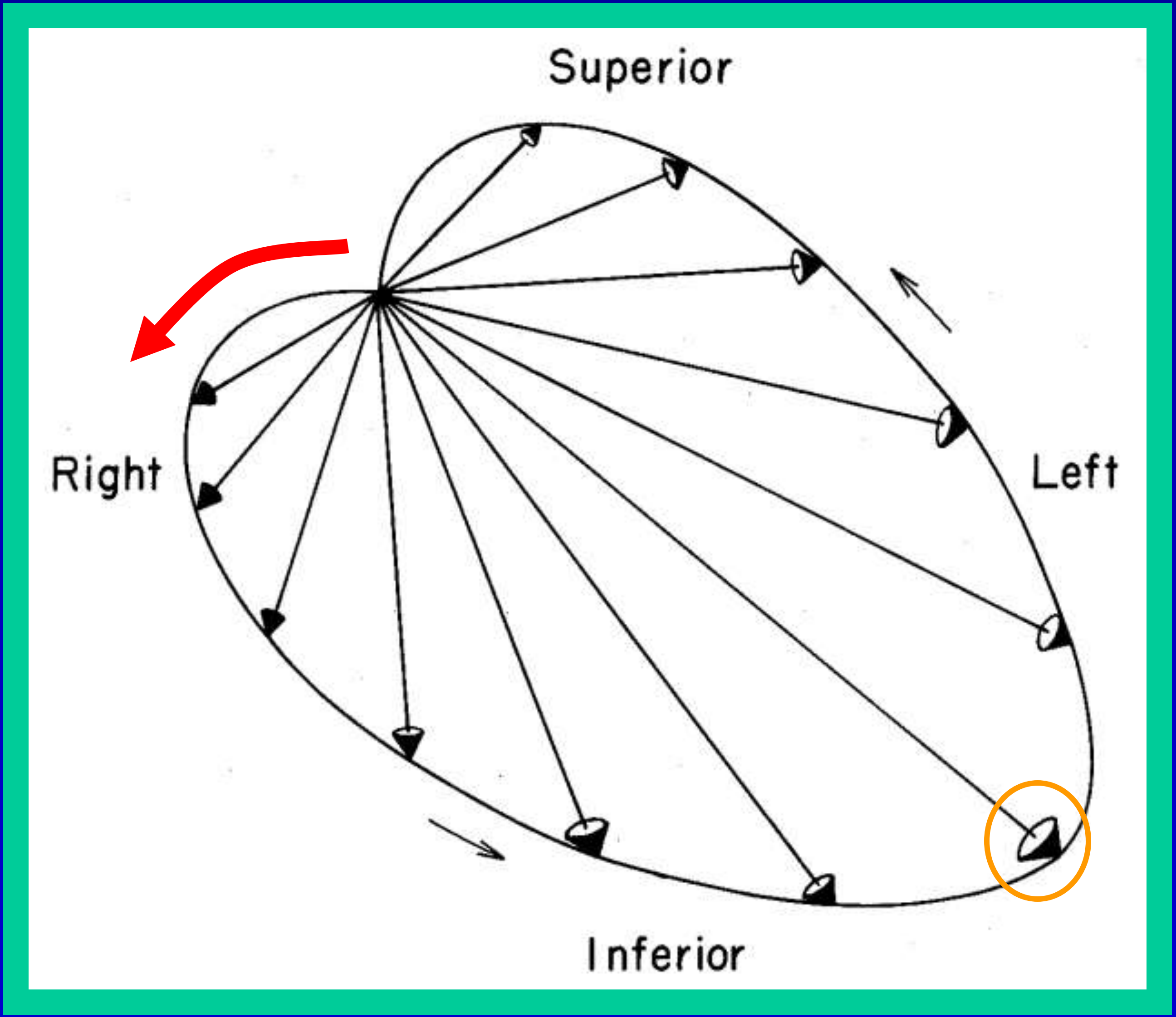


FRONTAL PLANE



TRANSVERSE PLANE

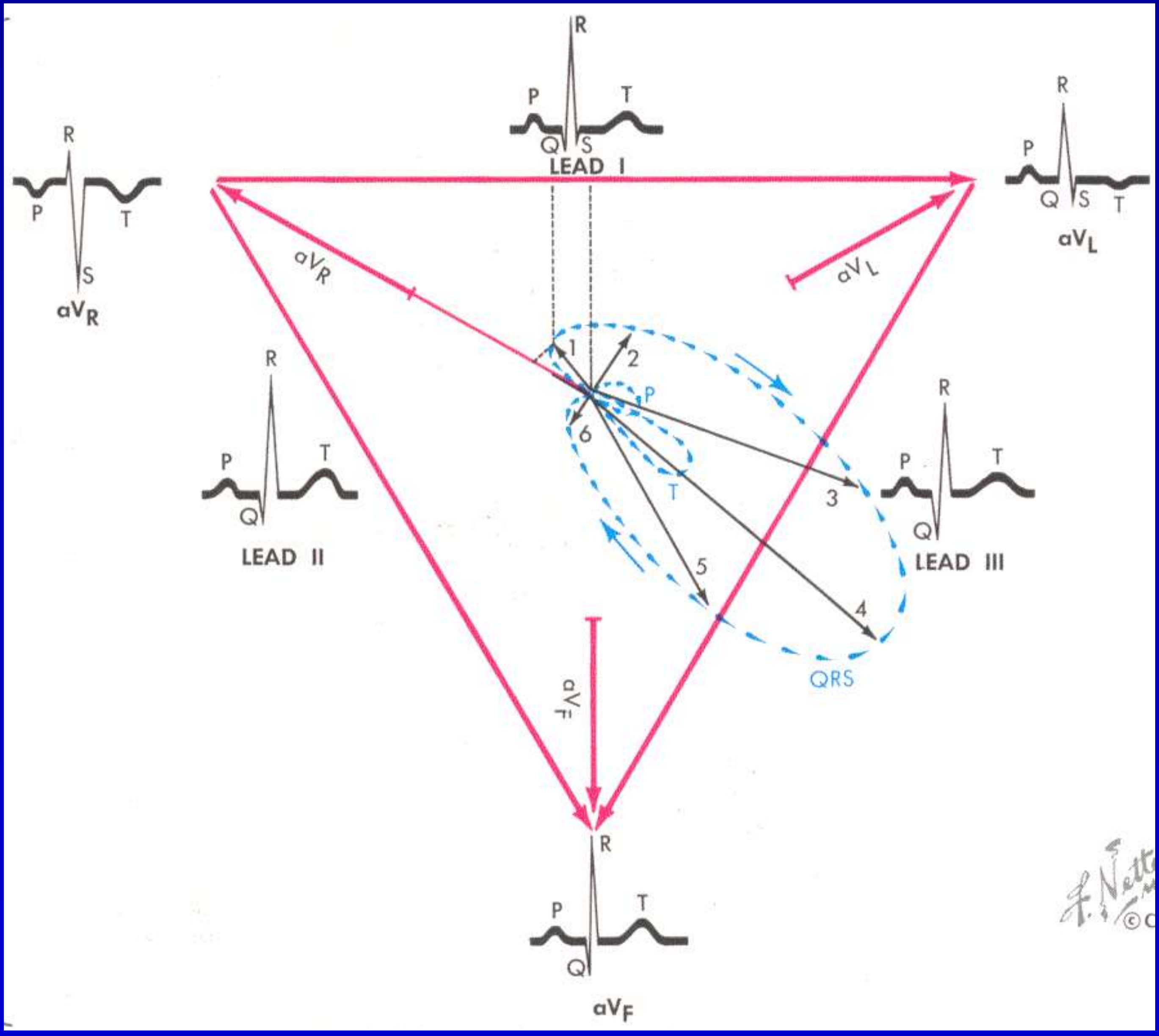
Normal Frontal Plane QRS Loop



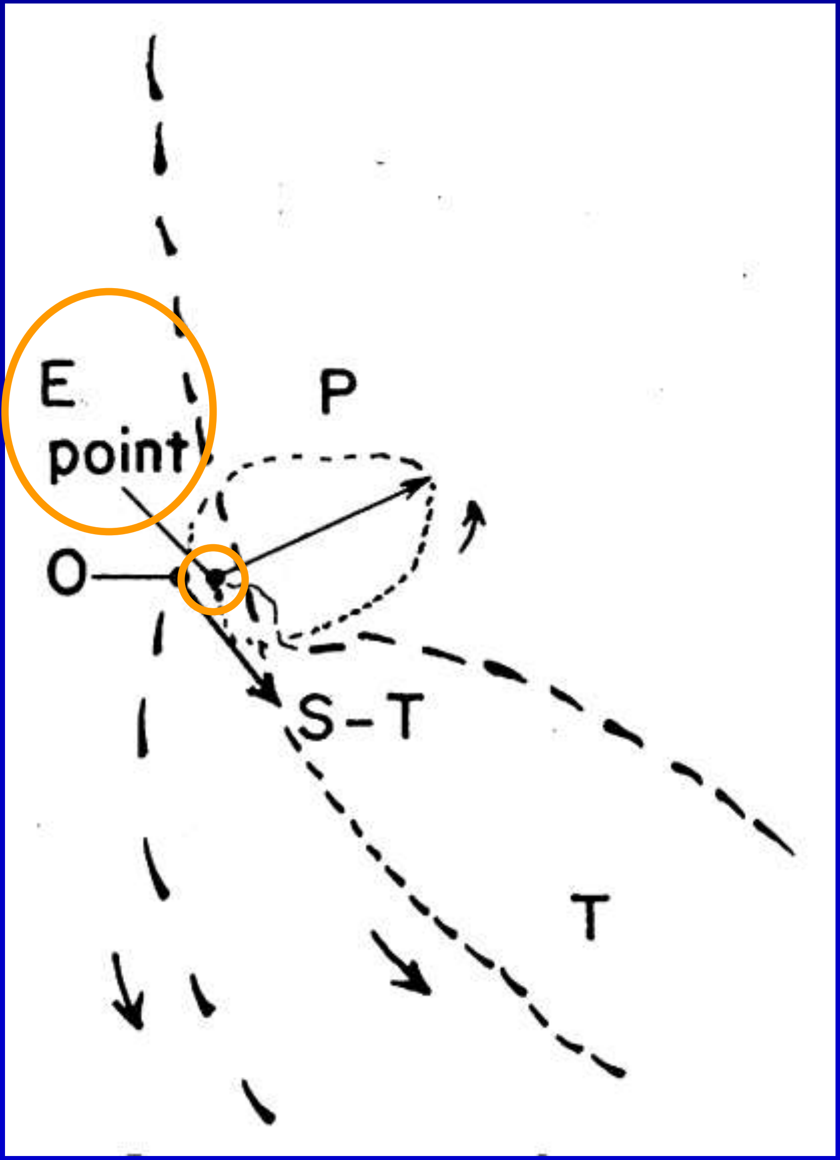
Mean maximal vector

Chou TC et al. Clinical Vectorcardiography, 2nd ed, 1974

Limb Lead ECG and VCG

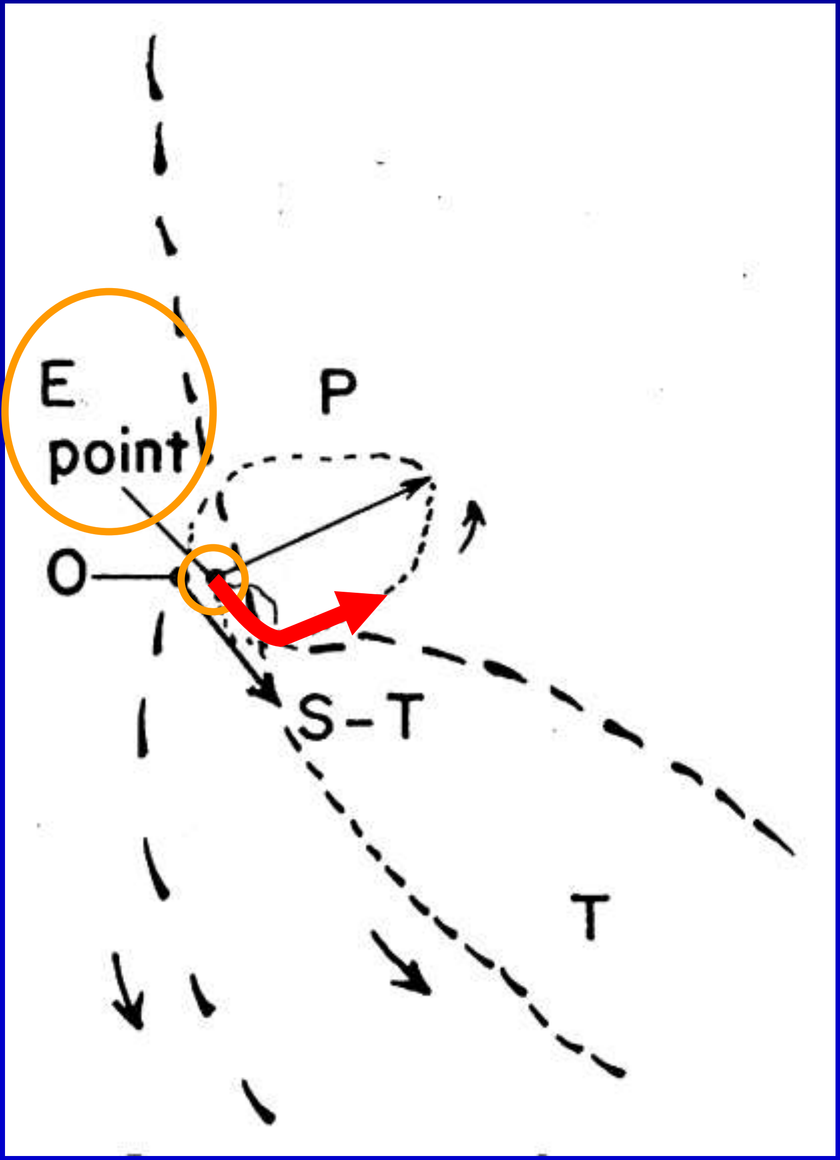


Transverse Plane



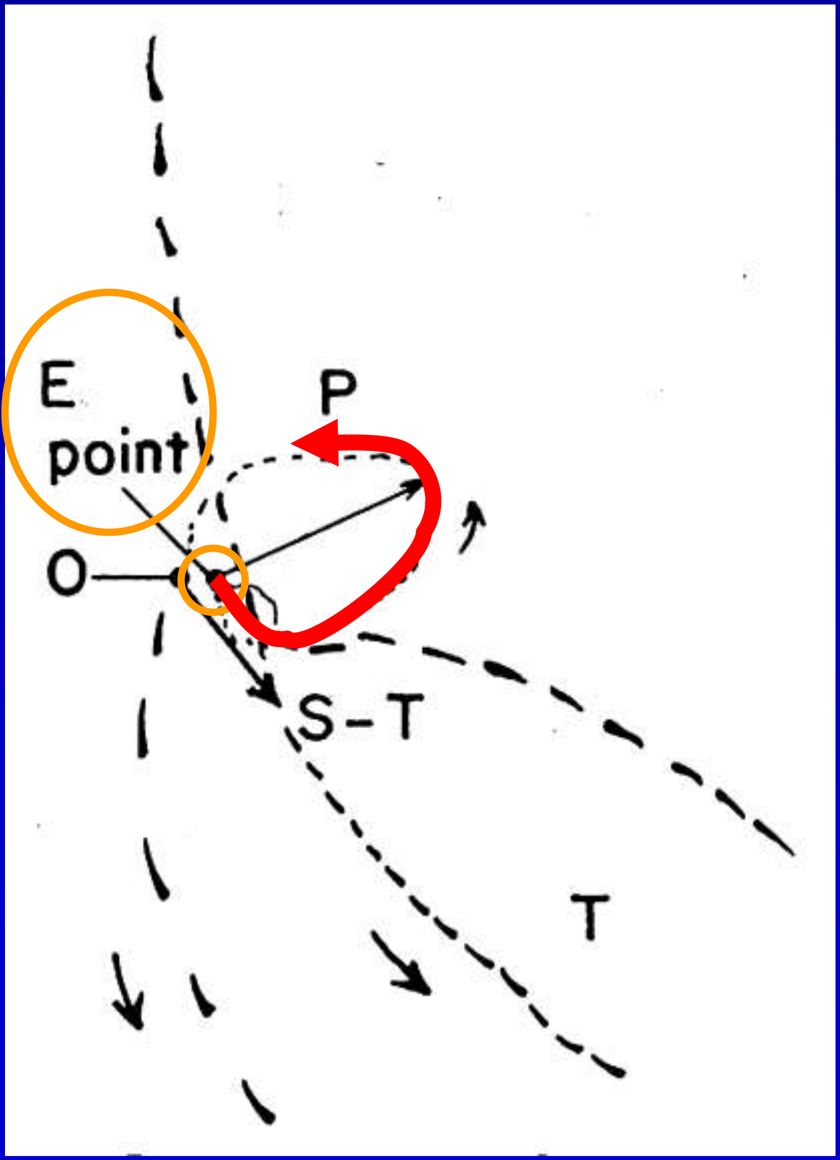
- E point is the beginning of the P wave, the end of the T-P segment
- O point is the end of the PR segment, the beginning of the QRS

Transverse Plane



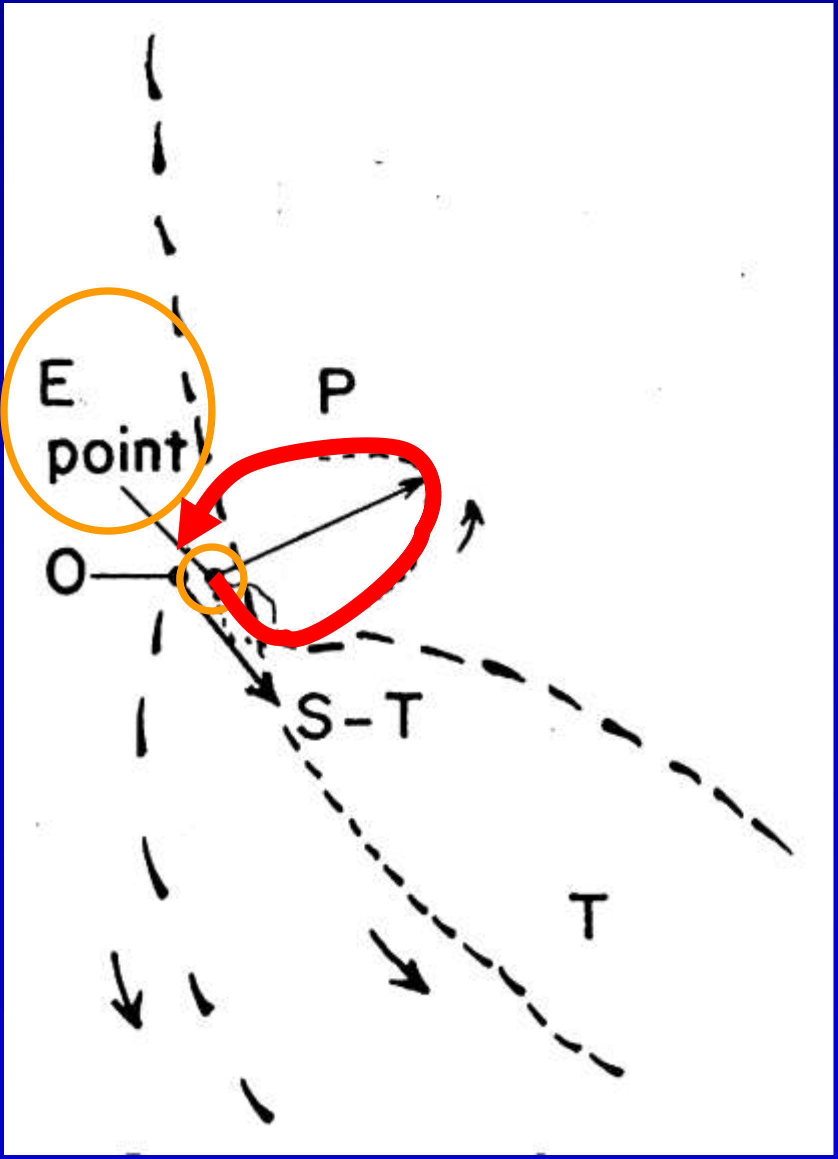
- E point is the beginning of the P wave, the end of the T-P segment
- O point is the end of the PR segment, the beginning of the QRS

Transverse Plane



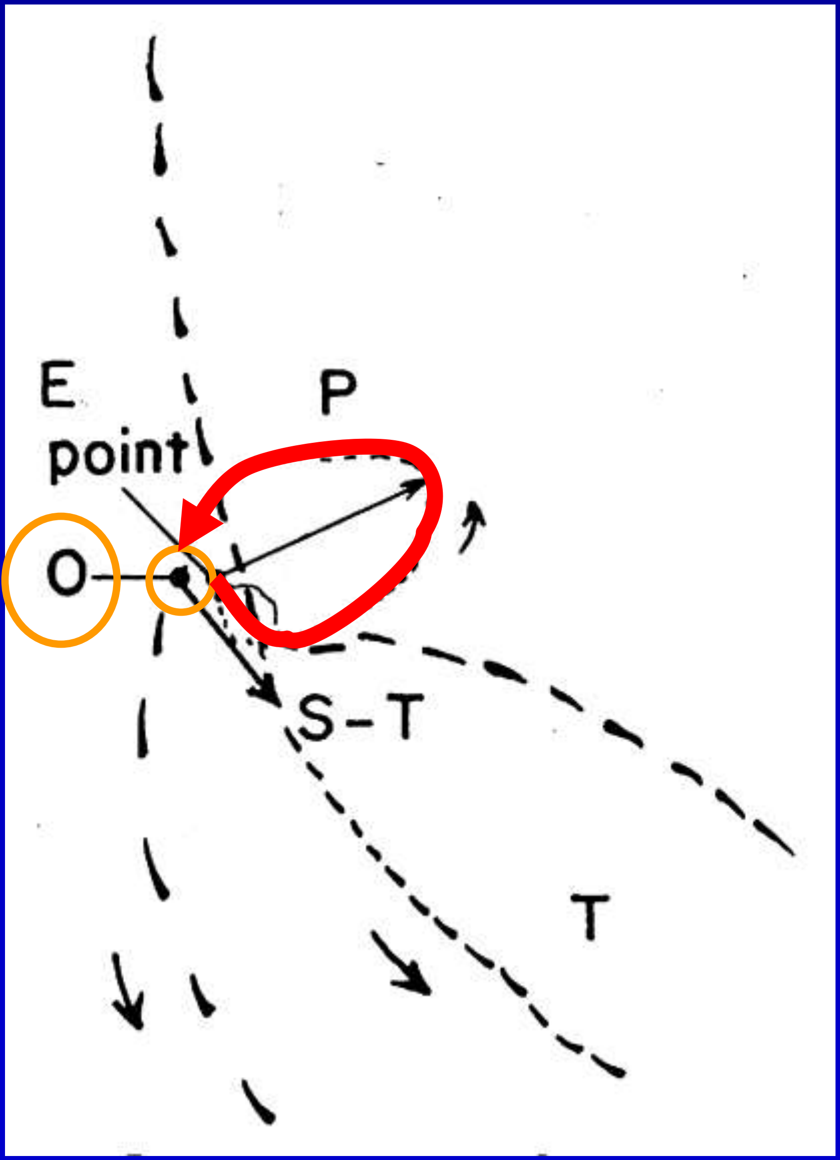
- E point is the beginning of the P wave, the end of the T-P segment
- O point is the end of the PR segment, the beginning of the QRS

Transverse Plane



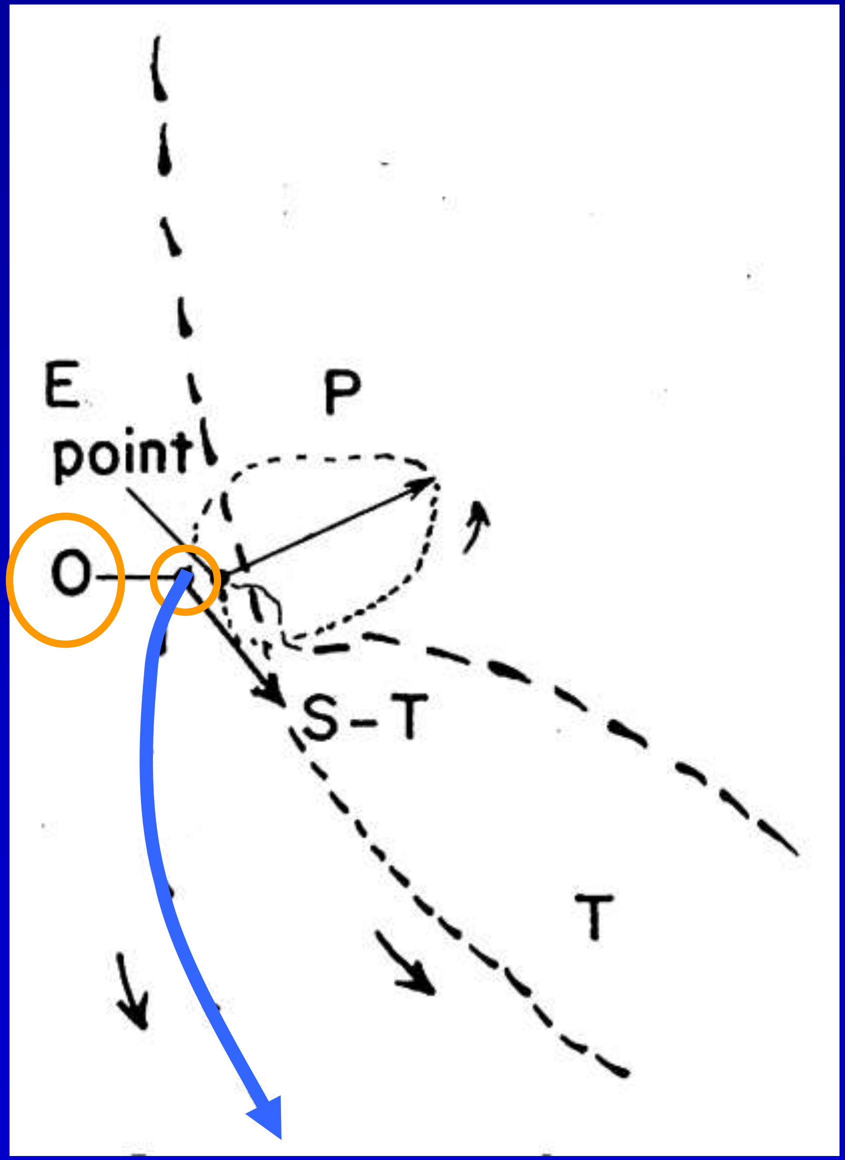
- E point is the beginning of the P wave, the end of the T-P segment
- O point is the end of the PR segment, the beginning of the QRS

Transverse Plane

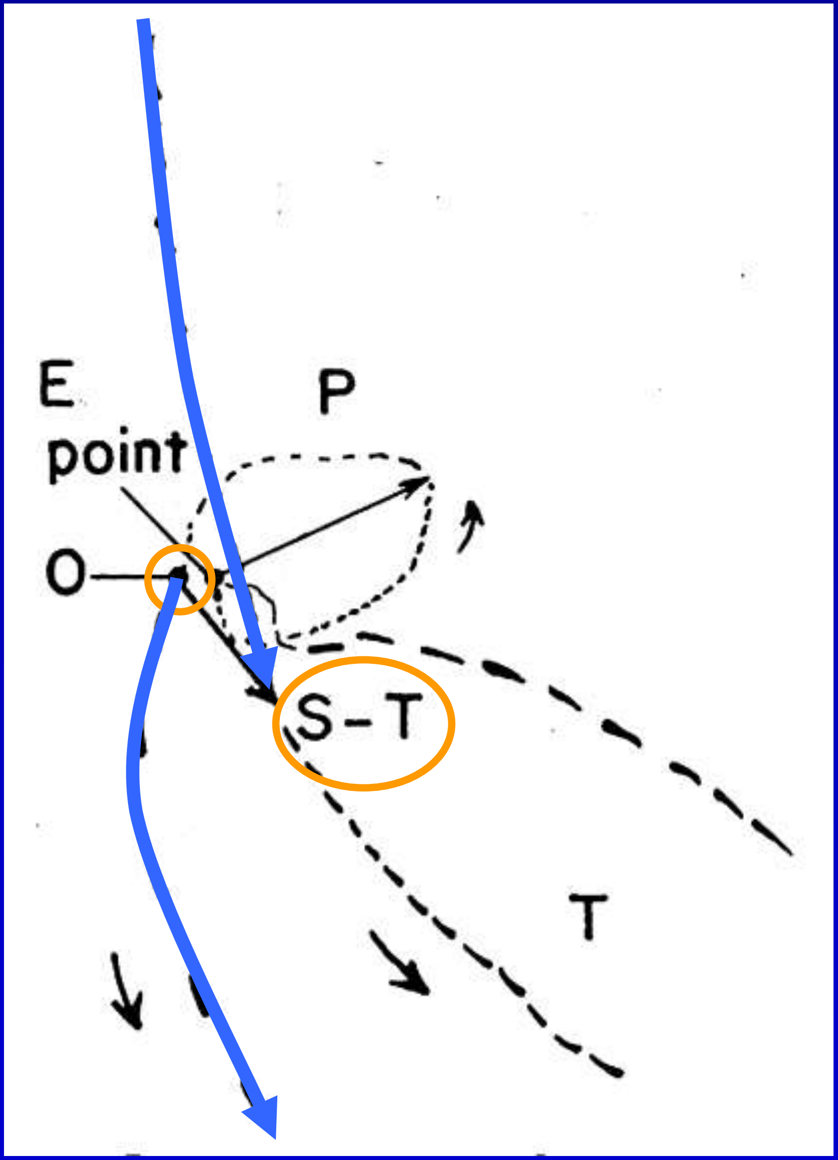


- E point is the beginning of the P wave, the end of the T-P segment
- O point is the end of the PR segment, the beginning of the QRS

Transverse Plane

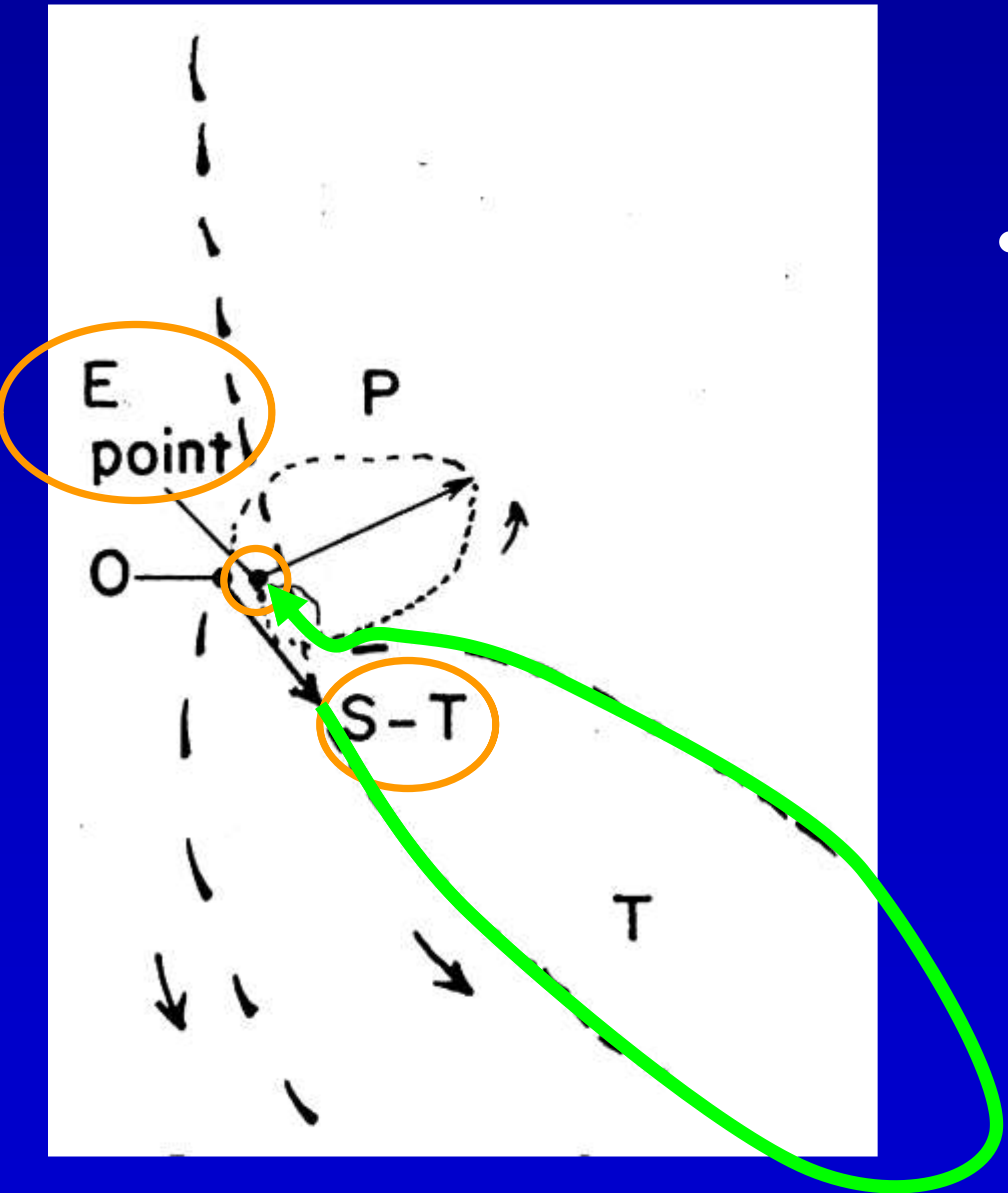


Transverse Plane

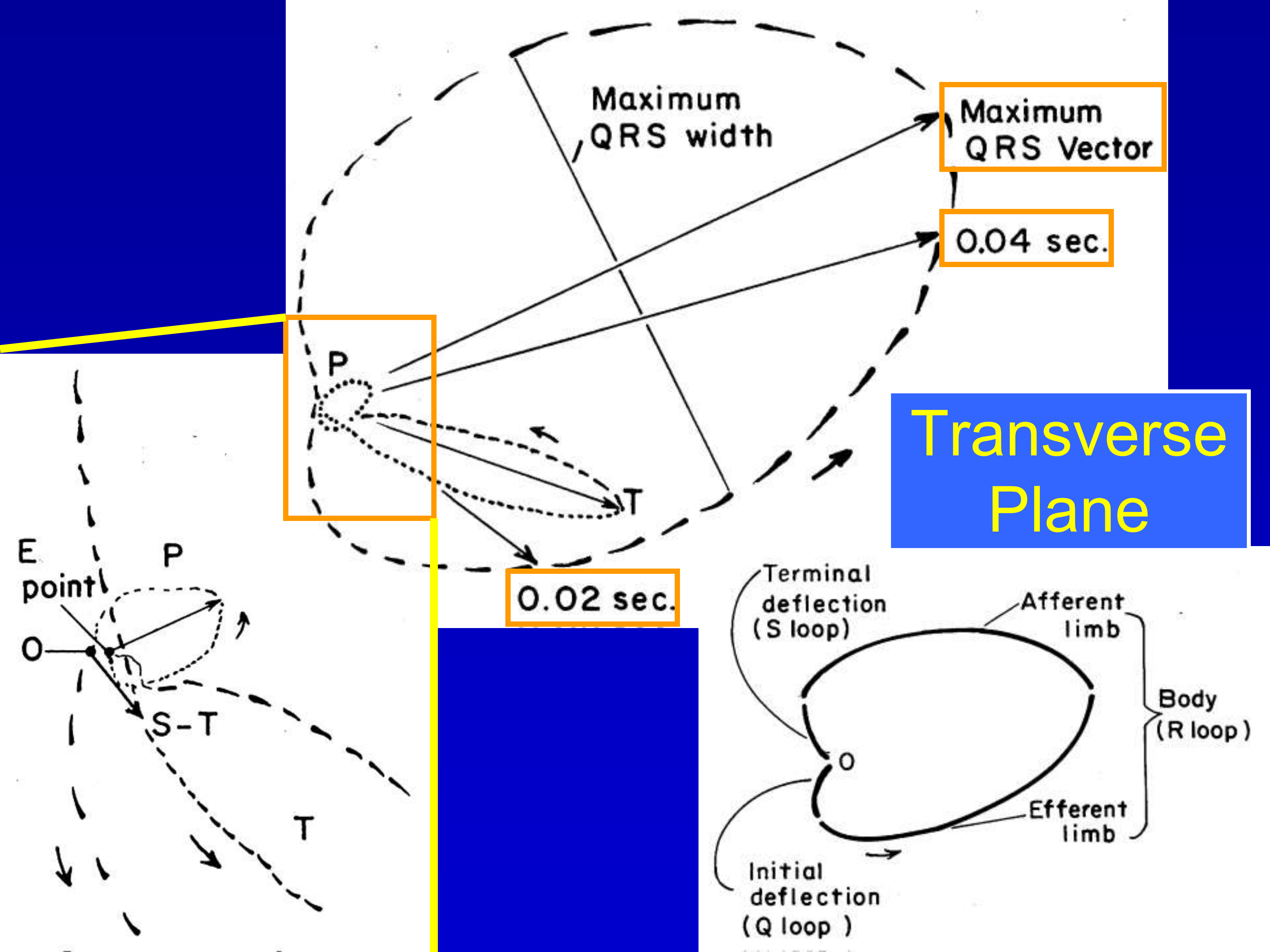


- The end of the QRS is not precisely at the same point as the beginning, so there is a normal ST segment, especially in the transverse plane.

Transverse Plane

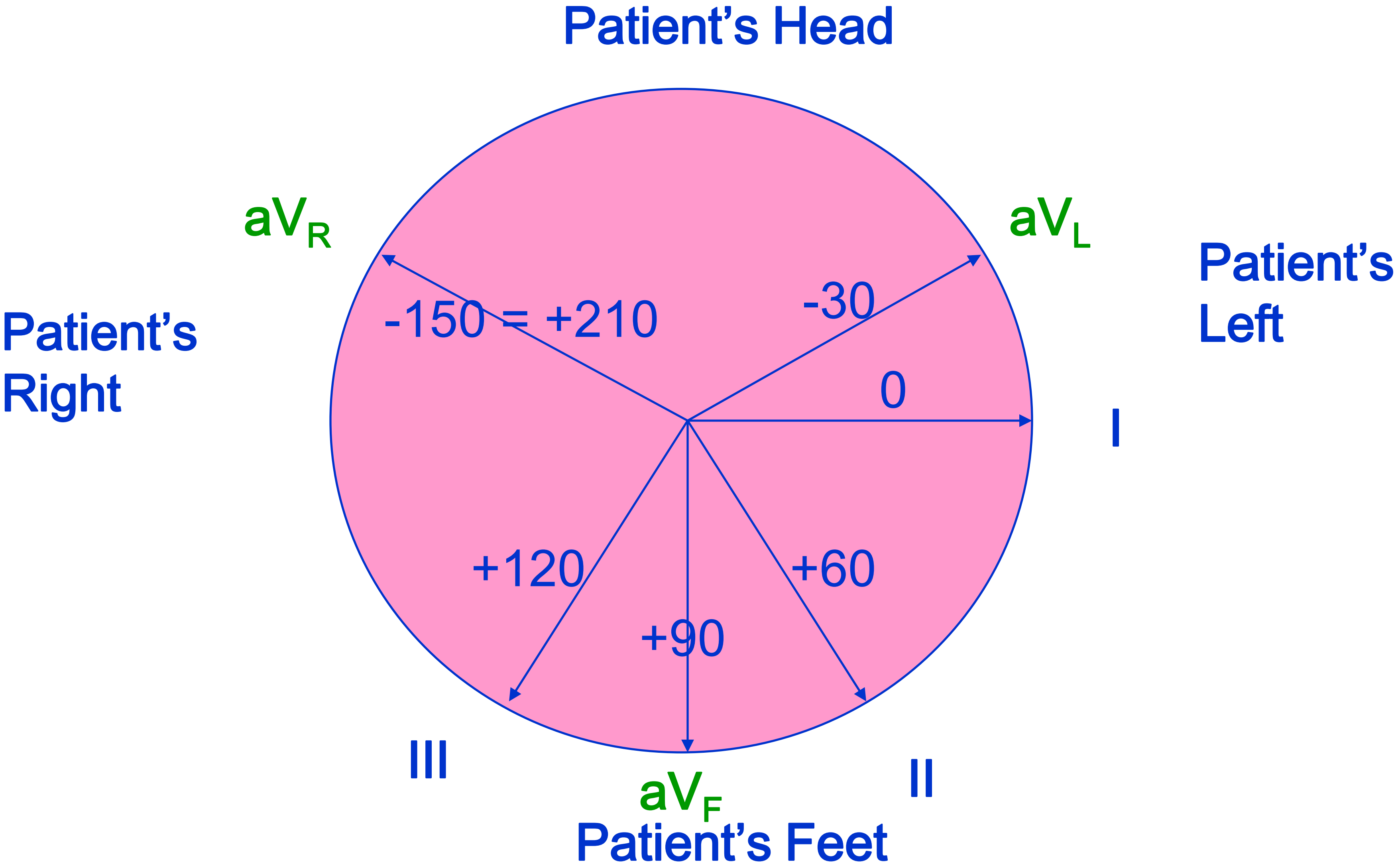


- The end of the T loop is back to the E point

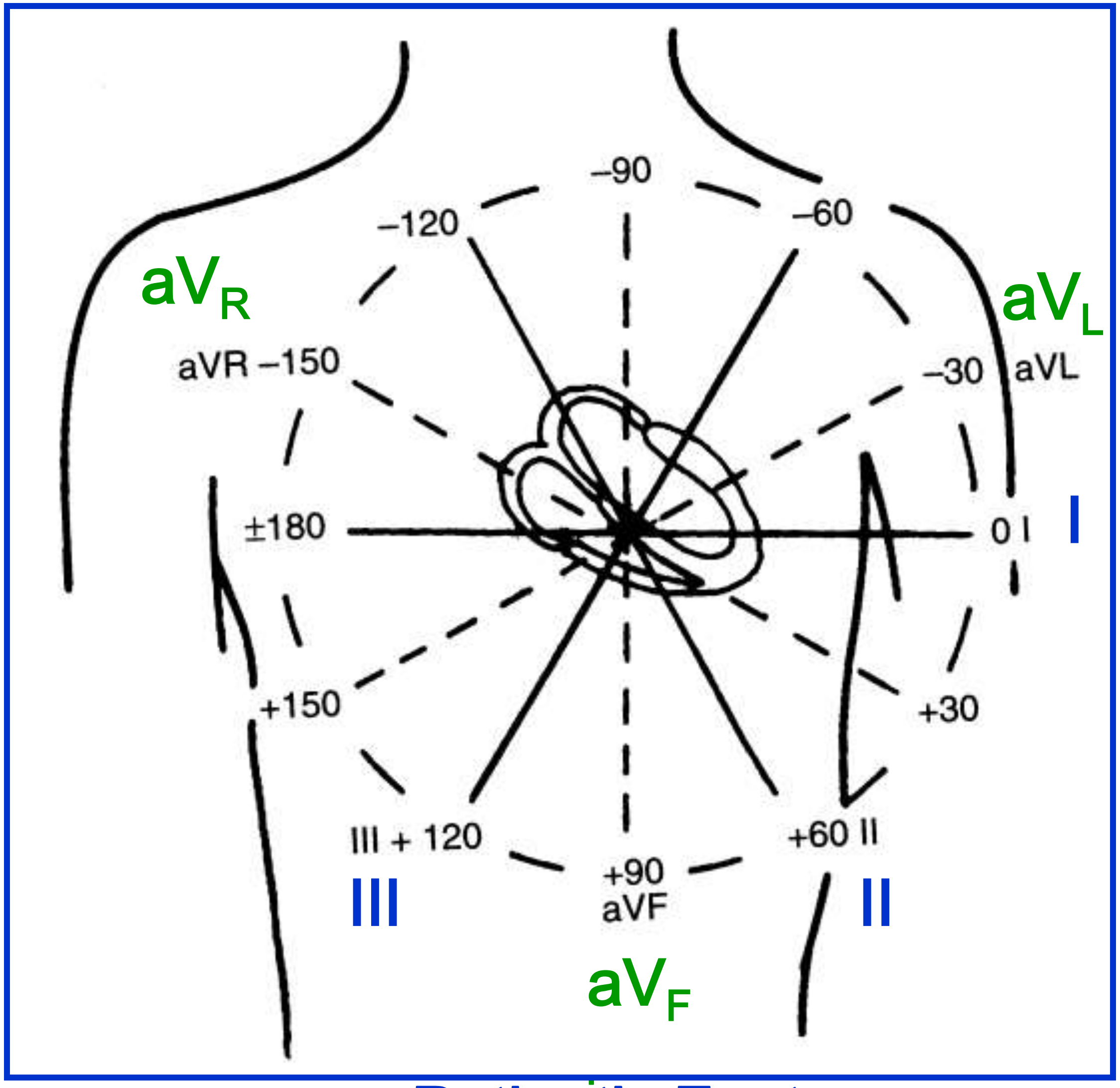


Transverse Plane

The Frontal Plane Axis



The Frontal Plane Axis



Patient's Right

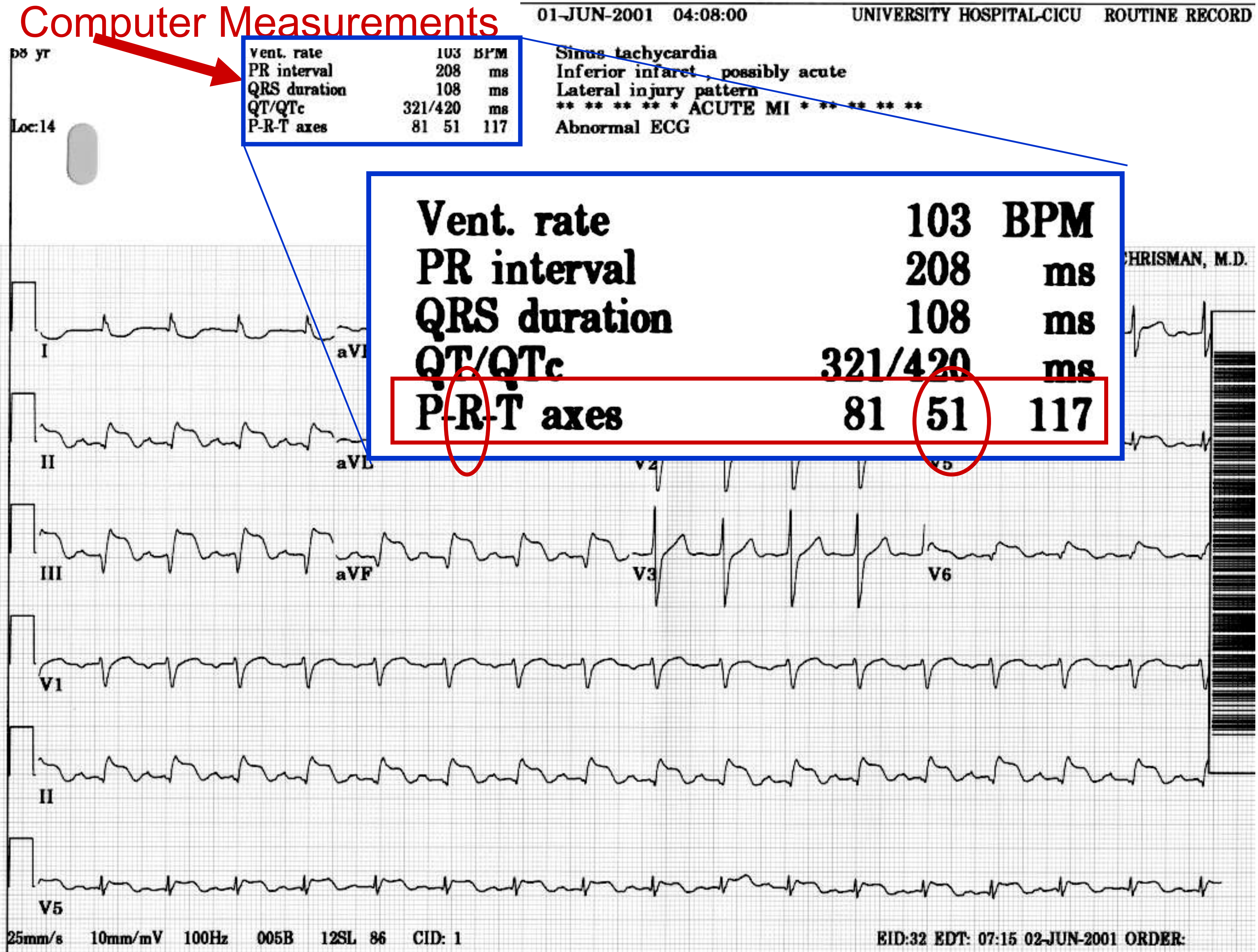
Patient's Left

Patient's Feet

Background: Measuring the Axis - 2

- We can measure the axis of any wave or part of a wave of depolarization or repolarization
- Usually we focus on measuring only the mean QRS axis in the frontal plane
- Computers generally give a calculated mean axis of the QRS, and also the P wave and the T wave axes

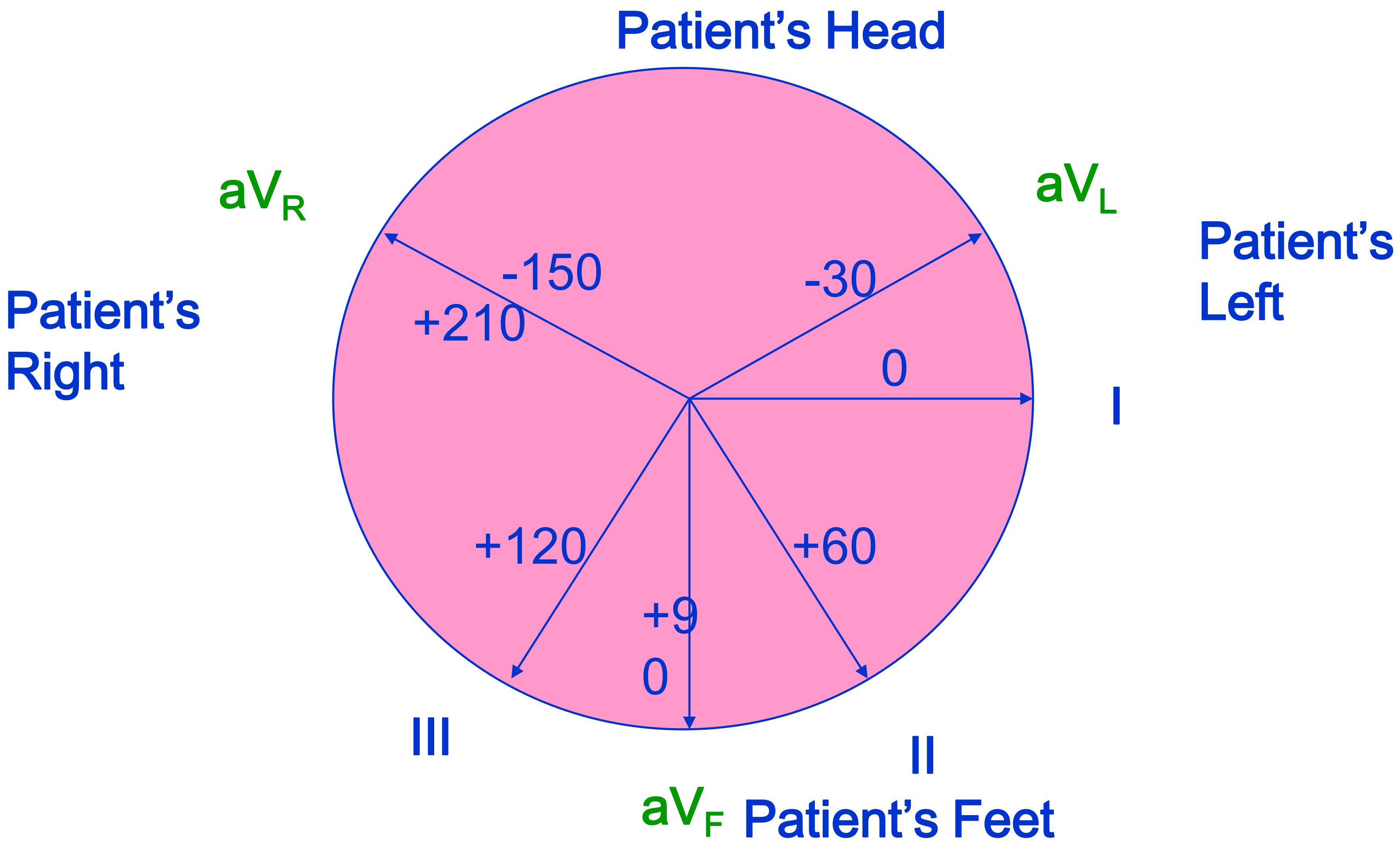
Computer Measurements



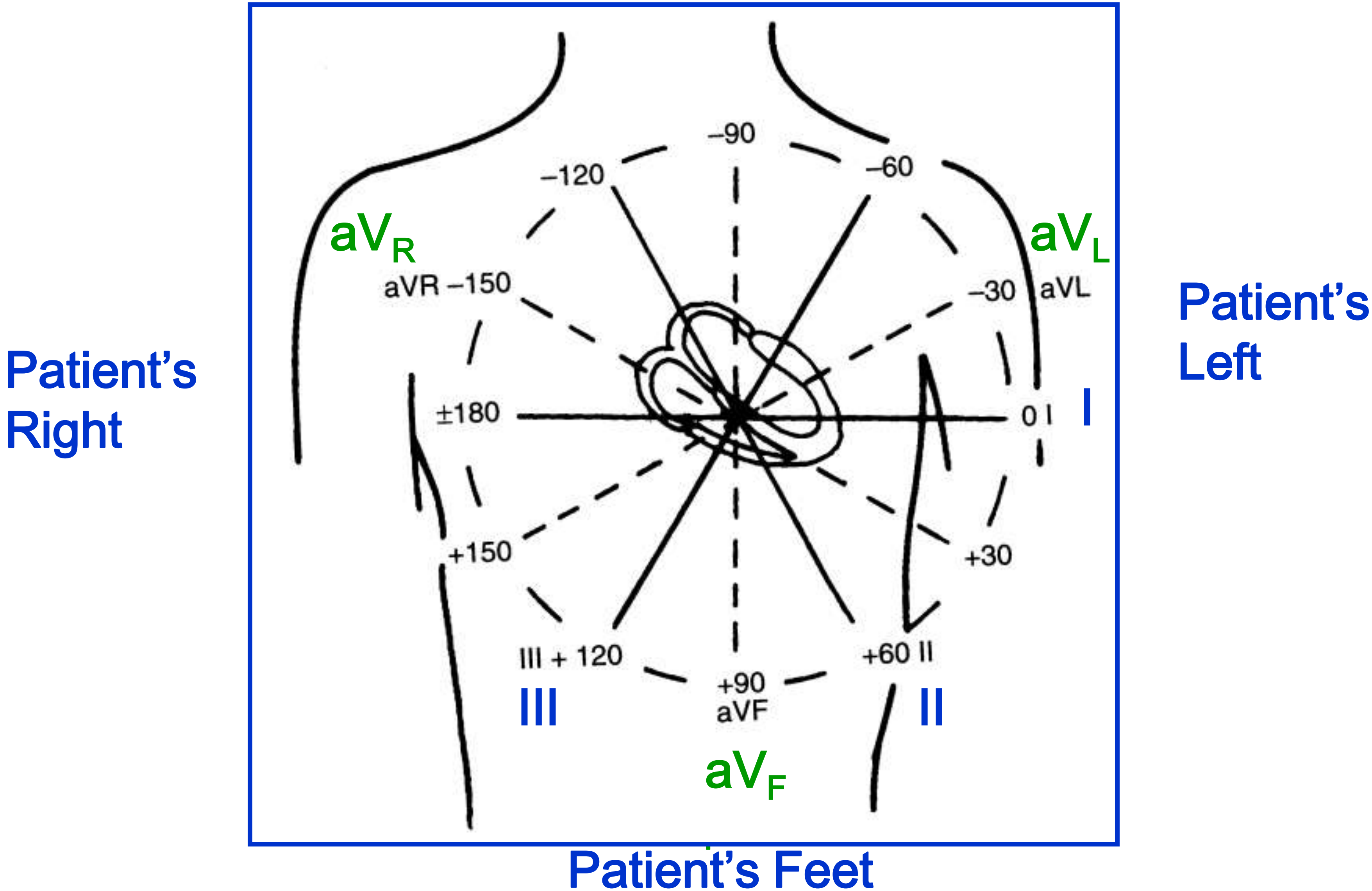
Background: Measuring the Axis - 3

- Each of the 12 ECG leads has a consistent vantage point, mapped to a constant direction in space AND must be memorized
  - I is to left and is 0 degrees
  - II is to left and inferior and is +60 degrees
  - III is to right and inferior and is +120 degrees
  - aVR is to right and superior and is +210 or -150 degrees
  - aVL is to left and superior and is -30 degrees
  - aVF is directly inferior and is +90 degrees

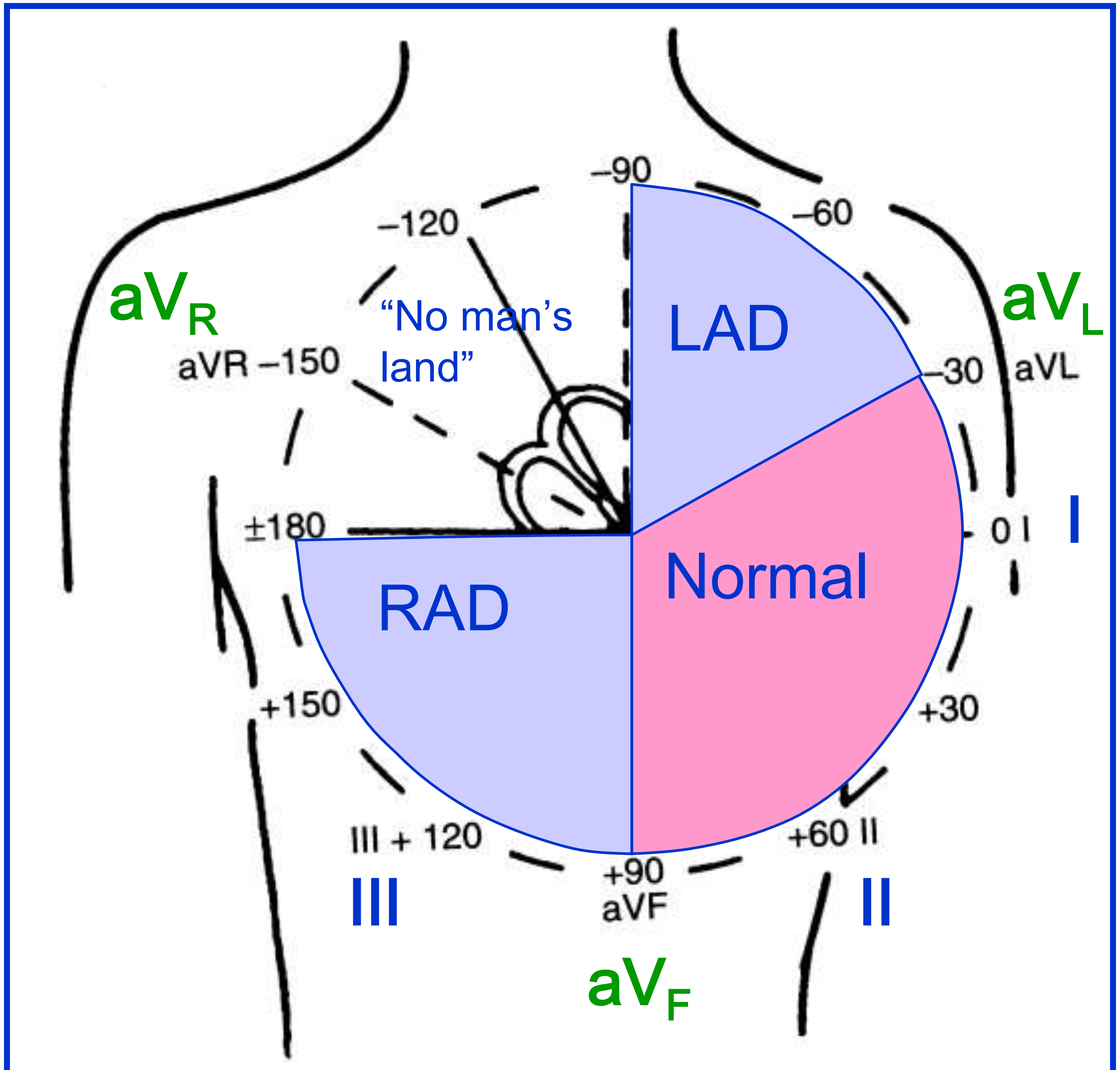
The Frontal Plane Axis



The Frontal Plane Axis



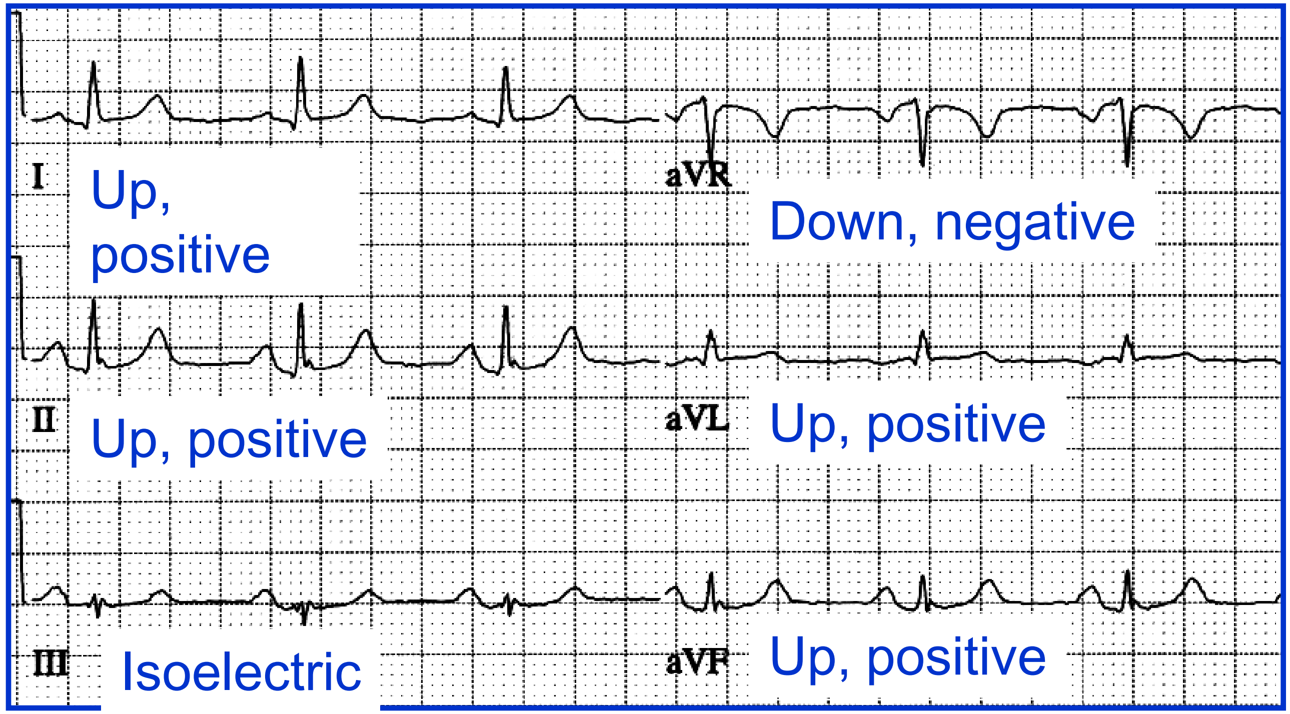
The Frontal Plane Axis



Background: Measuring the Axis - 4

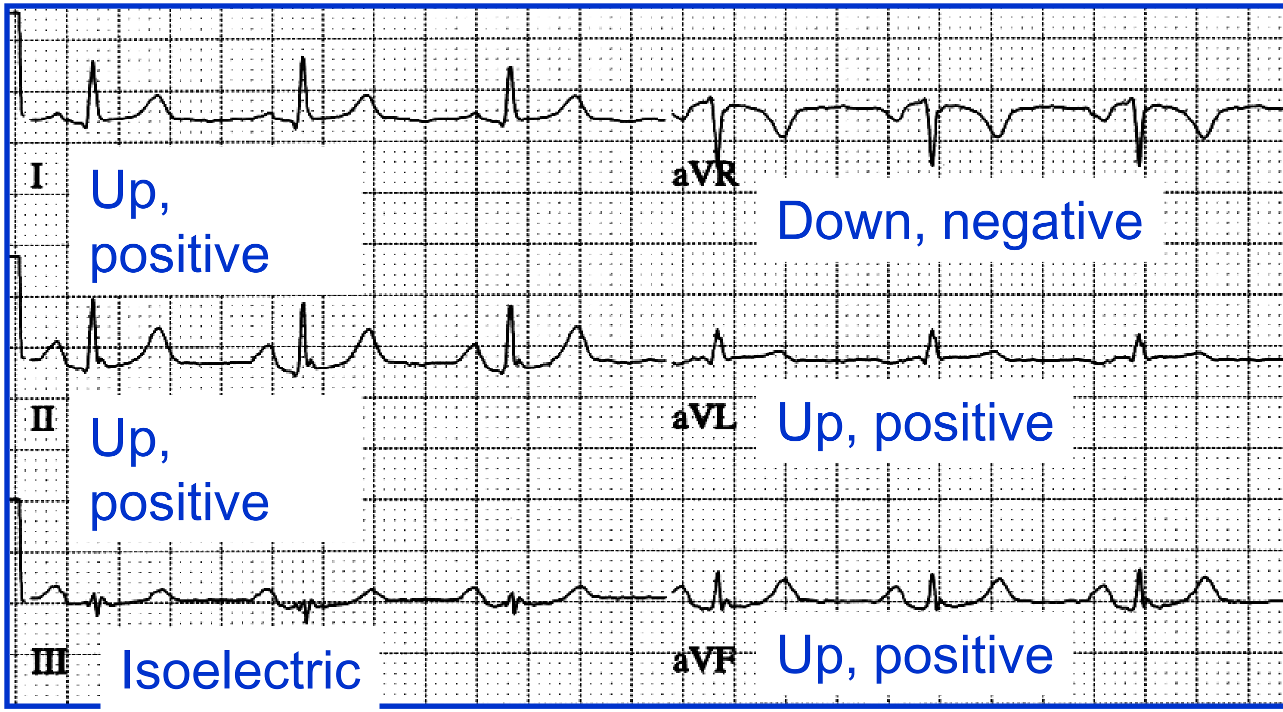
- It is critical to know the meaning of “**positive**”, “**negative**” and “**isoelectric**”, and to know that these terms are applied to individual leads.
- If the QRS is **positive** in a given lead, that means that the QRS **upward** deflection is dominant
- If the QRS is **negative** in a given lead, that means that the QRS **downward** deflection is dominant
- If the QRS is **isoelectric** in a given lead, that means that the QRS **upward and downward deflections are about the same**

Background: Measuring the Axis - 4



- If the QRS is positive in a given lead, that means that the QRS upward deflection is dominant
- If the QRS is negative in a given lead, that means that the QRS downward deflection is dominant
- If the QRS is isoelectric in a given lead, that means that the QRS upward and downward deflections are about the same

Background: Measuring the Axis - 5



- If the QRS is **positive** in a given lead, that means that the QRS axis is **within 90 degrees** of that lead direction
- If the QRS is **negative** in a given lead, that means that the QRS axis is **not within 90 degrees** of that lead direction
- If the QRS is **isoelectric** in a given lead, that means that the QRS axis is **just about 90 degrees** from that lead direction

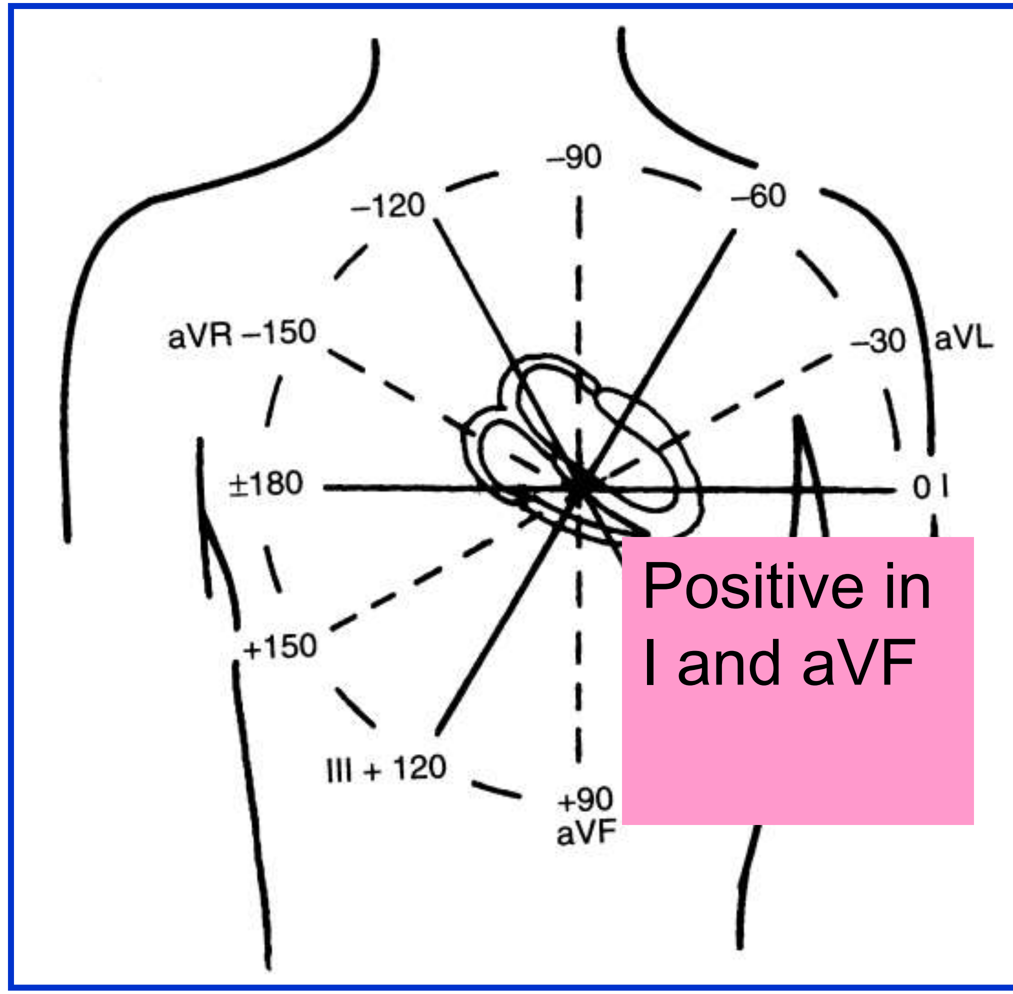
Measuring the Axis - 1

Remember: Positive = upward deflection!

- Assess leads I and aVF; these are perpendicular leads
- Determine the quadrant from these – 9 possibilities
  - Usually both I and aVF are positive, or upgoing, and the quadrant is left lower quadrant
  - If I is positive and aVF is negative, or downgoing, the quadrant is left upper
  - If I is negative and aVF is positive, the quadrant is right lower
  - If I and aVF are both negative, the quadrant is right upper
  - If I is isoelectric and aVF is positive, the axis is 90 degrees
  - If I is isoelectric and aVF is negative, the axis is -90 degrees
  - If I is positive and aVF is isoelectric, the axis is 0 degrees
  - If I is negative and aVF is isoelectric, the axis is 180 degrees
  - If both I and aVF are isoelectric, the axis is indeterminate!

Measuring the Axis - 1

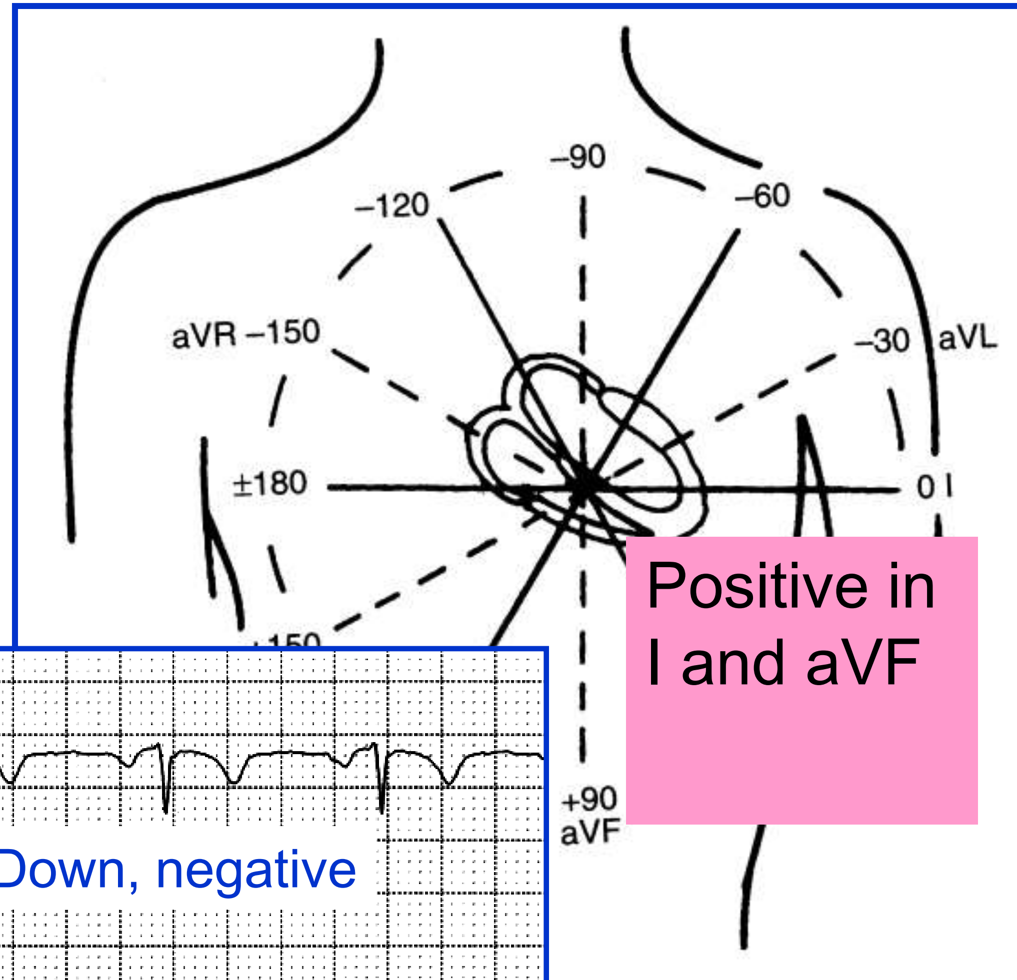
- Assess leads I and aVF, perpendicular leads
- Determine the quadrant from these
  - Usually both I and aVF are positive, or upgoing, and the quadrant is left lower quadrant
  - If I is positive and aVF is negative, the quadrant is left upper
  - If I is negative and aVF is positive, the quadrant is right lower



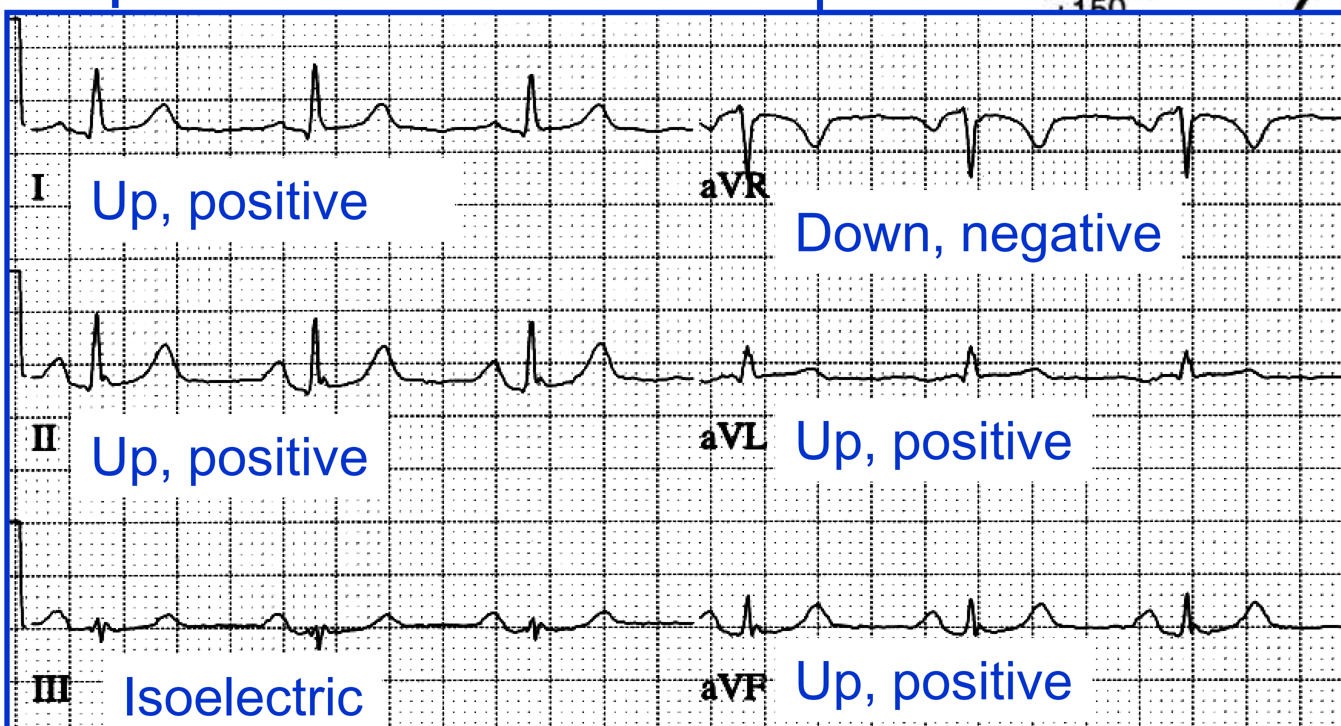
Remember: Positive = upward deflection!

Measuring the Axis - 1

- Assess leads I and aVF, perpendicular leads
- Determine the quadrant from these



Positive in I and aVF



Up, positive

Down, negative

Up, positive

Up, positive

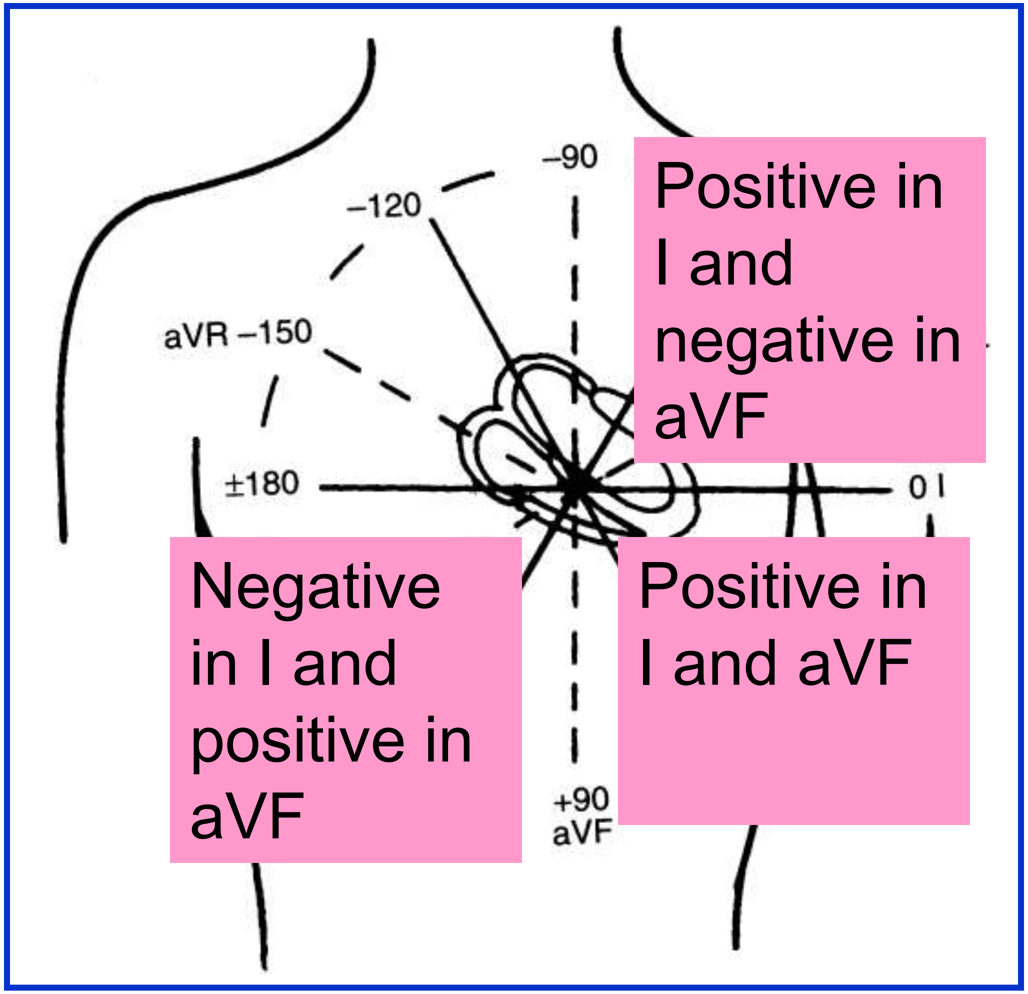
Isoelectric

Up, positive

Remember: Positive = upward deflection!

Measuring the Axis - 1

- Assess leads I and aVF, perpendicular leads
- Determine the quadrant from these
  - Usually both I and aVF are positive, or upgoing, and the quadrant is left lower quadrant
  - If I is positive and aVF is negative, the quadrant is left upper
  - If I is negative and aVF is positive, the quadrant is right lower



Remember: Positive = upward deflection!

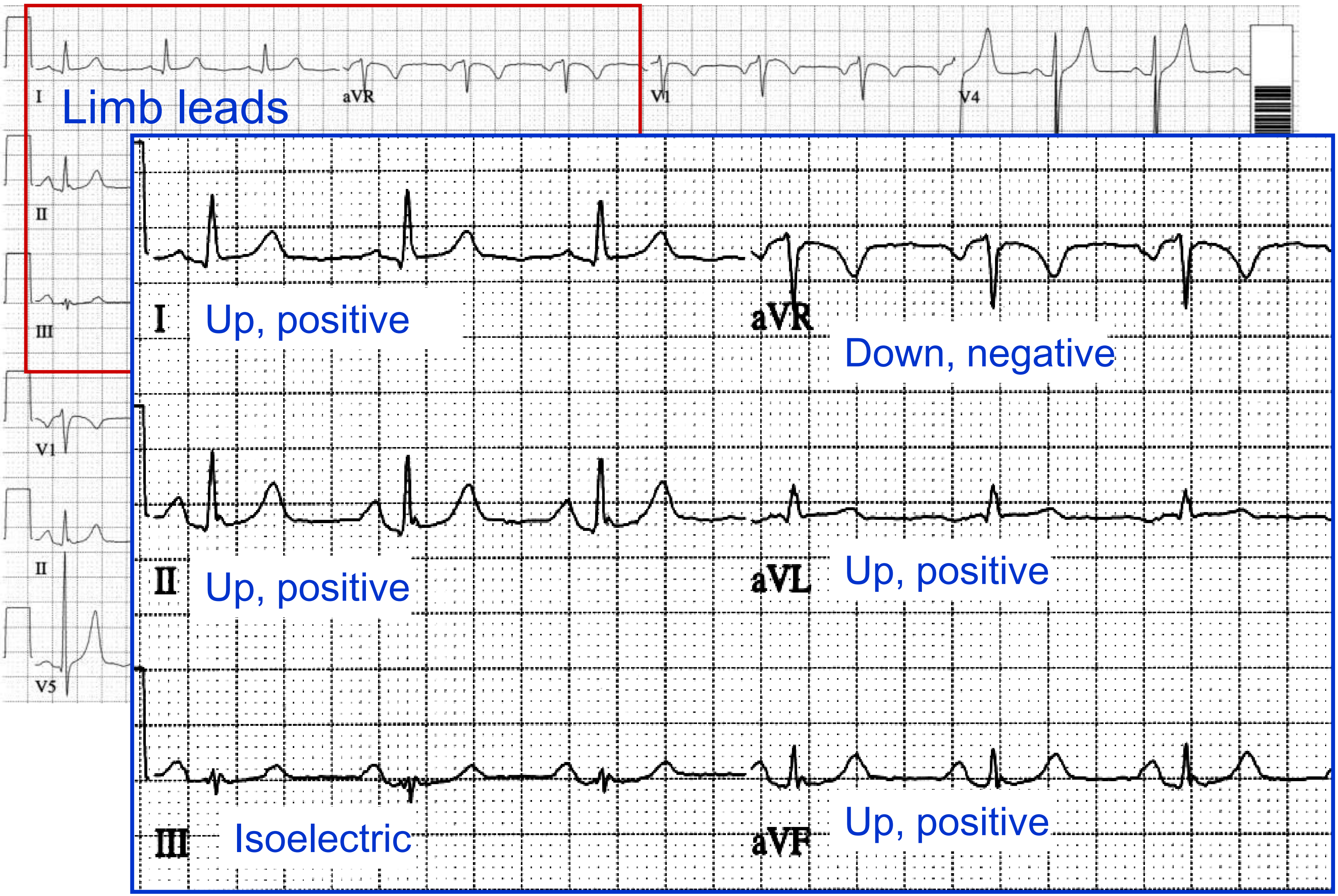
Measuring the Axis - 2

- After determining the quadrant, seek an isoelectric lead (positive and negative deflections are equal in magnitude)
- Recall that the <u>axis will be perpendicular to an isoelectric lead</u>, so find which of the 2 perpendiculars to the isoelectric lead is in the correct quadrant determined before from I and aVF. Then you have succeeded.

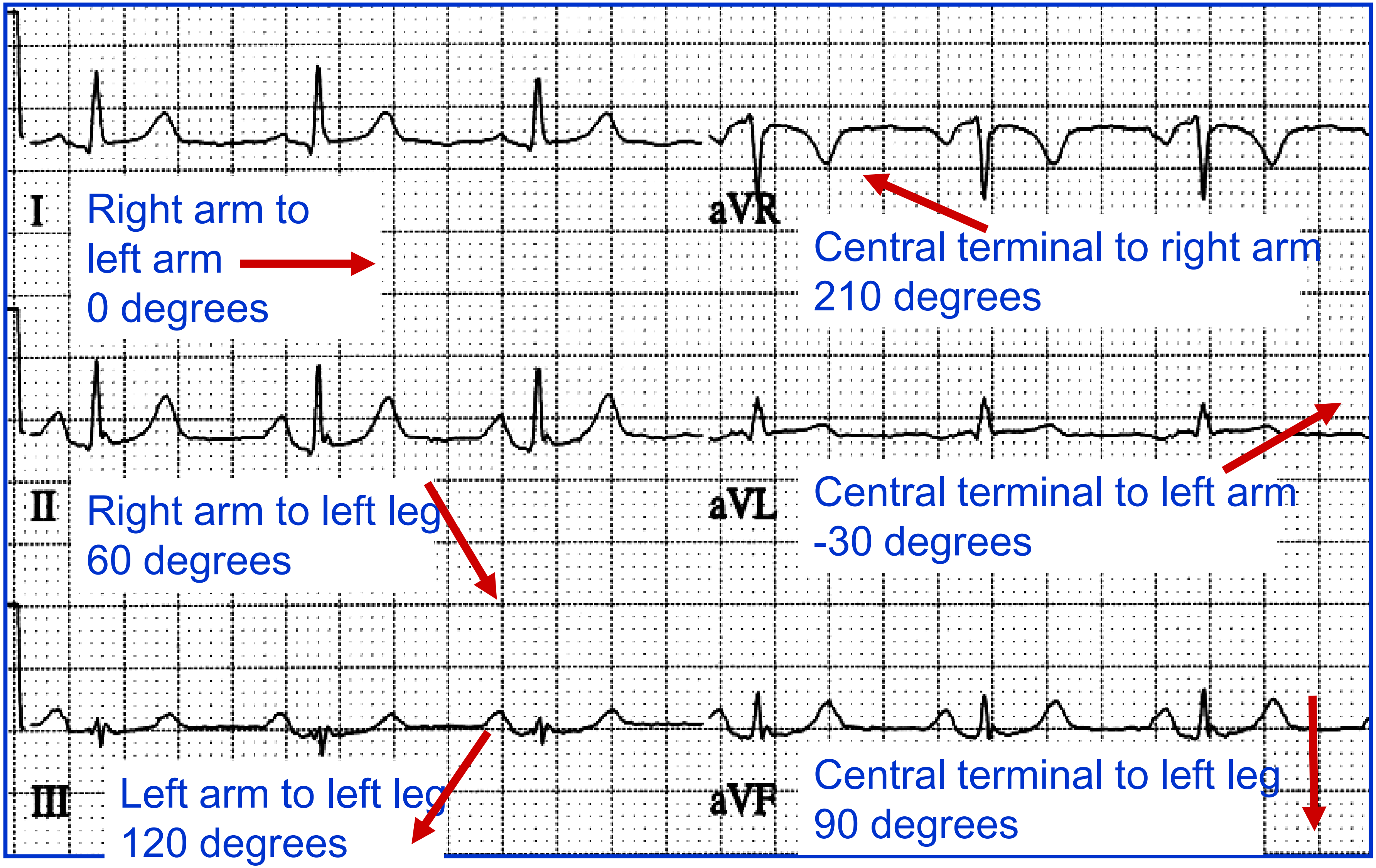
Measuring the Axis - 3

- If there is no isoelectric lead, find the 2 leads with the smallest deflections (closest to isoelectric)
- The axis will be between the perpendiculars of those 2 leads
- Once again be sure the perpendiculars are in the proper quadrant determined by I and aVF. Then you have succeeded.

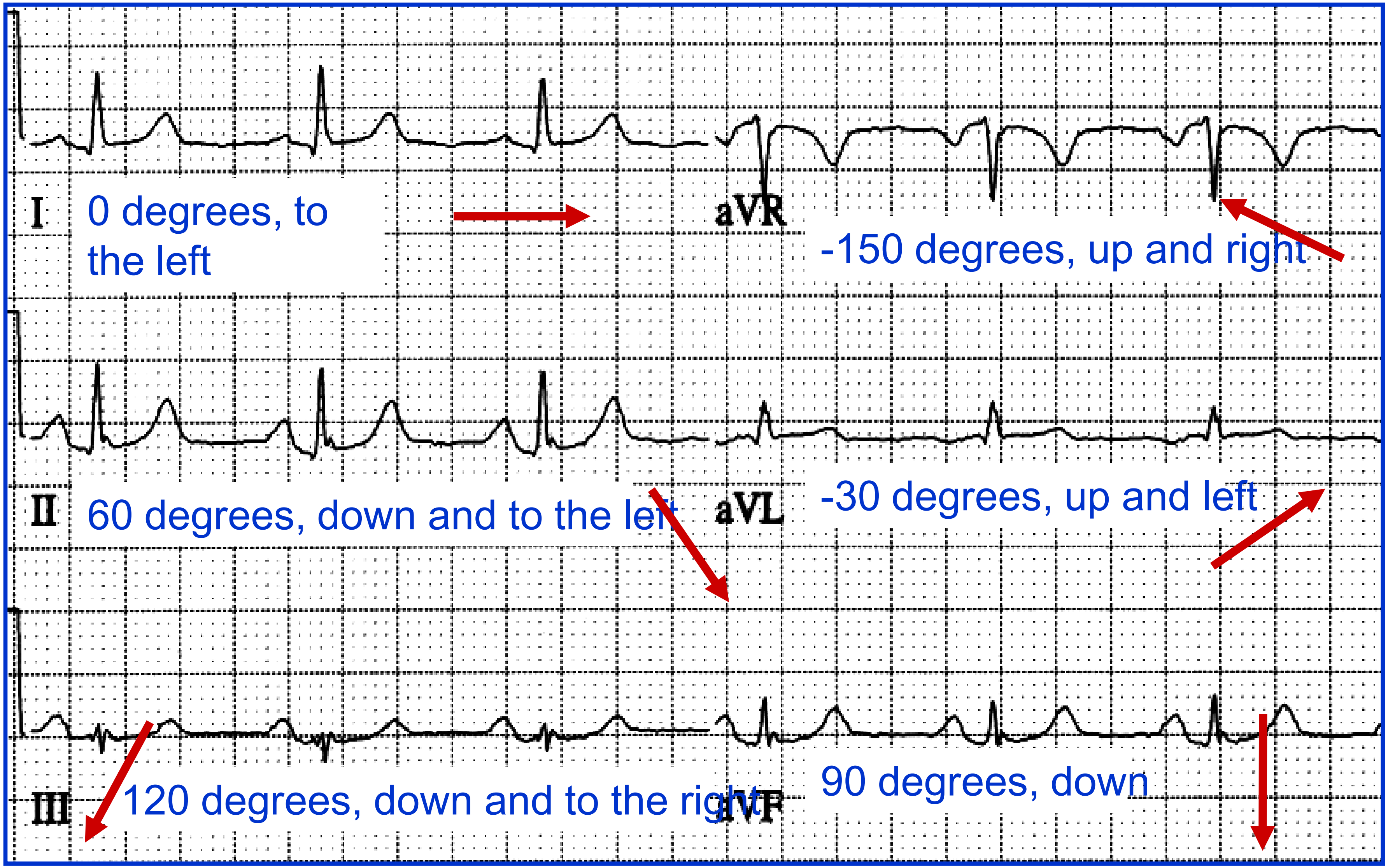
Measuring the QRS Axis



Limb Lead Information

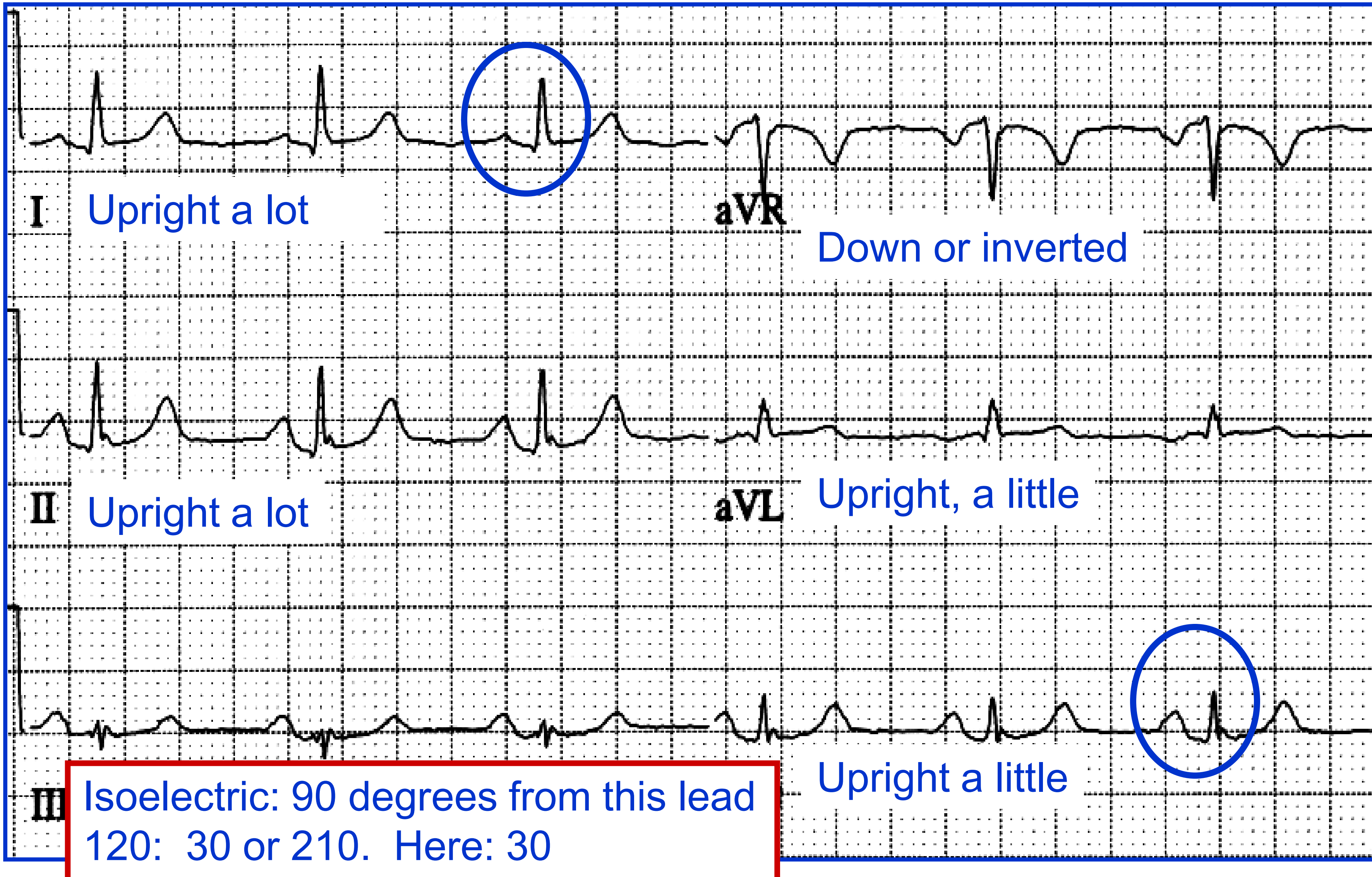


Measuring the QRS Axis



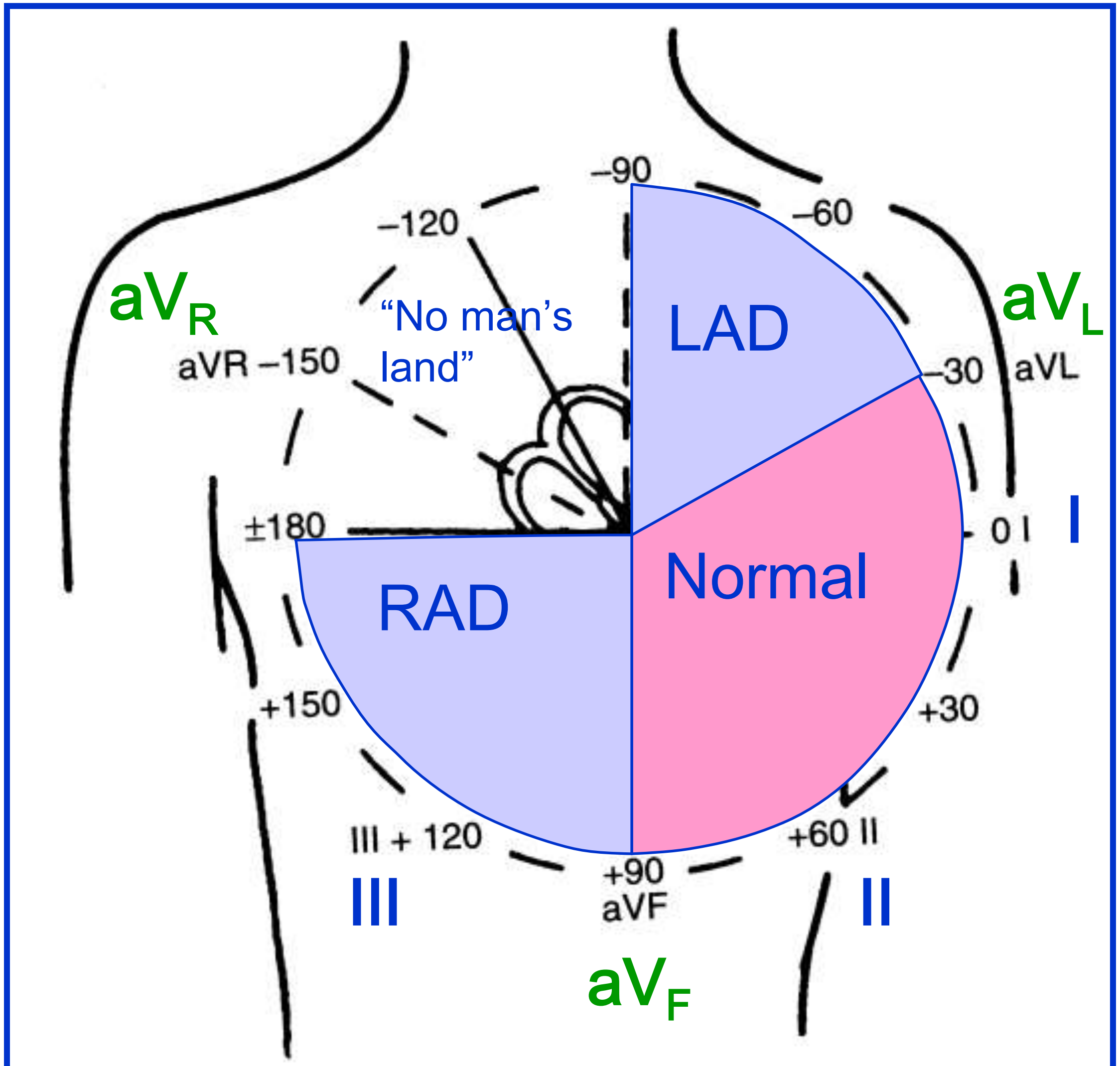
Measuring the QRS Axis

Upright in 1 and F = left lower quadrant, between 0 and 90 degrees



Examples of calculating QRS axis

The Frontal Plane Axis



Process in Determining QRS Axis in Frontal Plane

- Step 1: Look at lead I. If it is positive, look at lead II. If it is negative, look at lead aVF.
- Step 2: If it is positive in lead I and positive in II, the axis is normal.
- Step 3: If it is positive in lead I and negative in lead II, there is left axis deviation
- Step 4: If it is negative in lead I and positive in lead aVF, there is right axis deviation.
- Step 5: If it is negative in lead I and negative in lead aVF, there is a northwest axis ("no-mans land")

The Frontal Plane Axis

Diagnosis	Axis (degrees)	Lead projections
Normal	-30 to 90	Up in I and II
Left Axis Deviation	-90 to -30	Up in I, down in II
Right Axis Deviation	90 to 180	Down in I, up in aVF
Northwest Axis	180 to 270	Down in I, down in aVF

55 yr
M

Example 1

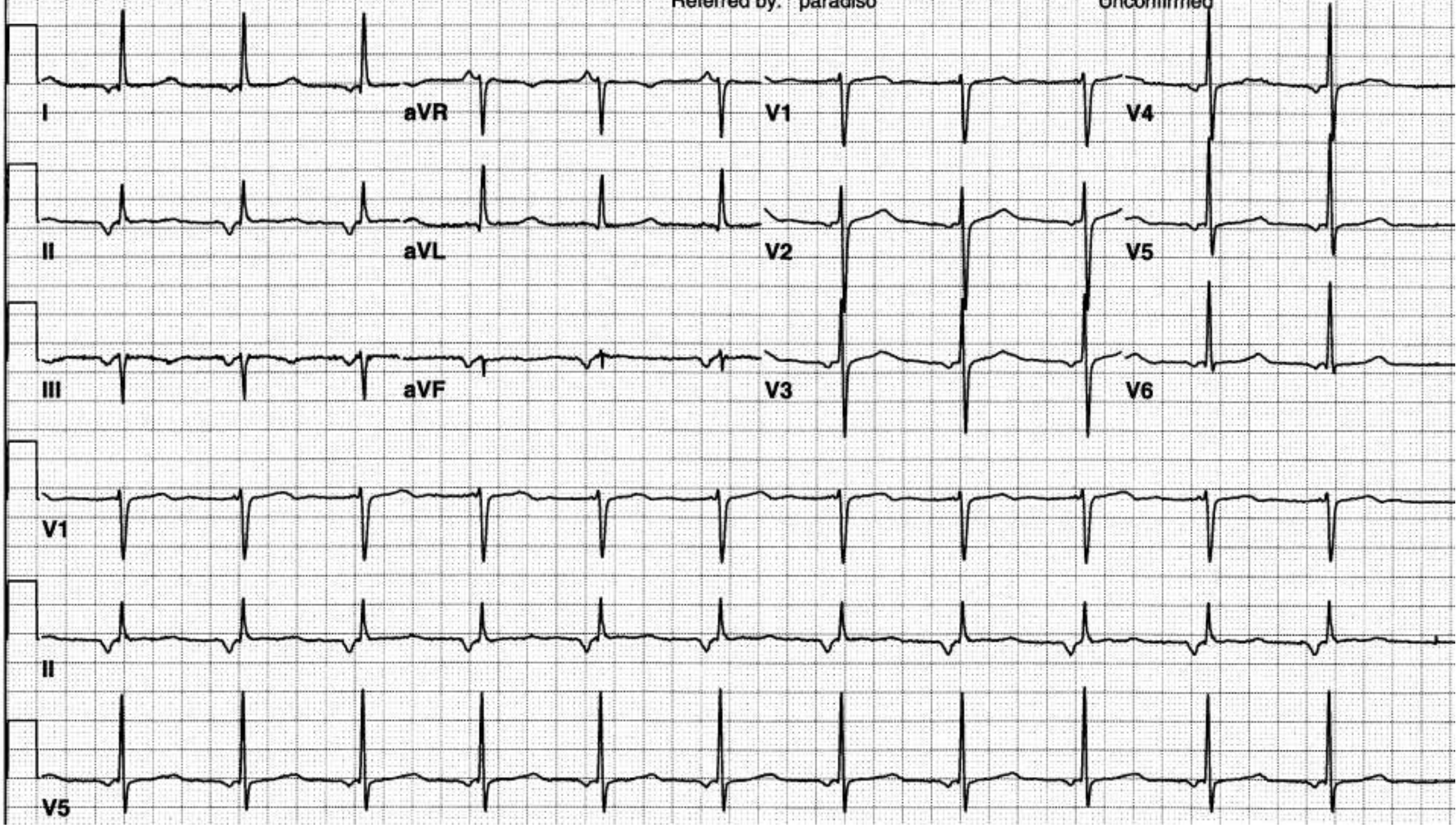
Vent. rate	71	BPM
PR interval	144	ms
QRS duration	86	ms
QT/QTc	456/495	ms
P-R-T axes	-103 -3	-15

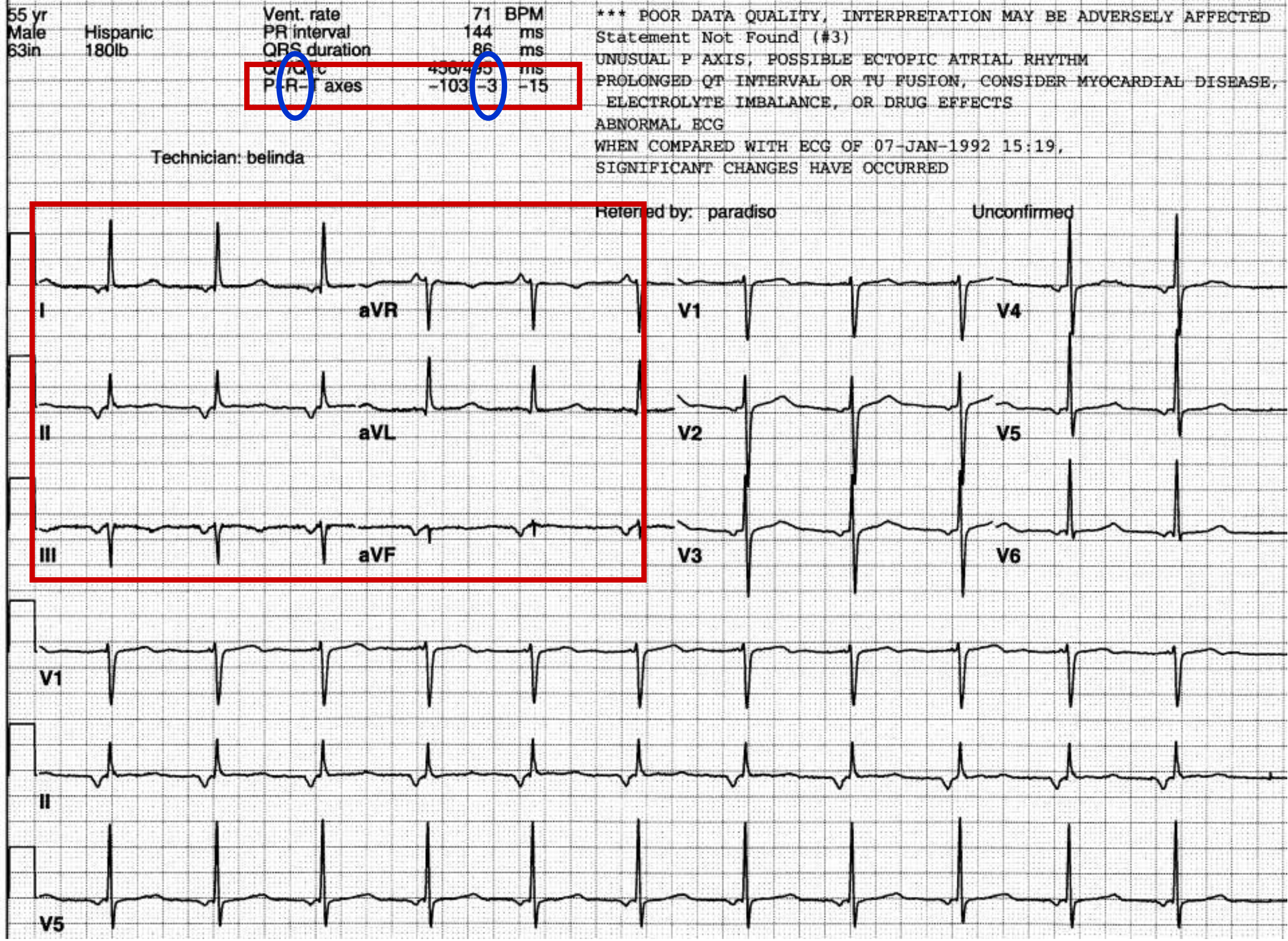
Technician: belinda

*** POOR DATA QUALITY, INTERPRETATION MAY BE ADVERSELY AFFECTED
Statement Not Found (#3)
UNUSUAL P AXIS, POSSIBLE ECTOPIC ATRIAL RHYTHM
PROLONGED QT INTERVAL OR TU FUSION, CONSIDER MYOCARDIAL DISEASE,
ELECTROLYTE IMBALANCE, OR DRUG EFFECTS
ABNORMAL ECG
WHEN COMPARED WITH ECG OF 07-JAN-1992 15:19,
SIGNIFICANT CHANGES HAVE OCCURRED

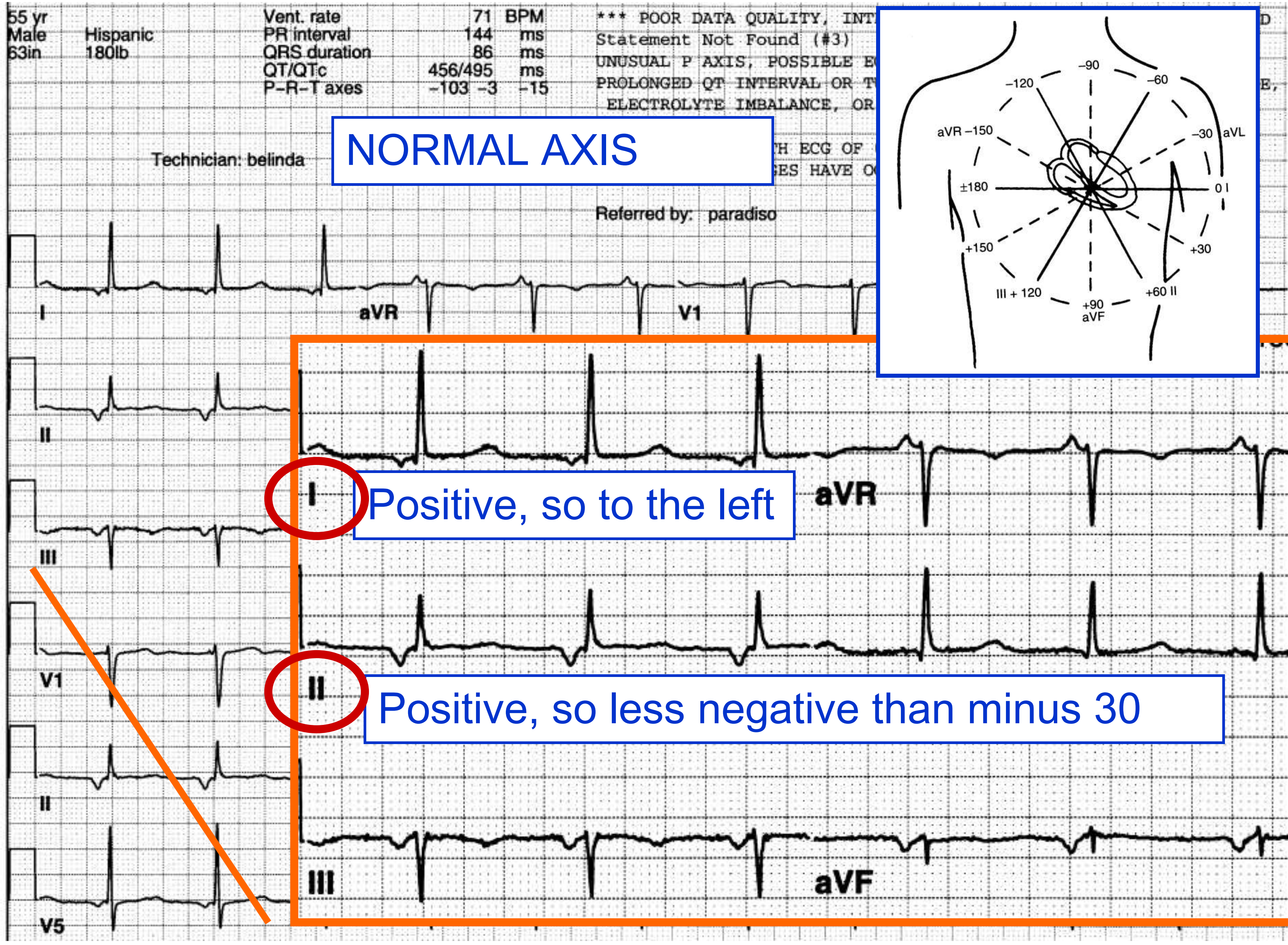
Referred by: paradiso

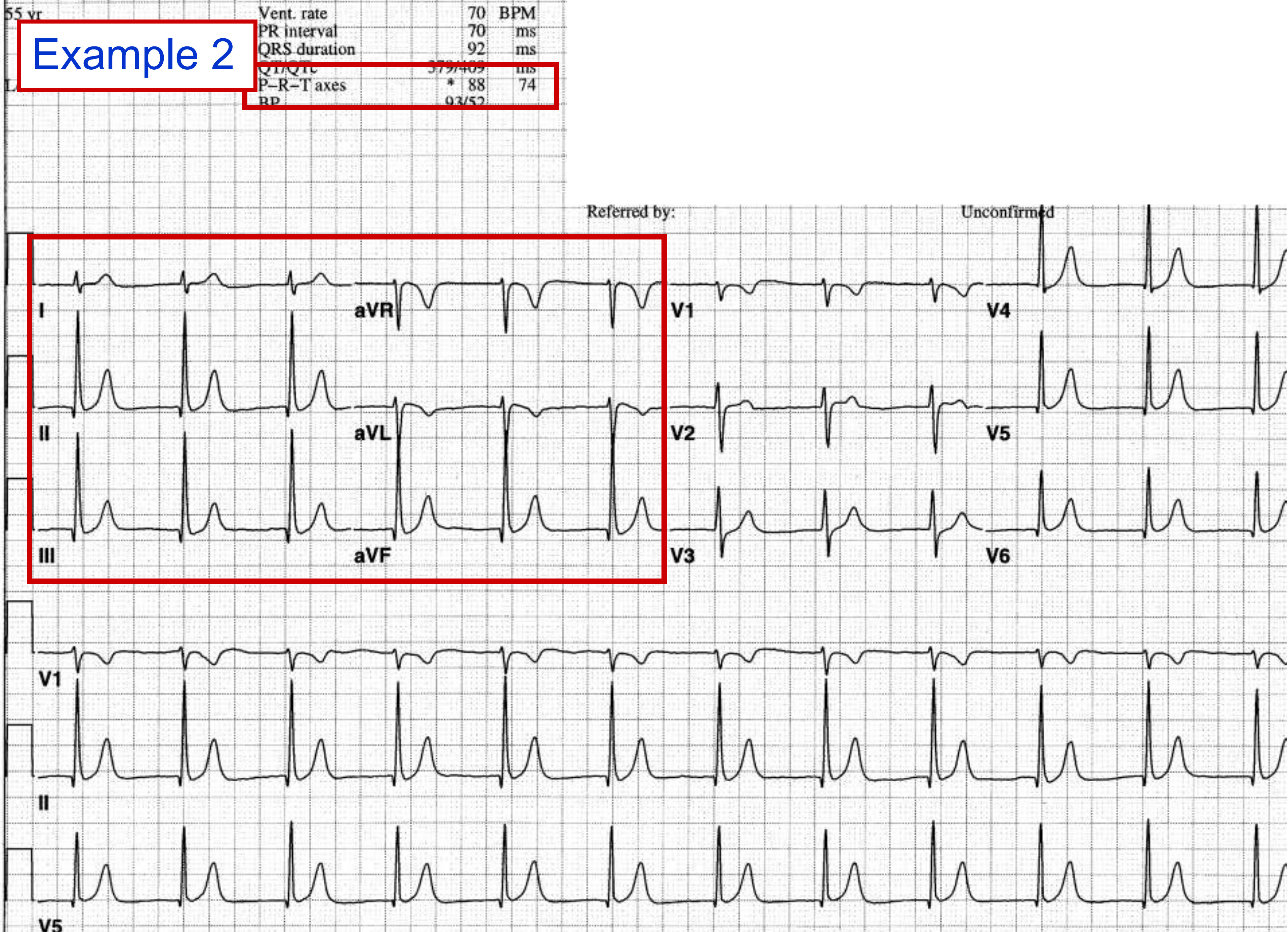
Unconfirmed



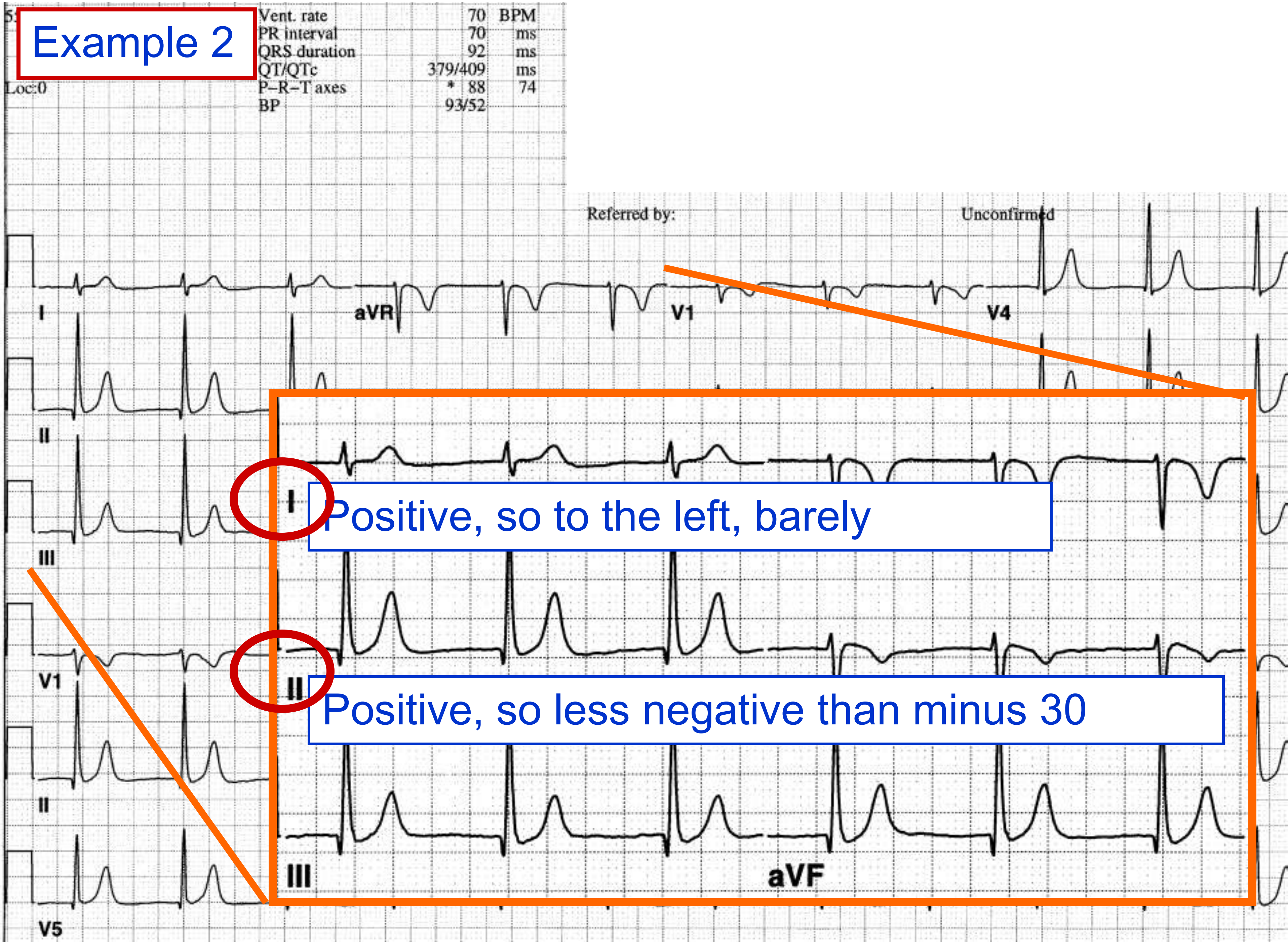

55 yr
Male Hispanic
63in 180lb
Vent. rate 71 BPM
PR interval 144 ms
QRS duration 86 ms
P-R-T axes -103 -3 -15
Technician: belinda
*** POOR DATA QUALITY, INTERPRETATION MAY BE ADVERSELY AFFECTED
Statement Not Found (#3)
UNUSUAL P AXIS, POSSIBLE ECTOPIC ATRIAL RHYTHM
PROLONGED QT INTERVAL OR TU FUSION, CONSIDER MYOCARDIAL DISEASE,
ELECTROLYTE IMBALANCE, OR DRUG EFFECTS
ABNORMAL ECG
WHEN COMPARED WITH ECG OF 07-JAN-1992 15:19,
SIGNIFICANT CHANGES HAVE OCCURRED
Referred by: paradiso
Unconfirmed
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

NORMAL AXIS


55 yr
Male
63in
Hispanic
180lb
Vent. rate 71 BPM
PR interval 144 ms
QRS duration 86 ms
QT/QTc 456/495 ms
P–R–T axes –103 –3 –15
Statement Not Found (#3)
Technician: belinda
Referred by: paradiso
I
aVR
V1
II
III
V5
Positive, so to the left
Positive, so less negative than minus 30
aVF
–90
–120
–60
aVR –150
–30 aVL
±180
0 I
+150
+30
III + 120
+90
aVF
+60 II

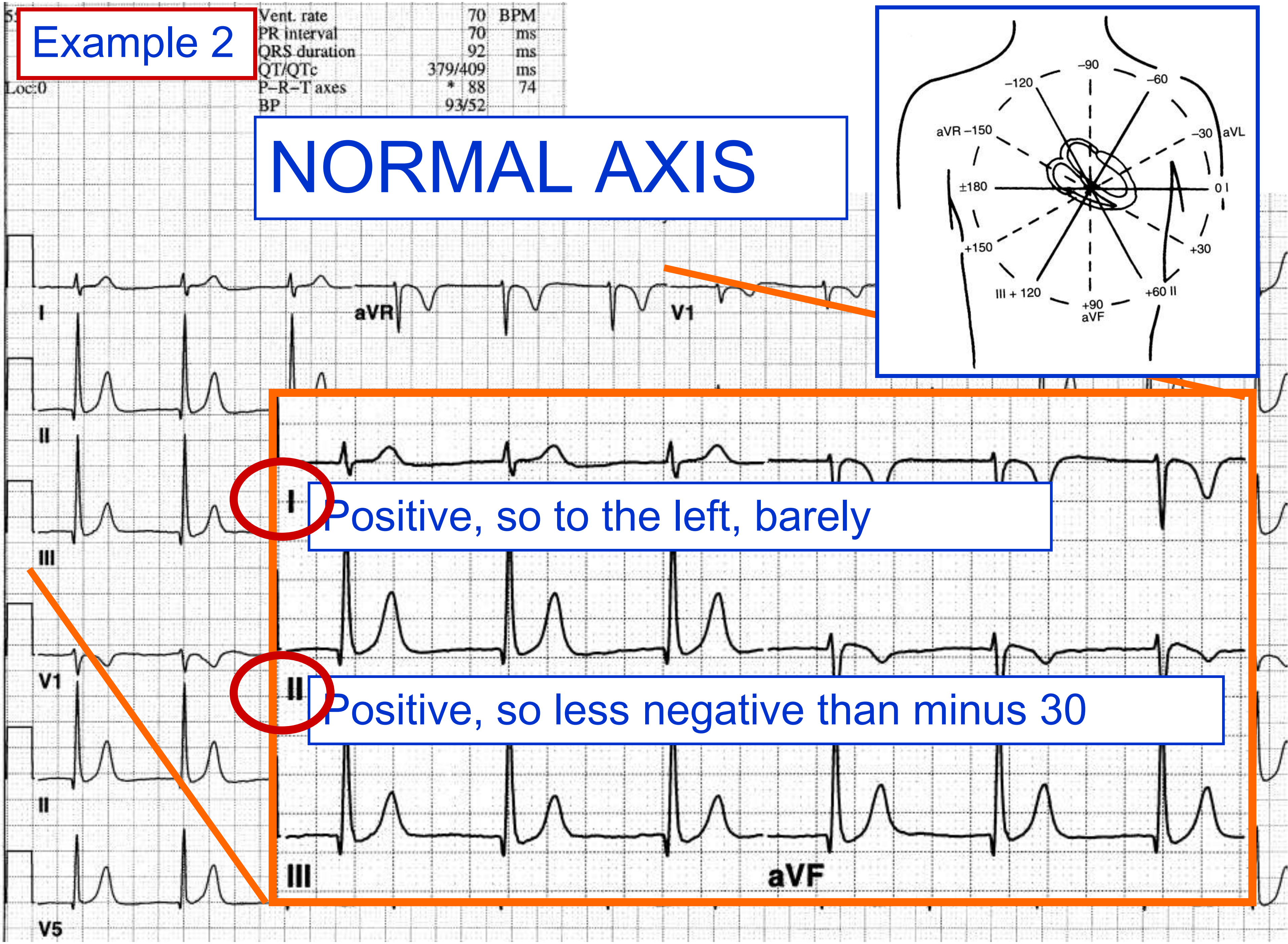


Example 2
55 yr
Vent. rate 70 BPM
PR interval 70 ms
QRS duration 92 ms
QT/QTc 379/409 ms
P–R–T axes * 88 74
BP 93/52
Referred by:
Unconfirmed
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5


Example 2
Vent. rate 70 BPM
PR interval 70 ms
QRS duration 92 ms
QT/QTc 379/409 ms
P–R–T axes * 88 74
BP 93/52
Loc:0
Referred by:
Unconfirmed
I
aVR
V1
V4
II
III
V1
II
V5
Positive, so to the left, barely
Positive, so less negative than minus 30
aVF

Example 2

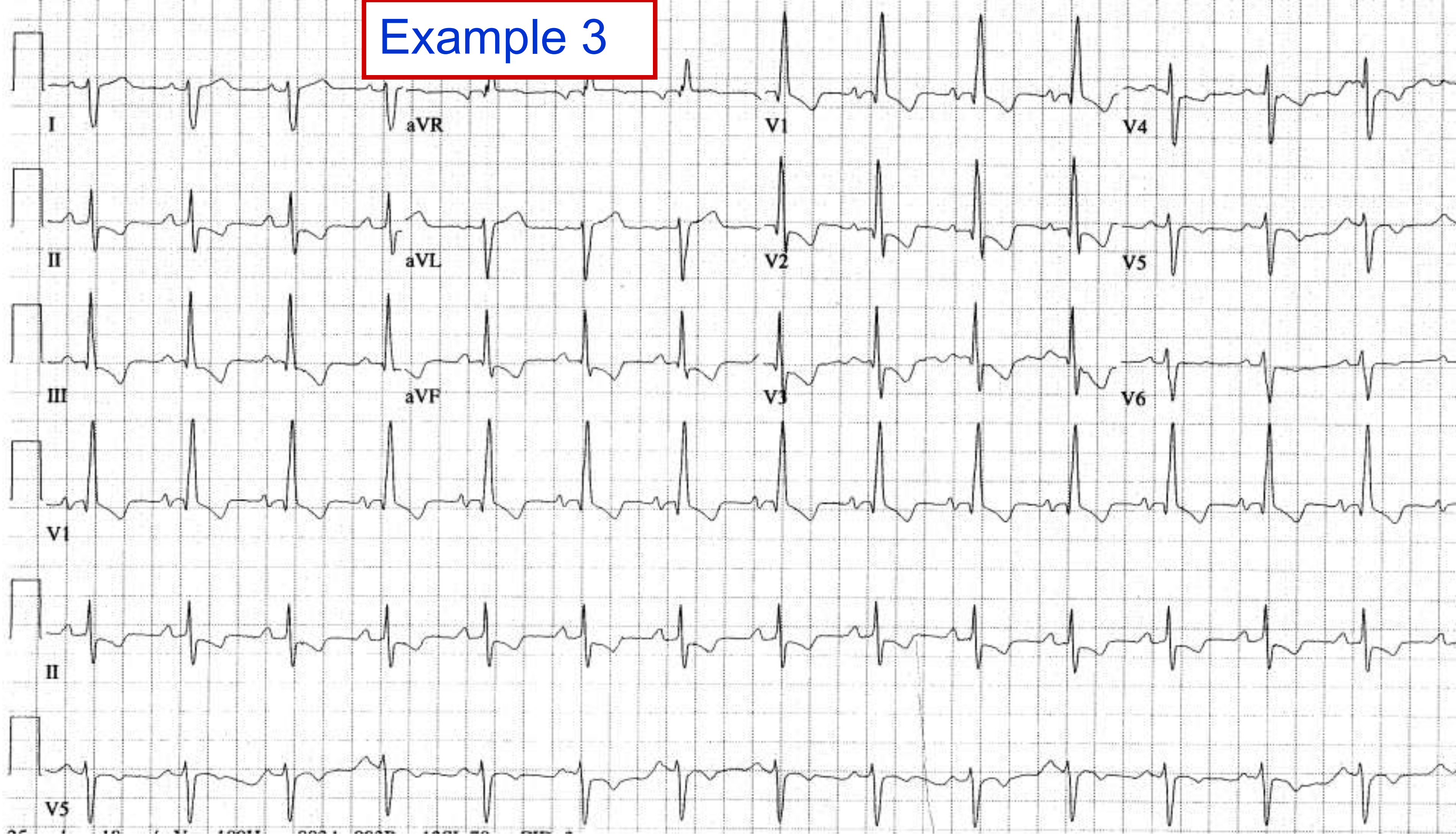
NORMAL AXIS



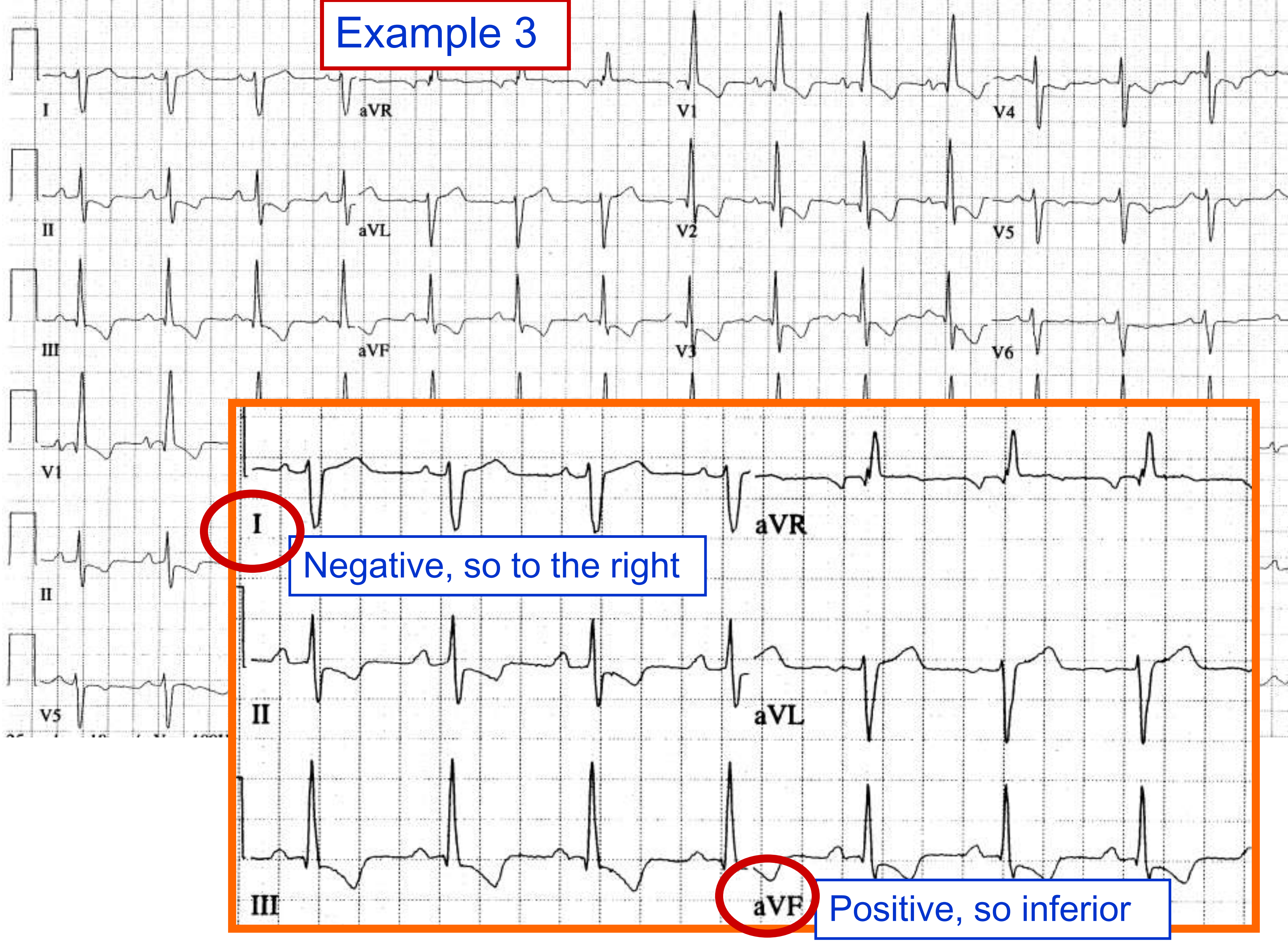
Positive, so to the left, barely

Positive, so less negative than minus 30

Example 3



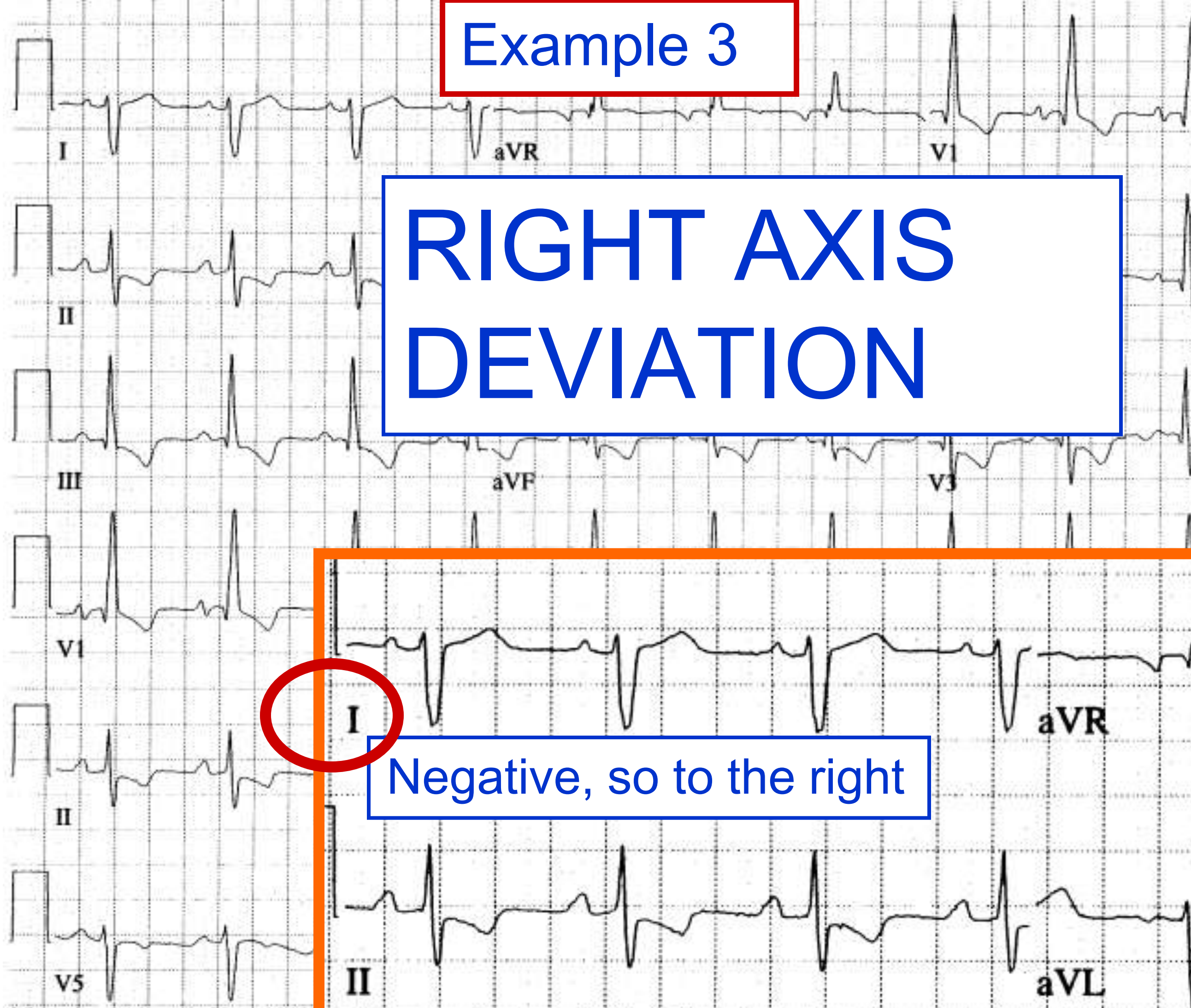
Example 3

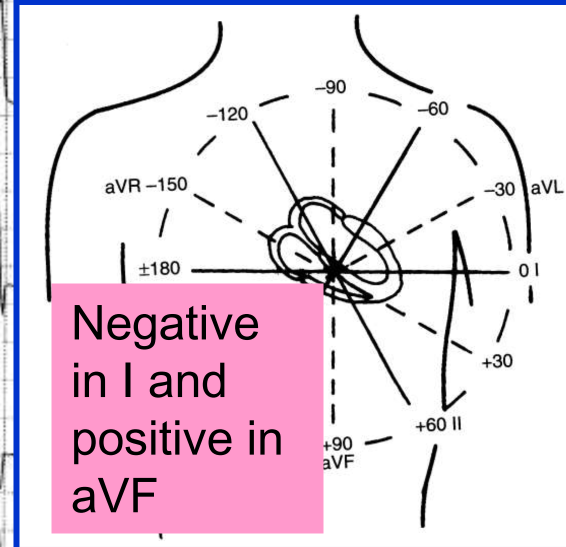


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5
I
aVR
Negative, so to the right
II
aVL
III
aVF
Positive, so inferior

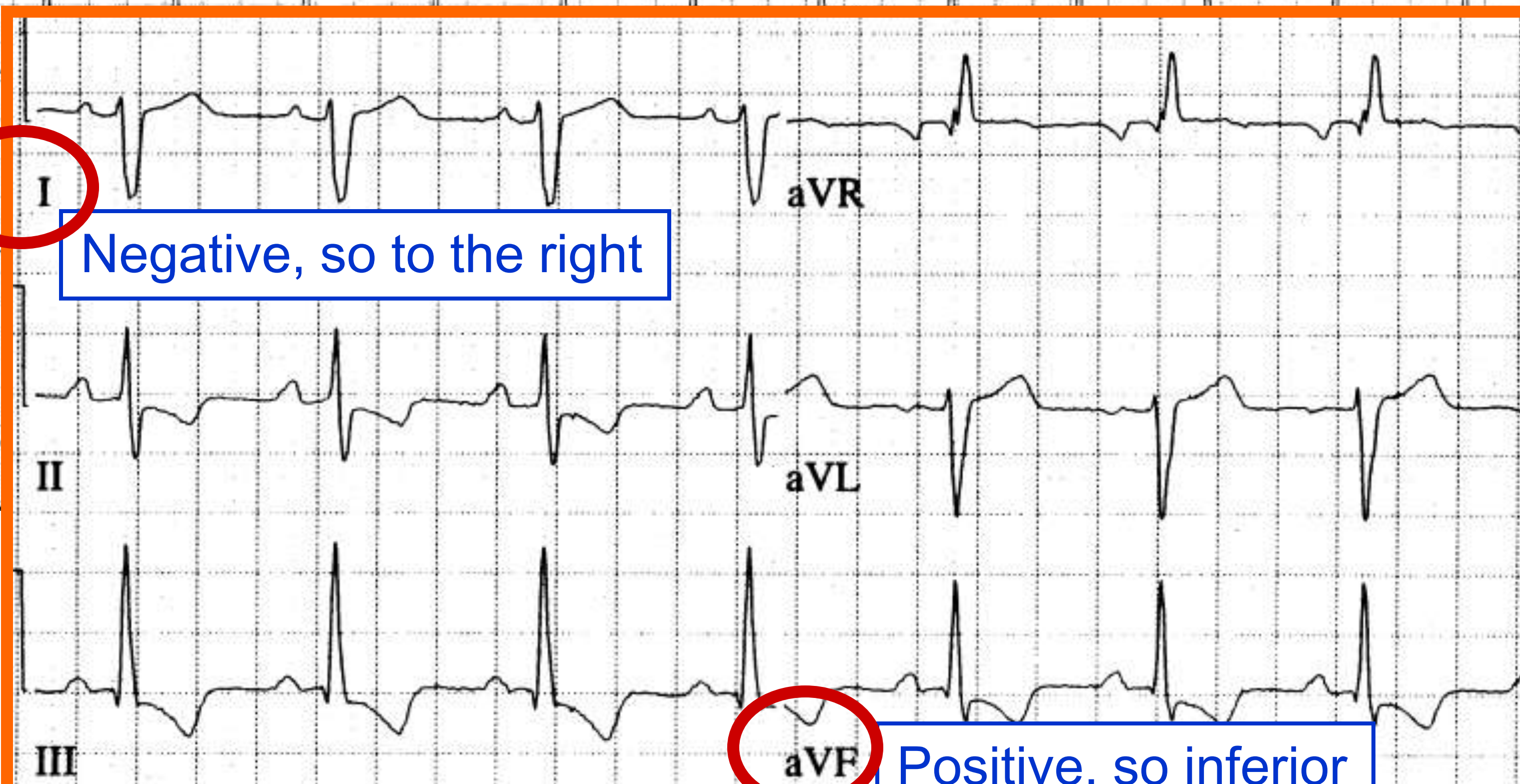
Example 3

RIGHT AXIS DEVIATION





Negative in I and positive in aVF

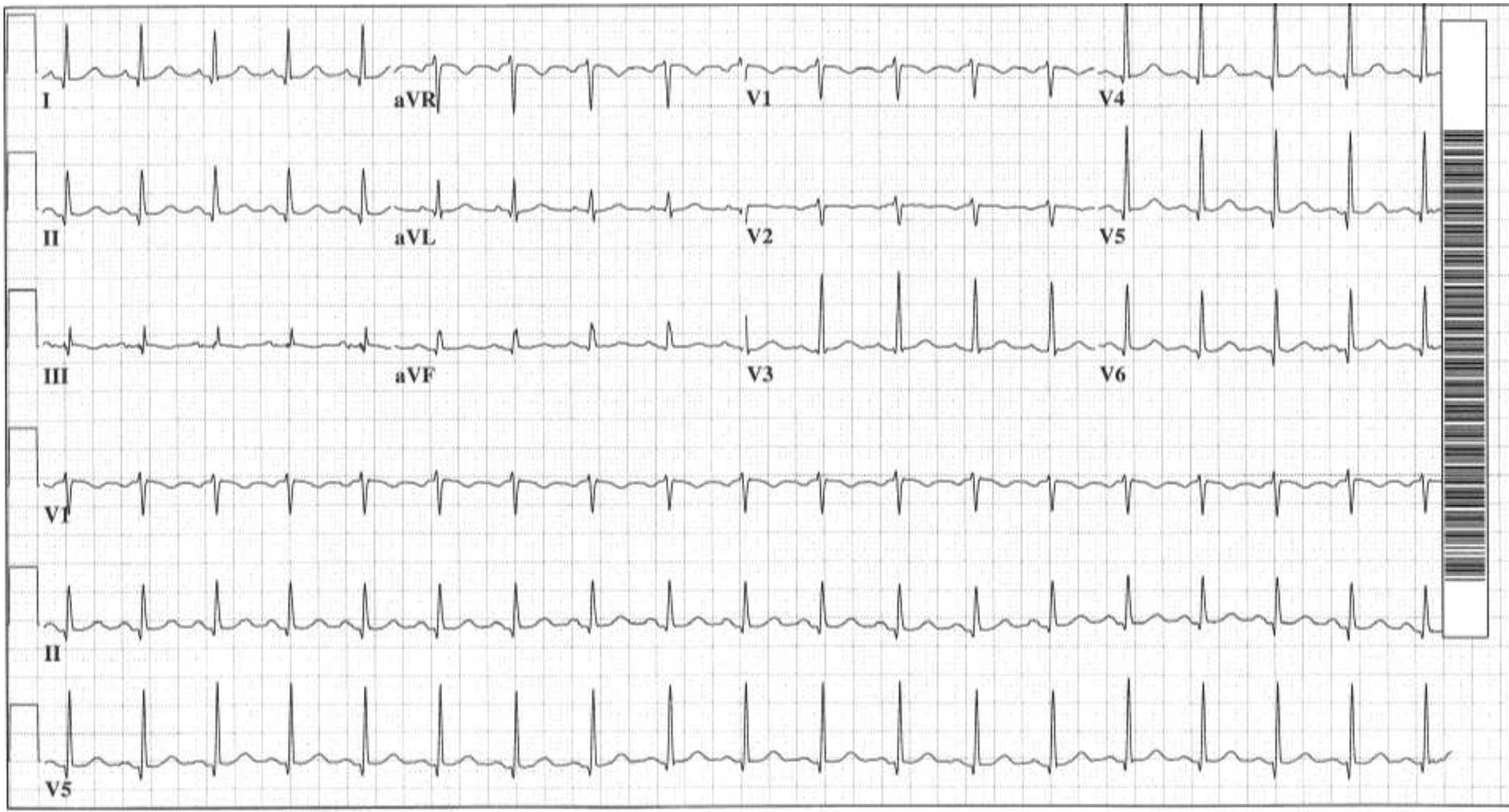


Negative, so to the right

Positive, so inferior

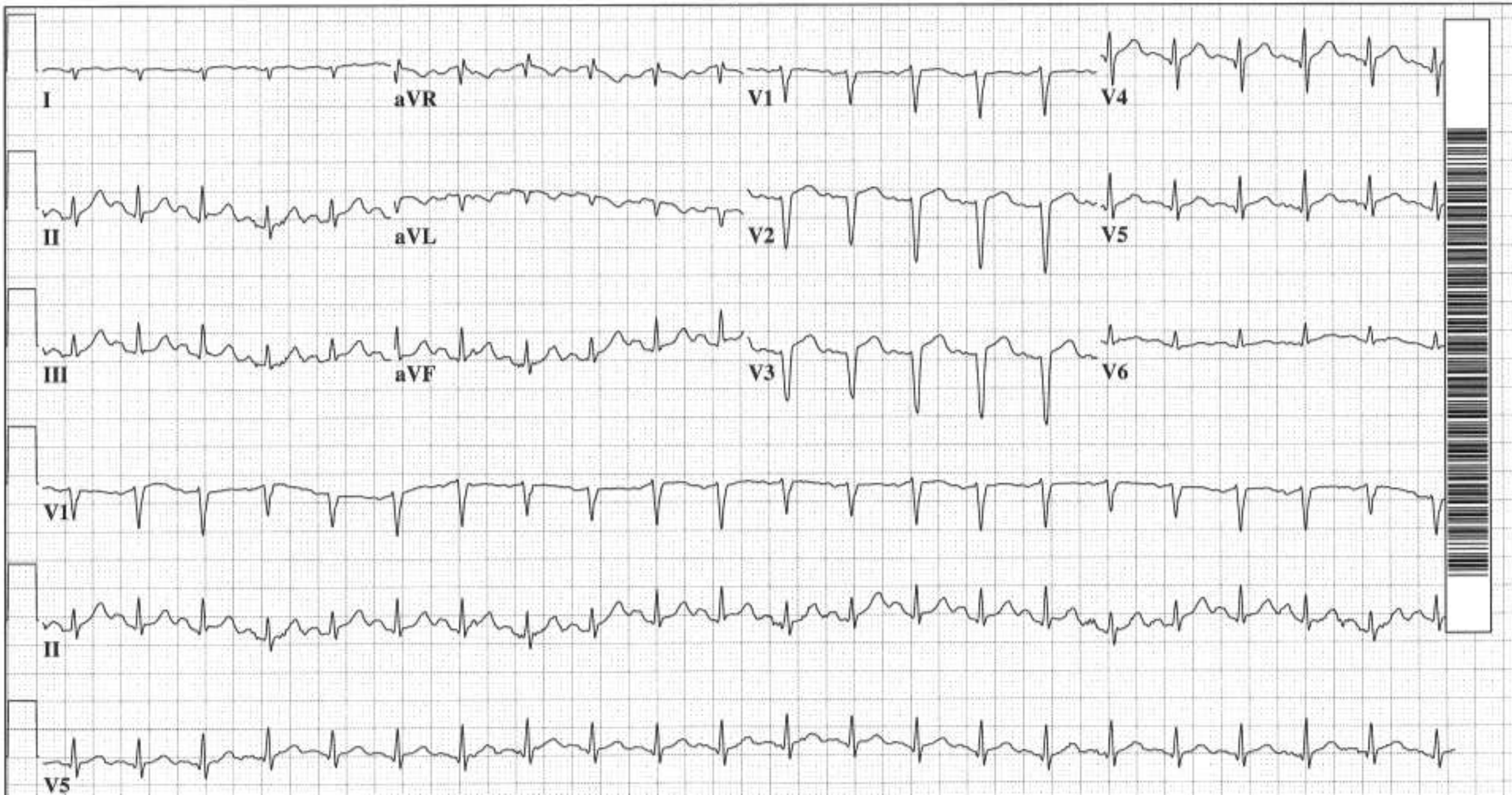
What is the QRS axis? - 1

45 degrees Normal Axis

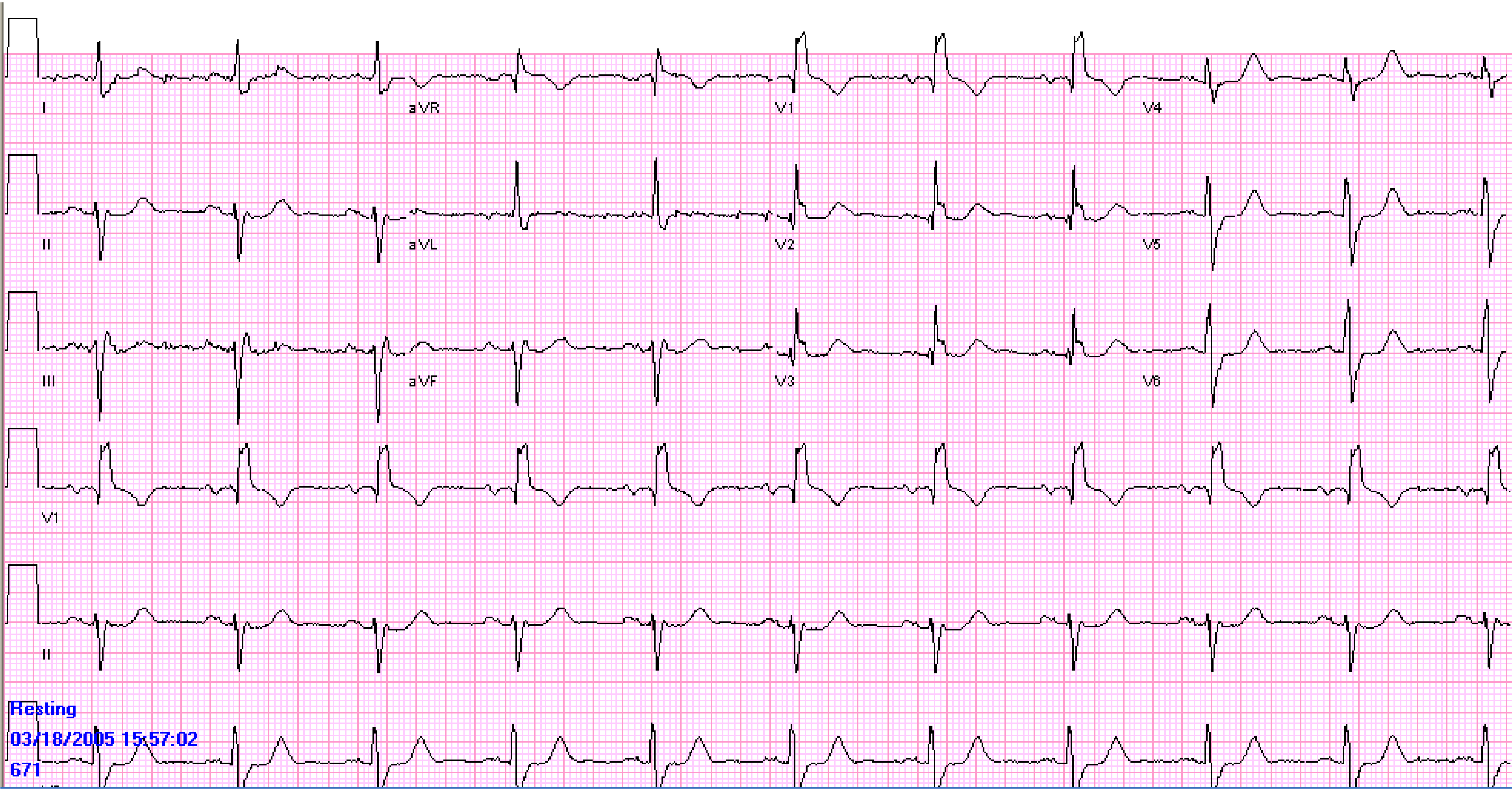


What is the QRS axis? - 2

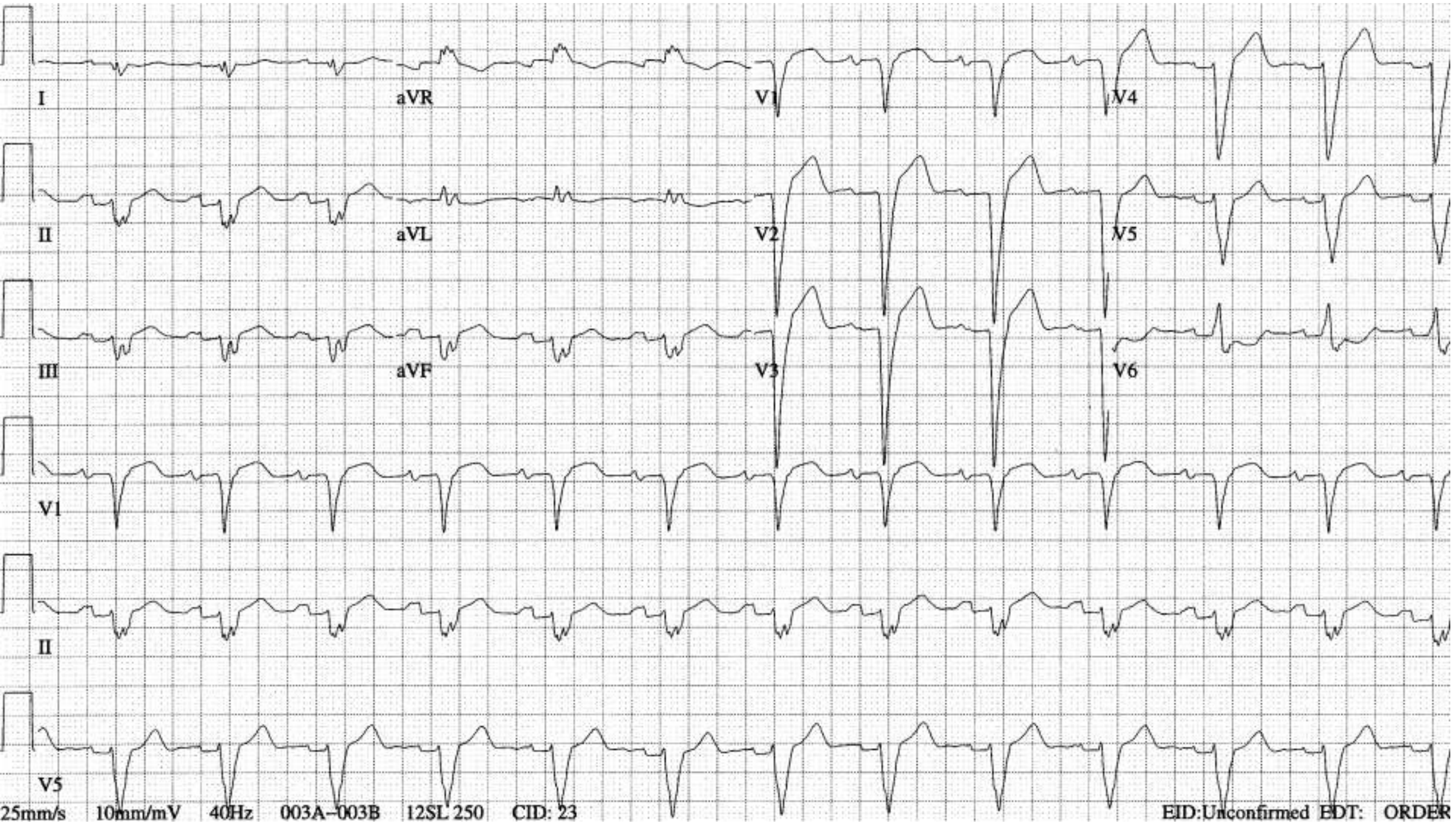
120 degrees – **Right Axis Deviation**



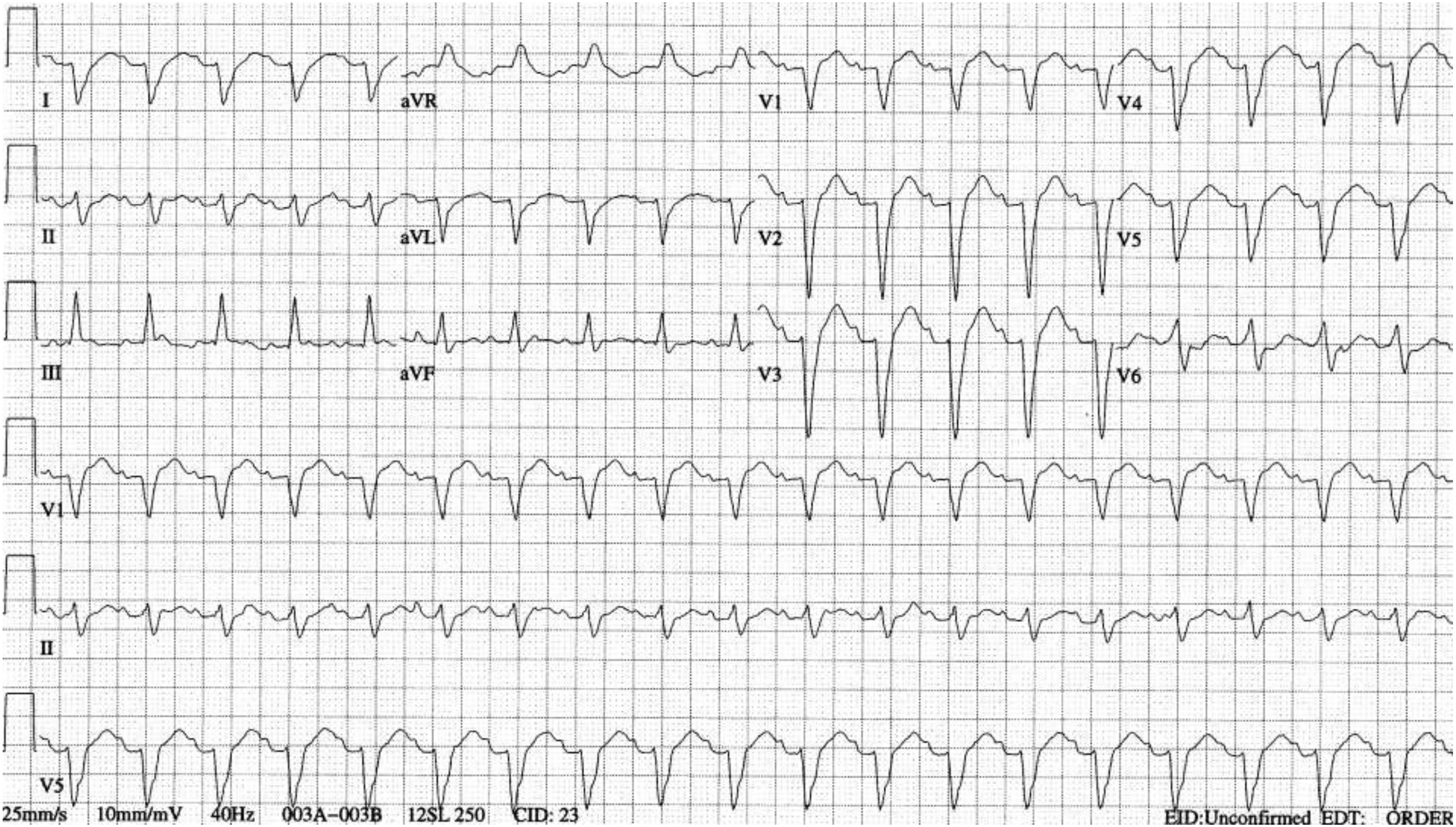
What is the QRS Axis? - 3



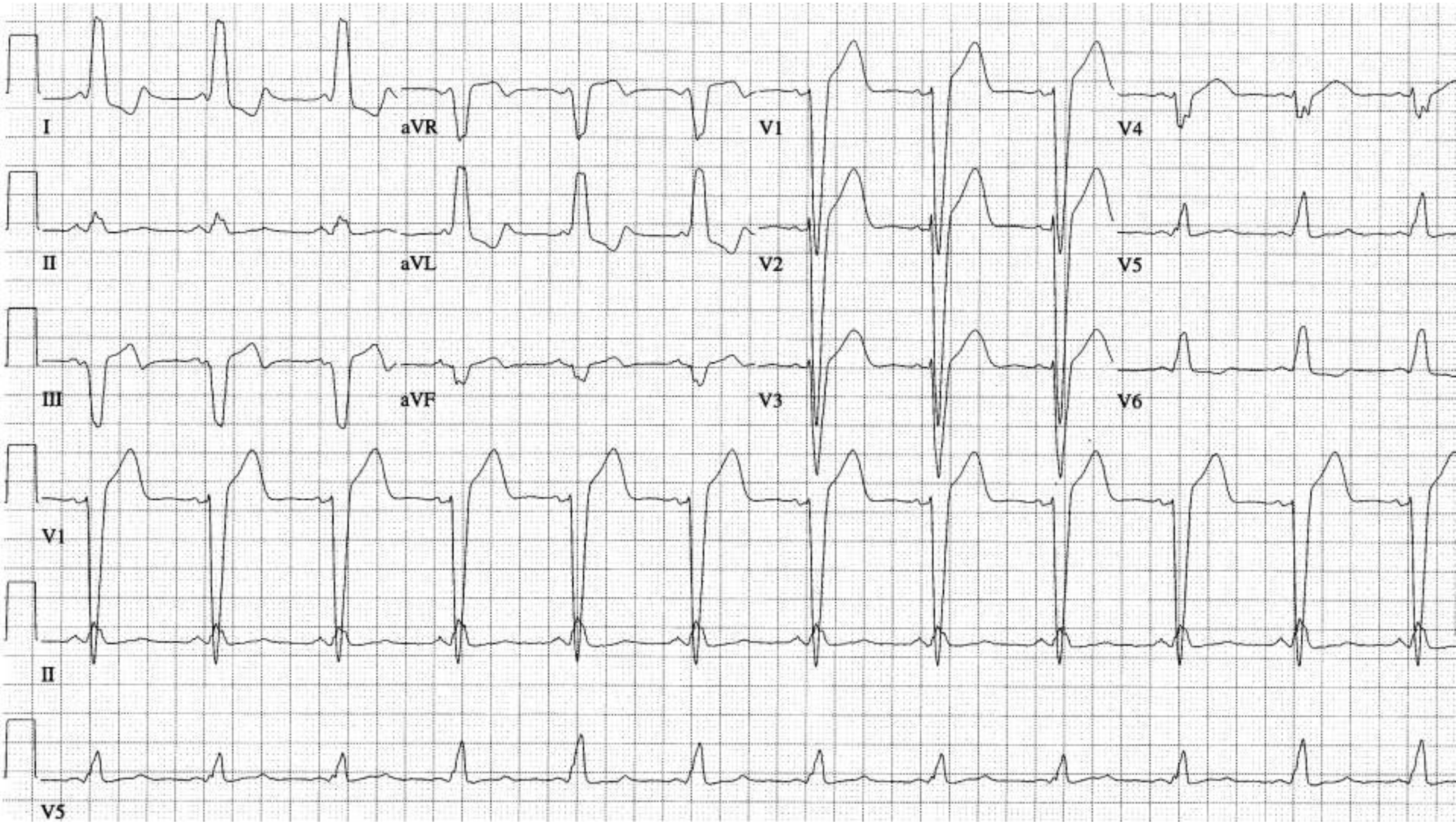
What is the QRS Axis? - 4



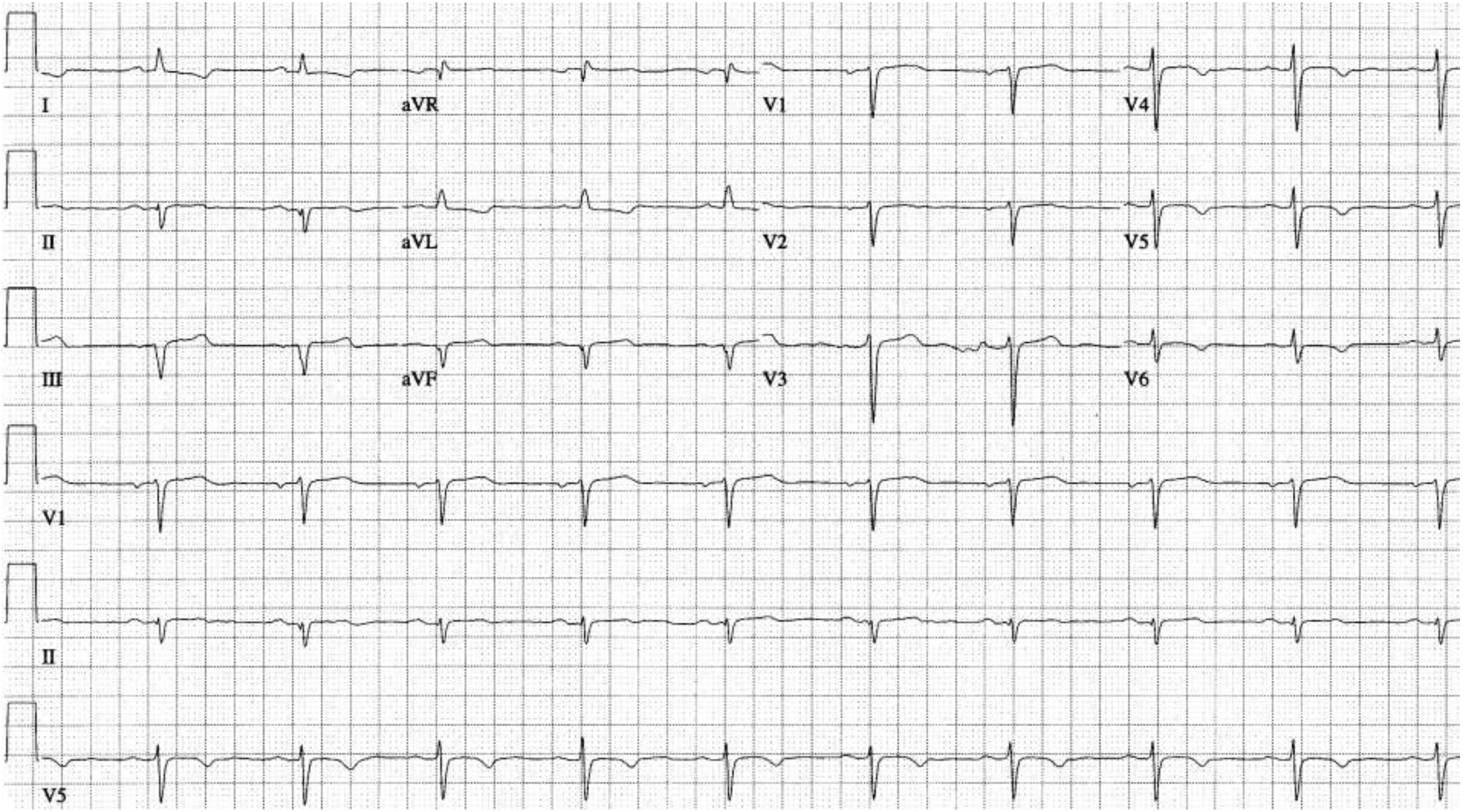
What is the QRS Axis? - 5



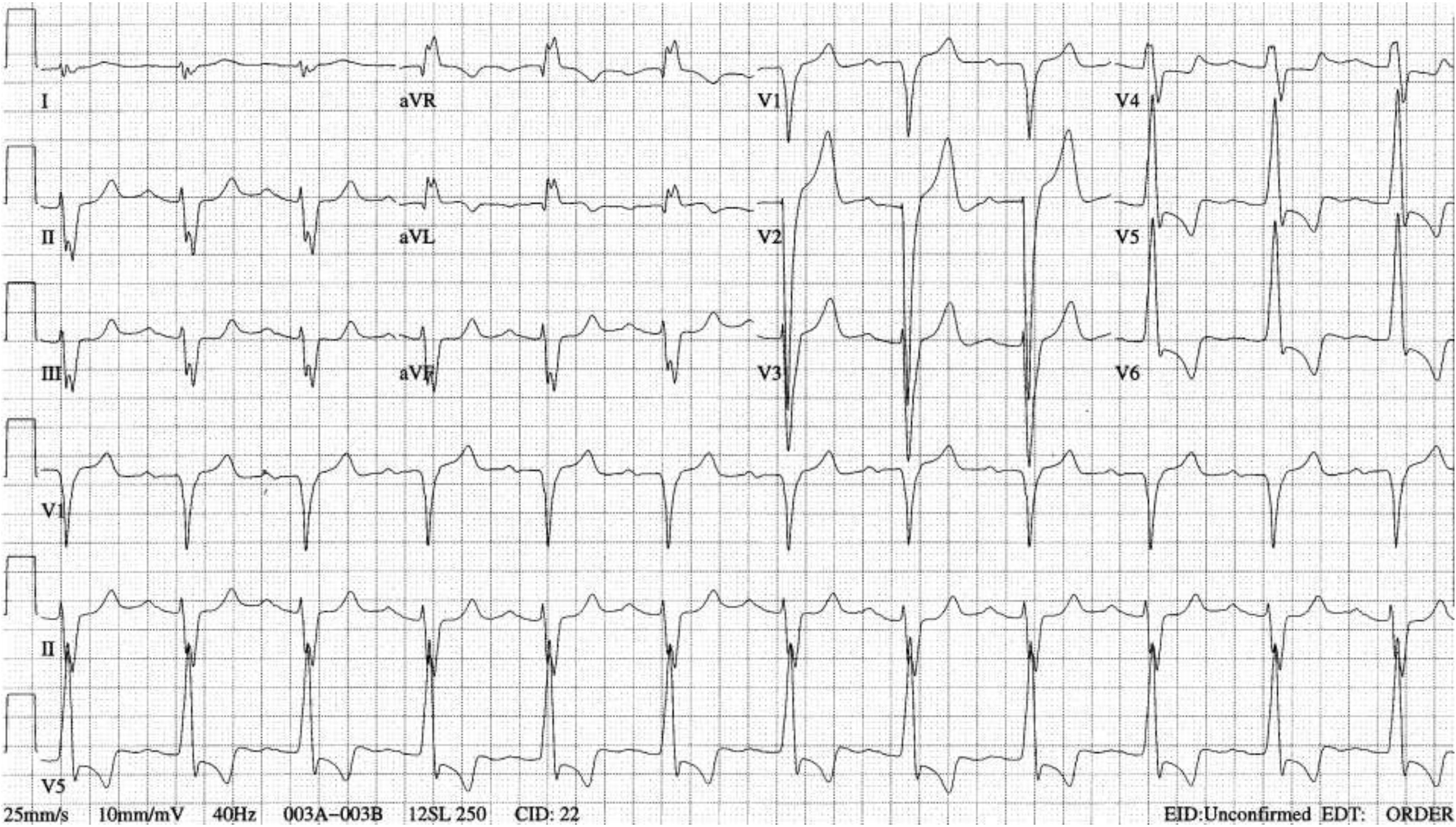
What is the QRS Axis? - 6



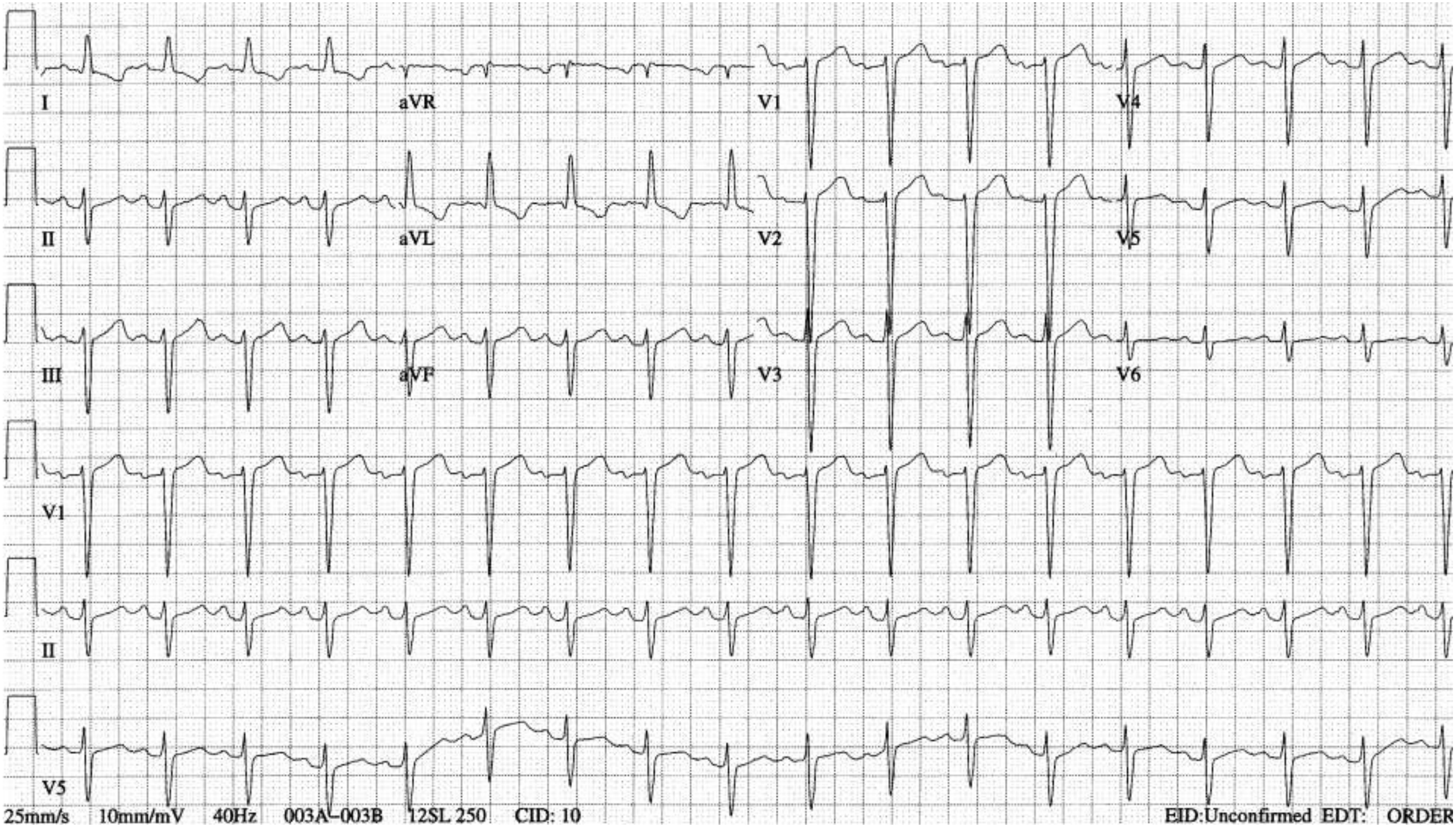
What is the QRS Axis? - 7



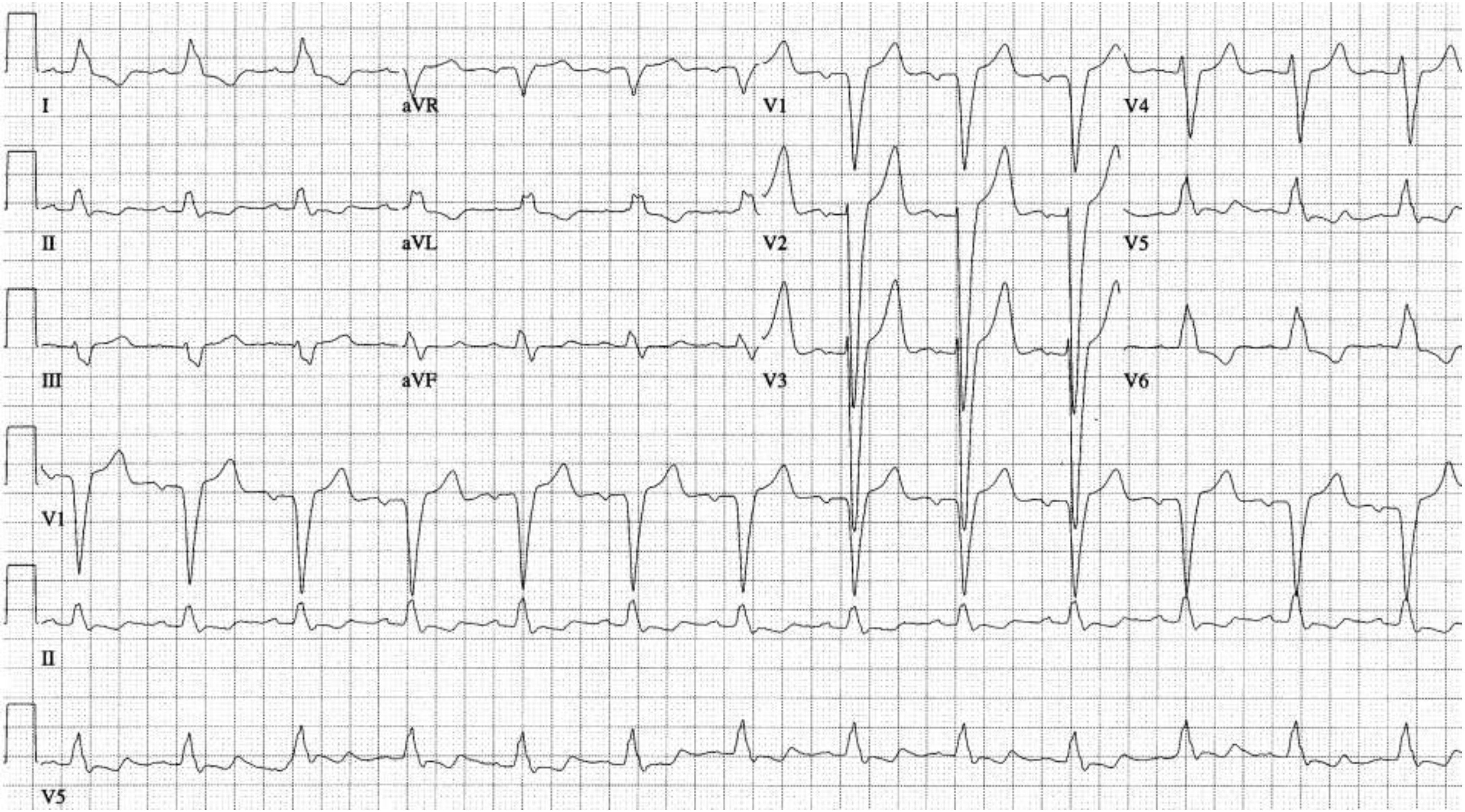
What is the QRS Axis? - 8



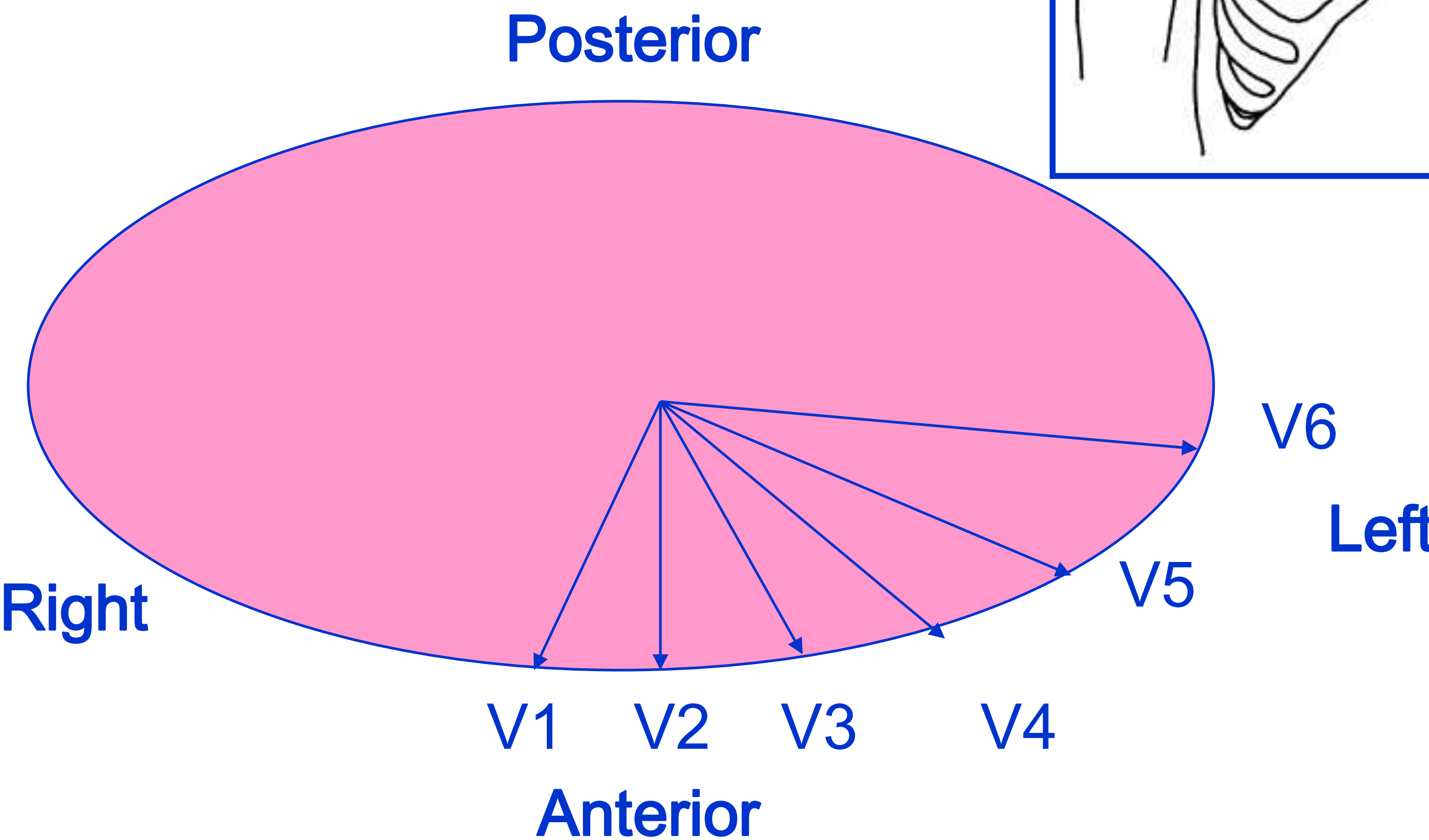
What is the QRS Axis? - 9

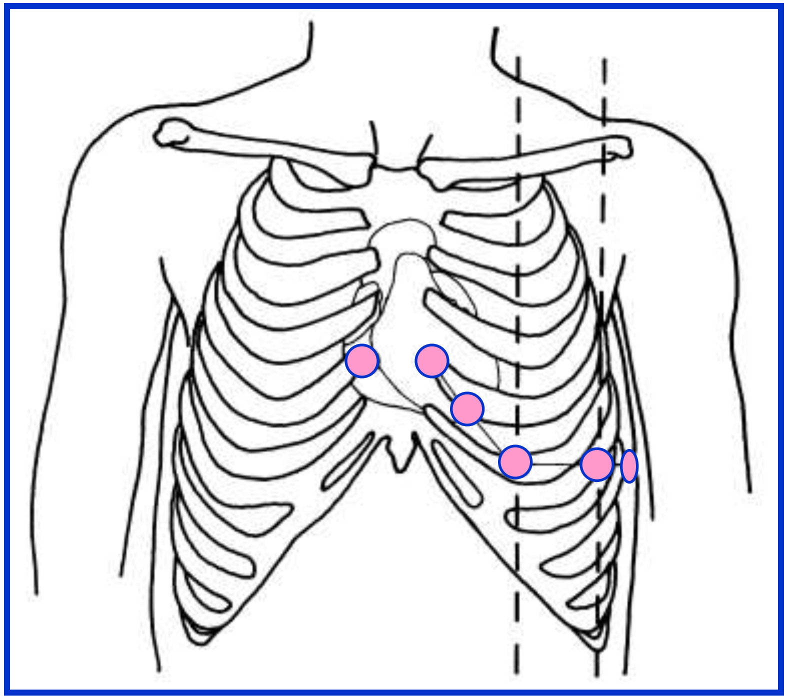


What is the QRS Axis? - 10



Transverse Plane





Outline

- Description of ECG recording page
- Review of pertinent cardiac physiology
- Identification of waves and intervals
- 3 methods for calculation of rate
- Calculation of QRS electrical axis
- **Steps in interpretation**
- Diagnosing normal and abnormal findings

Steps in Reading a 12-Lead ECG

1. Measure vital signs
2. Does it look normal?
   - Rate
   - Rhythm

Normal rhythm

- QRS width for conduction problem
- Hypertrophy
- MI

Abnormal rhythm

- Diagnose rhythm

Steps in Reading a 12-Lead ECG

1. Measure vital signs
   - Axis, intervals, rates
2. Does it look normal?
   - Rate
   - Rhythm

Normal rhythm

- QRS width for <u>conduction problem</u>
- Hypertrophy
- MI

Abnormal rhythm

- Diagnose rhythm

- Final Checks

Steps in Reading a 12-Lead ECG

1. **Measure and explain vital signs**
2. **Does it look normal?**
   1. heart rate normal
   2. QRS's are regular and uniform
   3. There is a normal P wave beginning 3-5 mm before each QRS

Yes - Normal rhythm

QRS Shape

- Assess QRS width and axis for conduction problem (BBB, IVCD, WPW, paced beat) or LVH.
- If so, diagnose conduction and assess repolarization effects.
- If not, assess for RVH, then for MI.
- Assess repolarization (isch, etc.).

No – Abnormal rhythm

- First, diagnose the atrial rate and activity
- Second, diagnose the ventricular rate and activity
- Compare rates and patterns to assess AV conduction (ante- and retrograde)

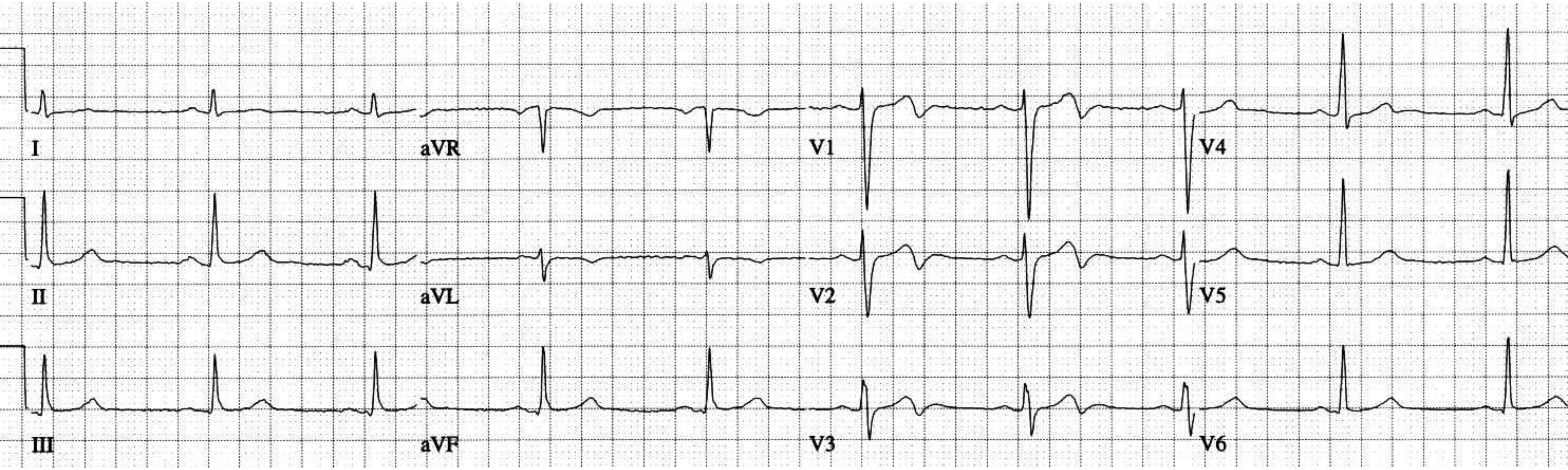
Final Checks:

- Assess P wave (LAE, RAE, ectopic origin)
- Double check for extra, or hidden P waves

Assess the ECG

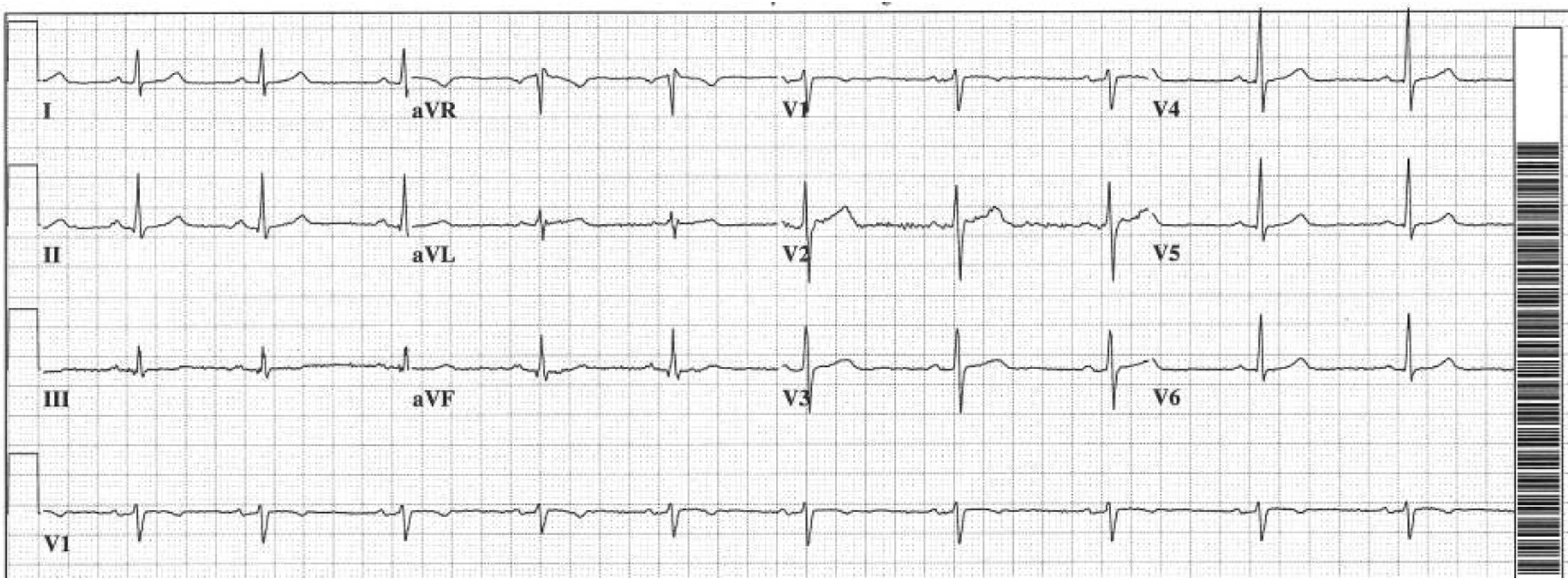
- Rate and regularity
- P wave
- PR interval
- QRS complex
- ST segment
- T wave
- U wave
- QTc interval
- Rhythm
  - rate and regularity
  - P wave morphology
  - PR interval
  - QRS morphology
  - Repolarization morphology

Rate and Regularity



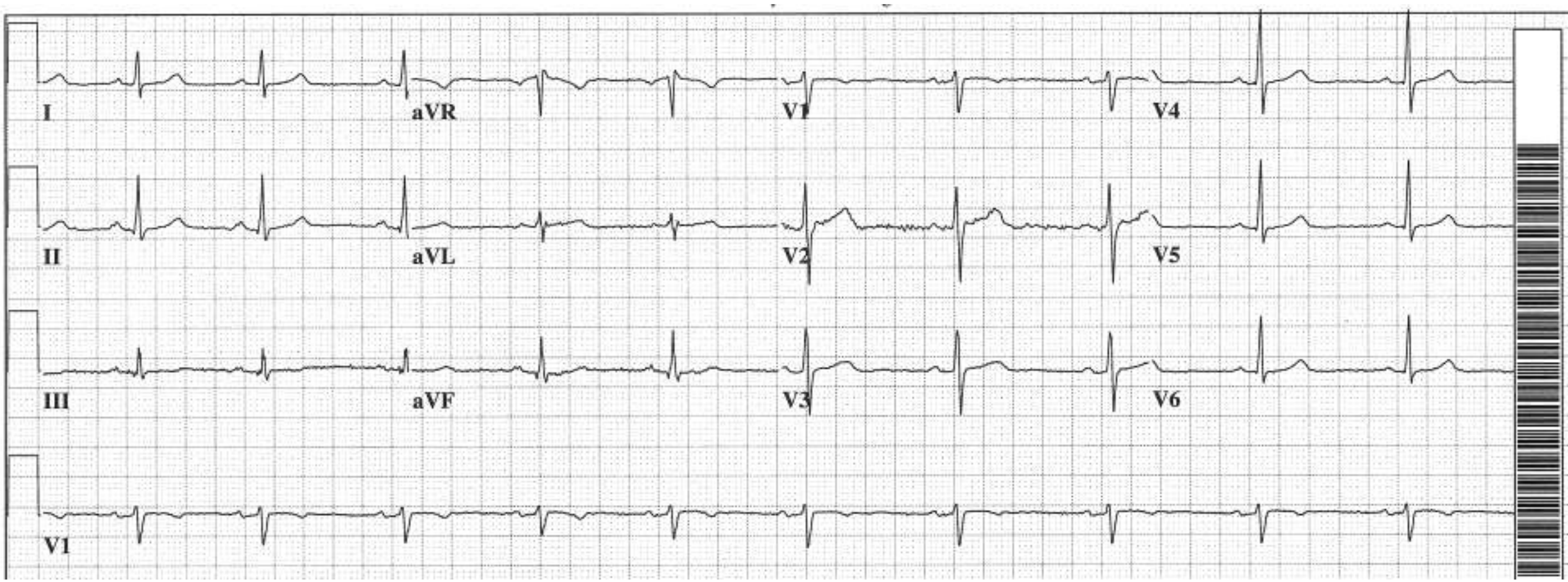
- Rate: 60-100 beats/min by definition is normal
- Regularity should be fairly consistent
- Bradycardia: rate less than 60
- Bradycardia may be normal in well-conditioned individuals or with sleep or from medications

P wave



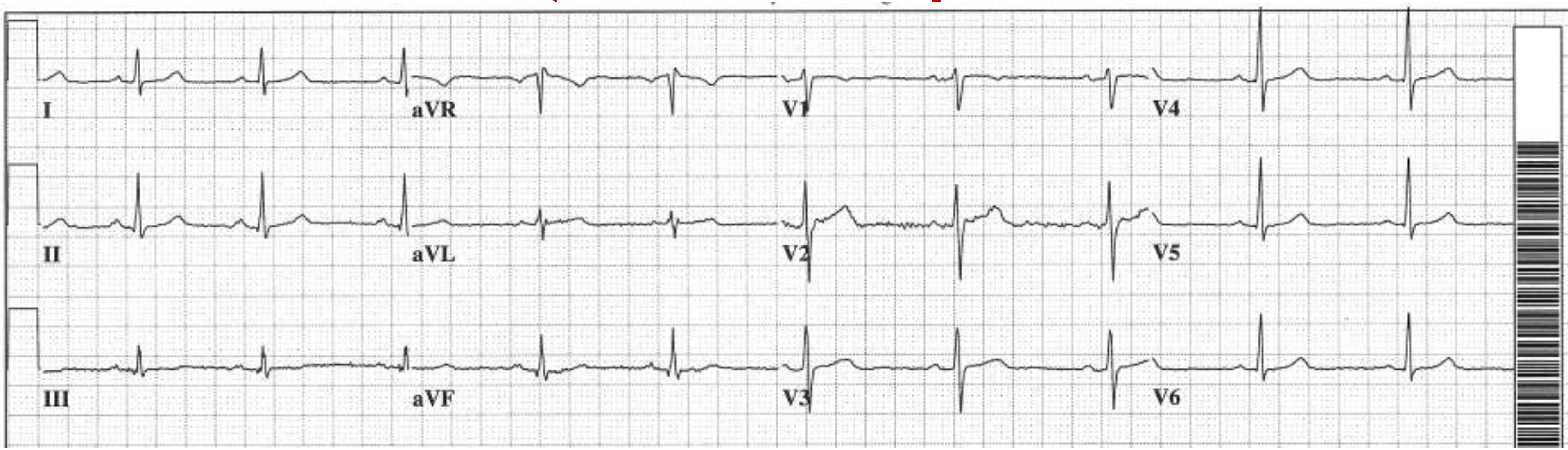
- Configuration normally uniform from beat to beat
- Axis from 0 (some say 30) to 70 degrees
- Duration 0.06-0.10 sec
- Height less than 2.5 mm
- In V1, initially positive and terminally negative

PR Interval



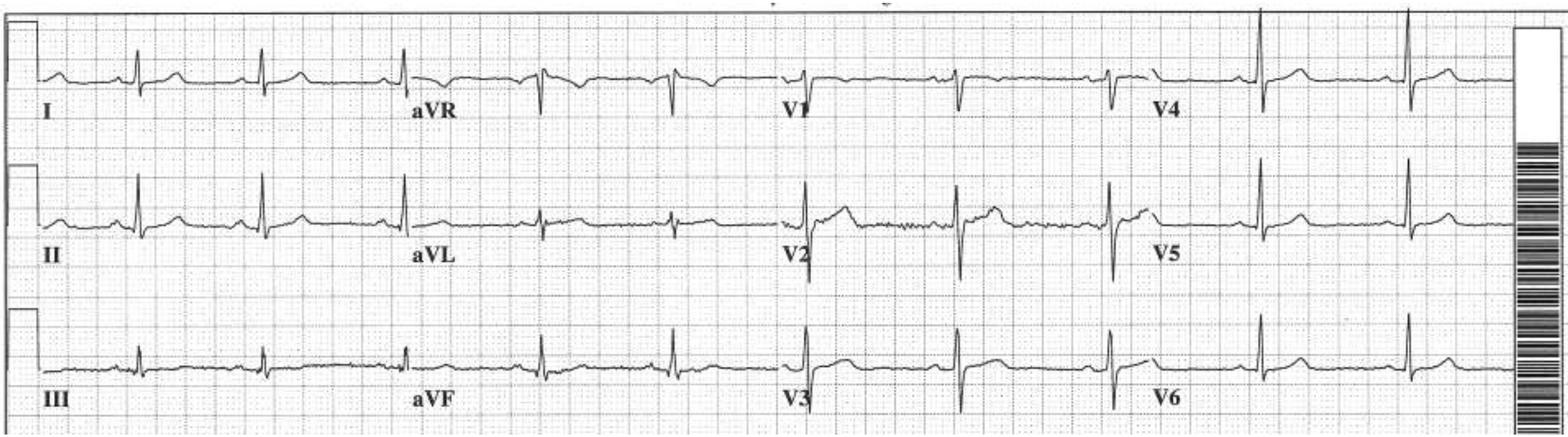
- Constant from beat to beat
- Duration 0.12-0.20 sec (3-5 mm if normal paper speed)
- PR segment should be isoelectric (same horizontal level) with T-P segment

QRS Complex



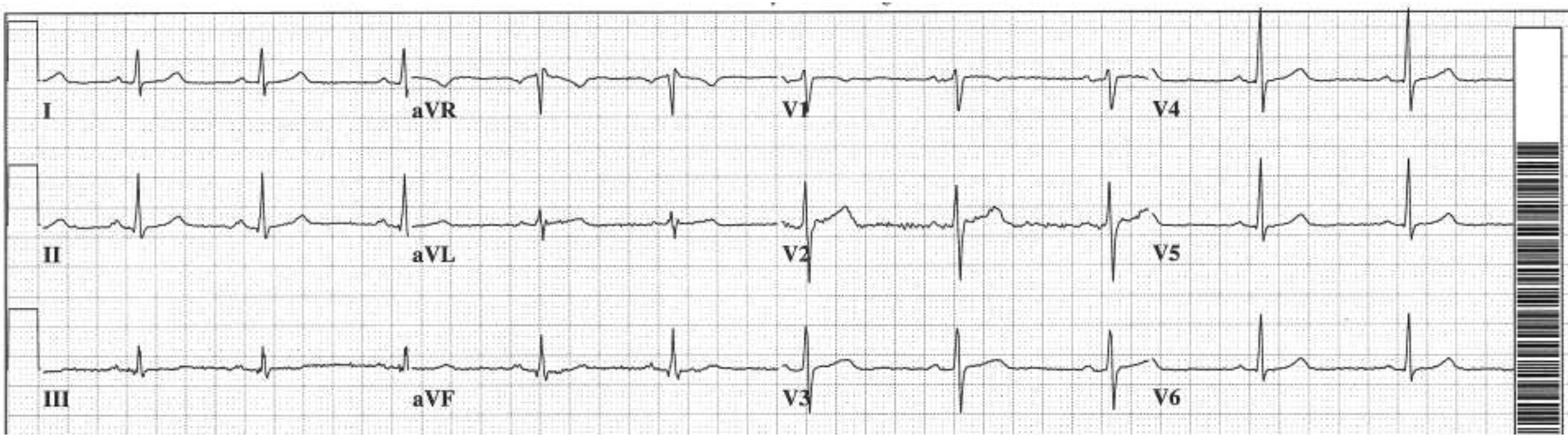
- Axis normally -30 to +90 degrees
- Duration normally 0.06-0.10 sec
- Q waves
  - 0.03 in I, II, III, L, F, and V5-V6
  - 0.02 in V4
  - Absent in V1-V3
- R waves
  - increase V1 to V4
  - R>S usually by V4
  - R<S usually in V1
  - all limb leads <20mm & all chest leads <30 mm
  - at least one limb lead >5 mm and
  - chest lead >10 mm (R+S)

ST Segment



- During plateau phase of ventricular cellular action potential
- Begins horizontally, at level of PR and T-P segments
- May be displaced 1 mm in the direction of the following T wave ("early repolarization")

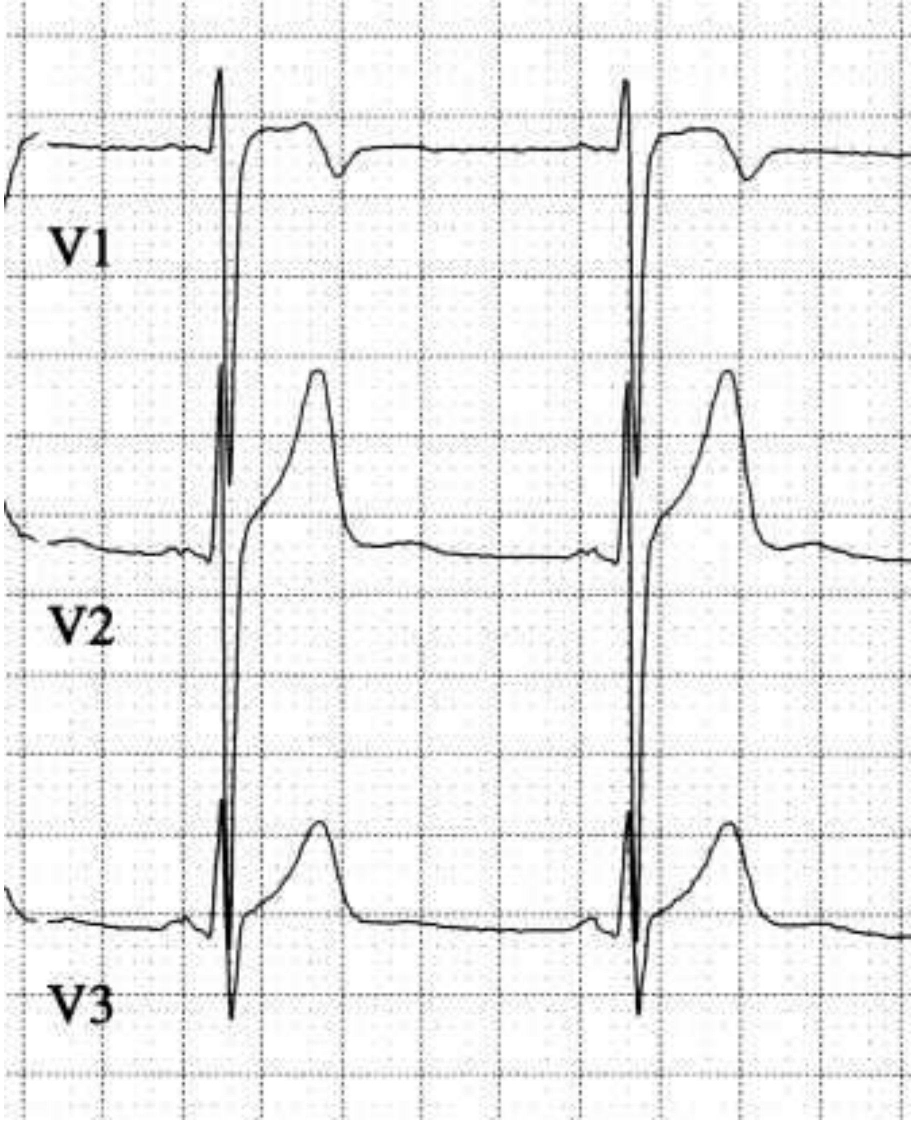
T wave



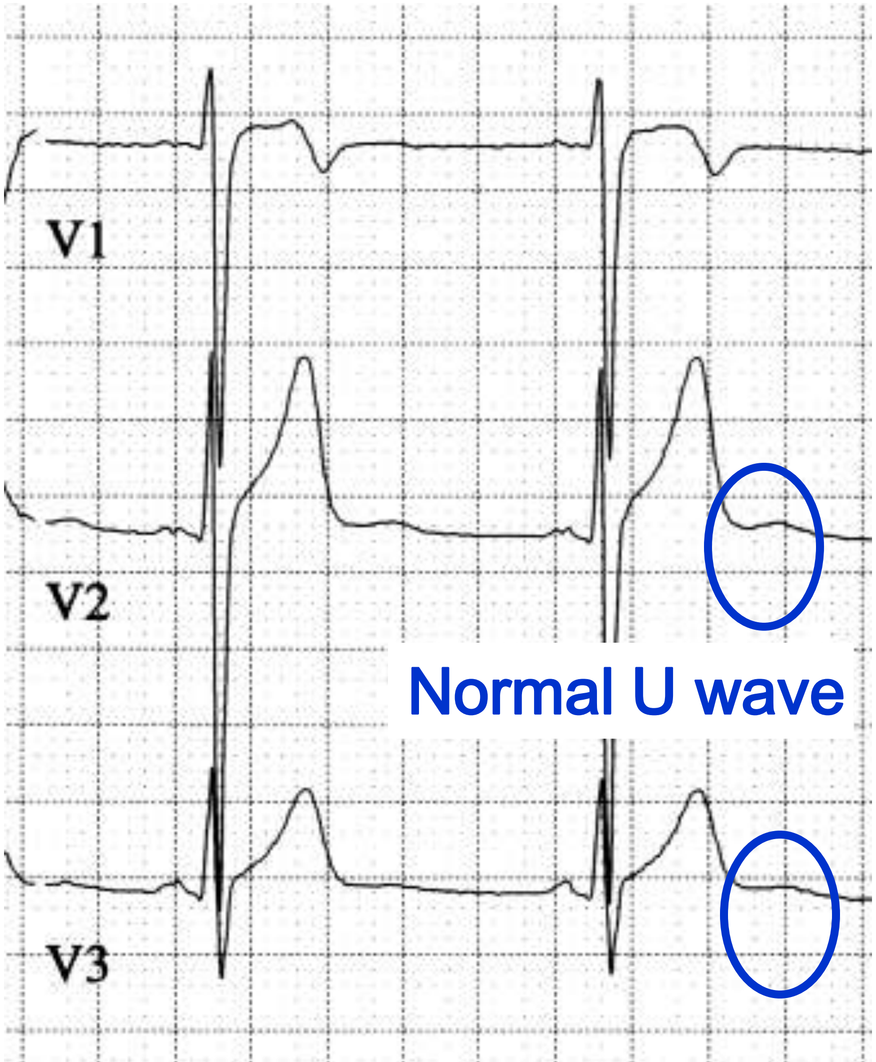
- Smooth, rounded monophasic or diphasic, more gradual onset and more sudden offset
- Amplitude usually
  - <5mm in limb and <10 mm in chest leads
  - <3mm in III and aVL and <5mm in V1 and V6
- Direction
  - Similar to QRS, <45 degrees in frontal plane
  - In transverse plane: Variable in V1, + in rest

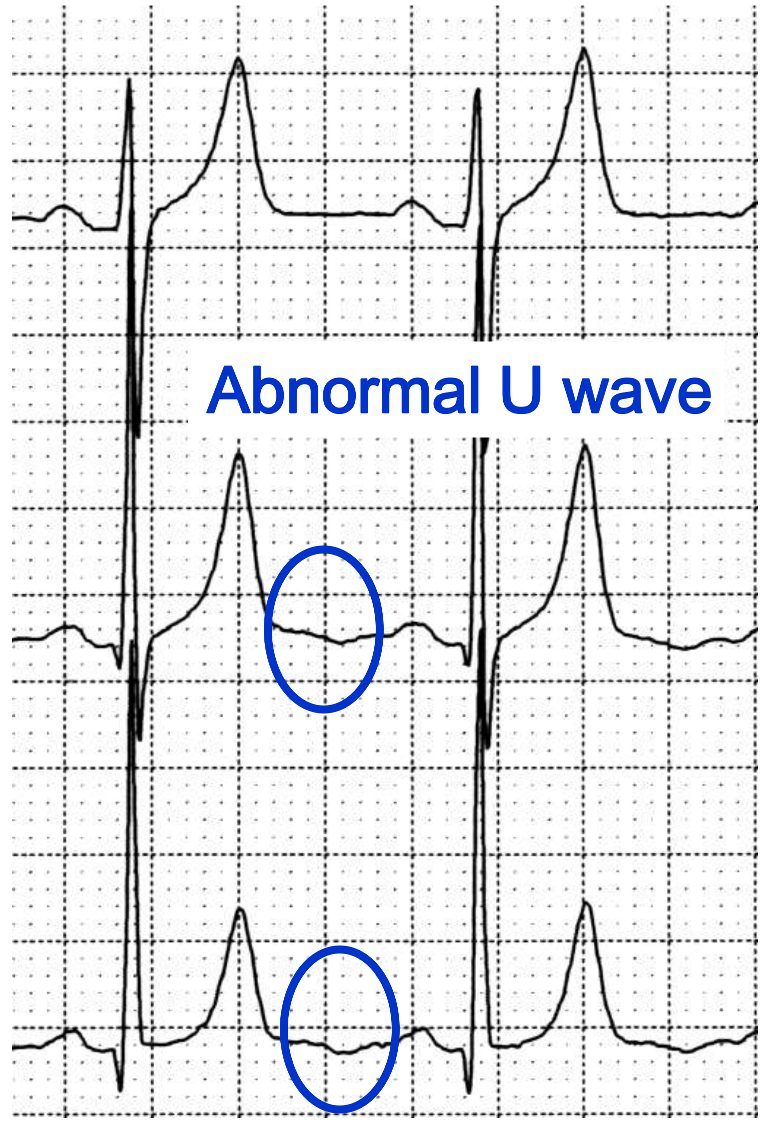
U wave

- May be absent
- Usually more prominent in bradycardia
- Same direction as T wave, but smaller, only 10% of T amplitude



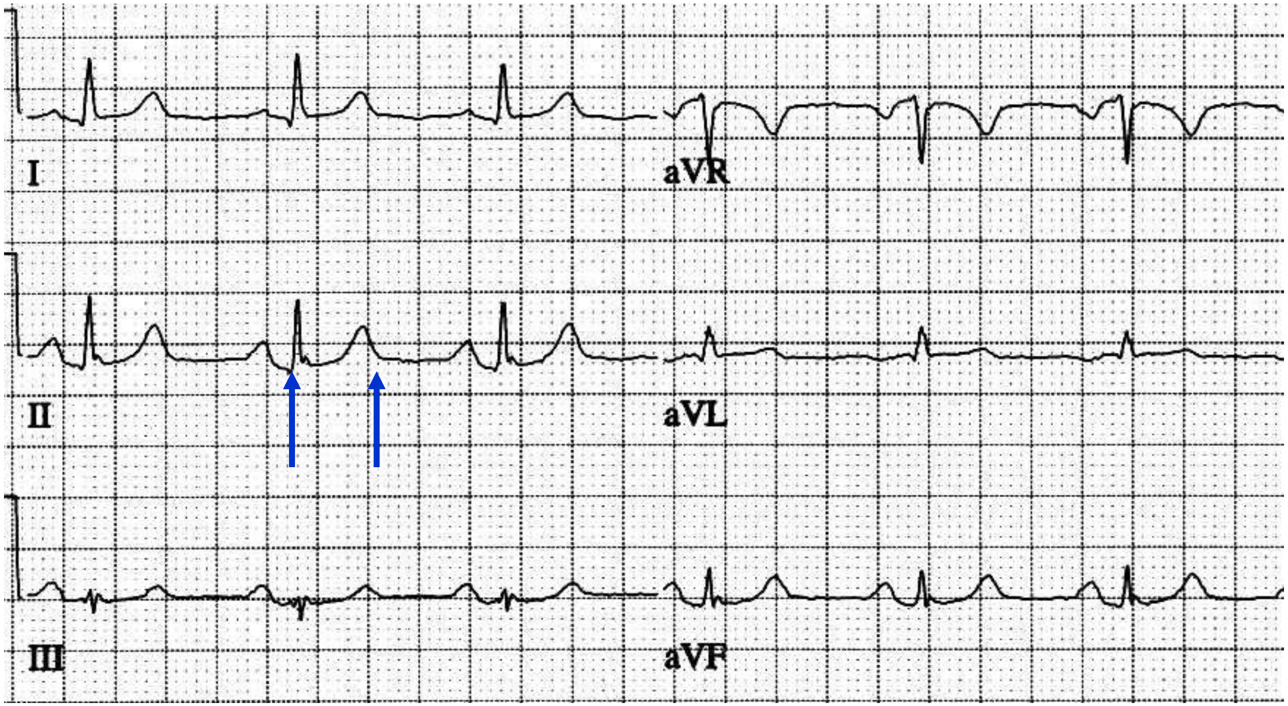
U wave





HR 72
QT 0.36
RR 0.84
QTc 0.39

Calculation:
SQRT 0.84=0.917
0.36/0.917=0.39
normal



QTc Interval

- Duration of activation & recovery of ventricles
- Varies directly with RR interval, inversely with rate
- QTc is QT corrected for rate
- In msec, QTc = QT/(SQRT RR interval)
- Normal QTc is 0.41 seconds

Rhythm Analysis

- Rate and regularity
- P wave morphology
  - Upright in I and aVF?
- PR interval
  - Normal?
  - Constant?
- QRS complex morphology - wide?
- Repolarization (look for P in T)

Outline

- Description of ECG recording page
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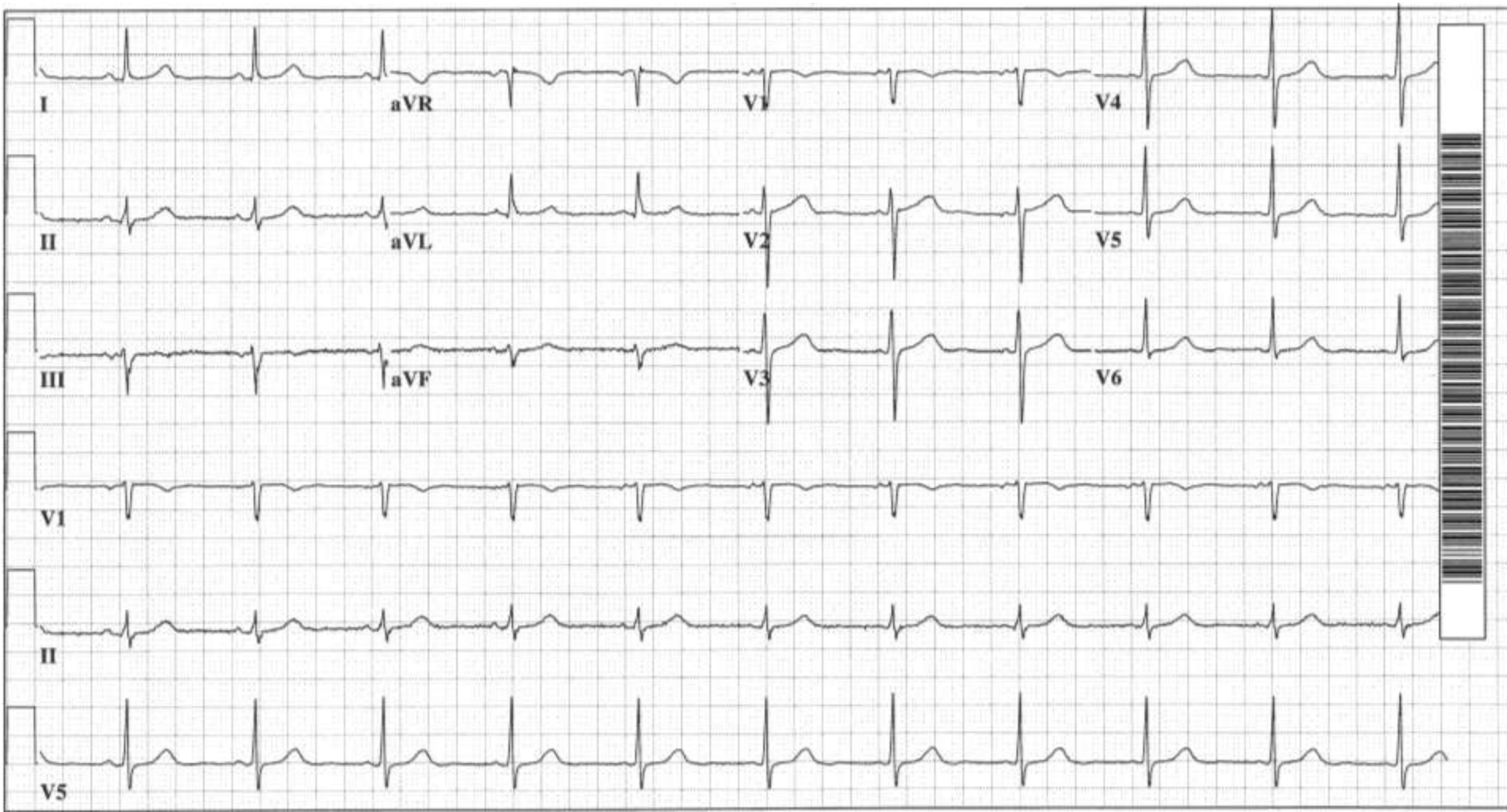
- Steps in interpretation
- **Diagnosing normal and abnormal findings**

☺Morphologic abnormalities
☺Arrhythmias

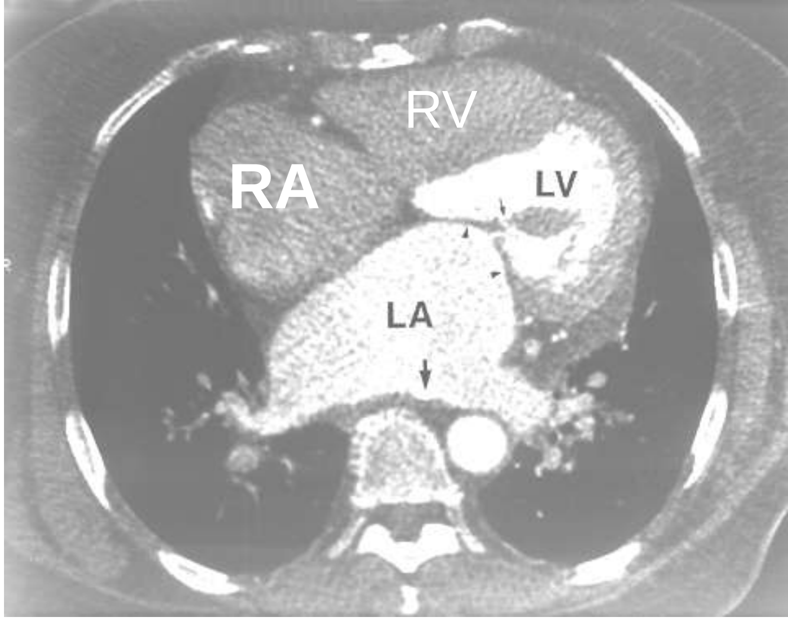
Normal ECG



Morphologic Abnormalities

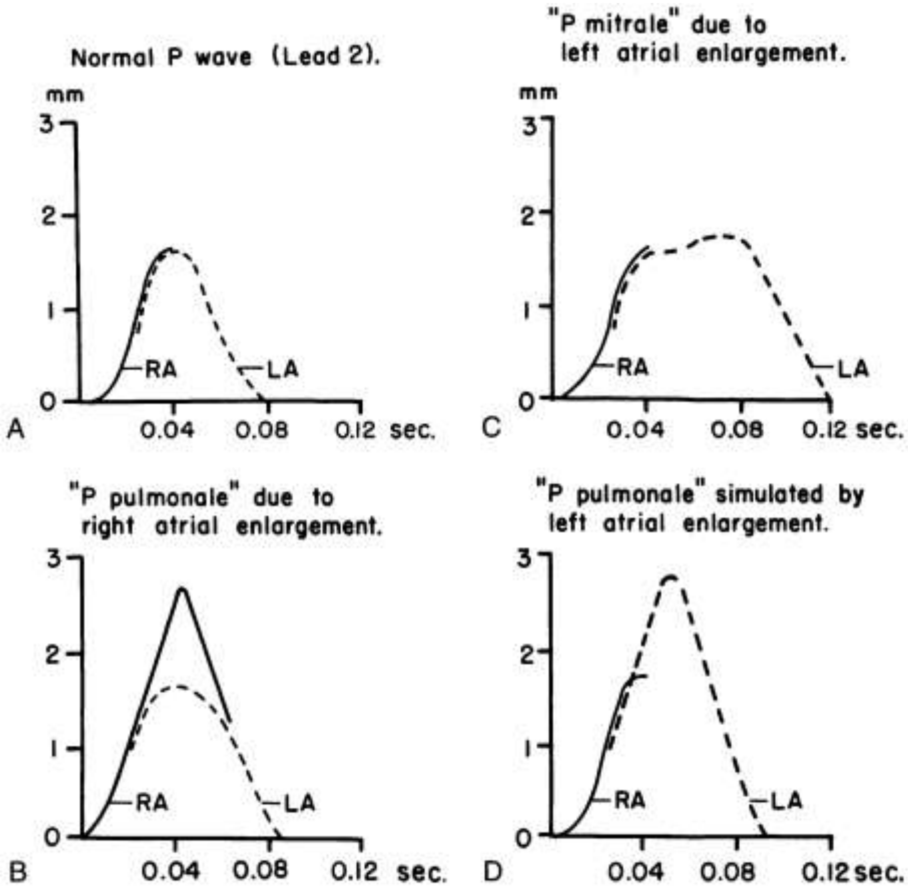
- **Chamber hypertrophy**
- Conduction abnormalities
- Ischemia, injury, infarction
- Repolarization abnormalities

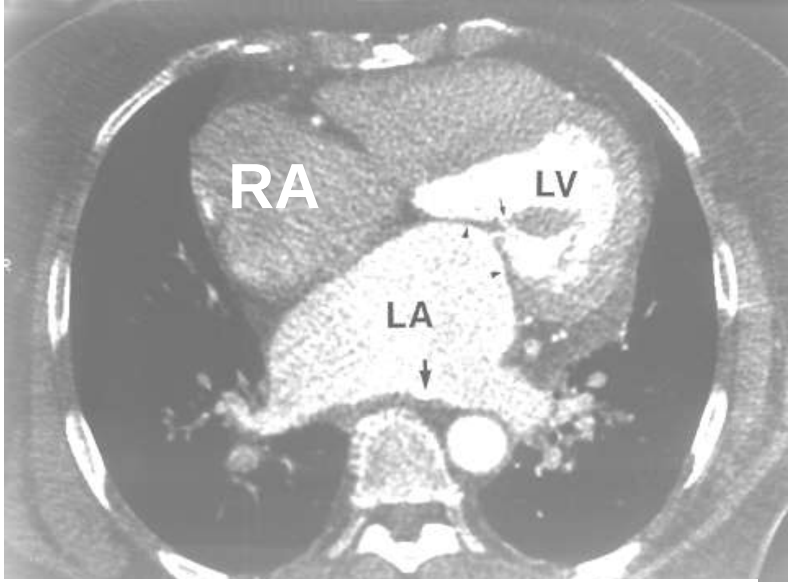
Atrial Enlargement or Hypertrophy

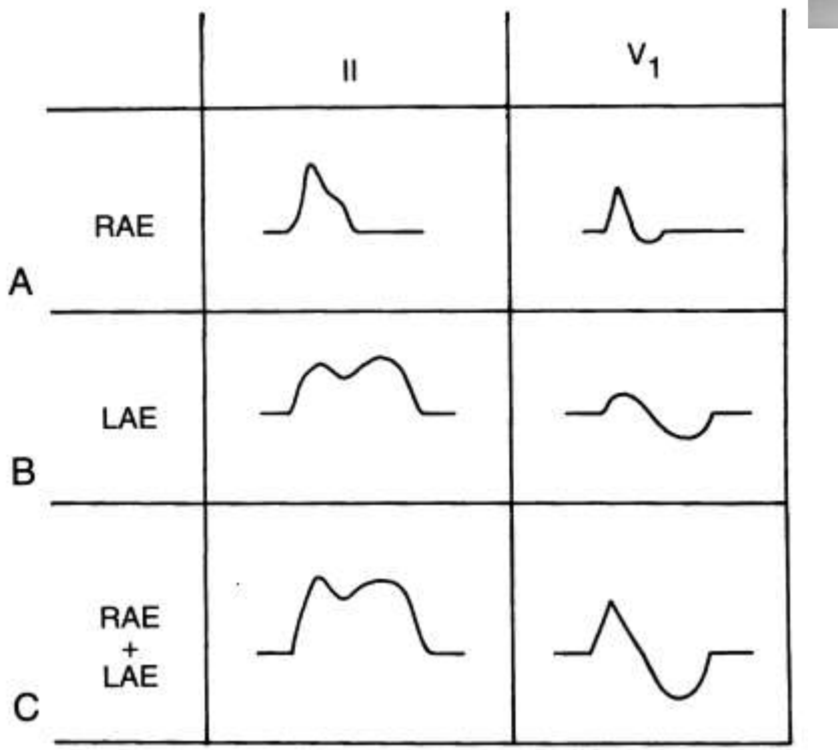


- Atrial abnormalities are usually with enlargement of one or both ventricles
- LAE
  - Notch in P wave with 0.04 sec between peaks, P duration increased ≥0.12 sec
  - P terminal force more than 1 mm deep and wide in V1
- RAE
  - 2.5 mm tall P wave in II, prominent initial force in V1

Atrial Enlargement







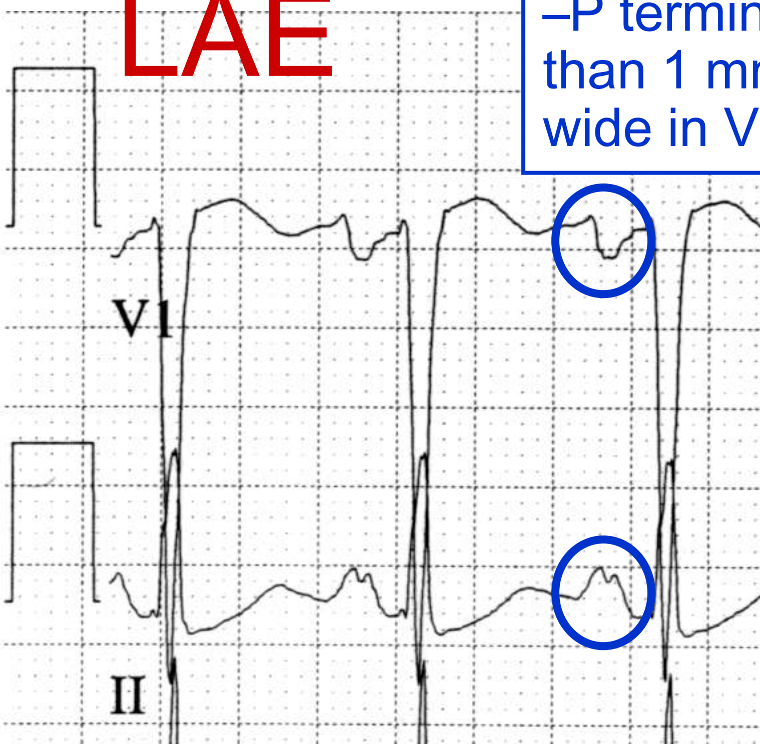
Surawicz B et al. Chou's ECG… 2001, p.35

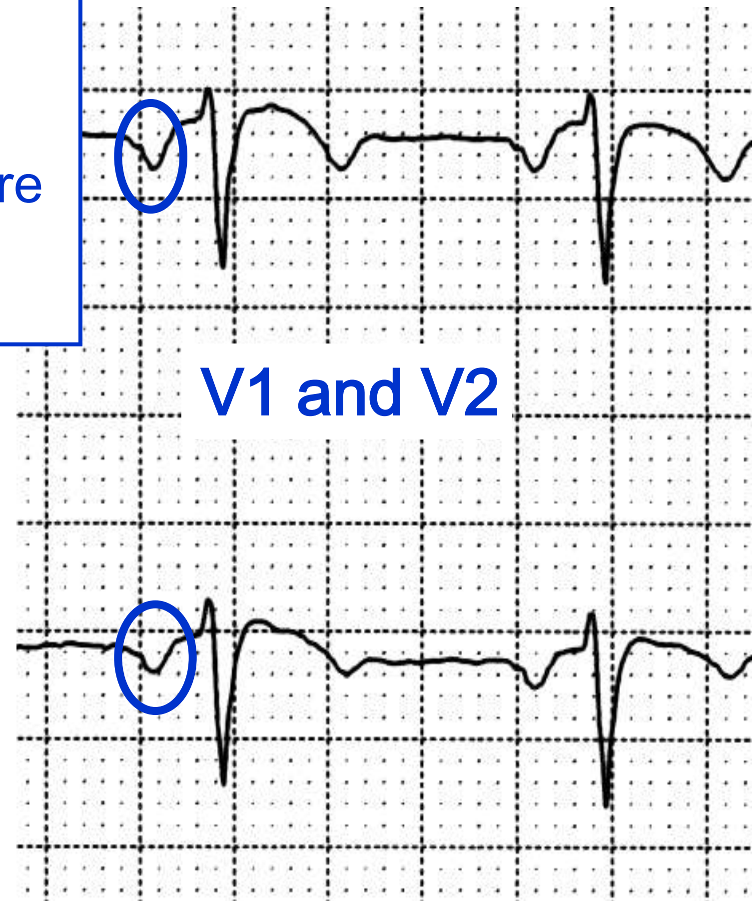
Wagner GS. Marriott's Practical Electrocardiography 1994, p.58

ECG - LAE

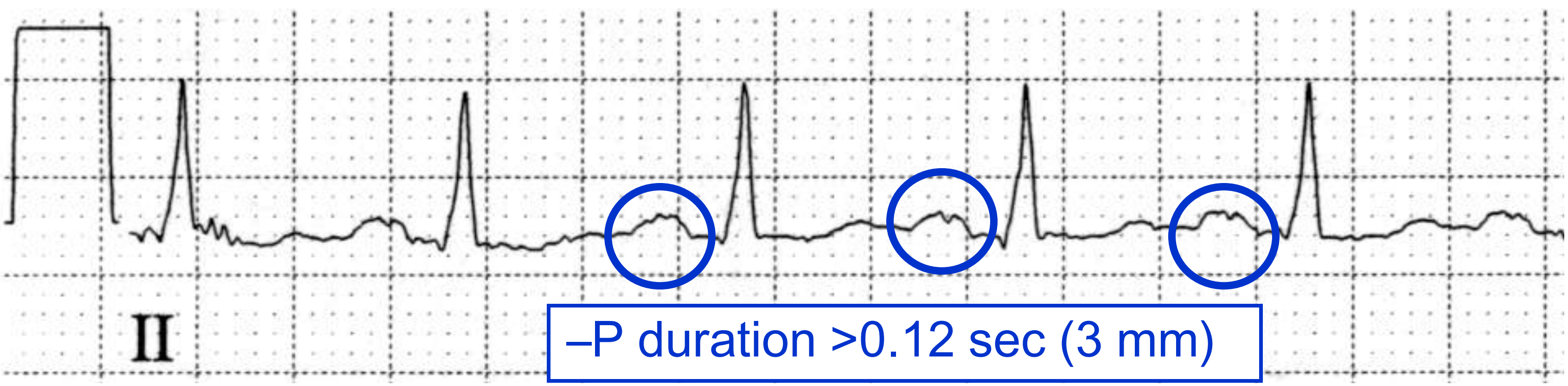
– Notch in P wave with 0.04 sec between peaks

– P terminal force more than 1 mm deep and wide in V1 *BEST



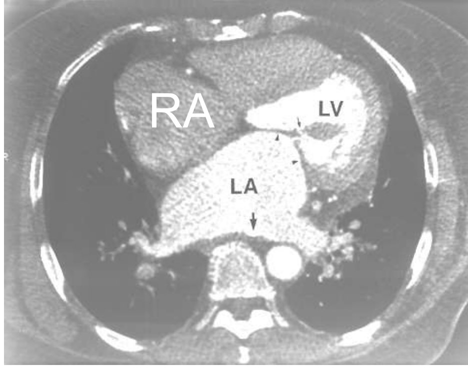


V1 and V2



– P duration >0.12 sec (3 mm)

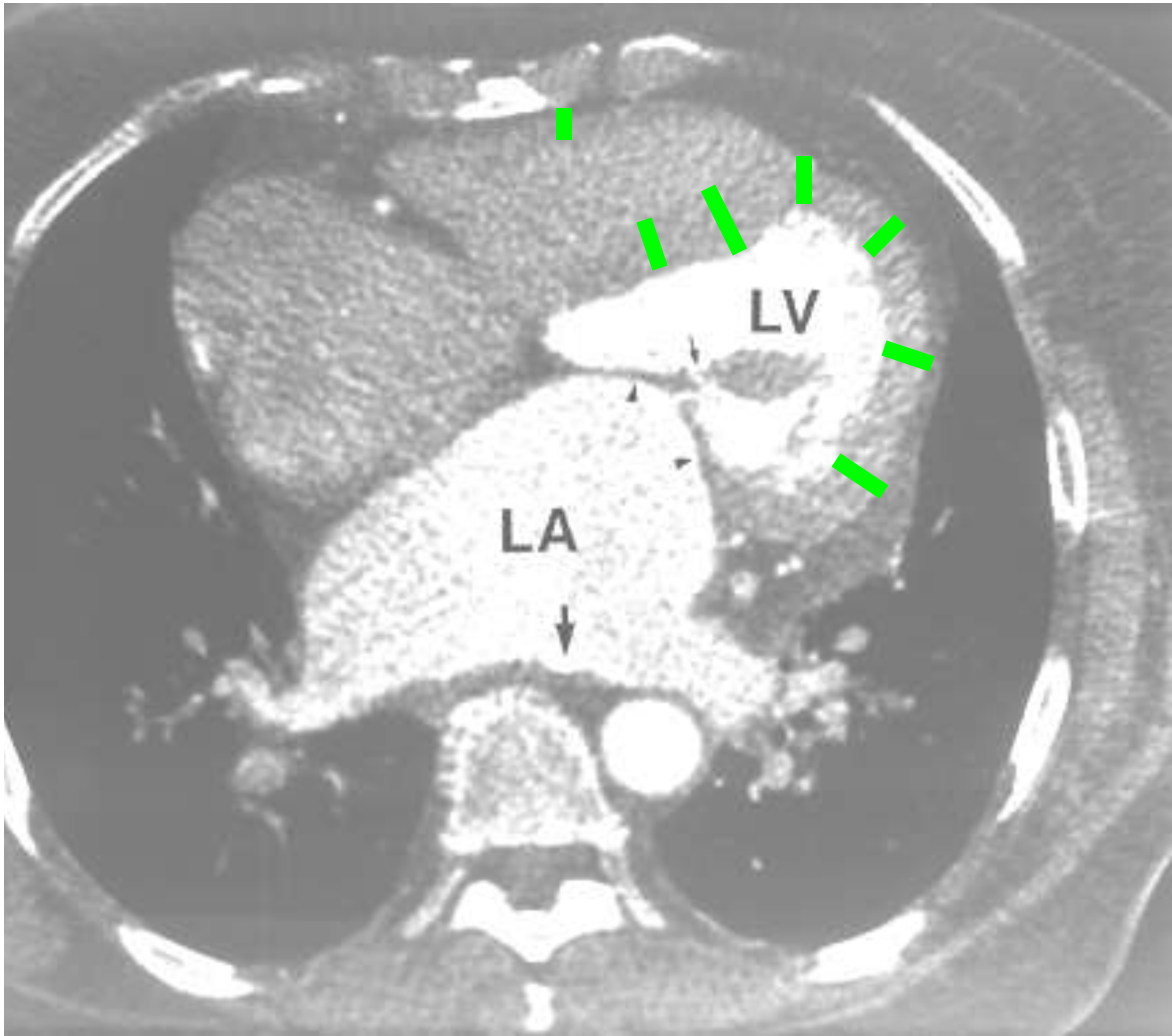
ECG - RAE



2.5 mm tall P wave in II, prominent initial force in V1

Left Ventricular Hypertrophy

- The LV normally dominates the QRS, since it is about 10 mm thick and the RV is only a few mm thick.
- When the LV mass increases, the ECG forces directed <u>leftward and inferiorly and posteriorly</u> increase.



Left Ventricular Hypertrophy

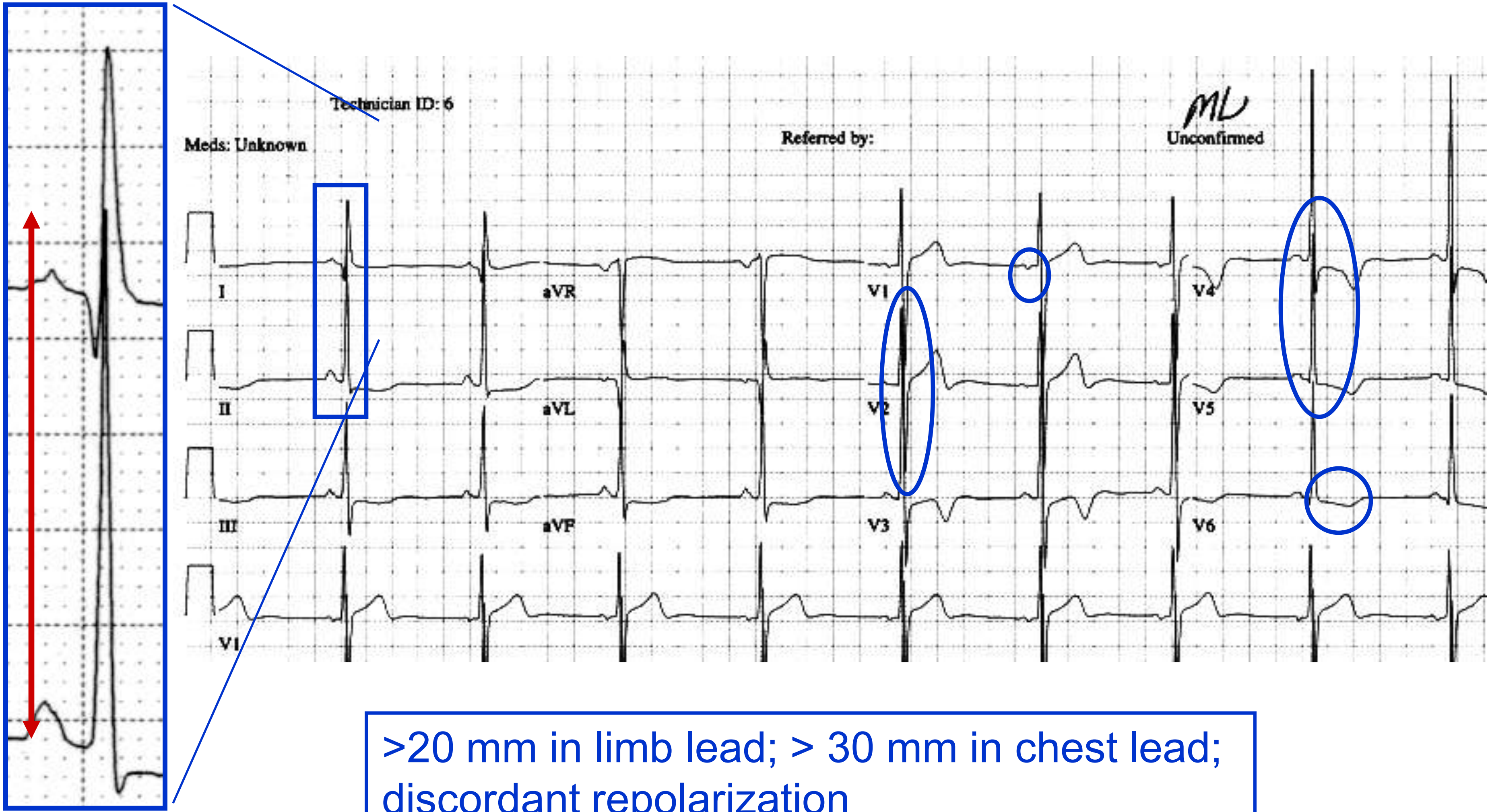
Point Score System

- 3 points: Voltage 20 mm in limb lead, 30 mm in chest lead (or Cornell voltage criteria, next slide)
- 3 points: Left atrial abnormality in V1
- 3 points: Repolarization abnormal off dig.
- 1 point: Repolarization abnormal on dig.
- Intrinsicoid deflection in V5-V6 >0.05 sec
- QRS duration 0.09-0.10 sec

Left Ventricular Hypertrophy

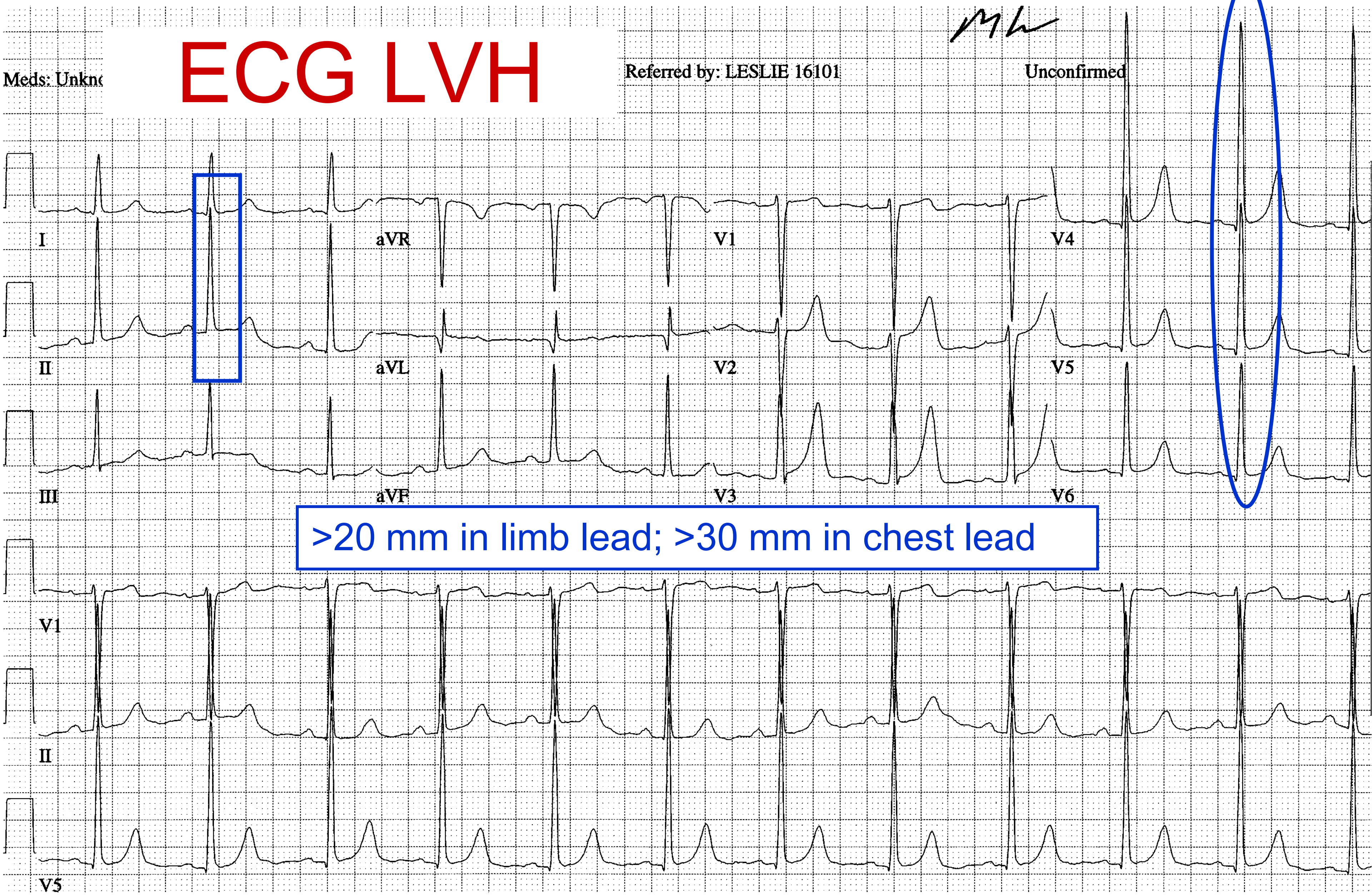
- Cornell Voltage Criteria
  - R wave in aVL + S wave in lead V3!
  - Women: >2.0 mV (20 mm)
  - Men: >2.8 mV (28 mm)
- Sokolow-Lyon Criteria
  - R in lead I plus S in lead III >25 mm

ECG LVH



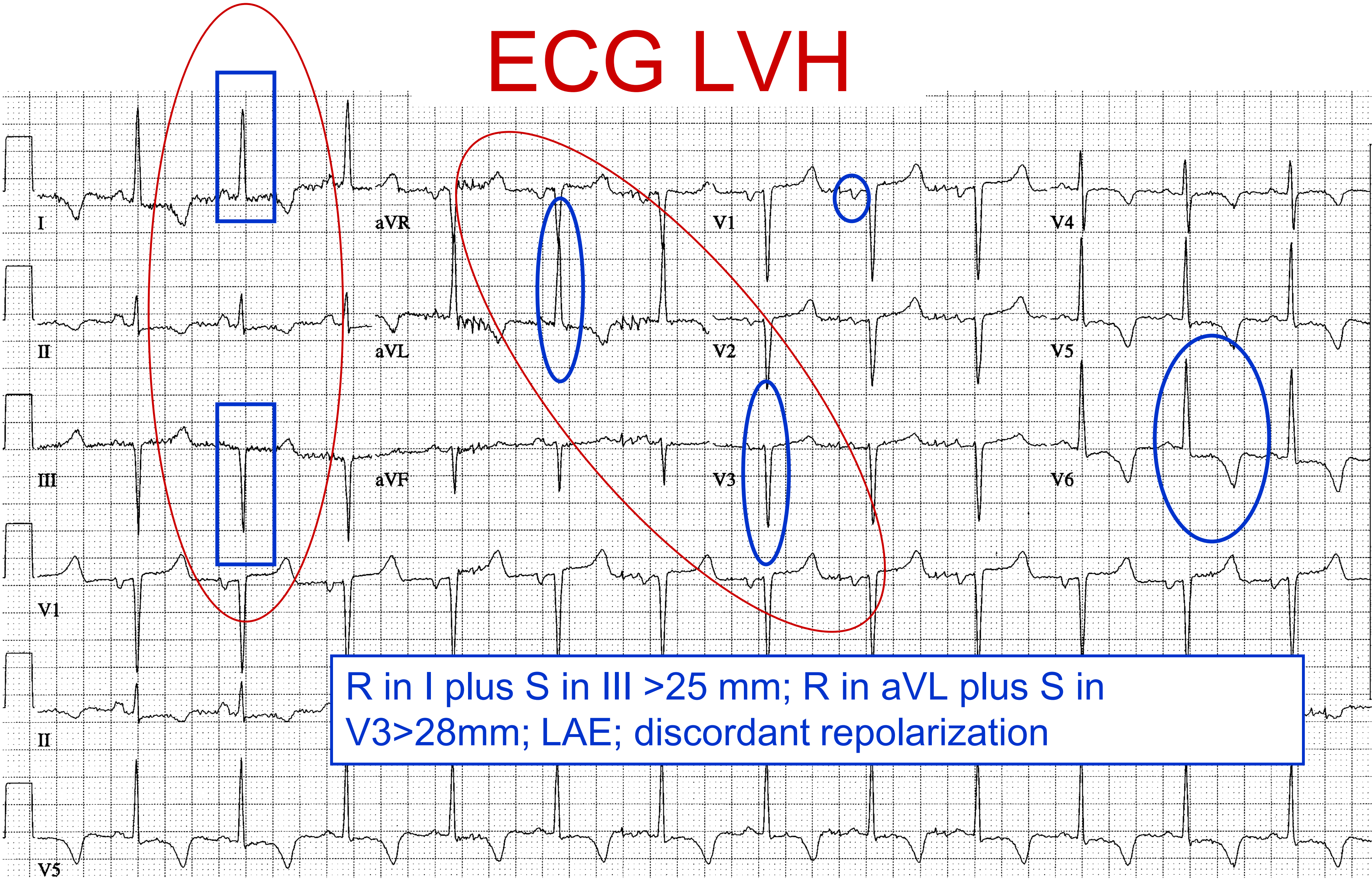
>20 mm in limb lead; > 30 mm in chest lead; discordant repolarization

ECG LVH



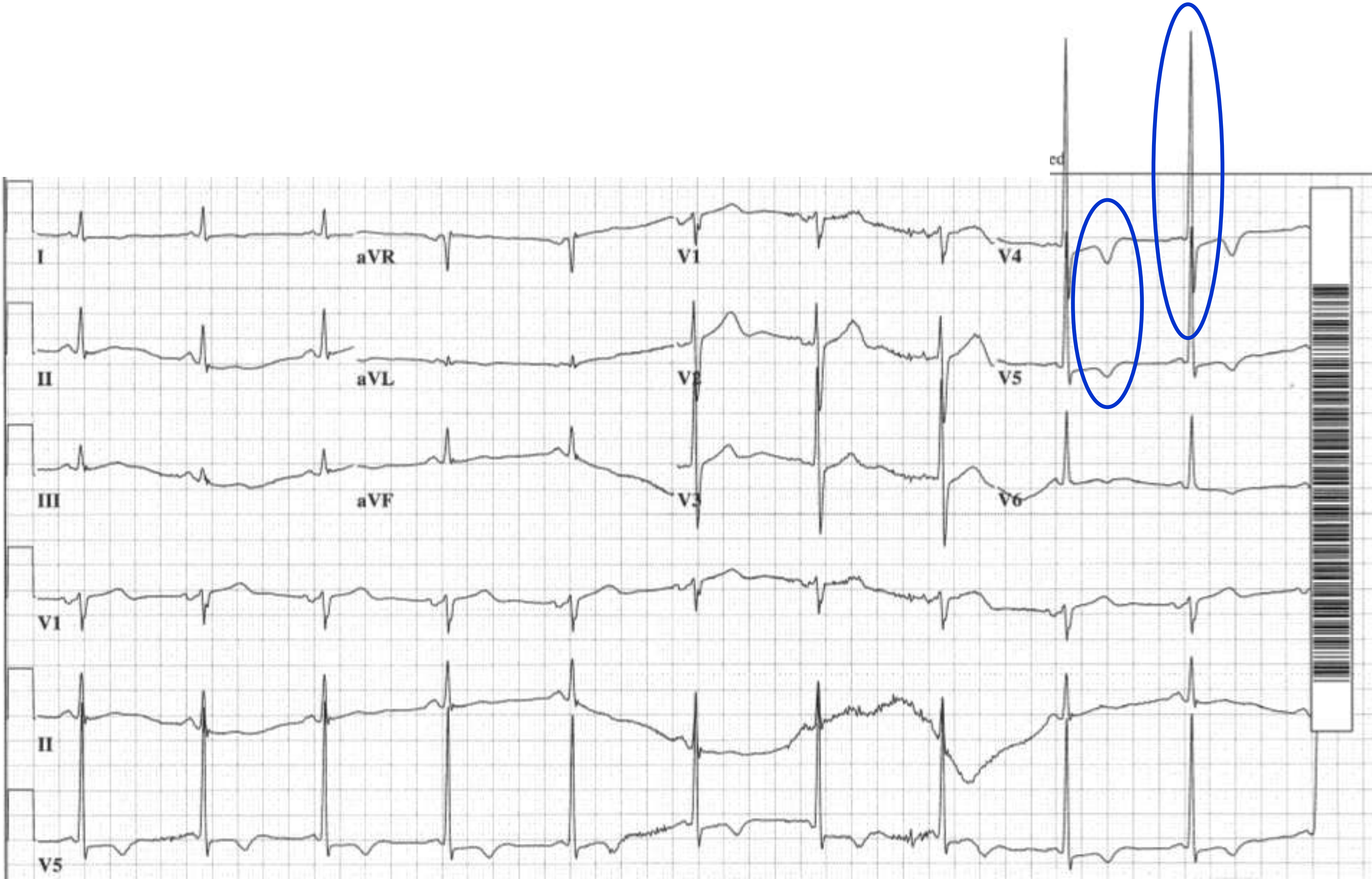
>20 mm in limb lead; >30 mm in chest lead

ECG LVH

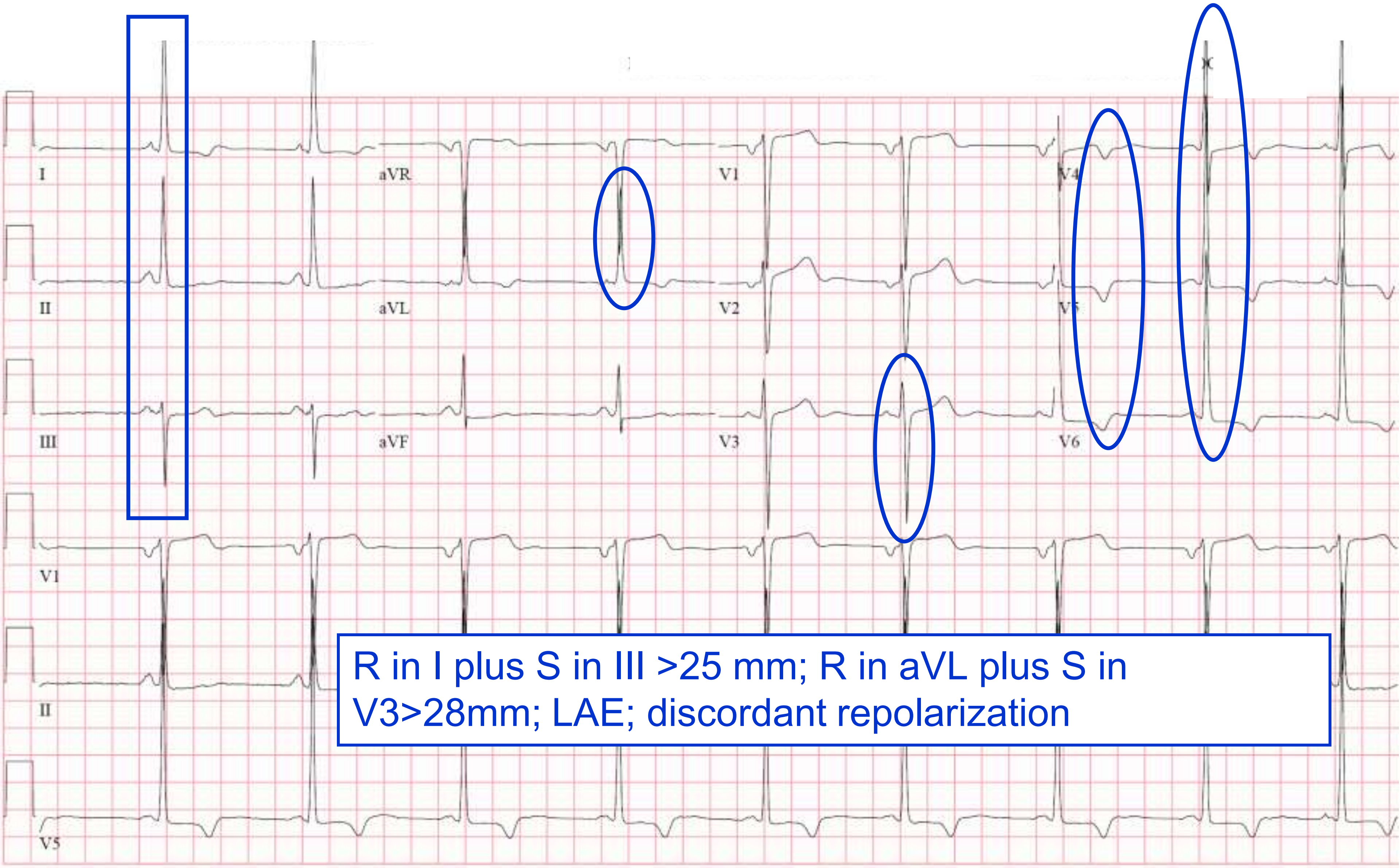


R in I plus S in III >25 mm; R in aVL plus S in V3>28mm; LAE; discordant repolarization

ECG LVH

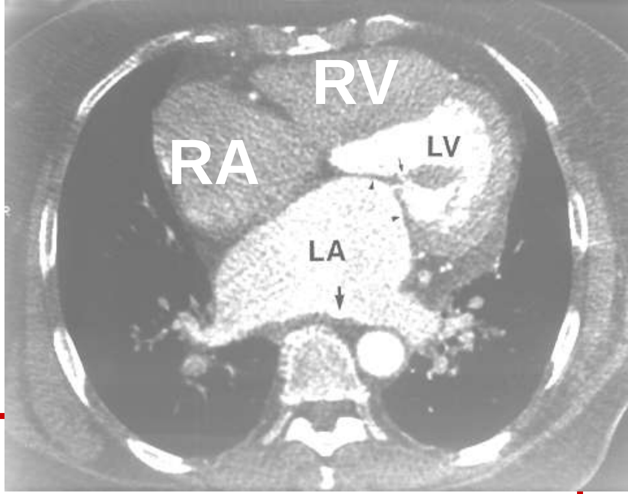


ECG LVH



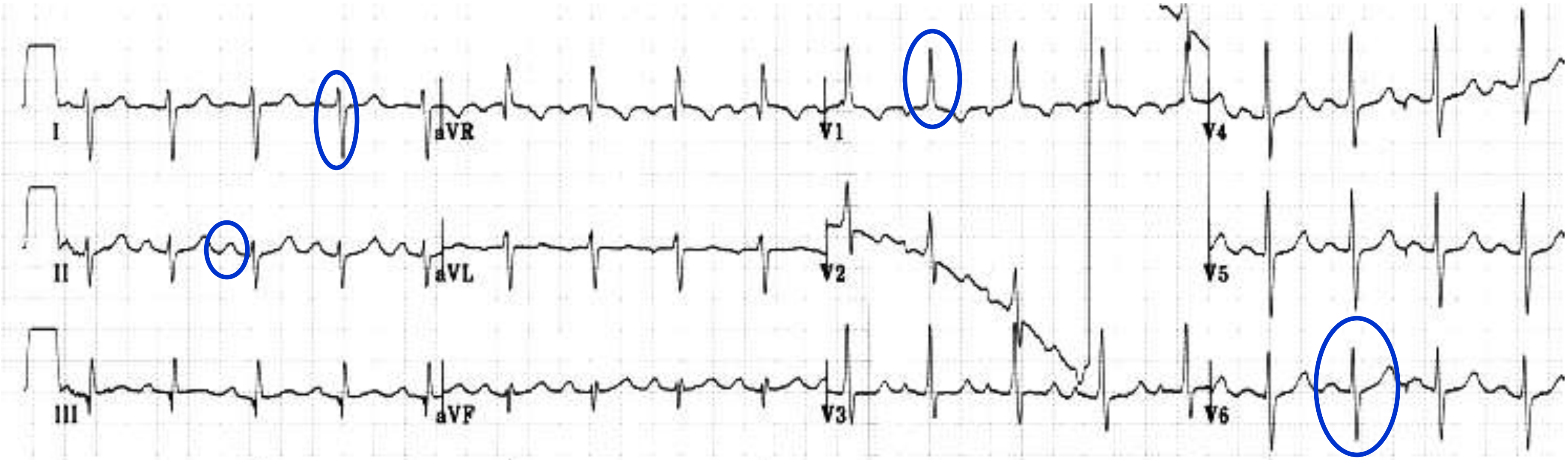
R in I plus S in III >25 mm; R in aVL plus S in V3>28mm; LAE; discordant repolarization

Right Ventricular Hypertrophy



- Tougher than LVH, because RV forces must increase more to overcome the normally dominant LV forces
- RV forces are rightward and anterior and inferior

- Criteria
  - Right axis >110 degrees
  - R/S in V1 or V3R >1
  - R in V1 >7mm
  - S in V1 <2mm
  - qR pattern in V1 or V3R
  - rSRprime in V1 with Rprime >10mm
  - also, ST depression and T inversion in V1-V2

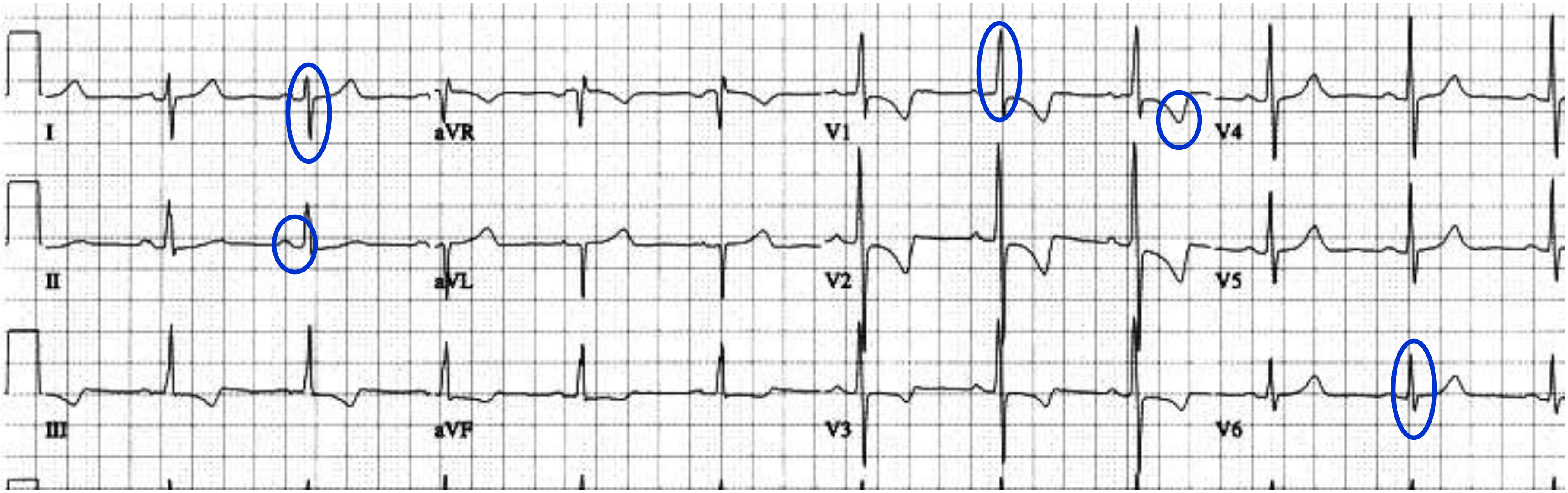


ECG - RVH

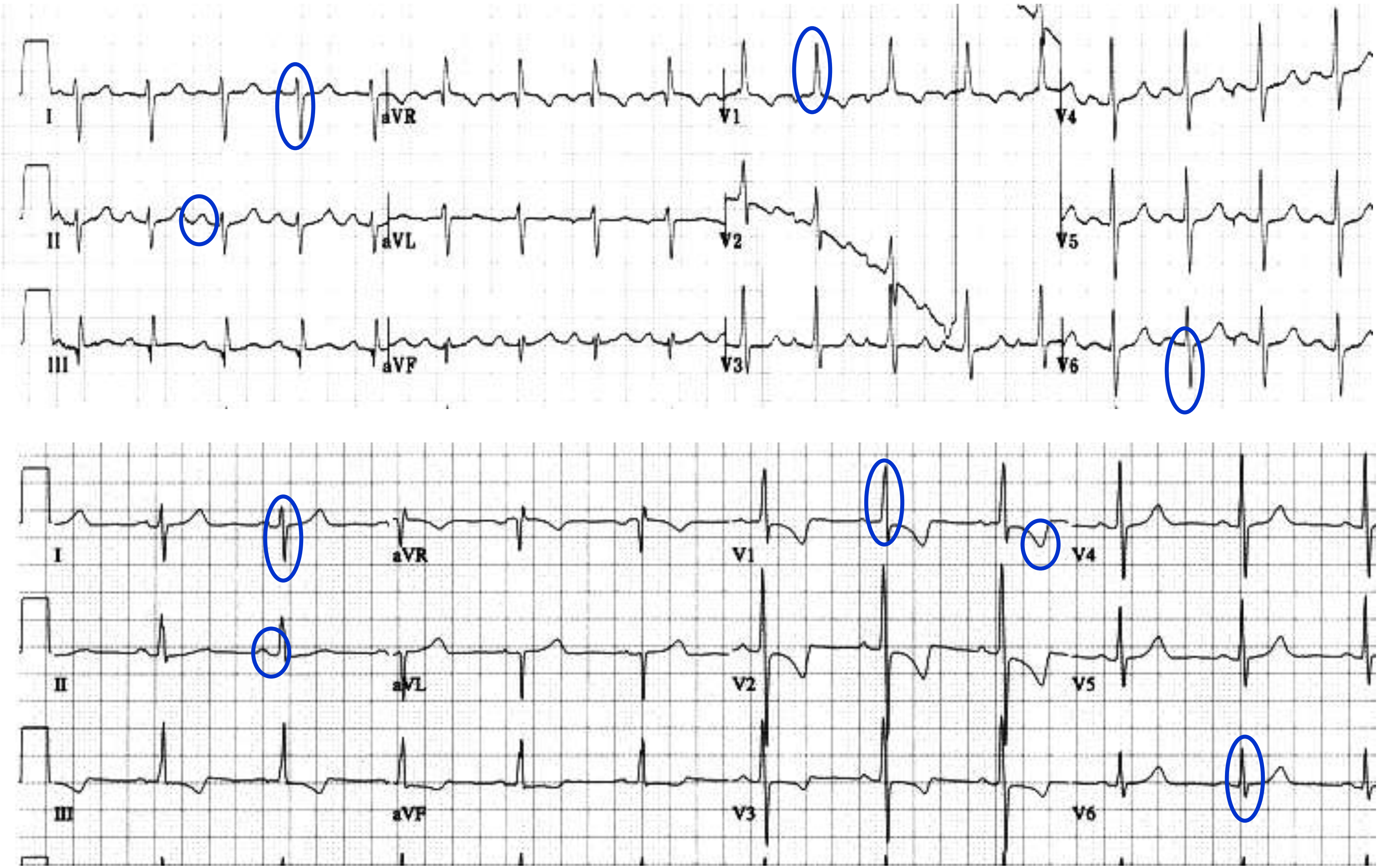
- –Right axis >110 degrees***
- –R/S in V1 or V3R >1***
- –R in V1 >7mm***
- –S in V1 <2mm***
- –qR pattern in V1 or V3R
- –rSRprime in V1 with Rprime >10mm
- –ST depression and T inversion in V1-V2***

ECG - RVH

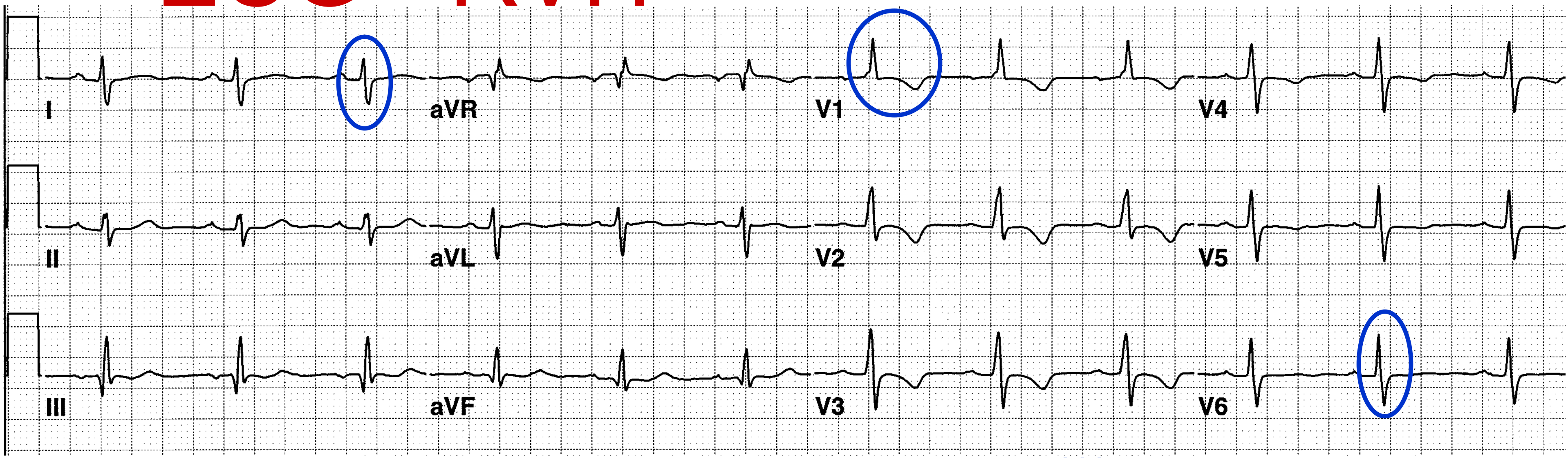
- –Right axis >110 degrees***
- –R/S in V1 or V3R >1***
- –R in V1 >7mm***
- –S in V1 <2mm
- –qR pattern in V1 or V3R
- –rSRprime in V1 with Rprime >10mm
- –also, ST depression and T inversion in V1-V2***



ECG - RVH

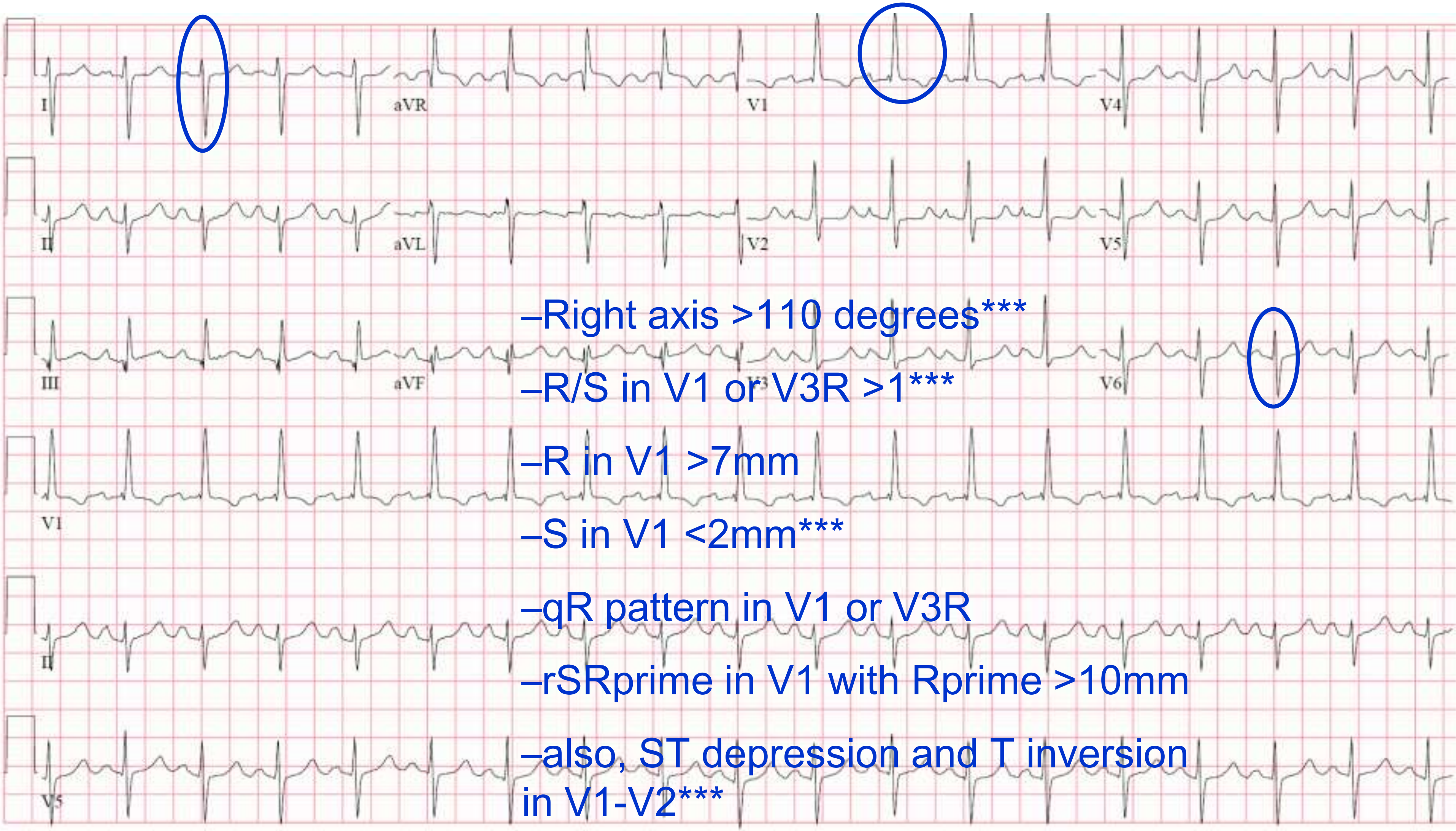

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

ECG - RVH



- –Right axis >110 degrees***
- –R/S in V1 or V3R >1***
- –R in V1 >7mm
- –S in V1 <2mm***
- –qR pattern in V1 or V3R
- –rSRprime in V1 with Rprime >10mm
- –also, ST depression and T inversion in V1-V2***

ECG - RVH



– Right axis >110 degrees***
– R/S in V1 or V3R >1***
– R in V1 >7mm
– S in V1 <2mm***
– qR pattern in V1 or V3R
– rSRprime in V1 with Rprime >10mm
– also, ST depression and T inversion in V1-V2***

Morphologic Abnormalities

- Chamber hypertrophy
- **Conduction abnormalities**
- Ischemia, injury, infarction
- Repolarization abnormalities

Conduction Abnormalities

(Causes of **wide QRS** complexes,
QRS duration at least 0.12 sec)

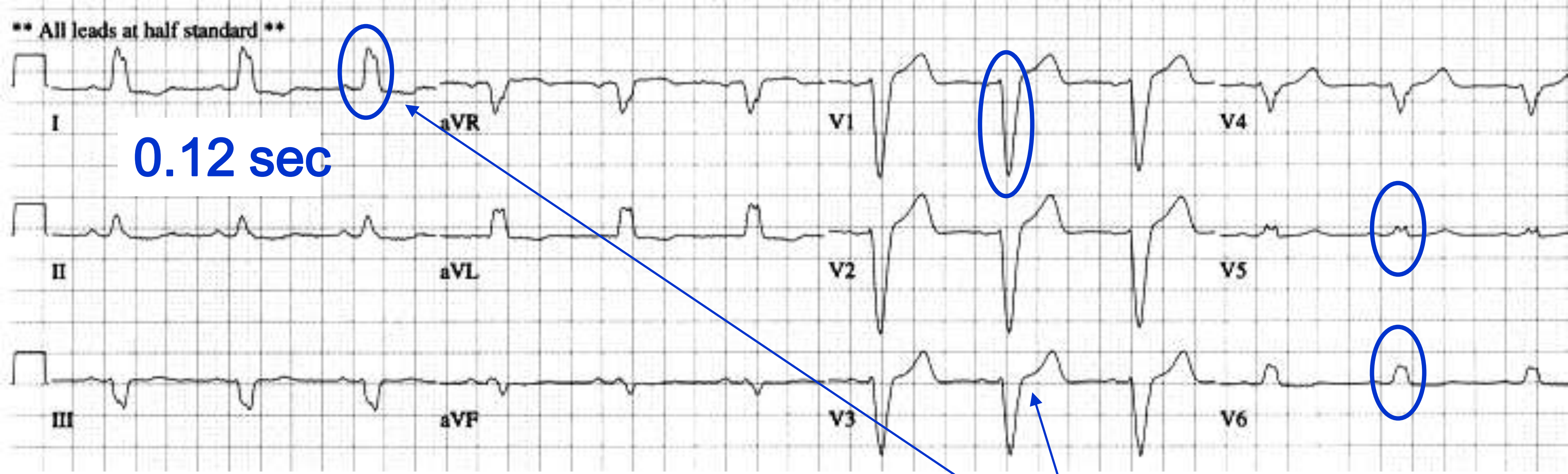
- Left bundle branch block (LBBB)
- Right bundle branch block (RBBB)
- Hemiblocks (not as wide) **Optional**
- Wolff-Parkinson-White (WPW)
- Intraventricular conduction delay
- Ventricular Origin QRS complexes
- Hyperkalemia

Left Bundle Branch Block

- QRS duration >= 0.12 sec
- Broad (usually notched) R in I, V5, and V6
- Absent Q waves in I, V5, and V6
- Delay in R peak time in V5 and V6
- Broad Deep S wave or QS complex in V1
- Repolarization: ST segment and T wave directed opposite to mean QRS

LBBB Implications

- The entire QRS is distorted by the bundle branch block
- Therefore it is not possible to diagnose pathologic Q waves of MI or high voltage of LVH in the setting of LBBB



Discordant T wave

ECG - LBBB

- QRS duration >= 0.12 sec***
- Broad (usually notched) R in I, V5, and V6***
- Absent Q waves in I, V5, and V6***
- Delay in R peak time in V5 and V6***
- Broad Deep S wave or QS complex in V1***
- Repolarization: ST segment and T wave directed opposite to mean QRS***

•QRS duration >= 0.12 sec

•Broad (usually notched) R in I, V5, and V6

•Absent Q waves in I, V5, and V6

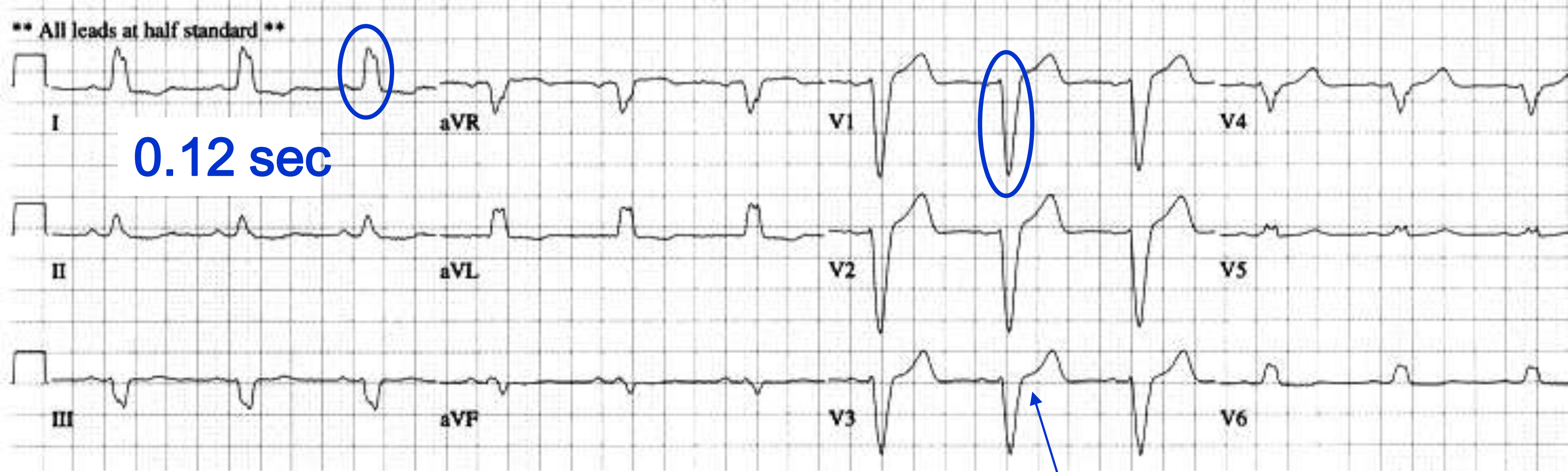
ECG - LBBB

•Delay in R peak time in V5 and V6

•Broad Deep S wave or QS complex in V1

•Repolarization: ST segment and T wave directed opposite to mean QRS

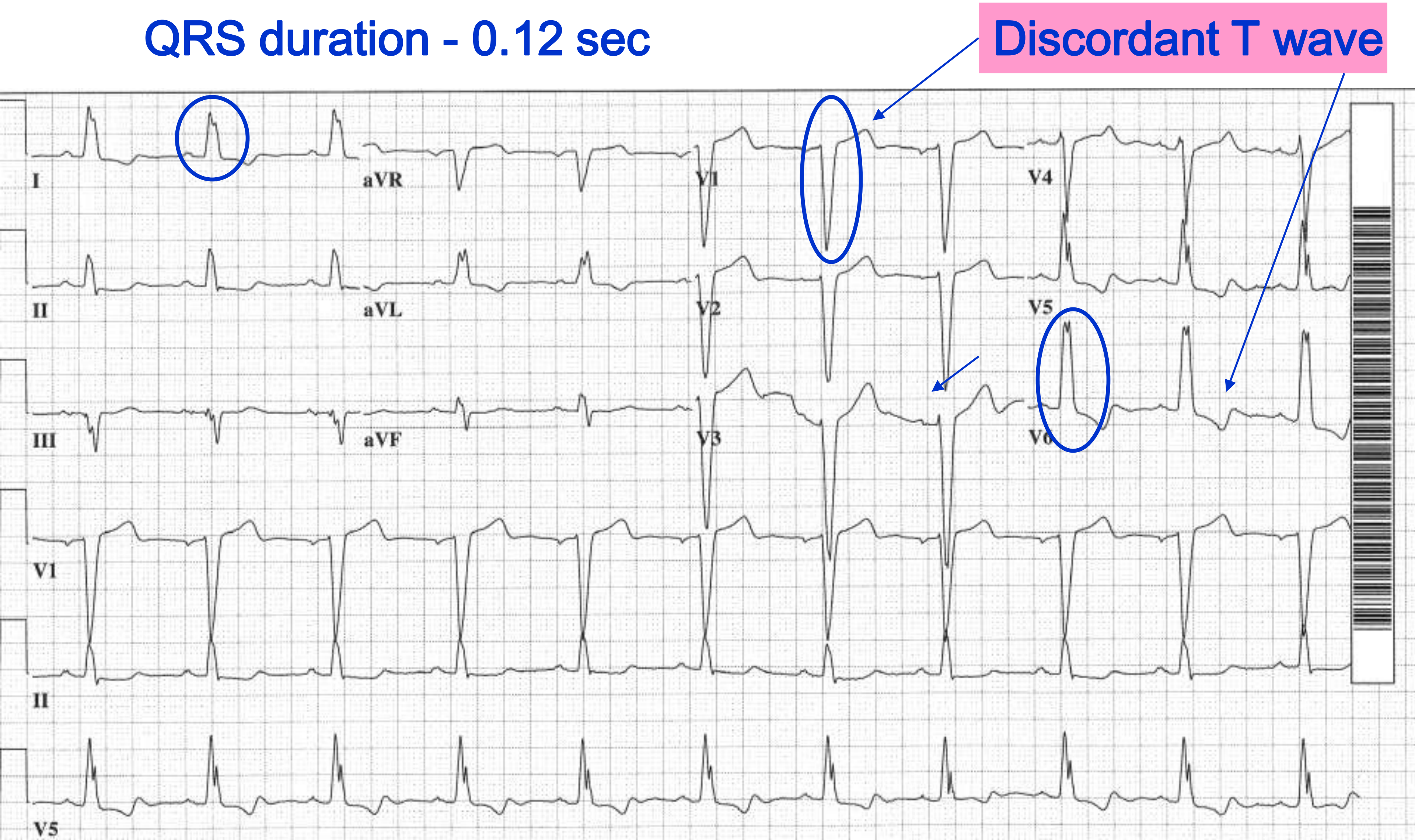
Discordant T wave



ECG - LBBB

Discordant T wave

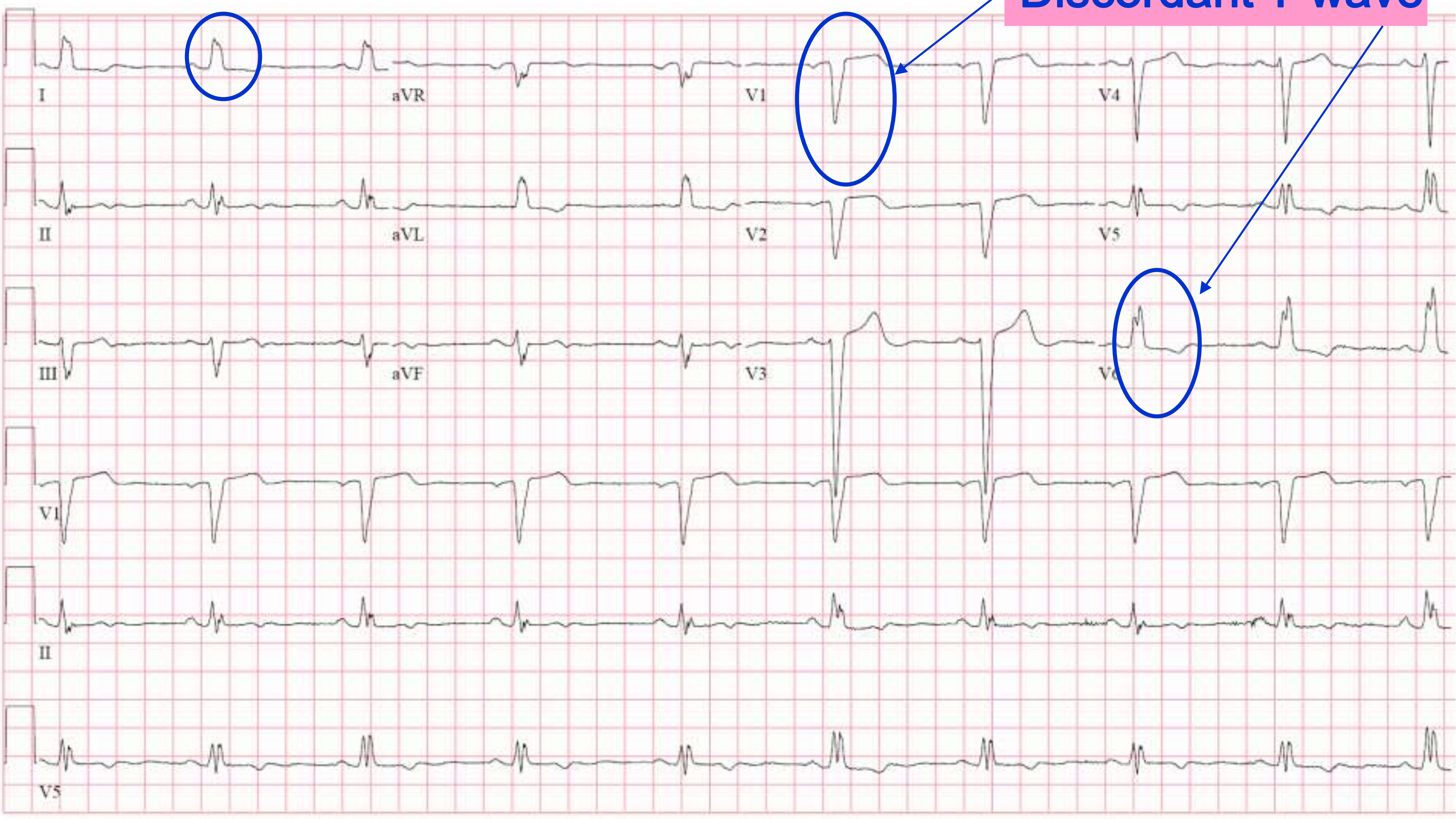
ECG - LBBB


QRS duration - 0.12 sec
Discordant T wave
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

ECG - LBBB

QRS duration - 0.12 sec

Discordant T wave



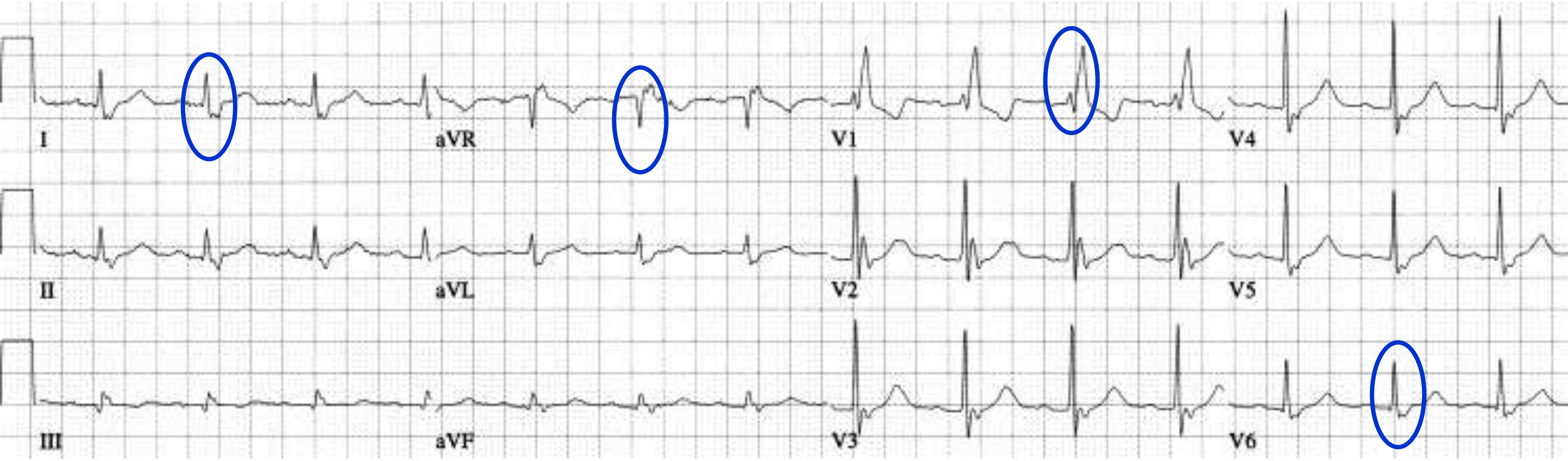
Right Bundle Branch Block

- QRS duration >= 0.12 sec
- R prime in V1 or V2 larger than R wave
- R prime in V1 usually 0.06 sec wide
- Wide (slurred) S wave in I, V5 and V6, often distinct onset
- Preserved initial forces
- Repolarization: T wave opposite the terminal delay

RBBB - Implications

- In a RBBB, the initial 0.06 seconds of the QRS complex are unchanged by the bundle branch (different from the case with LBBB)
- Therefore, it is possible to read pathologic Q waves of myocardial infarction the in setting of RBBB
- In an ECG with prior anteroseptal MI and RBBB, there will be no RSRprime pattern in V1. Rather there will be a QR pattern.

ECG - RBBB



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ECG - RBBB

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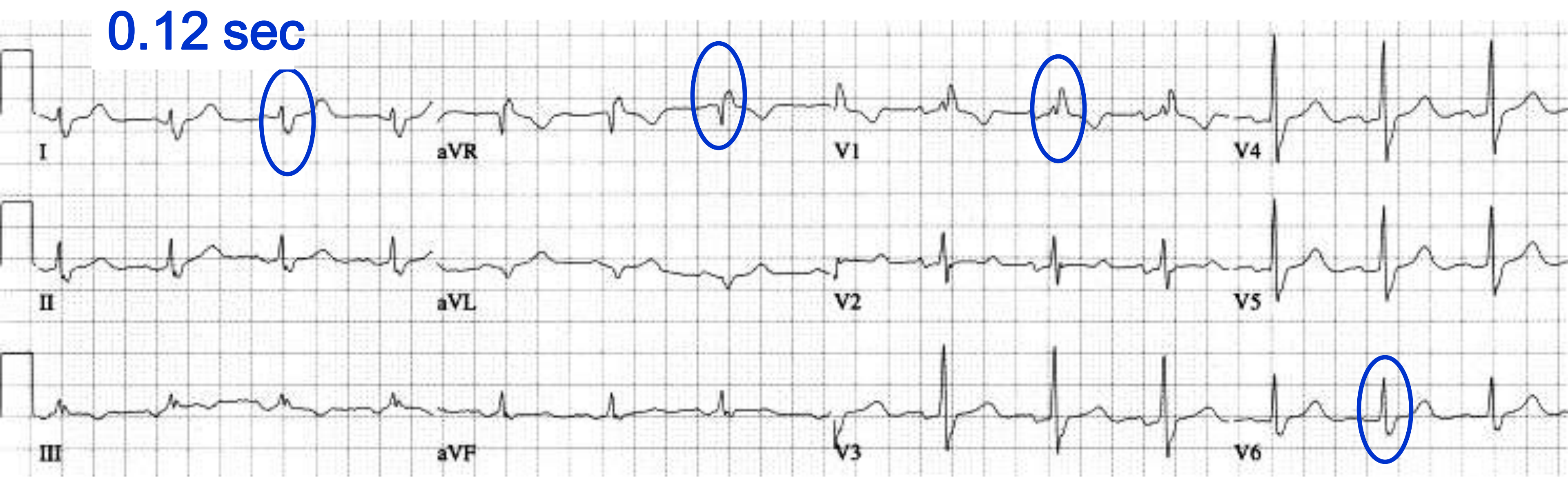
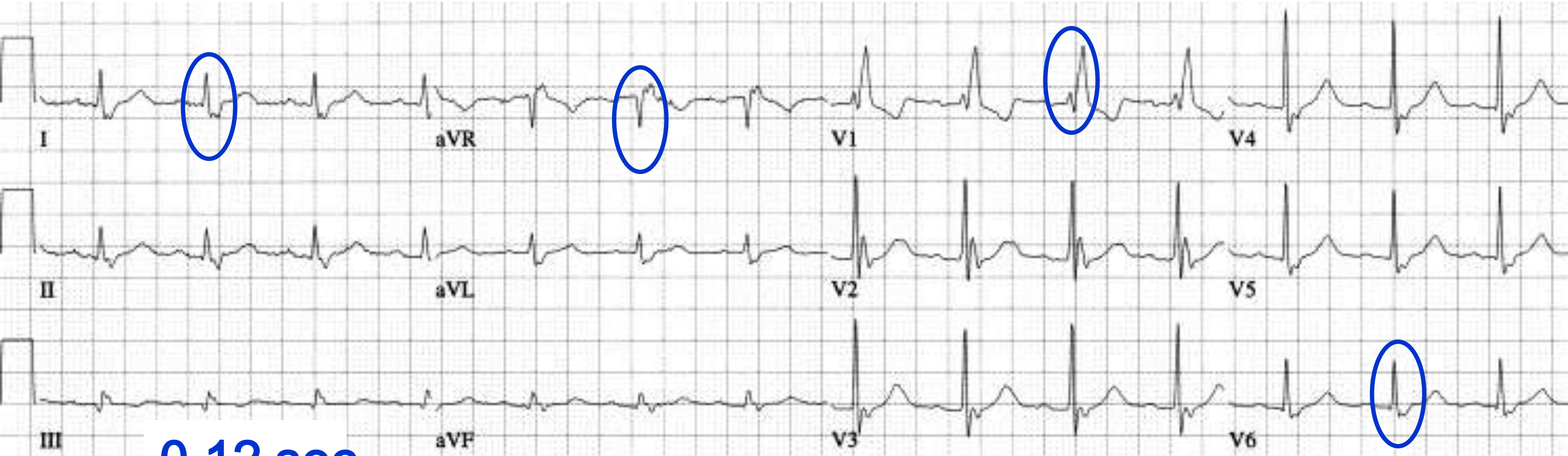
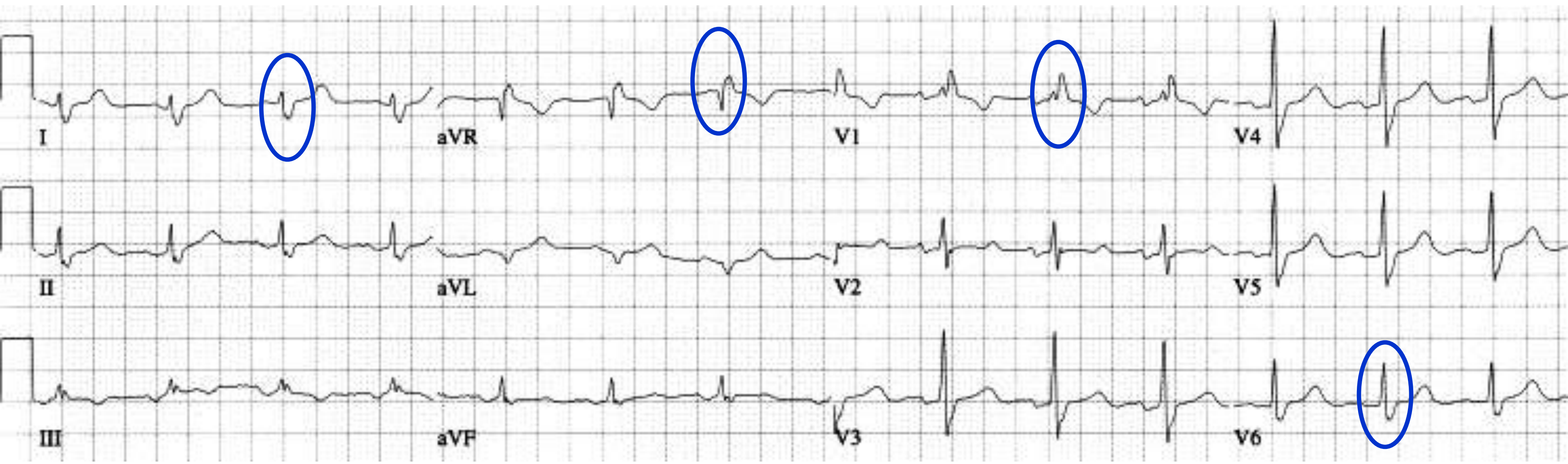
- Preserved initial forces
- Repolarization: T wave opposite the terminal delay



ECG - RBBB

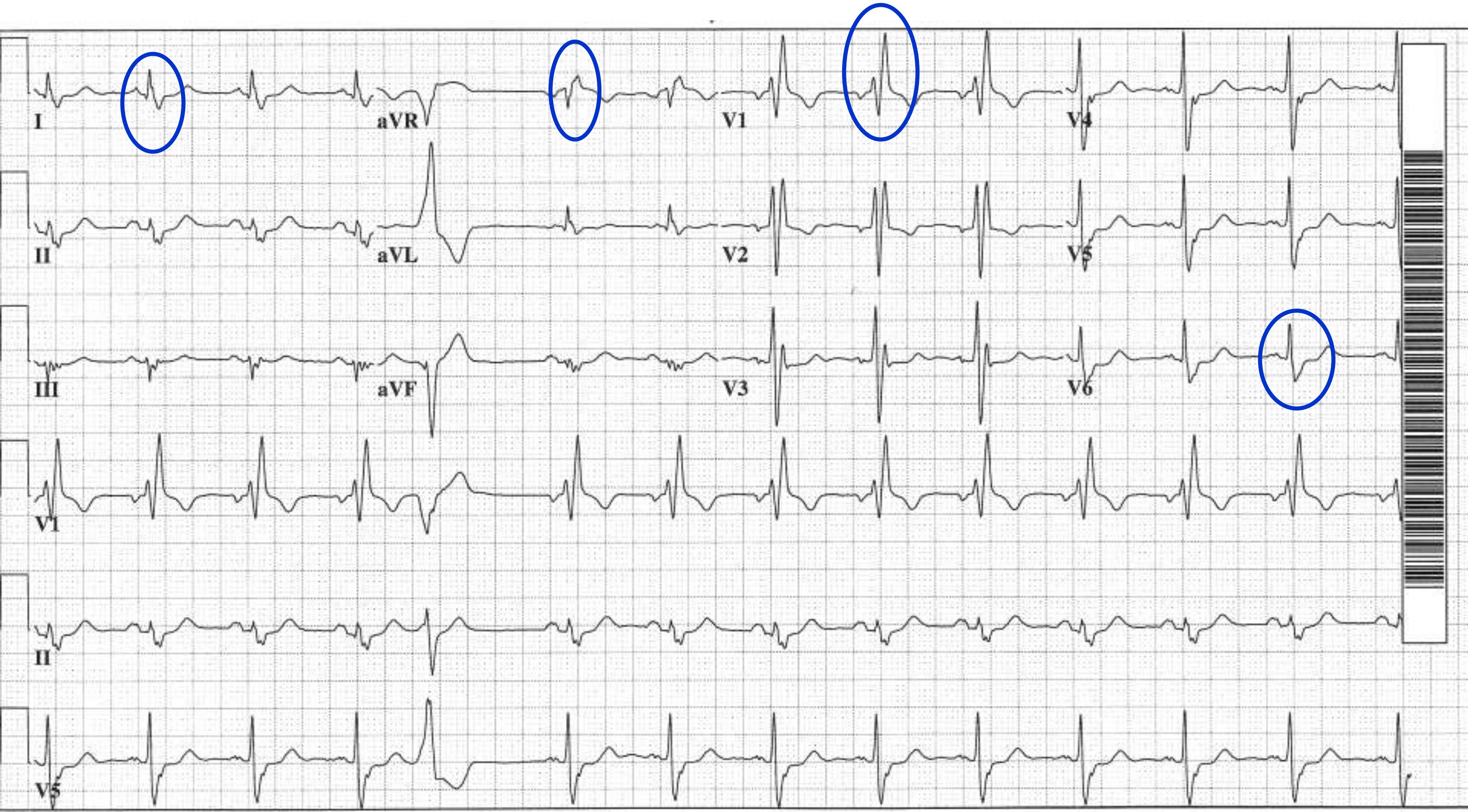


0.12 sec



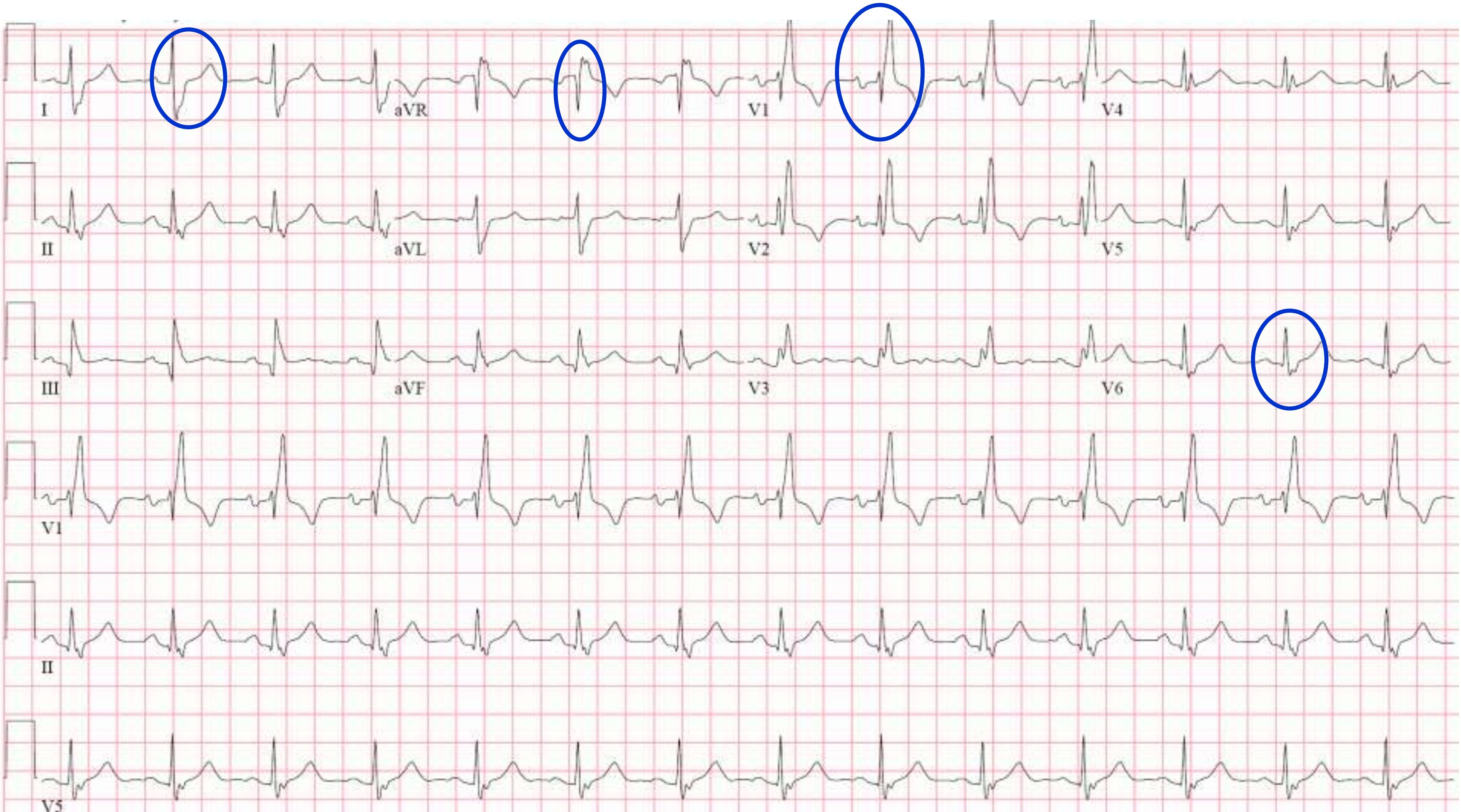
ECG - RBBB

QRS duration - 0.12 sec



ECG - RBBB

QRS duration - 0.12 sec



Optional

Hemiblocks

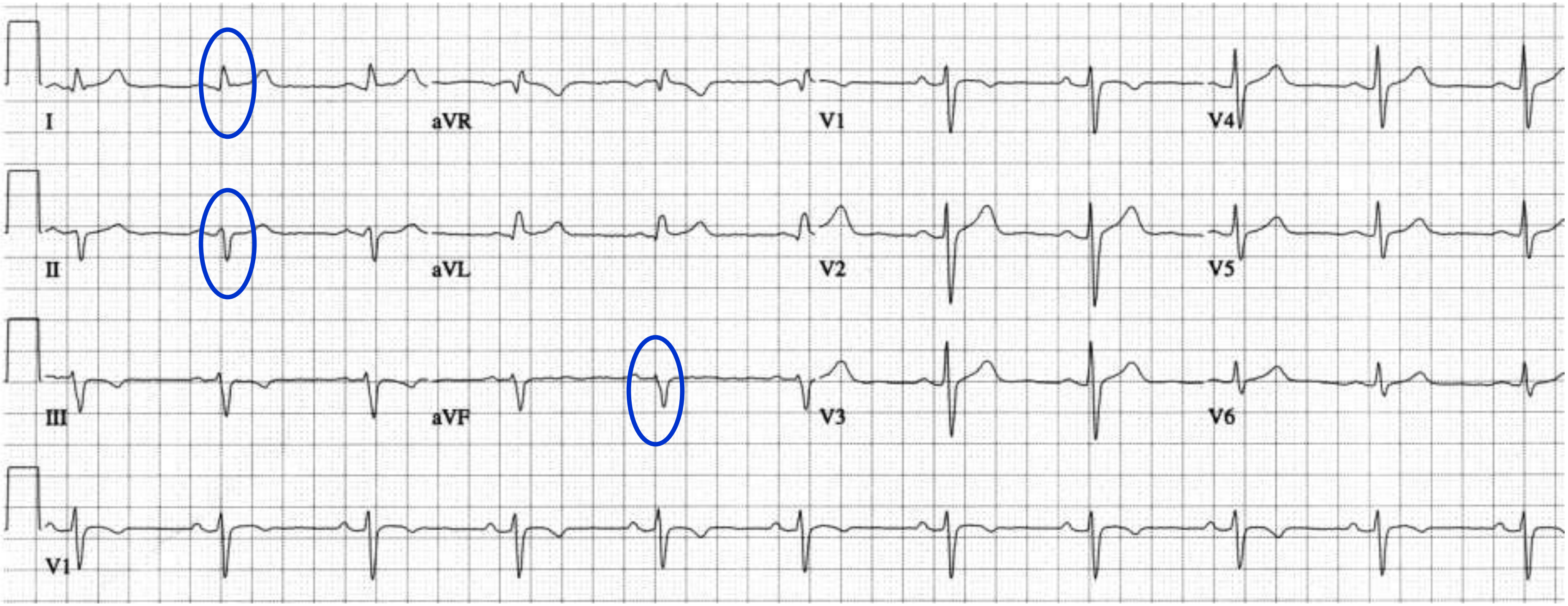
- Left anterior hemiblock
  - Axis -45 to -90 degrees
  - qR complex or R wave in I and aVL
  - rS complex in II, III, and aVF
  - normal or slightly long QRS duration
  - T wave usually tall in II, III, and aVF
- Left posterior hemiblock
  - Axis +90 to +180 degrees
  - S in I and often aVL
  - Q in III and often II and aVF
  - normal or slightly long QRS duration
  - T wave usually inverted in II, III, and aVF

Left axis deviation

Right axis deviation

ECG - LAFB

Optional



- Axis -45 to -90 degrees
- qR complex or R wave in I and aVL
- rS complex in II, III, and aVF
- normal or slightly long QRS duration
- T wave usually tall in II, III, and aVF

Combinations of Conduction Abnormalities **Optional**

- LBBB - doesn't really combine
- RBBB plus anterior hemiblock
  - intuitive criteria
- RBBB plus posterior hemiblock
  - intuitive criteria
- RBBB with anterior or posterior hemiblock is called <u>Bifascicular </u>block
- Bifascicular block with first or second degree AV block is called <u>Trifascicular</u> block

Other Conduction Abnormalities

Optional

- IVCD - Intraventricular conduction delay or defect - QRS duration of 0.11 or more without RBBB or LBBB criteria, also called nonspecific or diffuse IVCD
- Peri-infarction block - mild terminal delay in conduction directed toward infarcted area, slurred downstroke of the R wave in a lead with pathologic Q wave

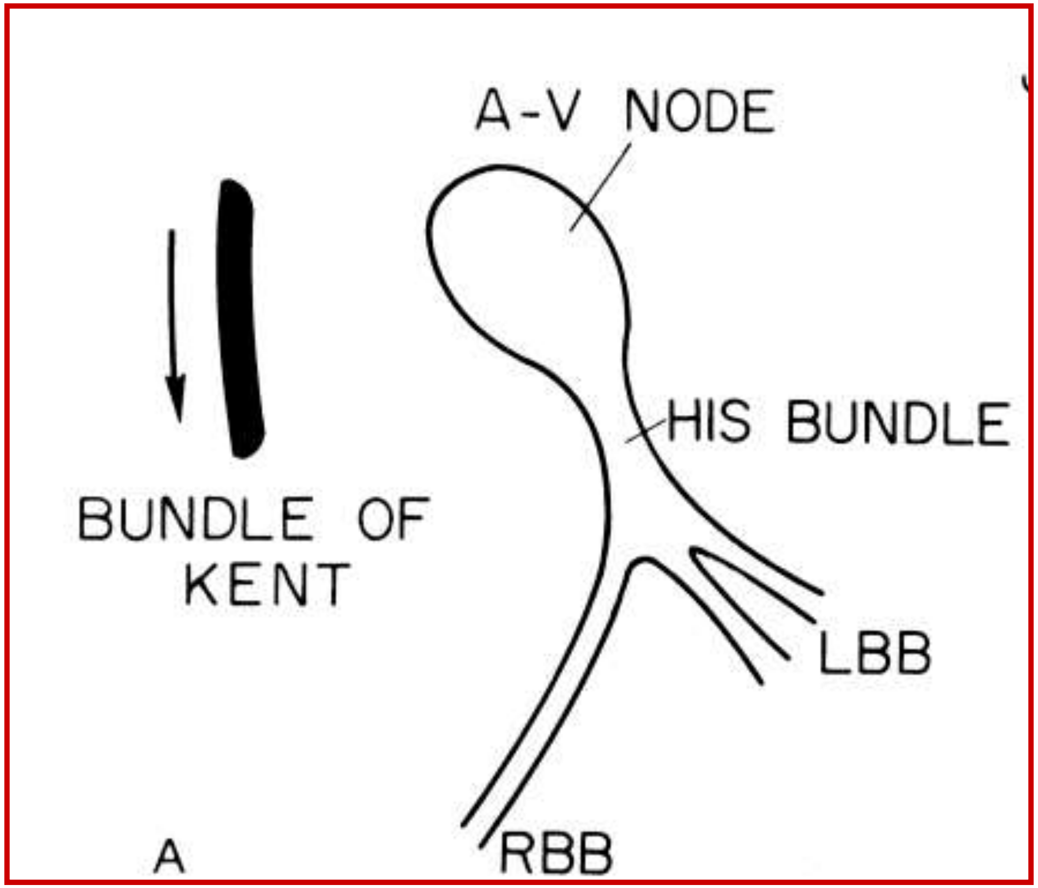
Wolff-Parkinson-White Pattern (WPW)

- Short PR interval (<0.12 sec)
- Wide QRS complex (>= 0.11 sec)
- Slurred initial forces of QRS - Delta wave (the delta wave is included in the measurement of the QRS duration)
- Secondary ST segment and T wave abnormality
- A frequent association of paroxysmal tachycardia, usually supraventricular is WPW syndrome (rather than just pattern)

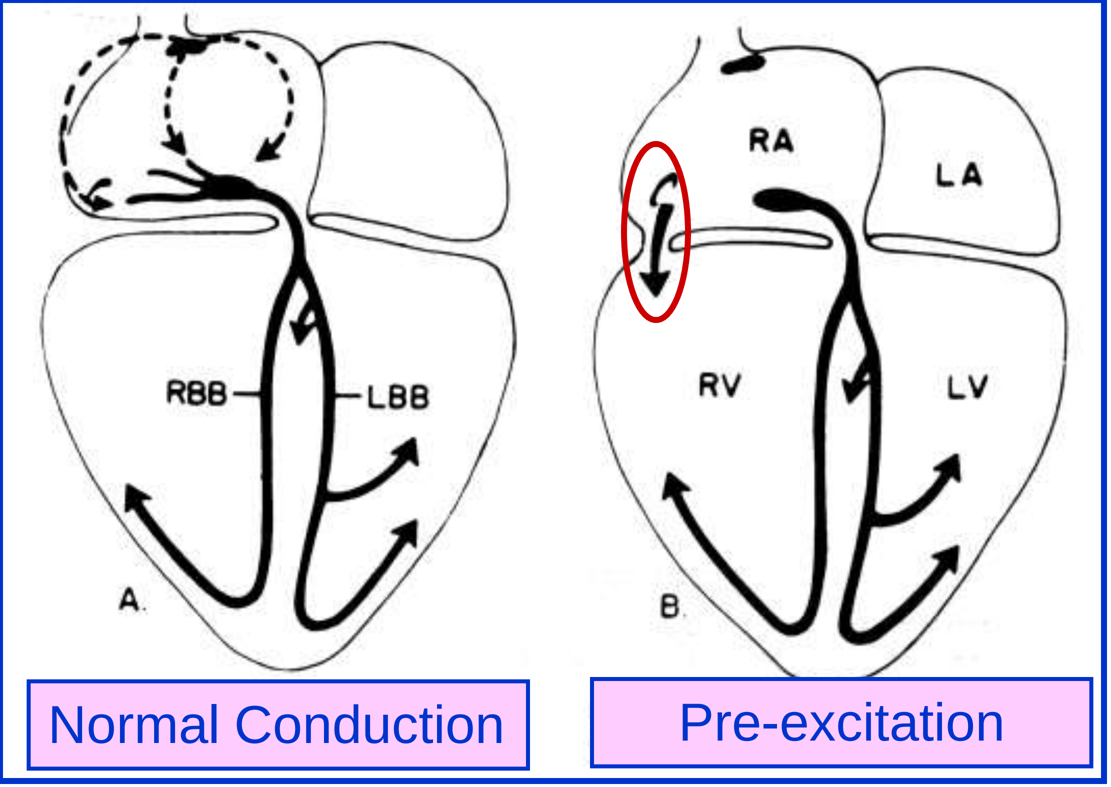
Wolff-Parkinson-White Syndrome (WPW) - 2

- Every beat is a fusion beat
  - Part of QRS from AV node and normal His-Purkinje system
  - Part of QRS from conduction through the accessory AV connection (“Bundle of Kent”) from atrial muscle to ventricular muscle
  - Variable conduction depends on how much of the ventricle is excited from the normal versus the accessory pathway

Anatomy of Pre-excitation



From Chou, 1996, p. 473

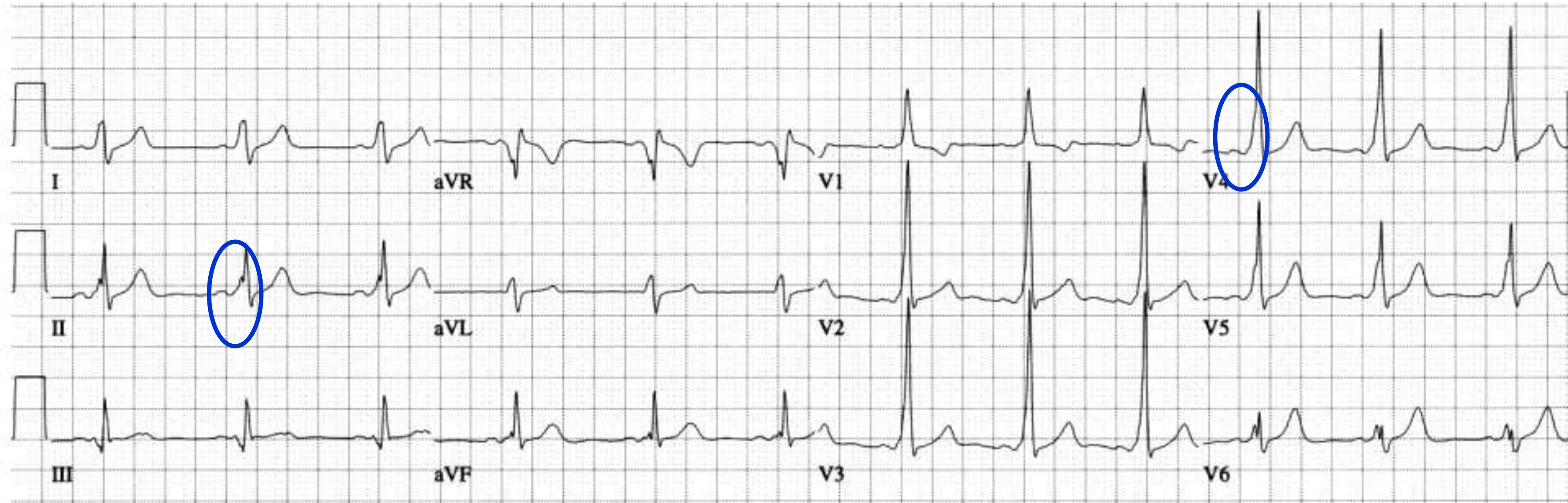


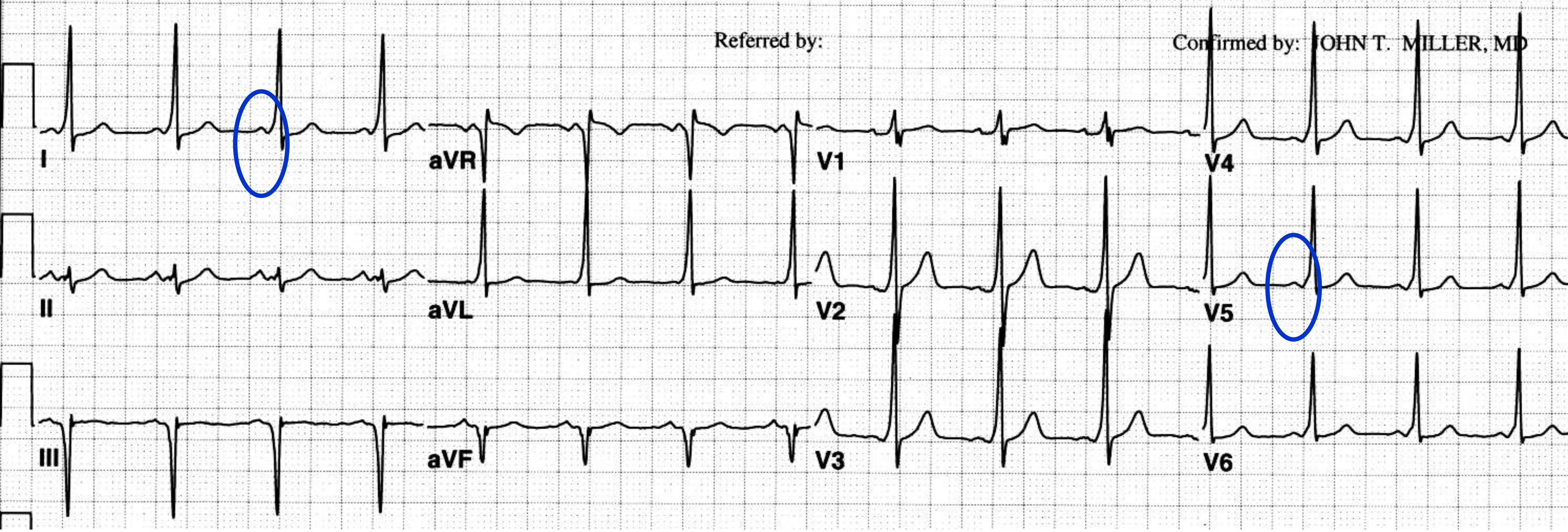
WPW

From Chou, 1996, p. 473

- Short PR interval (<0.12 sec)
- Wide QRS complex (>= 0.11 sec)
- Slurred initial forces of QRS - Delta wave
- Secondary ST segment and T wave abnormality

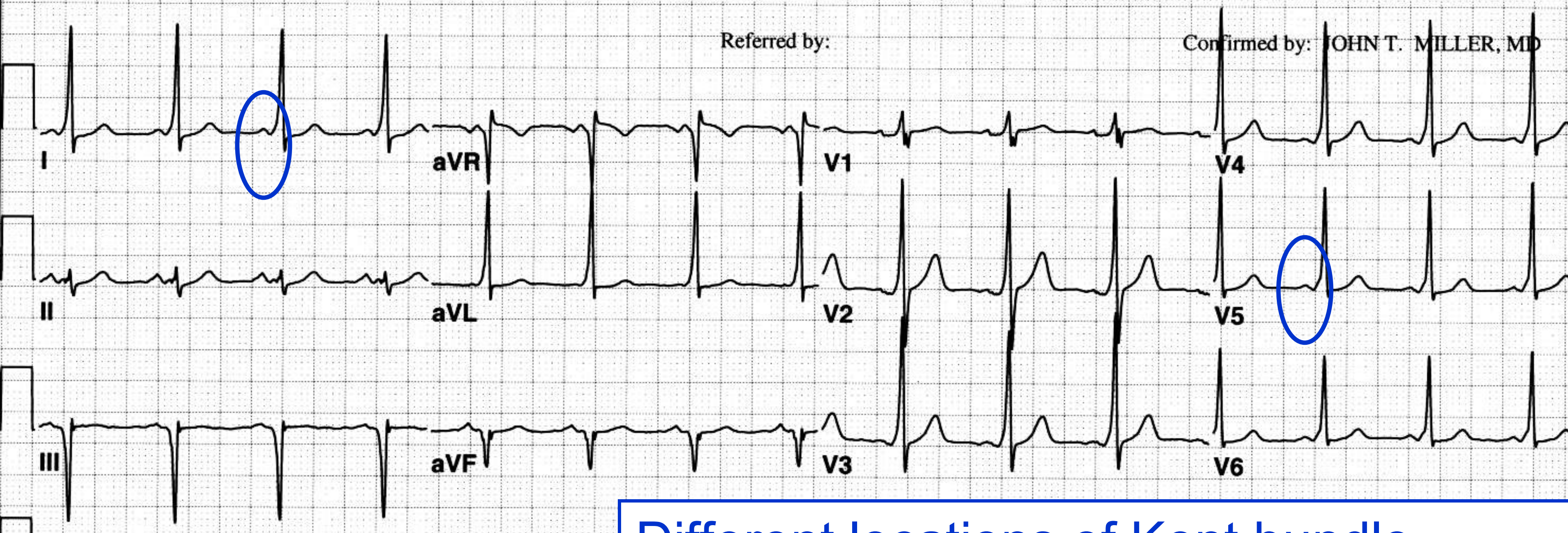
WPW - ECG





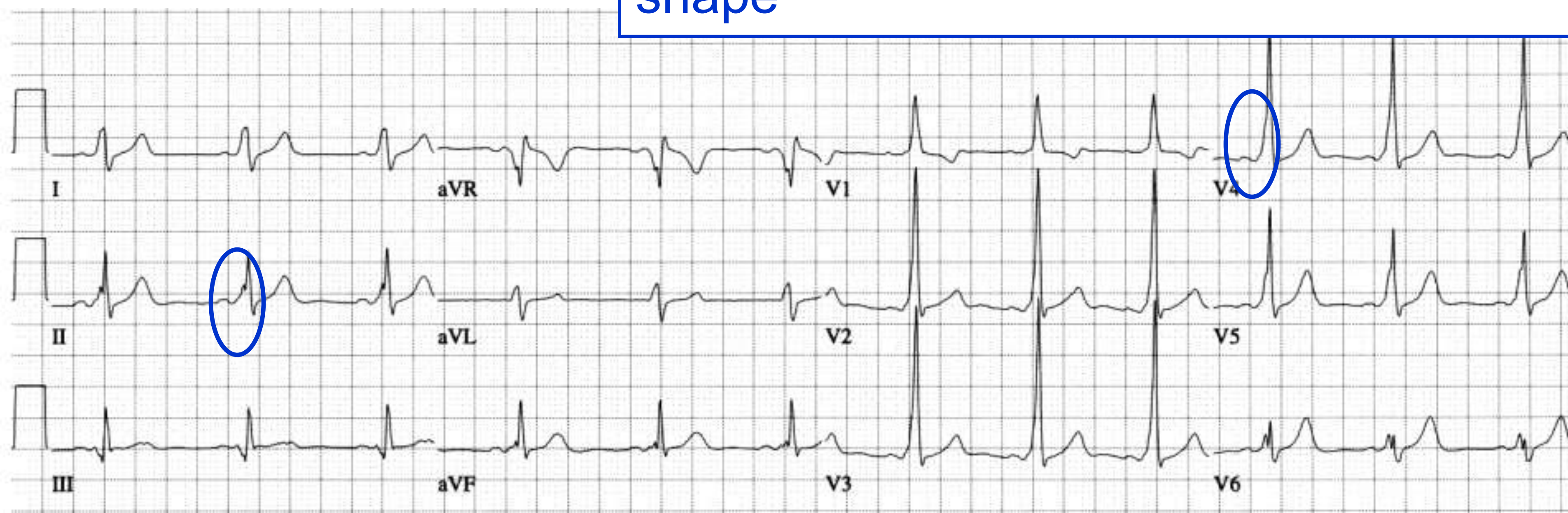
WPW - ECG

- Short PR interval (<0.12 sec)
- Wide QRS complex (>= 0.11 sec)
- Slurred initial forces of QRS - Delta wave
- Secondary ST segment and T wave abnormality

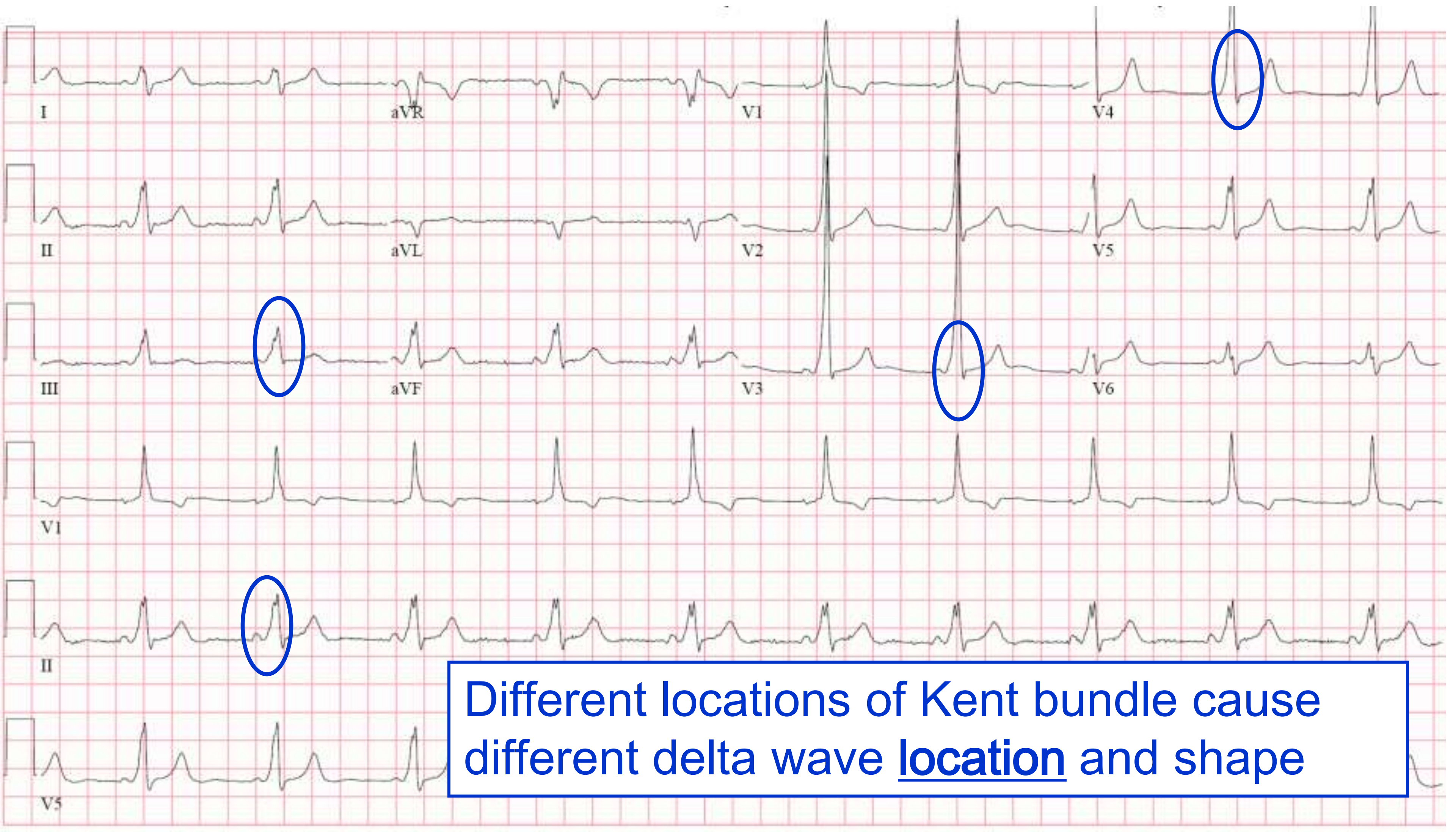


WPW - ECG

Different locations of Kent bundle cause different delta wave location and shape



WPW - ECG

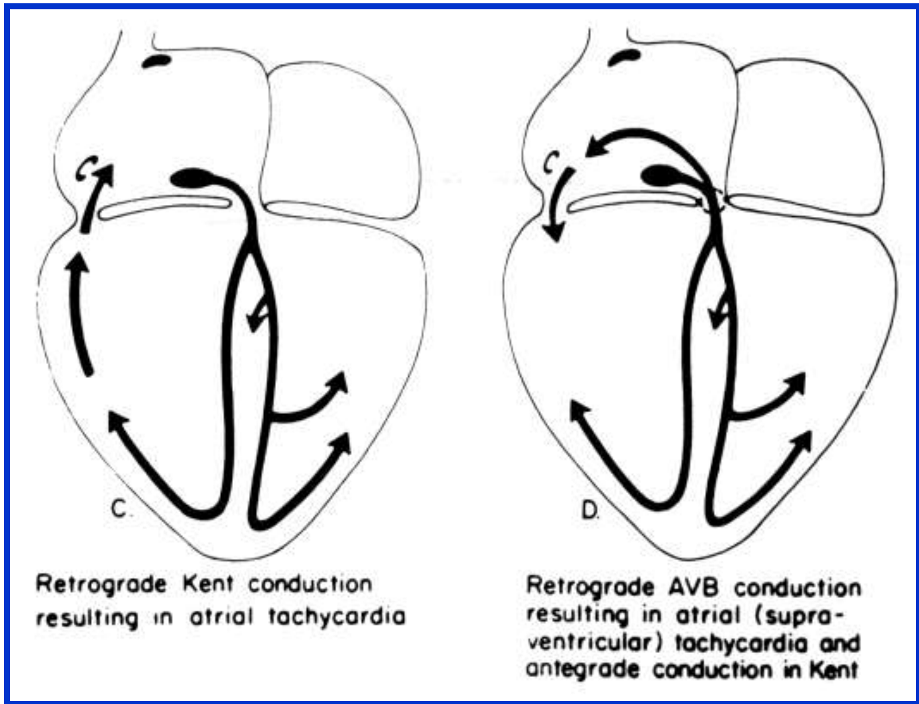


Different locations of Kent bundle cause different delta wave **location** and shape

Wolff-Parkinson-White Syndrome (WPW) - 3

- Tachycardia is often due to electrical activity travelling in a circular pathway
- One Possible Pathway
  - AV node
  - Ventricular muscle
  - Accessory pathway
  - Atrial muscle

- “Circus movement”
- Atrioventricular reentrant tachycardia (AVRT)



Morphologic Abnormalities

- Chamber hypertrophy
- Conduction abnormalities
- **<u>Ischemia, injury, infarction</u>**
- Repolarization abnormalities

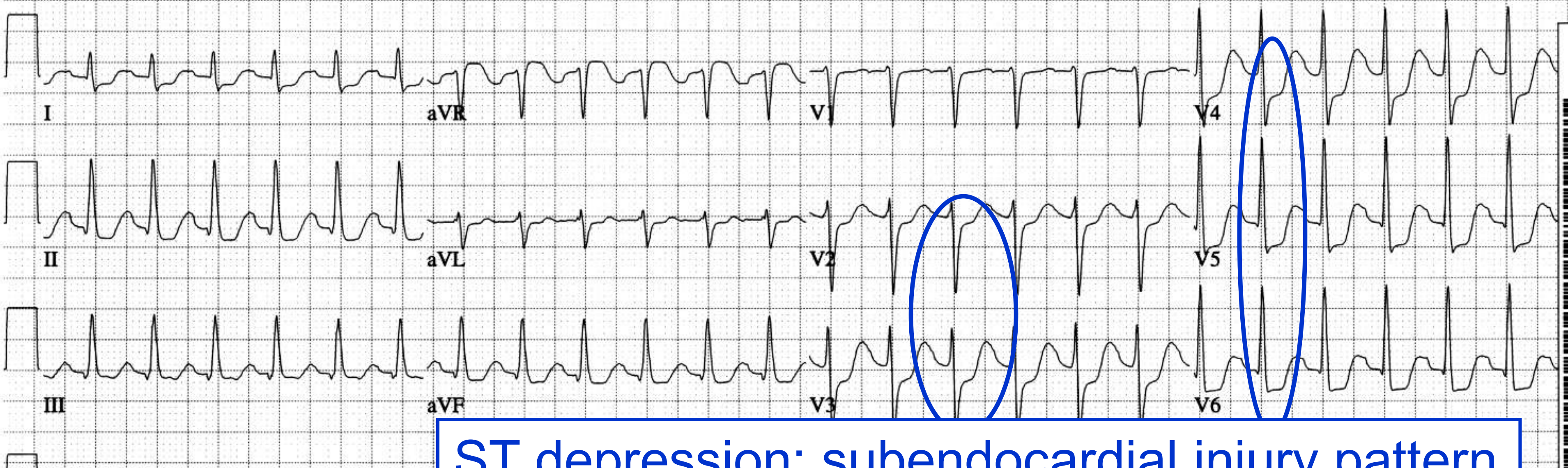
Ischemia, Injury, Infarction - 1
Physiology of Infarction

- Coronary blood supply must meet demand
- Coronary oxygen extraction is near max at rest
- More oxygen supply requires more coronary blood flow, reserve is about 4-fold
- Demand is increased by higher heart rate, contractility, chamber size, and systolic pressure
- Supply decreased by coronary obstruction or impaired oxygen delivery of blood

Supply/Demand!

Ischemia, Injury, Infarction - 2

- Ischemia and Injury
  - generally a severe imbalance
  - ST elevation is transmural or subepicardial injury - this localizes (STEMI – need to move quickly to PCI or lytics)
  - ST depression is subendocardial injury - this doesn't localize

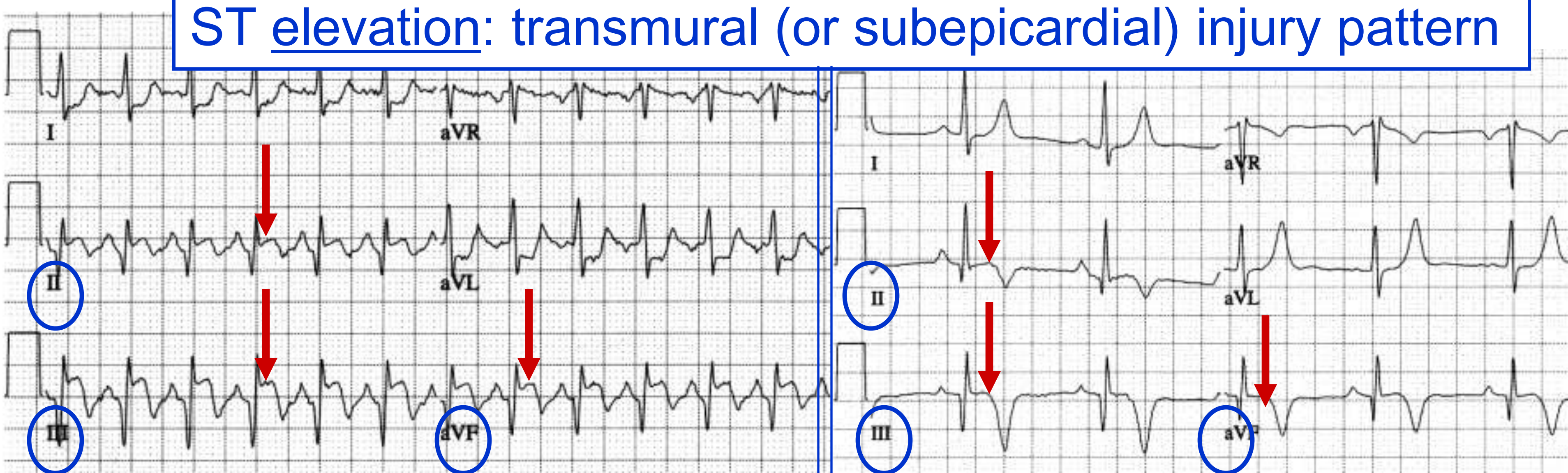


ST <u>depression</u>: subendocardial injury pattern

ECG Ischemia or Injury

ST segment displacement

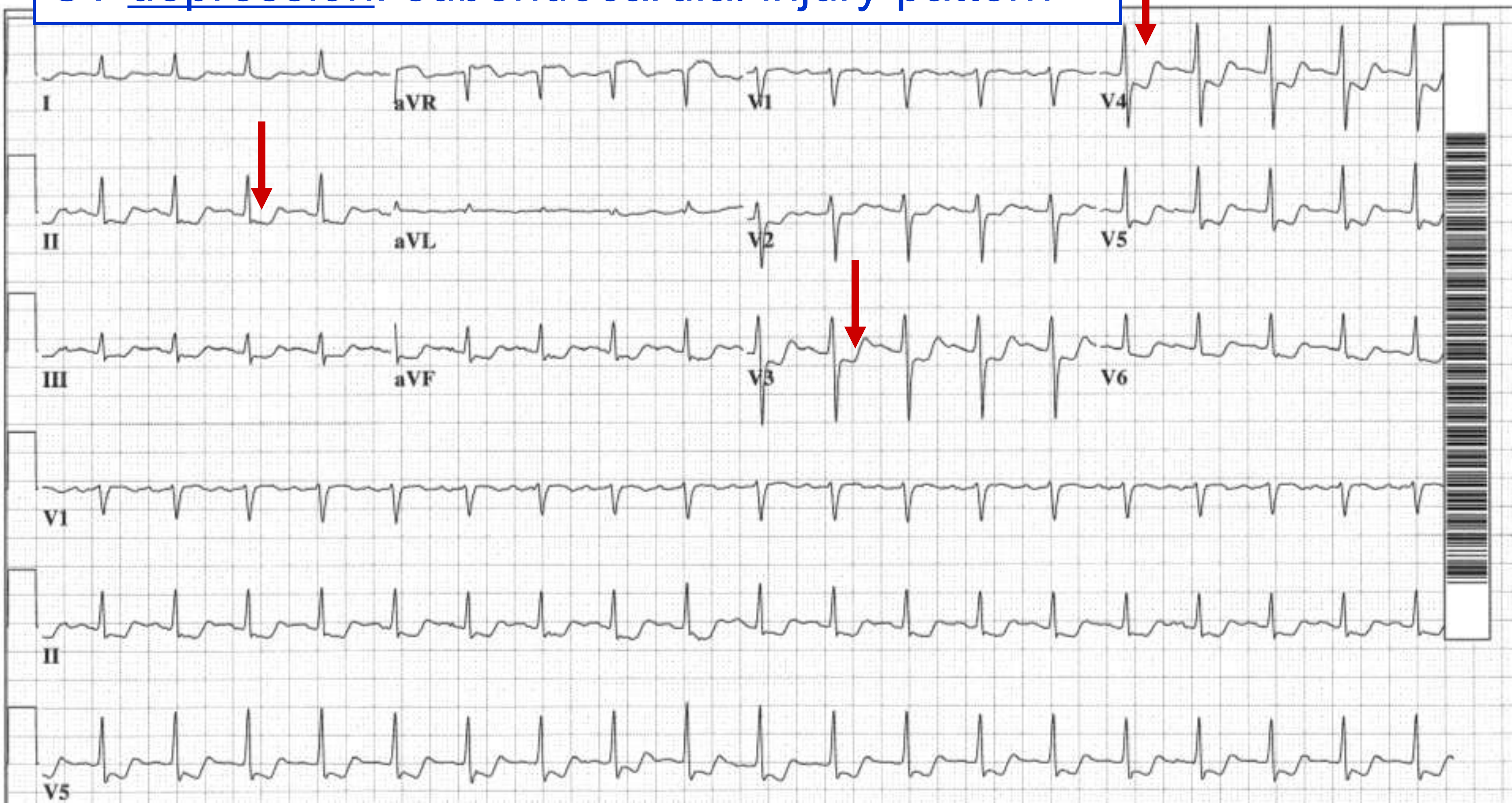
ST <u>elevation</u>: transmural (or subepicardial) injury pattern



ECG Injury

ST segment displacement

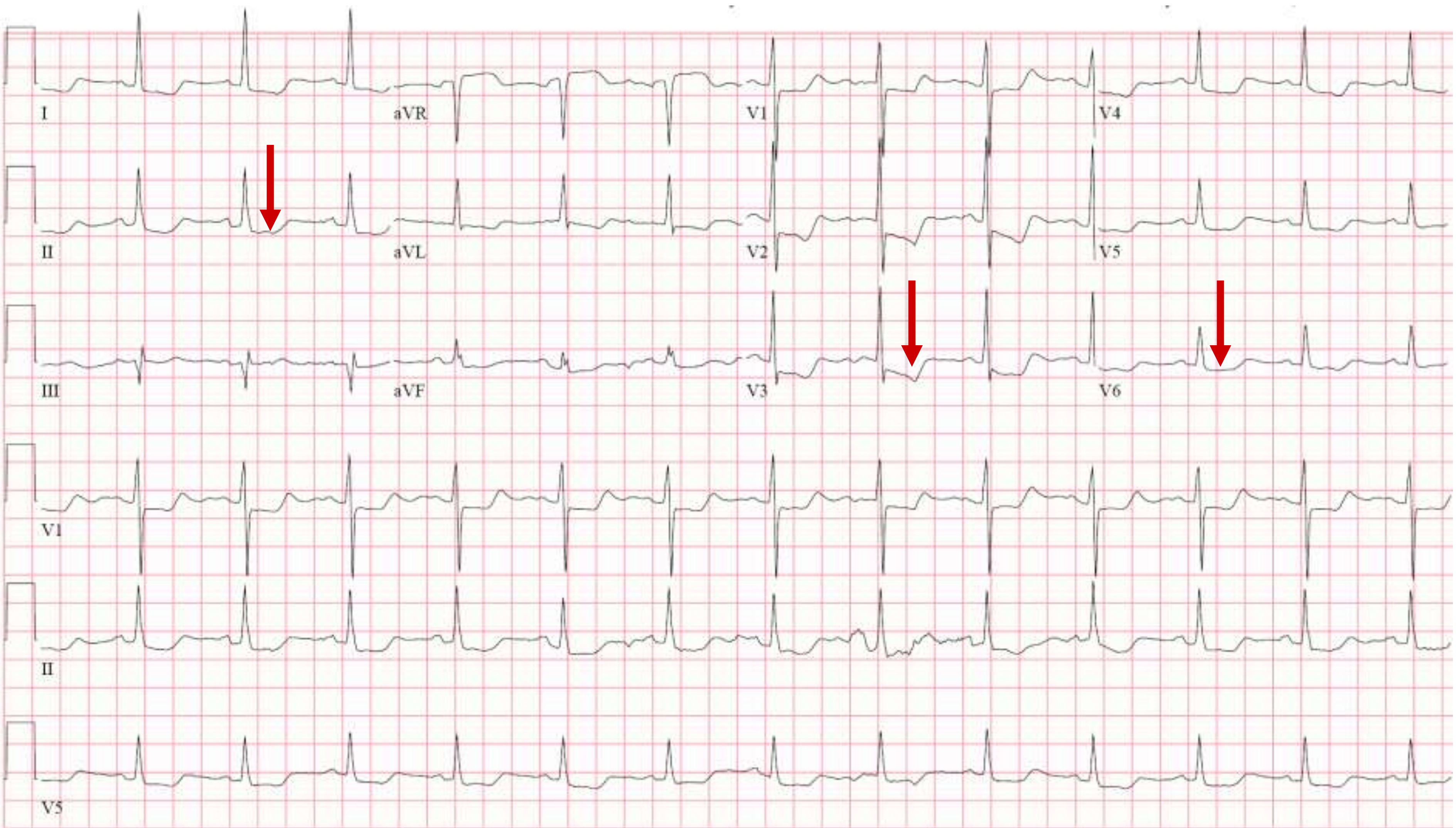
ST depression: subendocardial injury pattern

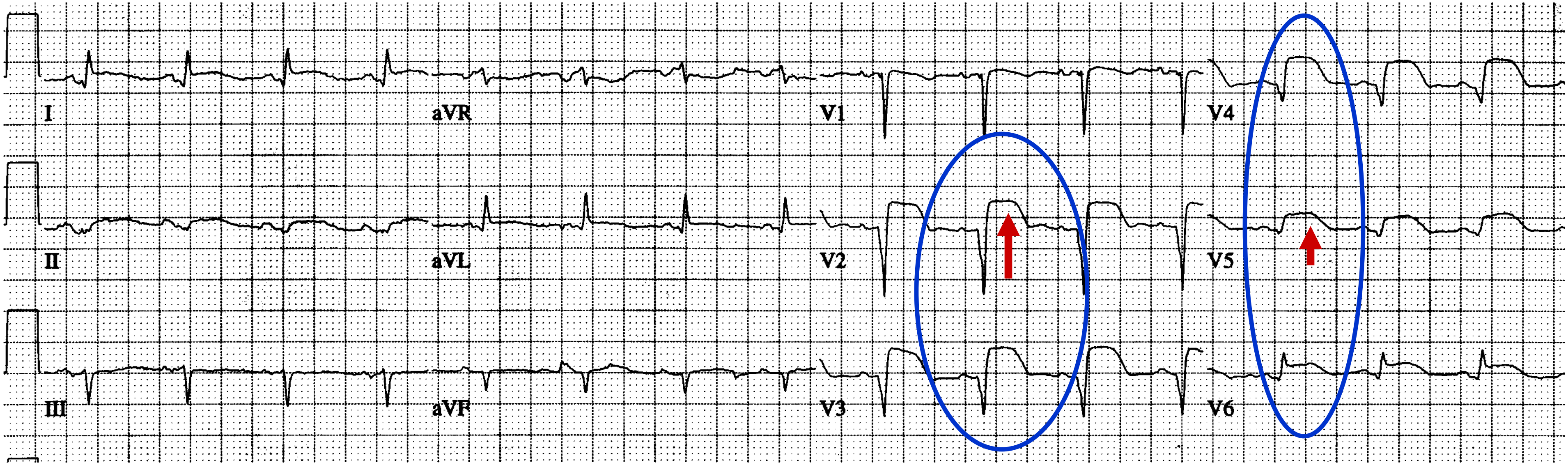


ECG Injury

ST segment displacement

ST <u>depression</u>:
subendocardial injury pattern

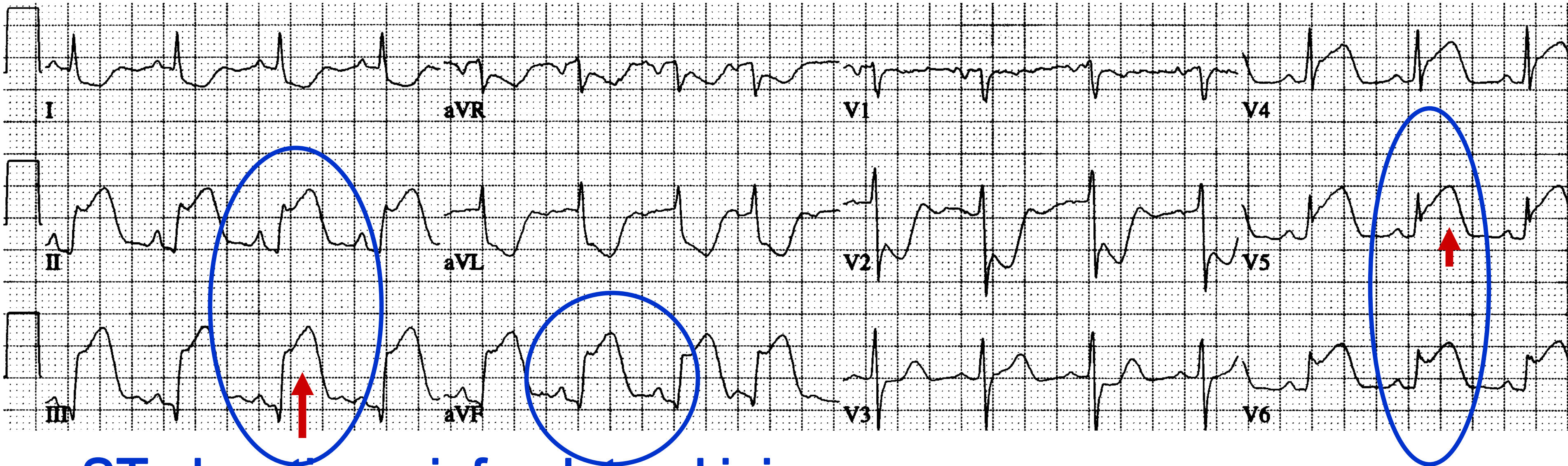




ST elevation – anterolateral injury

ECG Injury

ST elevation – transmural injury – often indicates acute infarction – should trigger immediate revascularization attempts



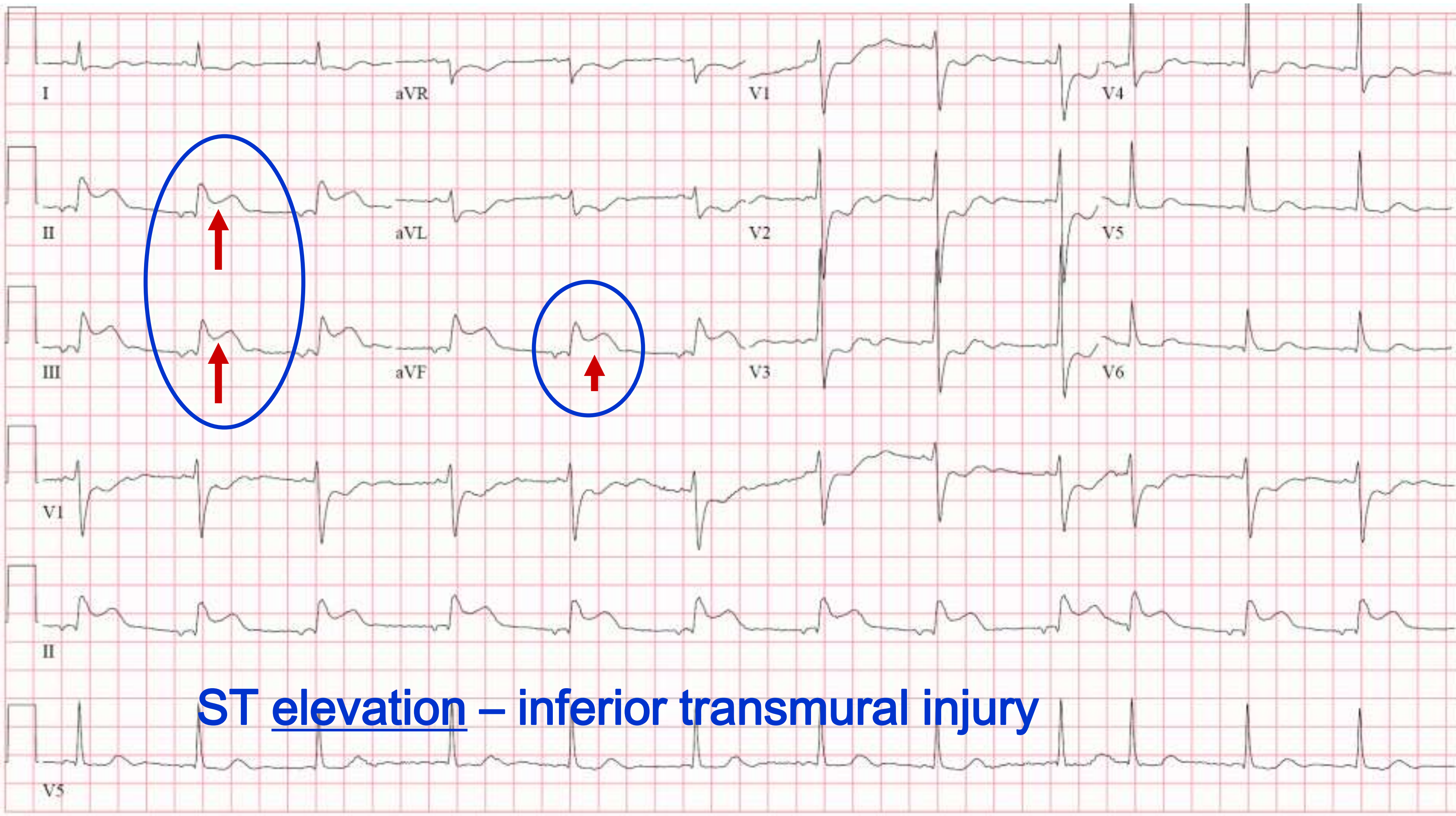
ST elevation – inferolateral injury

ECG Injury

ST elevation – transmural injury – often indicates acute infarction – should trigger immediate revascularization attempts

ECG Injury

ST elevation – transmural injury – often indicates acute infarction – should trigger immediate revascularization attempts



ST <u>elevation</u> – inferior transmural injury

Ischemia, Injury, Infarction - 3

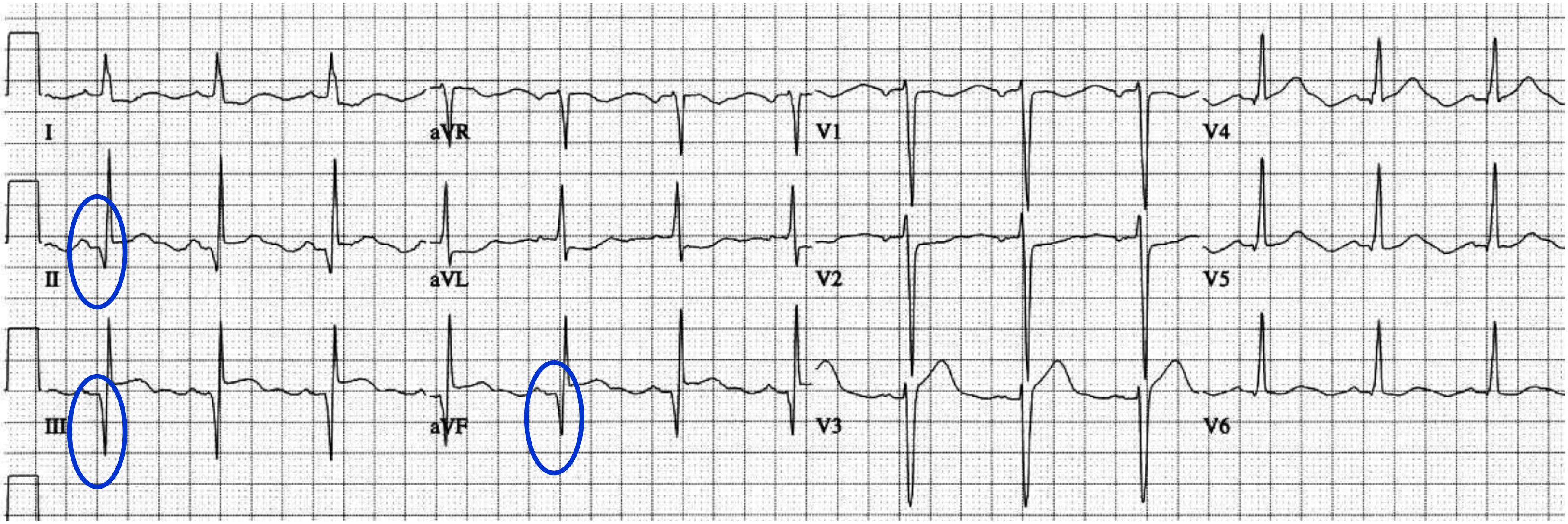
- Infarction - irreversible loss of myocardium, replaced eventually by electrically silent collagen
  - ECG - initial forces directed away from area of infarction, with abnormal Q wave in affected leads
  - Abnormal Q (Pathologic Q) - 0.04 sec wide and depth of 25% of height of R wave in that lead.

Infarction Q waves

- In addition to the classic definition of pathologic Q waves (25% of the height of the R wave and 0.04 sec duration), there are 2 other additional facts
- In diagnosing anterior MI, true Q waves anteriorly are not always needed – anterior MI also shows as R wave decrement rather than R wave progression
- In diagnosing posterior MI, since there is no ECG lead in the back, the infarction is seen as a very tall and broad initial R wave in V1 and V2 (“upside-down Q waves”)

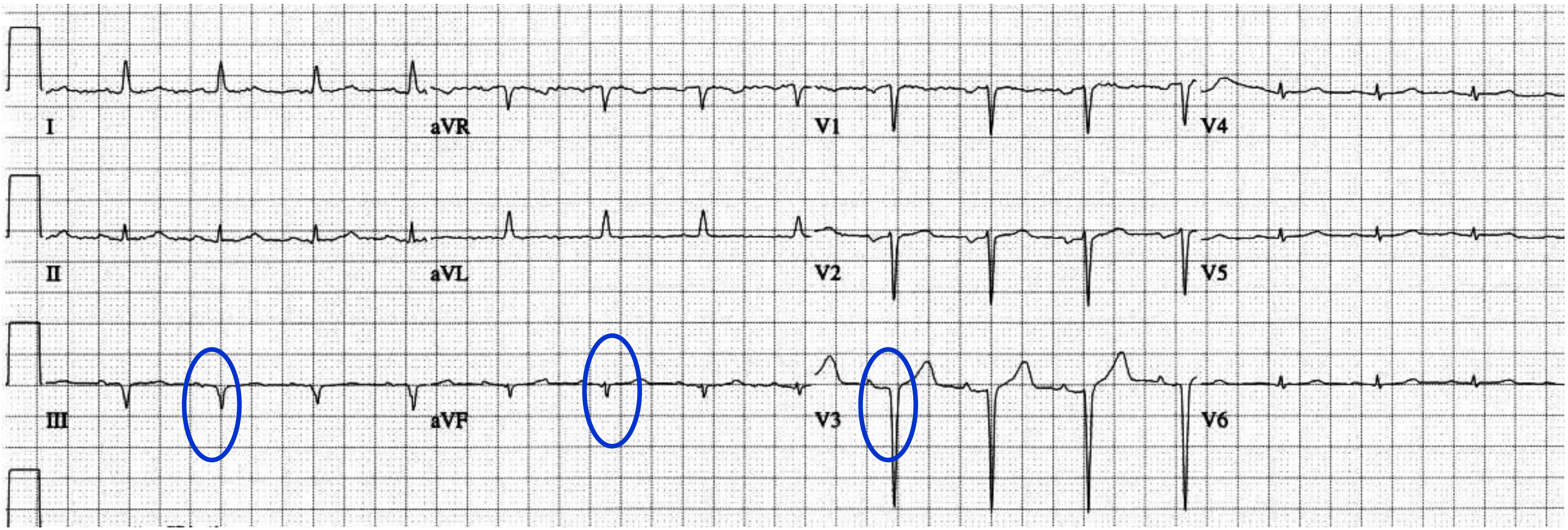
Ischemia, Injury, Infarction - 4

- Infarction - irreversible loss of myocardium, replaced eventually by electrically silent collagen
  - ECG - initial forces directed away from area of infarction, with abnormal Q wave in affected leads
  - Abnormal Q (Pathologic Q) - 0.04 sec wide and depth of 25% of height of R wave in that lead



Ischemia, Injury, Infarction - 5

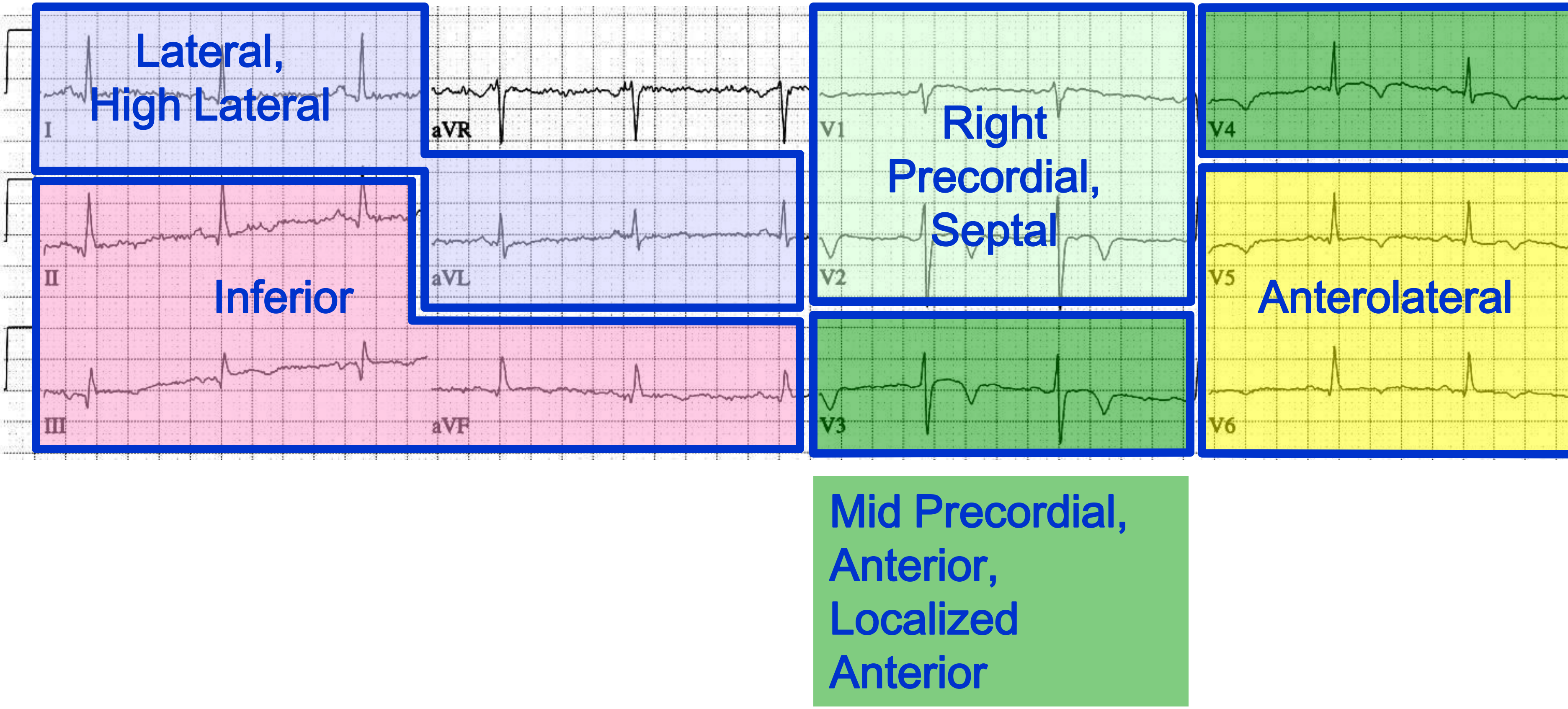
- Infarction - irreversible loss of myocardium, replaced eventually by electrically silent collagen
  - ECG - initial forces directed away from area of infarction, with abnormal Q wave in affected leads
  - Abnormal Q (Pathologic Q) - 0.04 sec wide and depth of 25% of height of R wave in that lead



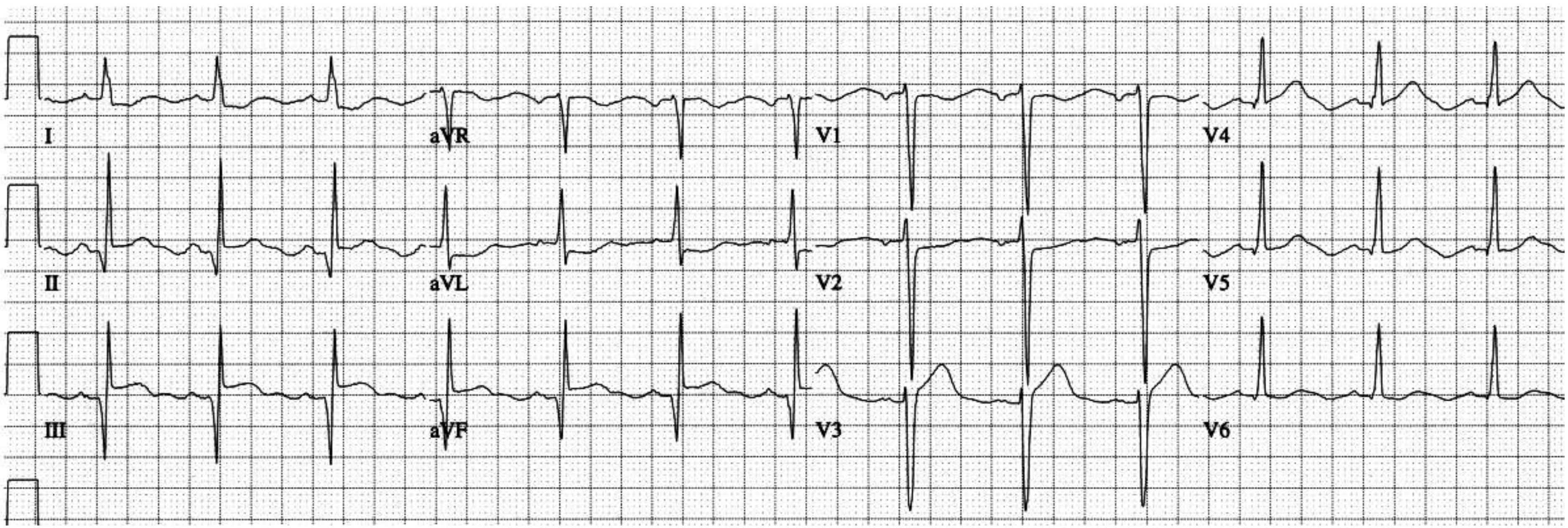
Localization of Infarction

Inferior	II, III, aVF	Extensive Anterior	Nearly all of V1-V6, I and aVL
Inferolateral	II, III, aVF, and V5-V6	High lateral	I, aVL
Anteroseptal	V1-V3, or V4	True posterior	Upside-down V1-V2
Anterior	V2-V4	Inferoposterior	Inferior and posterior
Anterolateral	V5-V6, or V4, I, aVL	Posterolateral	Posterior and anterolateral

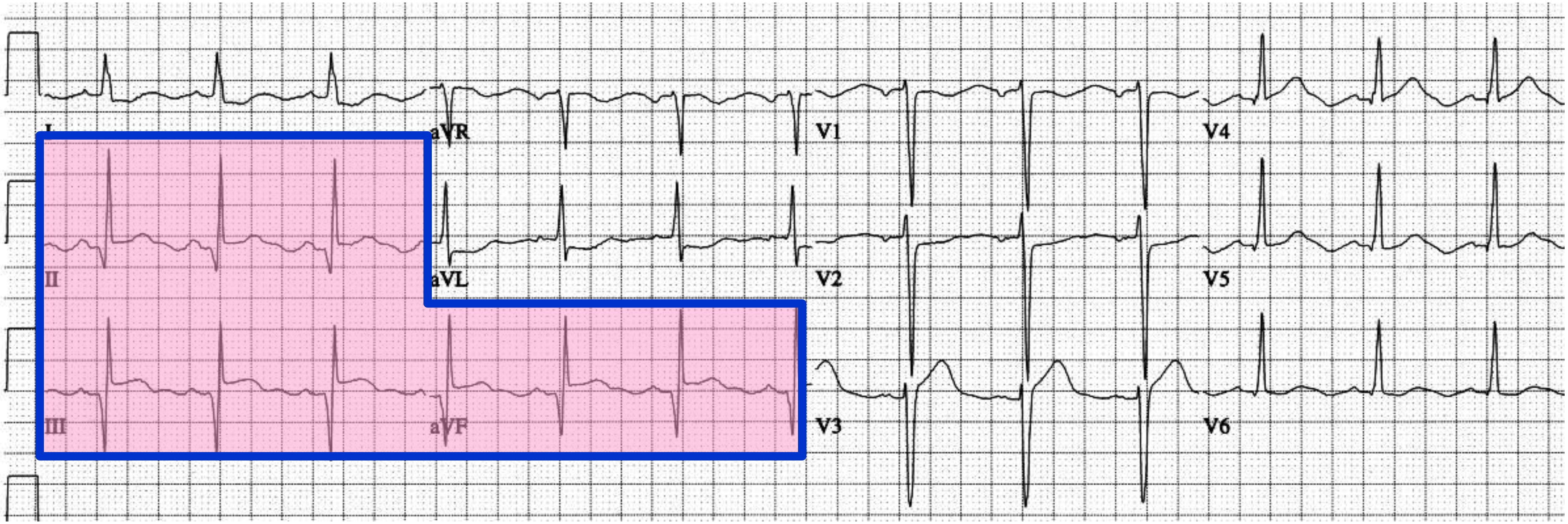
Infarction Location



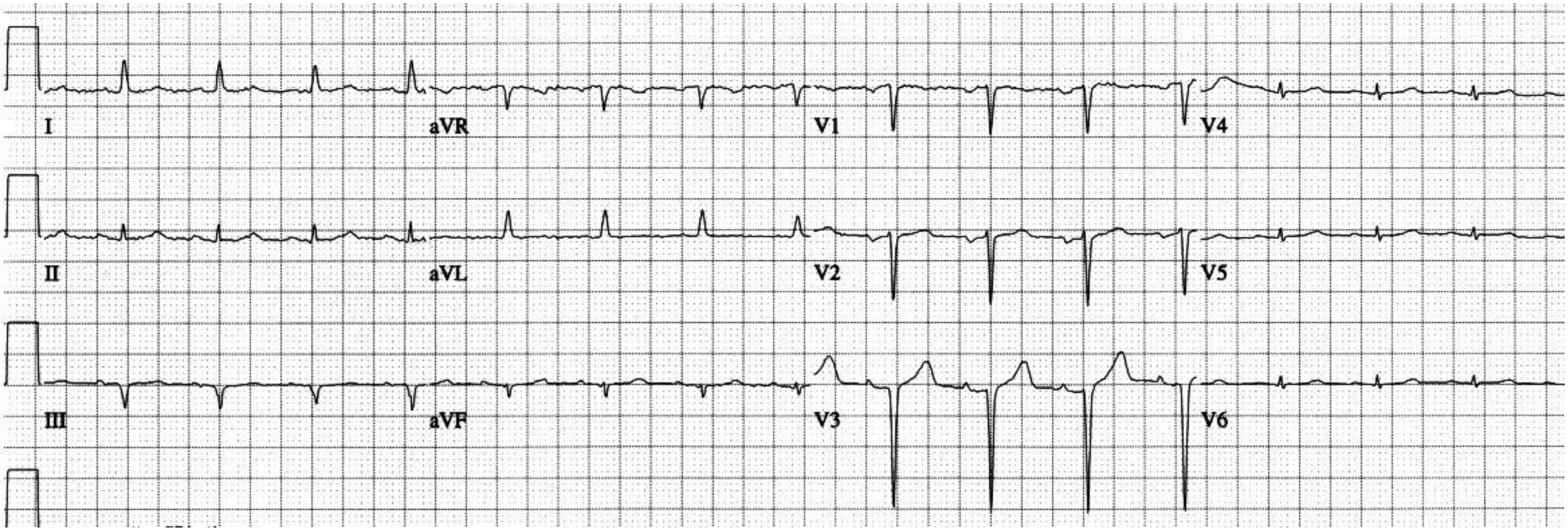
Inferior Infarction



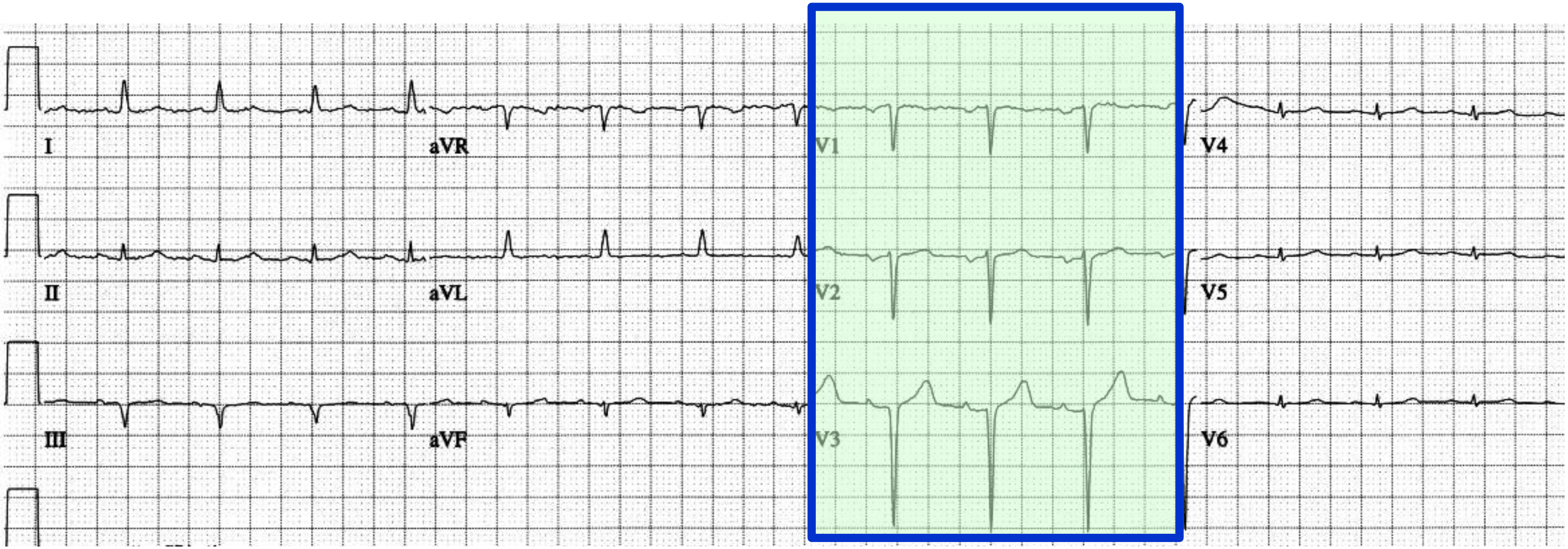
Inferior Infarction



Anterior MI



Anterior MI



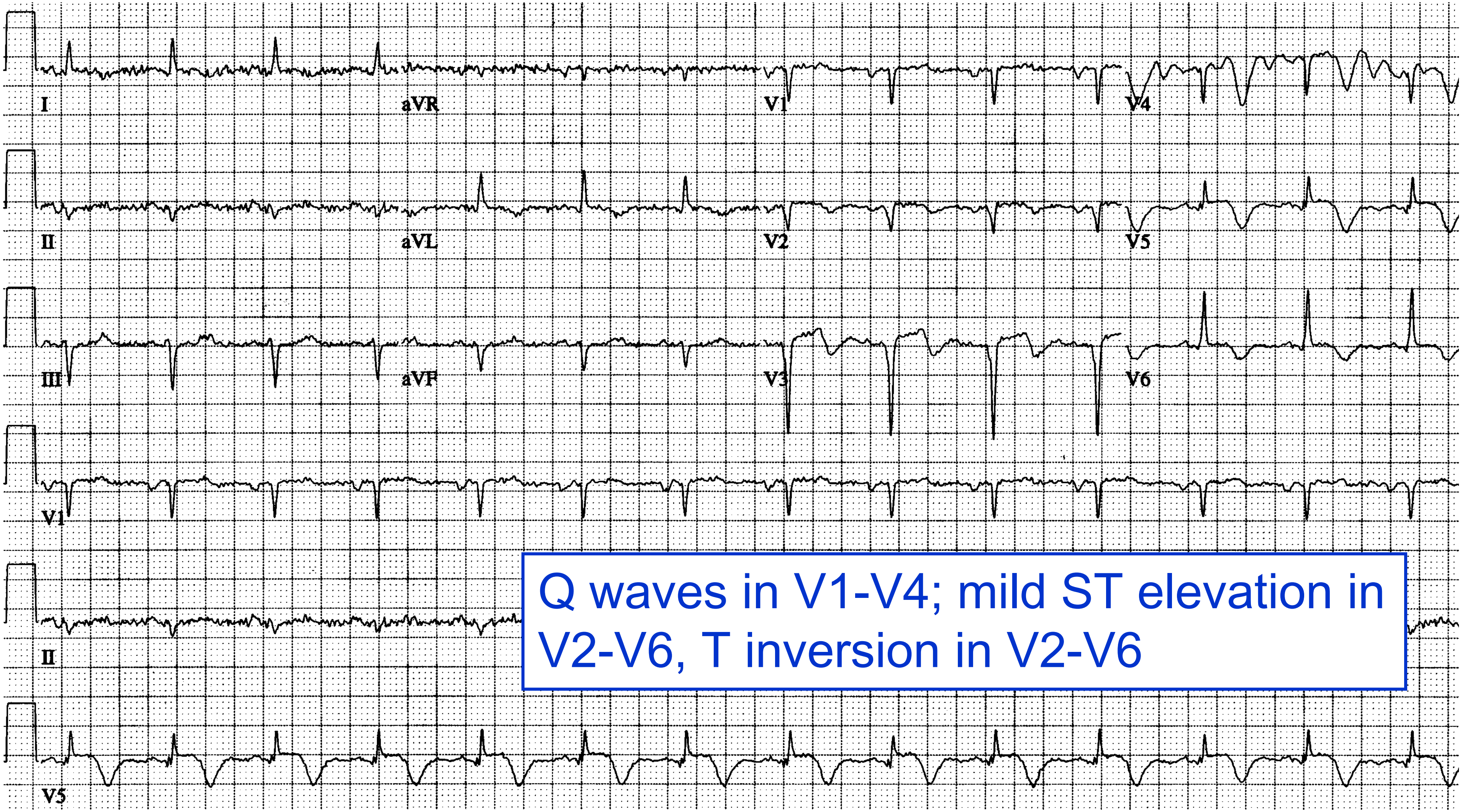
Time Course of Infarction - 1

- Hyperacute T waves - peaked positive T waves directed toward infarction, only a few minutes
- ST depression - any time in infarction, doesn't localize, may mean "Non-Q MI", or Non-ST elevation MI – NSTEMI.
- ST elevation - begins in minutes, greatest in 7-12 hr, BEST criterion for urgent intervention (PCI or thrombolysis)

Time Course of Infarction - 2

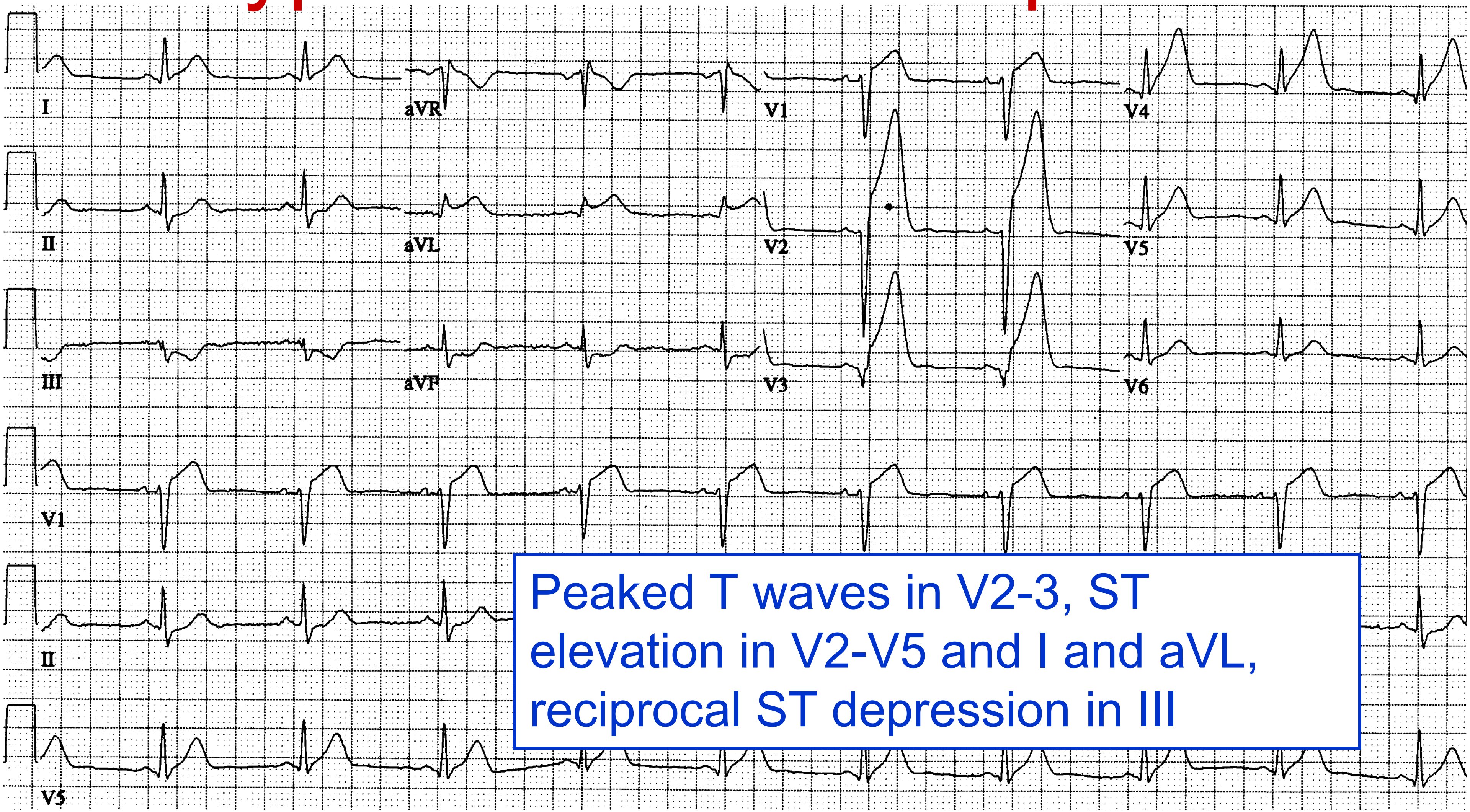
- <u>Q wave formation</u> - begins at 6-12 hours, usually permanent
- <u>T wave inversion</u> - begins after a day or a few days, lasts often months to years
- <u>ST segment elevation usually resolved</u> by 2 to 8 weeks; afterwards indicates LV aneurysm

Recent Anterolateral MI



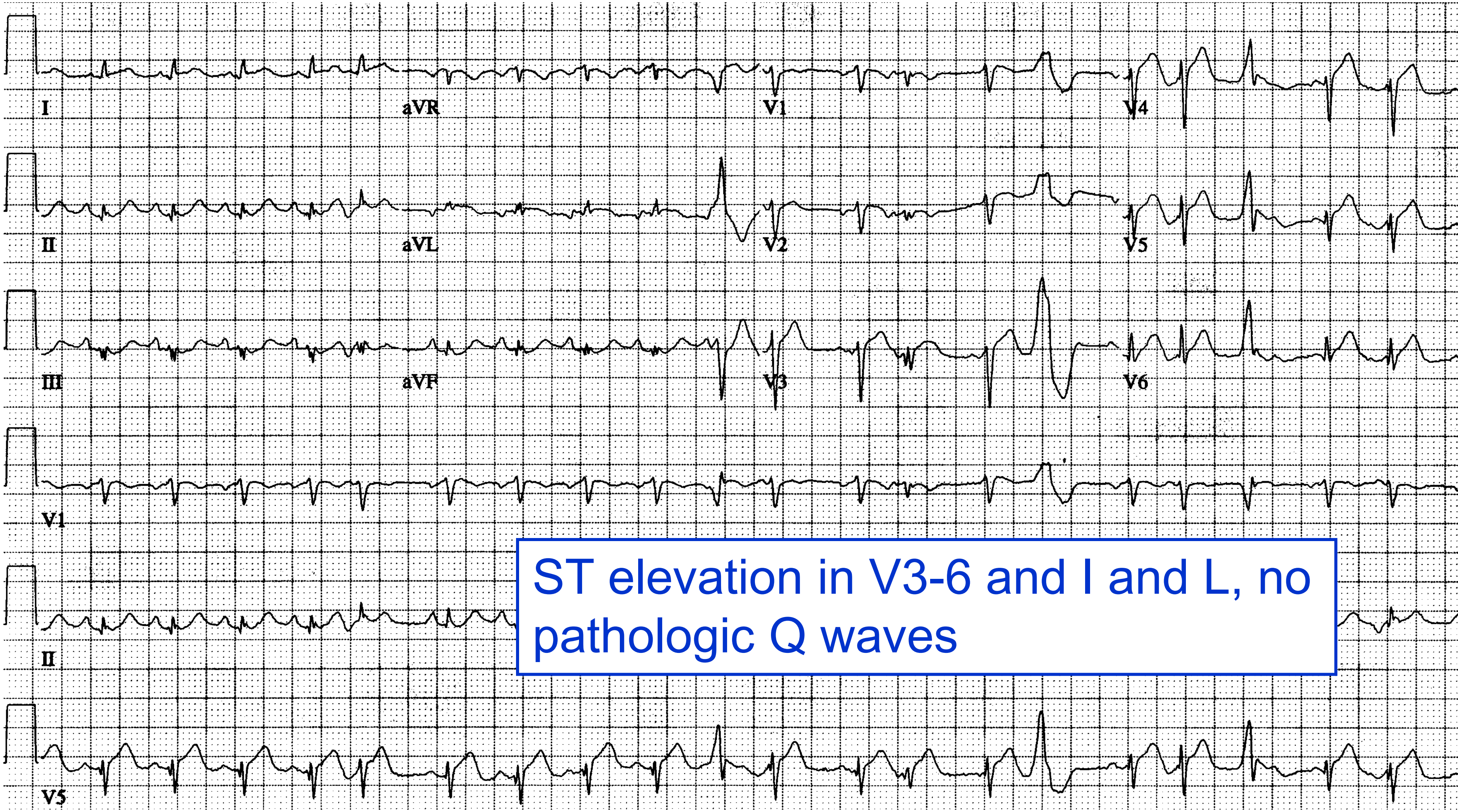
Q waves in V1-V4; mild ST elevation in V2-V6, T inversion in V2-V6

Hyperacute Anteroseptal MI



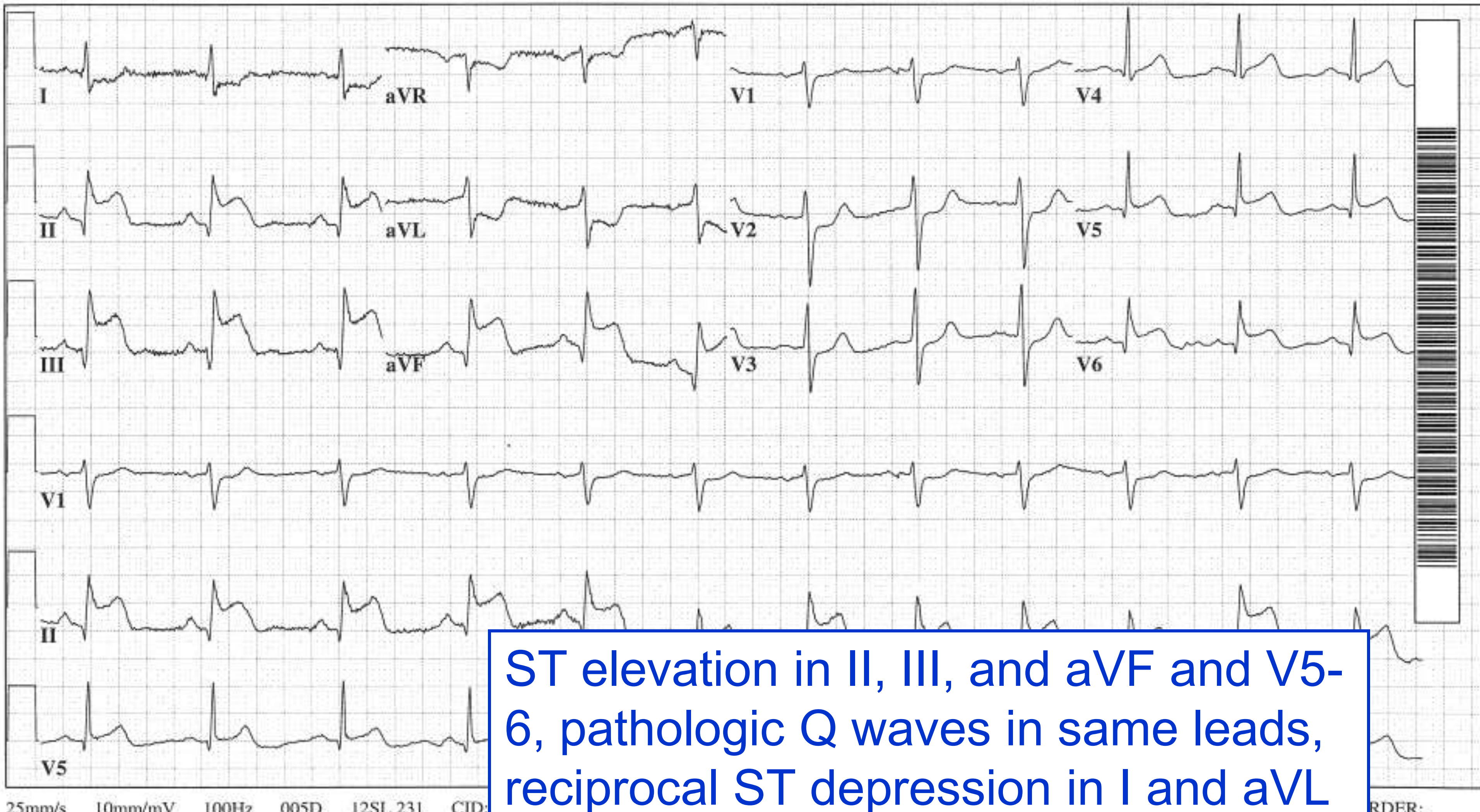
Peaked T waves in V2-3, ST elevation in V2-V5 and I and aVL, reciprocal ST depression in III

Acute Anterolateral MI



ST elevation in V3-6 and I and L, no pathologic Q waves

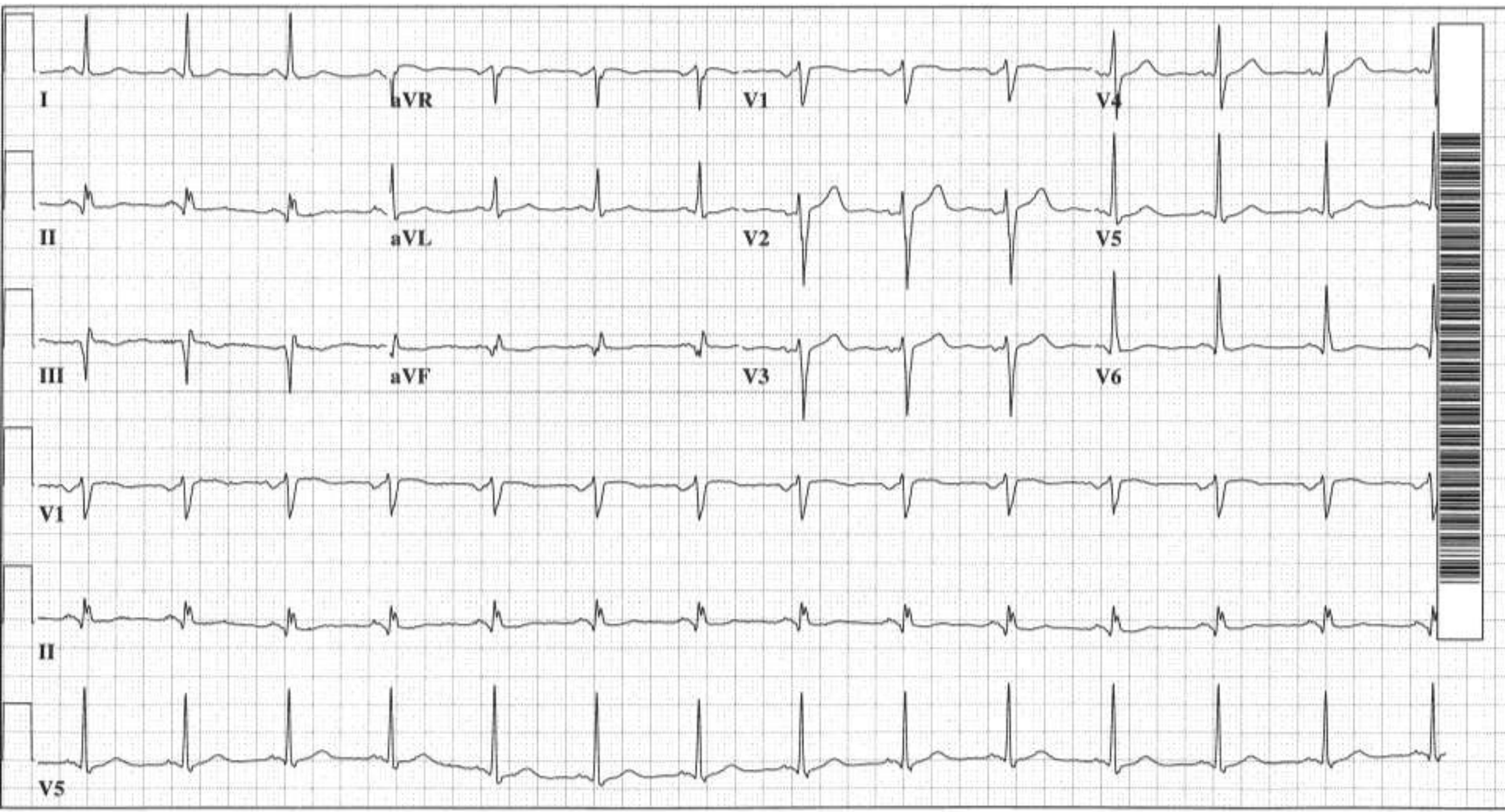
Acute Inferolateral MI



ST elevation in II, III, and aVF and V5-6, pathologic Q waves in same leads, reciprocal ST depression in I and aVL

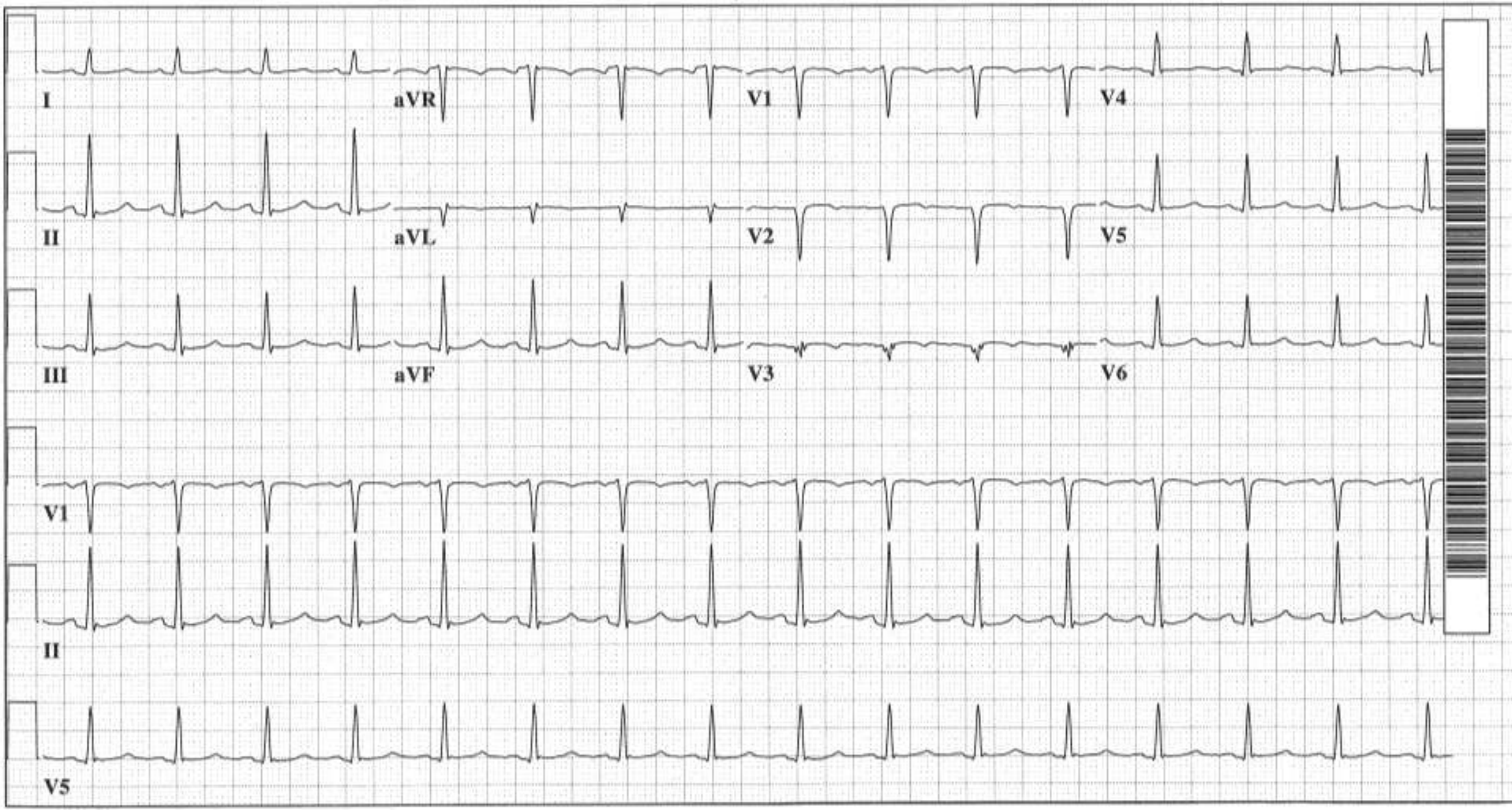
Prior Inferior Wall MI

Pathologic Q waves in II, III,and aVF, persistent T inversion, not deep, no ST segment elevation



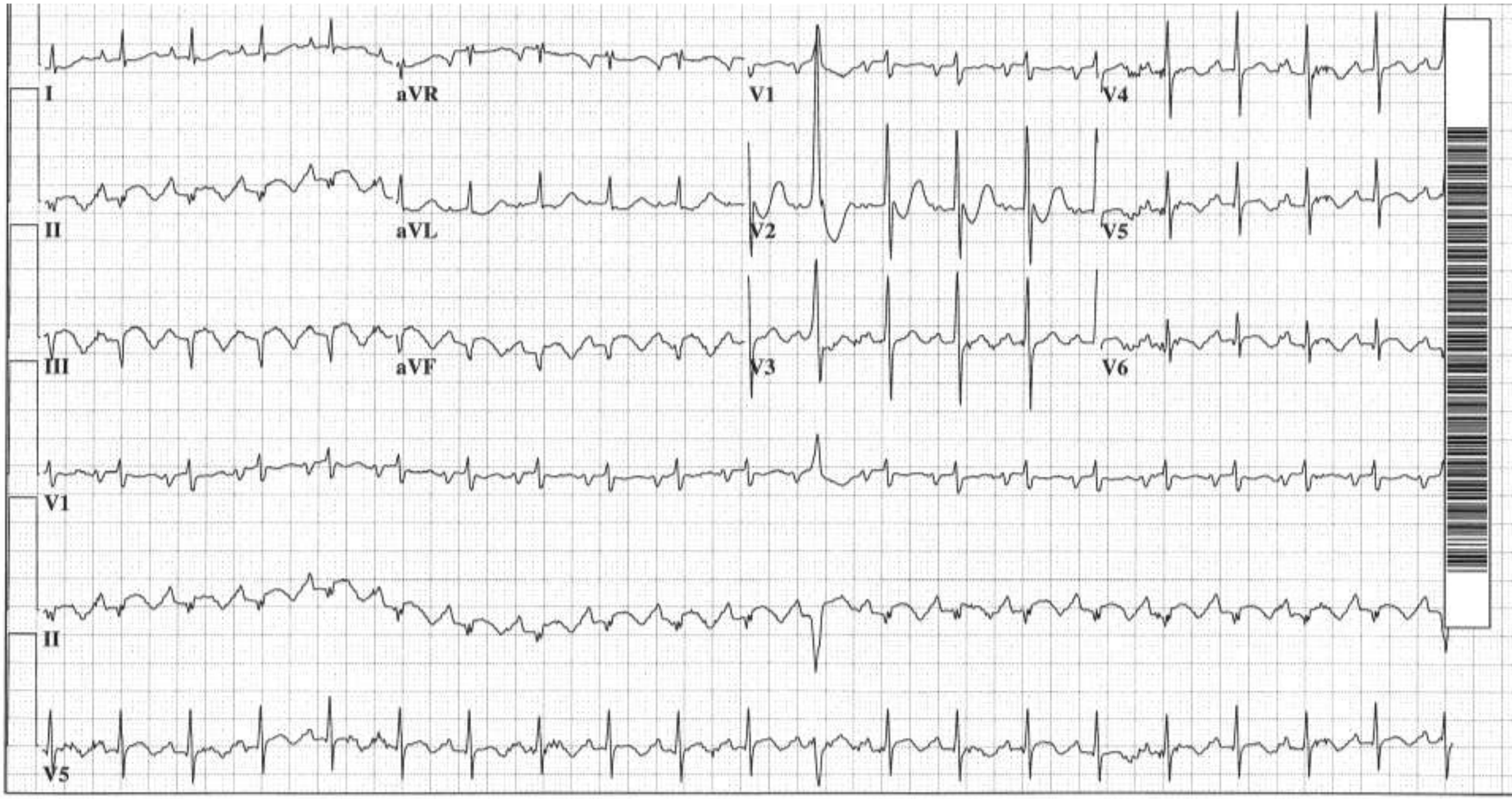
Prior Anterior Wall MI

Pathologic Q waves in V2-V3, T inversion in V3, not deep, no ST segment elevation



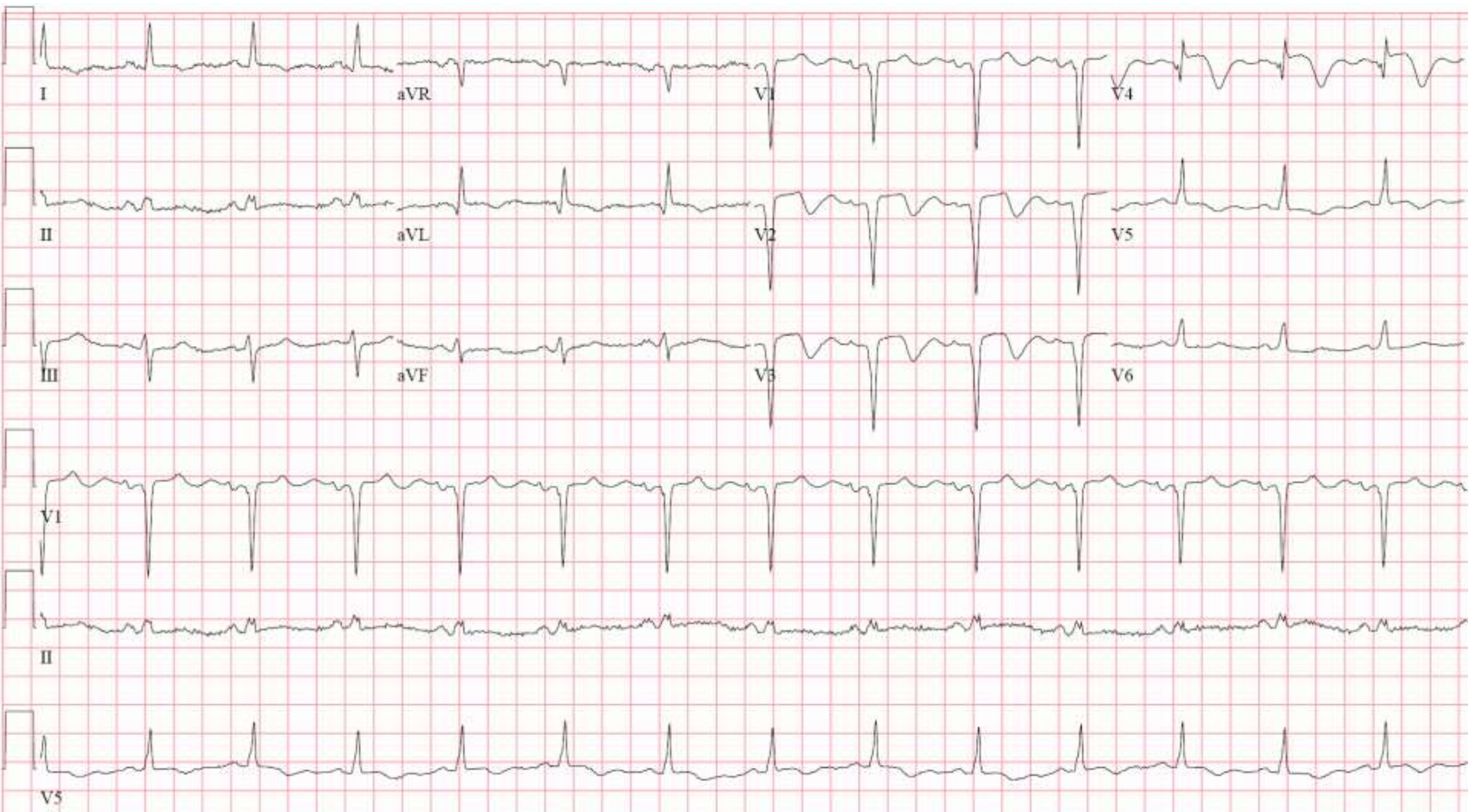
Acute or Recent Inferior Wall MI

Pathologic Q waves and ST segment elevation in II, III, and aVF, (incidentally note tracing is at double standard)



Prior Anterior Wall MI

Pathologic Q waves and mild persistent ST segment elevation and T wave inversion in left and mid precordial leads

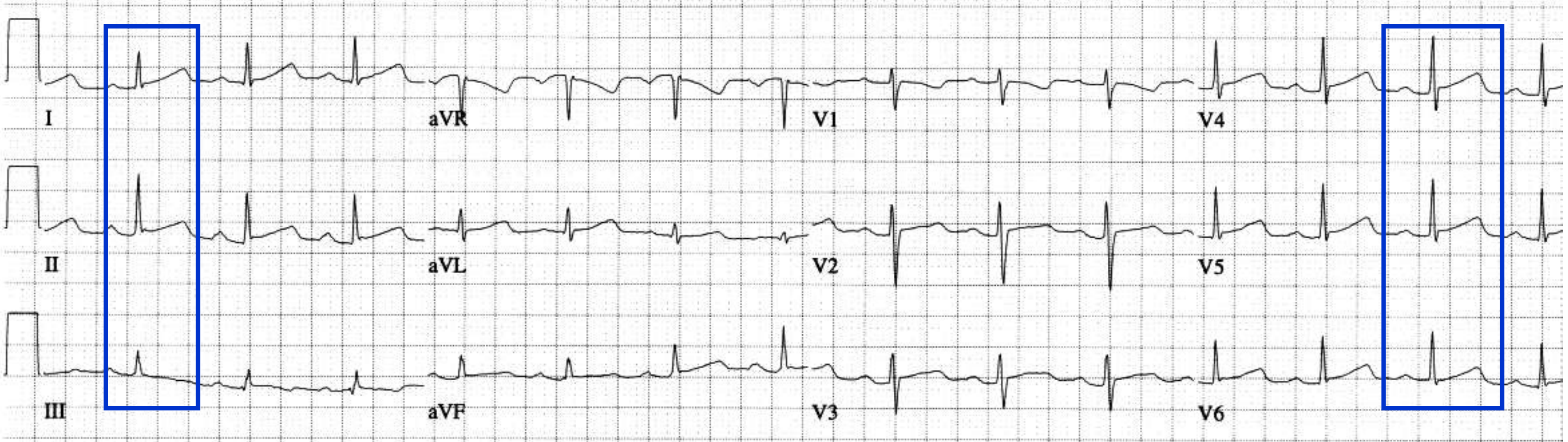


Morphologic Abnormalities

- Chamber hypertrophy
- Conduction abnormalities
- Ischemia, injury, infarction
- **<u>Repolarization abnormalities</u>**

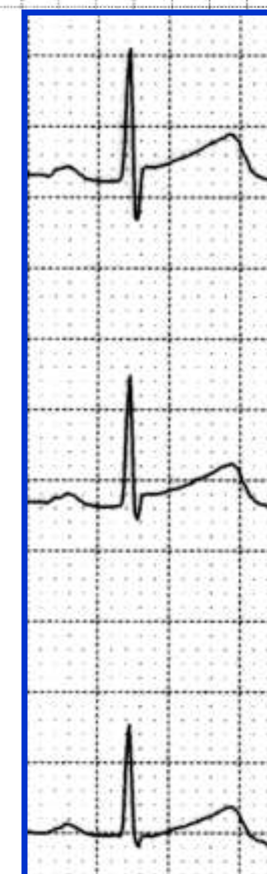
Other (Besides Ischemia or Injury) Repolarization Abnormalities

- Pericarditis
  - PR segment depression
  - ST segment elevation
  - later T inversion
  - No change in QRS complex
- Electrolyte abnormalities
  - Hypokalemia - low T and large U wave and arrhythmia
  - Hyperkalemia - peaked T wave, QRS prolongation
  - Hypercalcemia - short ST segment
  - Hypocalcemia - long ST segment



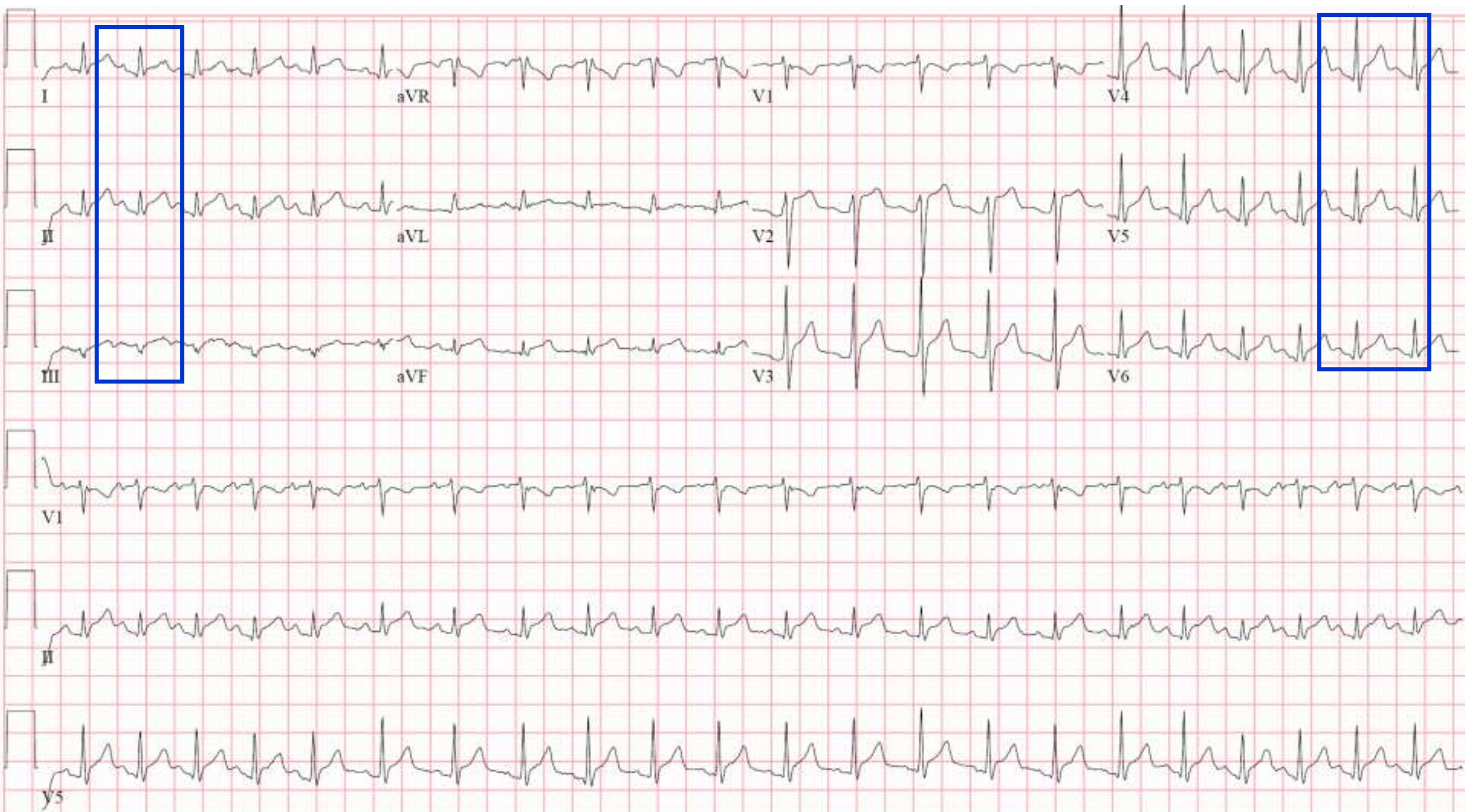
ECG - Pericarditis

= Diffuse ST elevation
= PR segment depression
= No reciprocal changes
except aVR



ECG - Pericarditis

= Diffuse ST elevation
= PR segment depression
= No reciprocal changes
except aVR

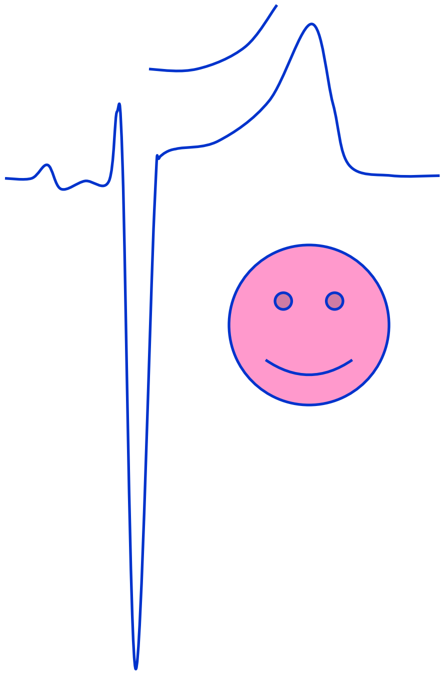


Pericarditis vs STEMI

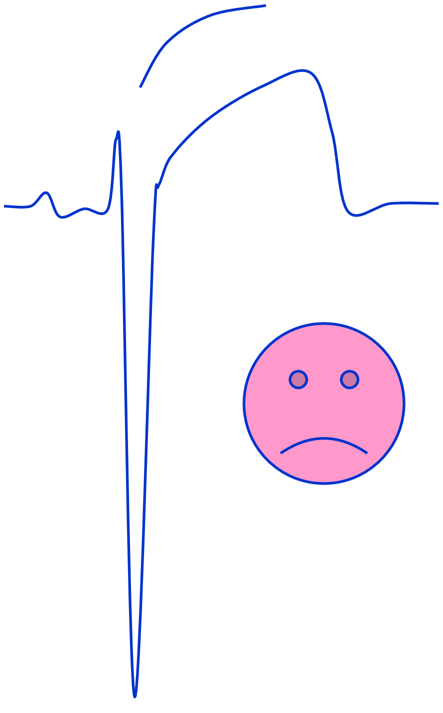
- May be impossible to distinguish totally
- In pericarditis, the ST elevation is generally less dramatic than in STEMI
- In pericarditis, the ST elevation is generally more diffuse, in particular may involve inferior, anterior and lateral leads, but is not necessary to involve all leads
- In pericarditis, the ST elevation is more likely to be concave up, whereas in STEMI, the ST elevation is more likely to be concave down.

ST Segment Concavity

- Concave UP



- Concave DOWN



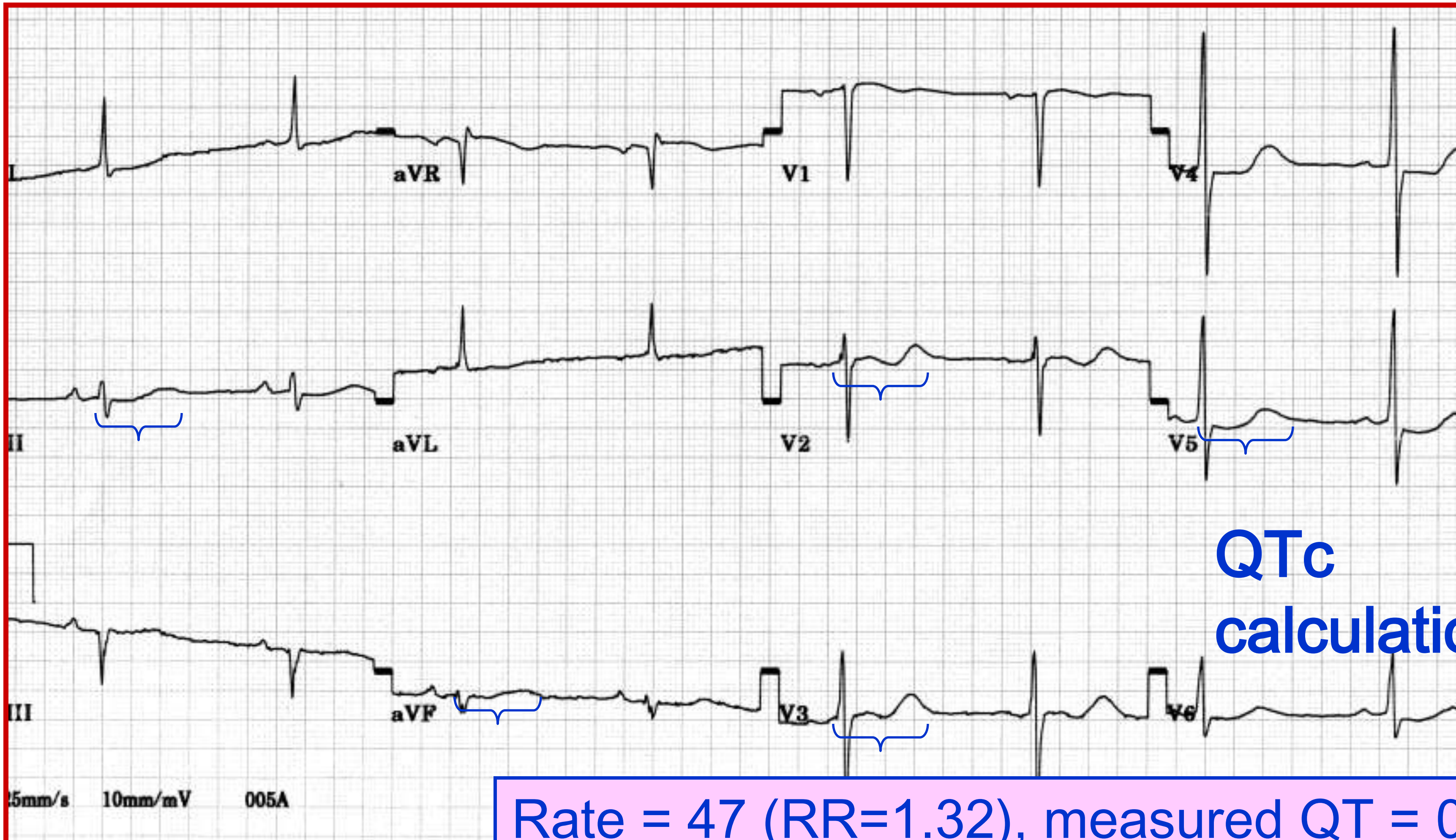
Optional

Other Repolarization Abnormalities - 2

- CNS disturbances - diffuse T inversion and striking QT prolongation
- Early repolarization - normal, stable ST elevation and small terminal delay in V5-V6
- Persistent juvenile pattern - normal, stable T inversion in V1-V3

Other Repolarization Abnormalities - 3

- Congenital prolongation of the QT interval
  - Risk of sudden death
  - Several different varieties, from abnormal channel proteins
  - Cleft or alternating T waves
- Acquired prolongation of the QT interval frequently due to pharmacologic agents such as antimicrobial or antiarrhythmic agents



QTc calculation

Rate = 47 (RR=1.32), measured QT = 0.60

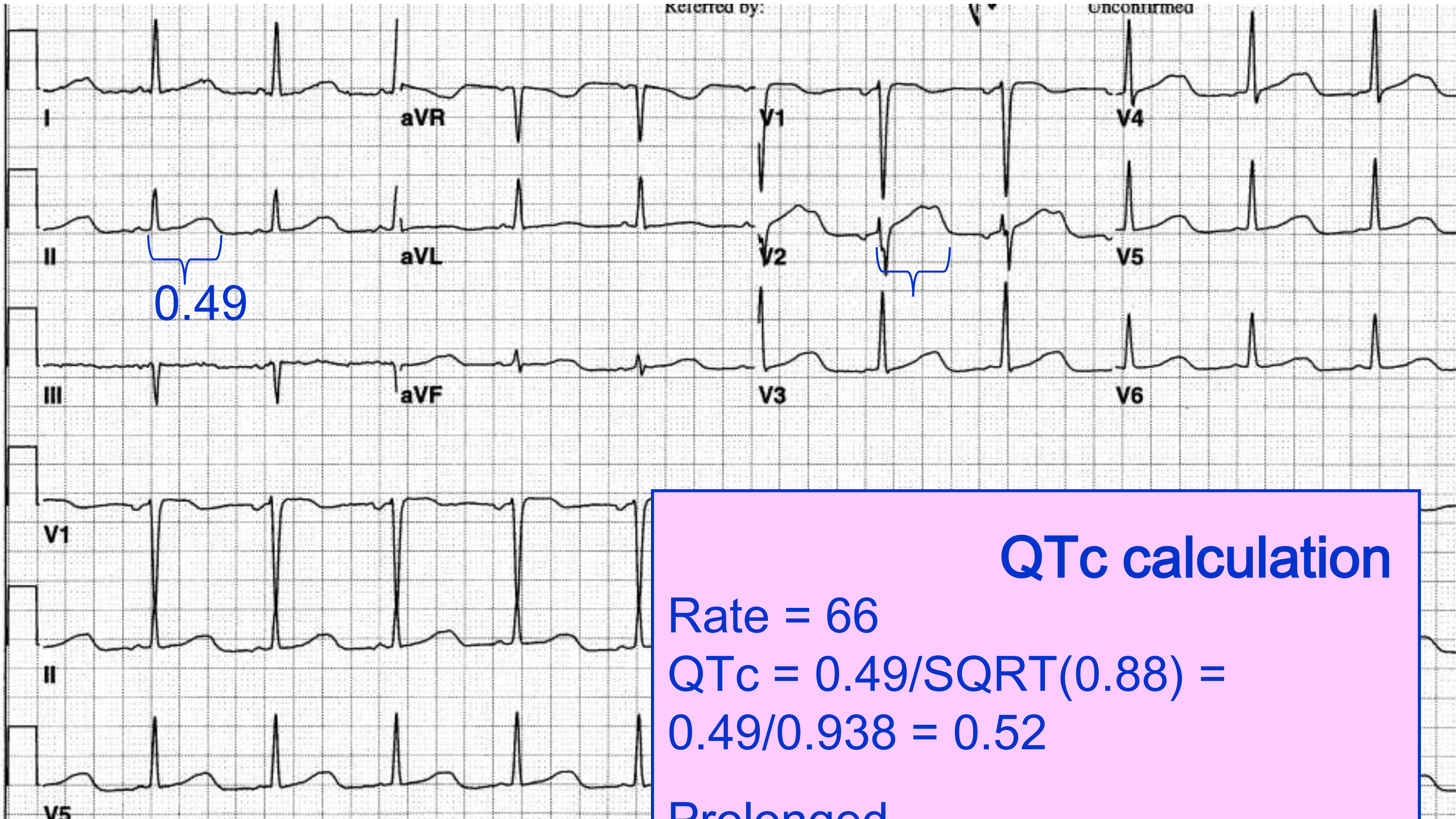
QT_c = 0.60/SQRT(1.32) = 0.60/1.149 = 0.52

Prolonged is >0.44 or 0.46

65 year old man in MICU

Rate about 47/min

QT Prolongation from IV Quinidine



QTc calculation

Rate = 66

QTc = 0.49/SQRT(0.88) = 0.49/0.938 = 0.52

Prolonged

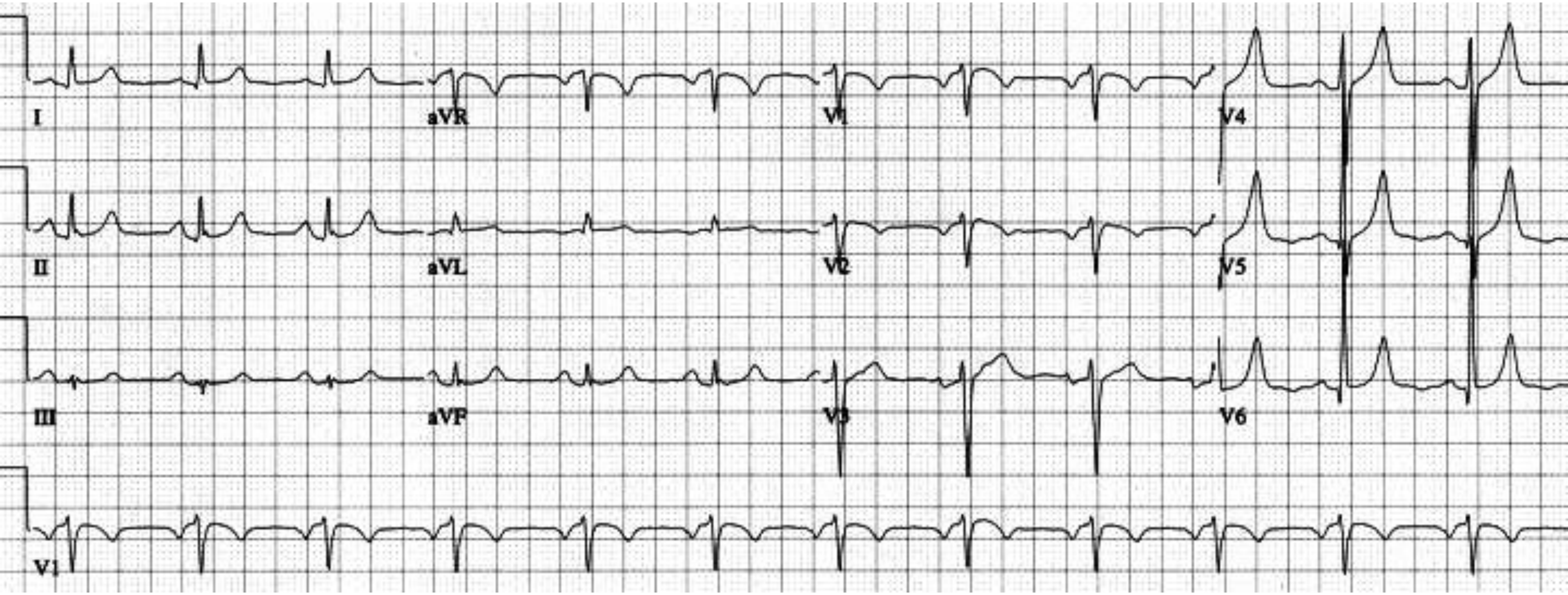
Normal and Abnormal Rhythms

- Sinus rhythms
- Atrial rhythms
- Rhythms of the AV Junction or AV node
- Ventricular rhythms

Sinus Rhythms - 1

- Normal sinus rhythm (NSR)
  - Rate 60-100 beats/min
  - P wave axis 0 to 70 degrees
  - PR interval 0.12-0.20 sec
  - P wave uniformity
  - P-P interval uniformity (regularity)

ECG - NSR



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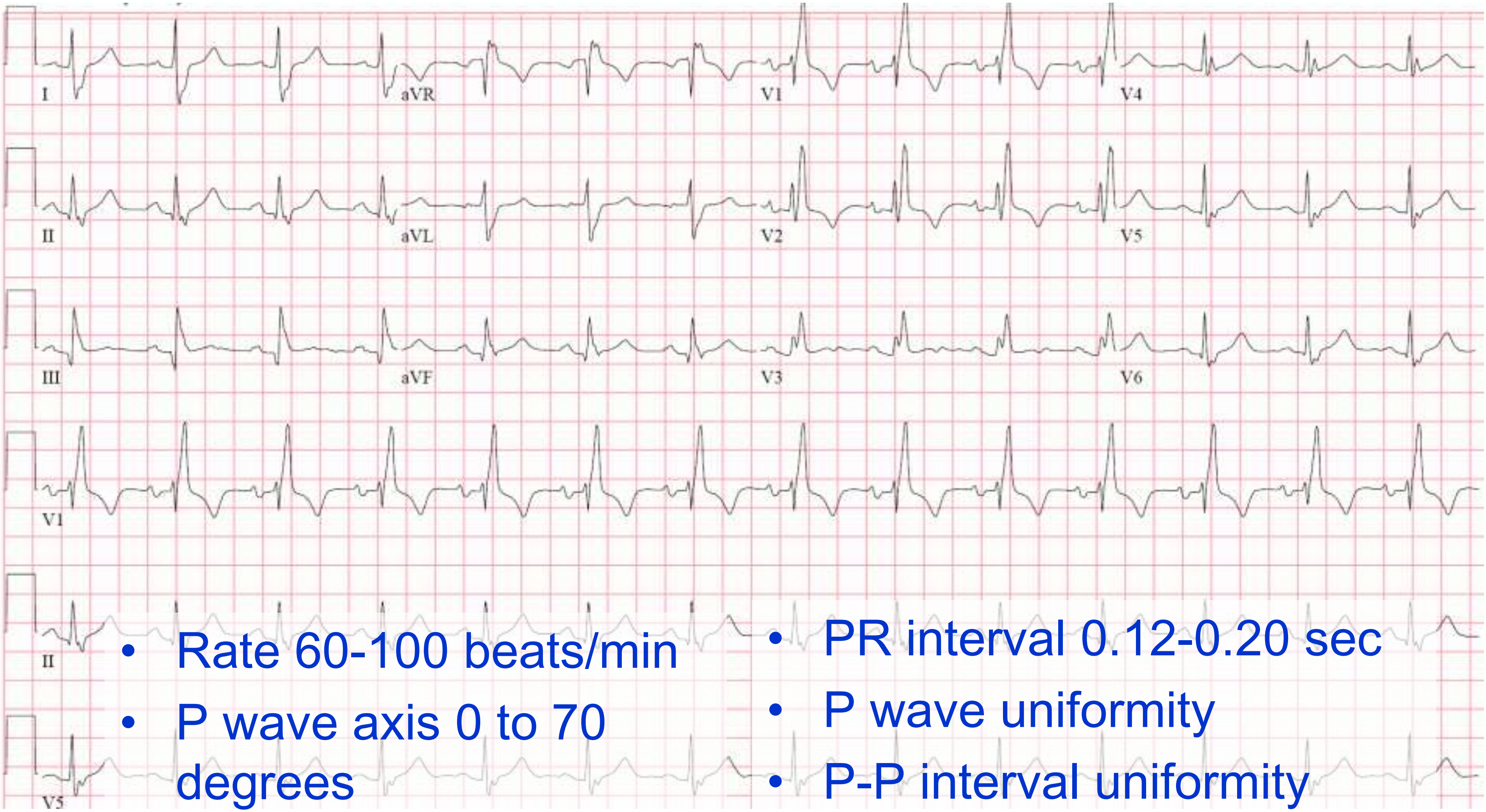
- P-P interval uniformity (regularity)

ECG - NSR



- Rate 60-100 beats/min
- P wave axis 0 to 70 degrees
- PR interval 0.12-0.20 sec
- P wave uniformity
- P-P interval uniformity (regularity)

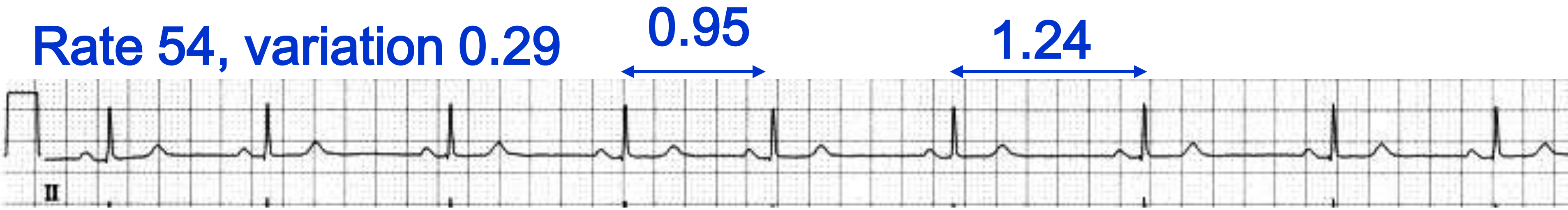
Sinus Rhythms - 2

- Sinus Arrhythmia
  - P-P interval varies by 0.16 sec
  - Respiratory-phasic
    - rate increases with inspiration
  - Non-respiratory-phasic
    - often elderly or heart disease
  - Ventriculophasic - only in AV block
    - P-P interval with intervening QRS is shorter

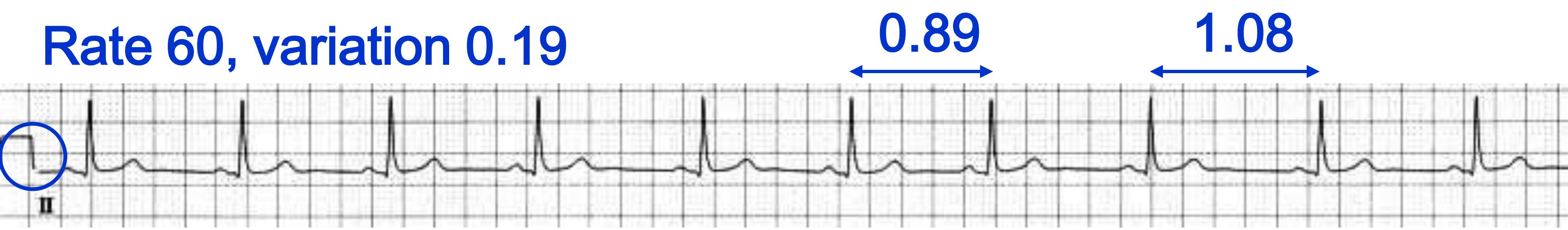
ECG - Sinus Arrhythmia

P-P interval varies by 0.16 sec

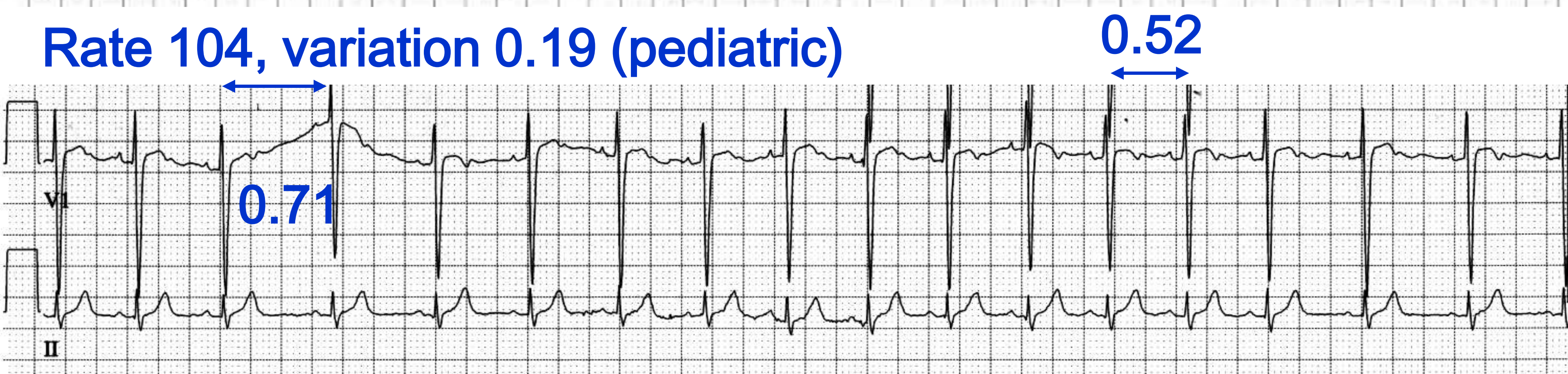
Rate 54, variation 0.29



Rate 60, variation 0.19



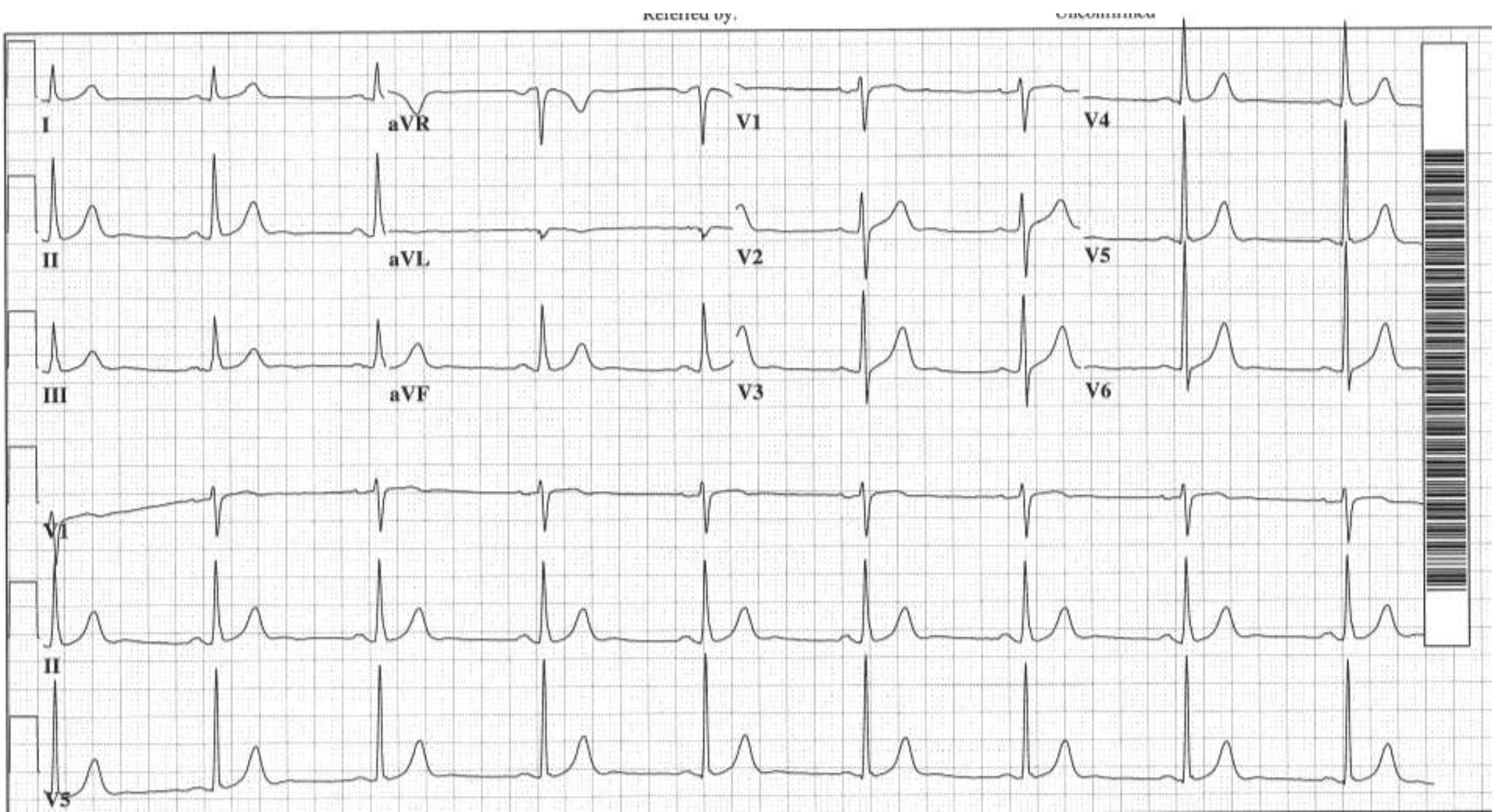
Rate 104, variation 0.19 (pediatric)



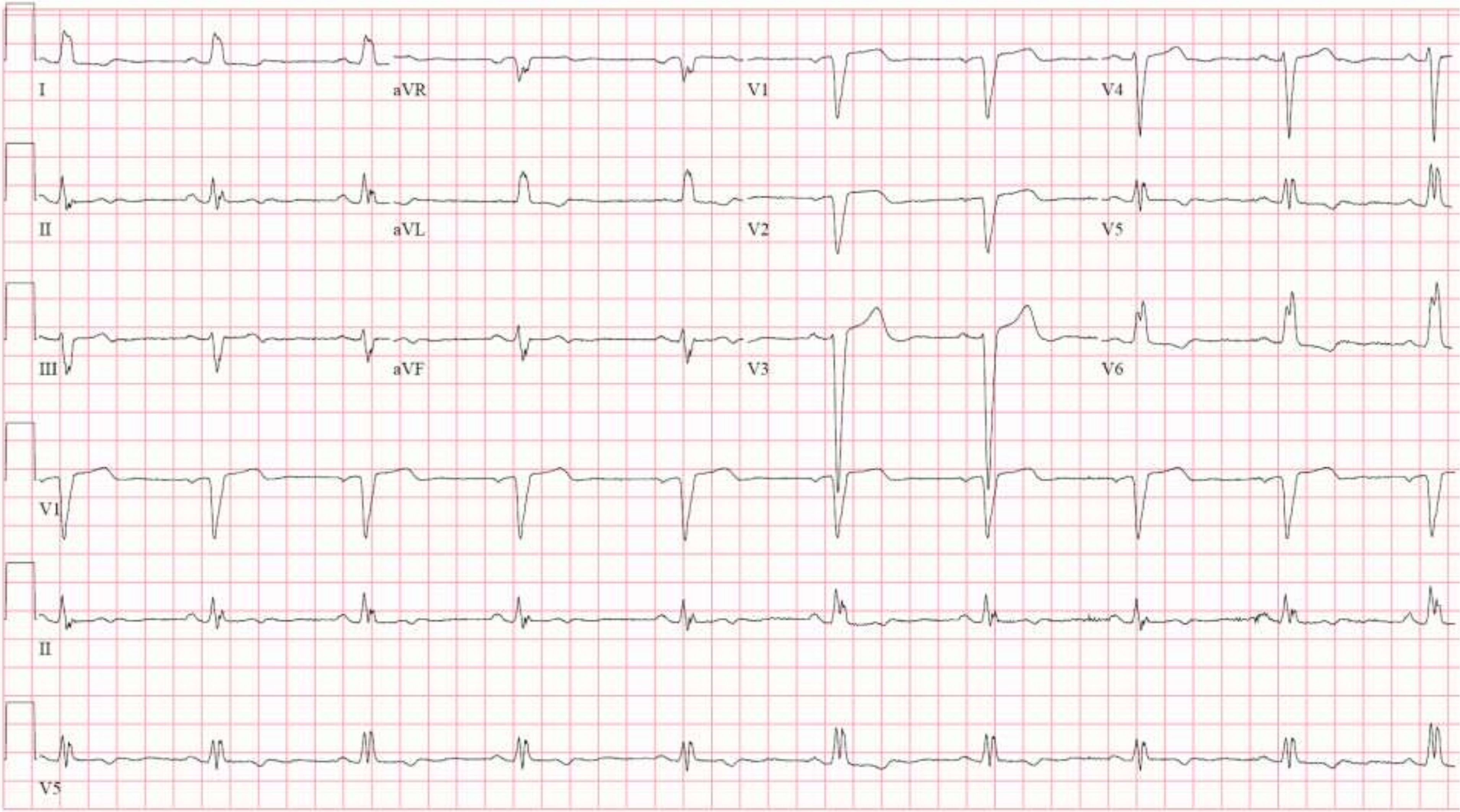
Sinus Rhythms - 3

- Sinus tachycardia - rate >100 beats/min
- Sinus bradycardia - rate <60 beats/min
- Sinus arrest or pause, or SA arrest or pause
  - pause with no P wave
  - not multiple of intrinsic intervals
- Sinus exit block, or SA exit block
  - like sinus pause, but IS multiple of intrinsic intervals

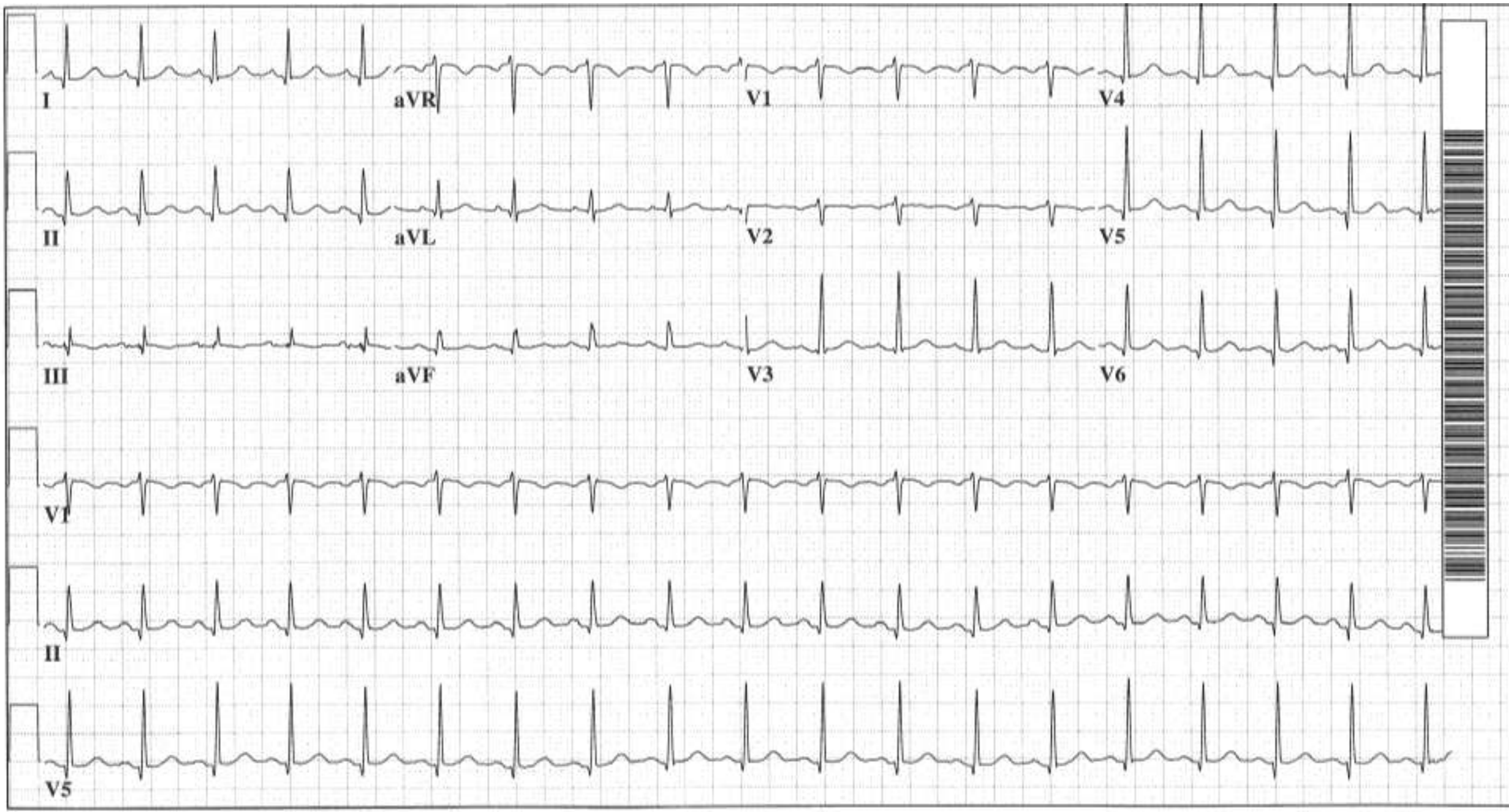
Sinus Bradycardia



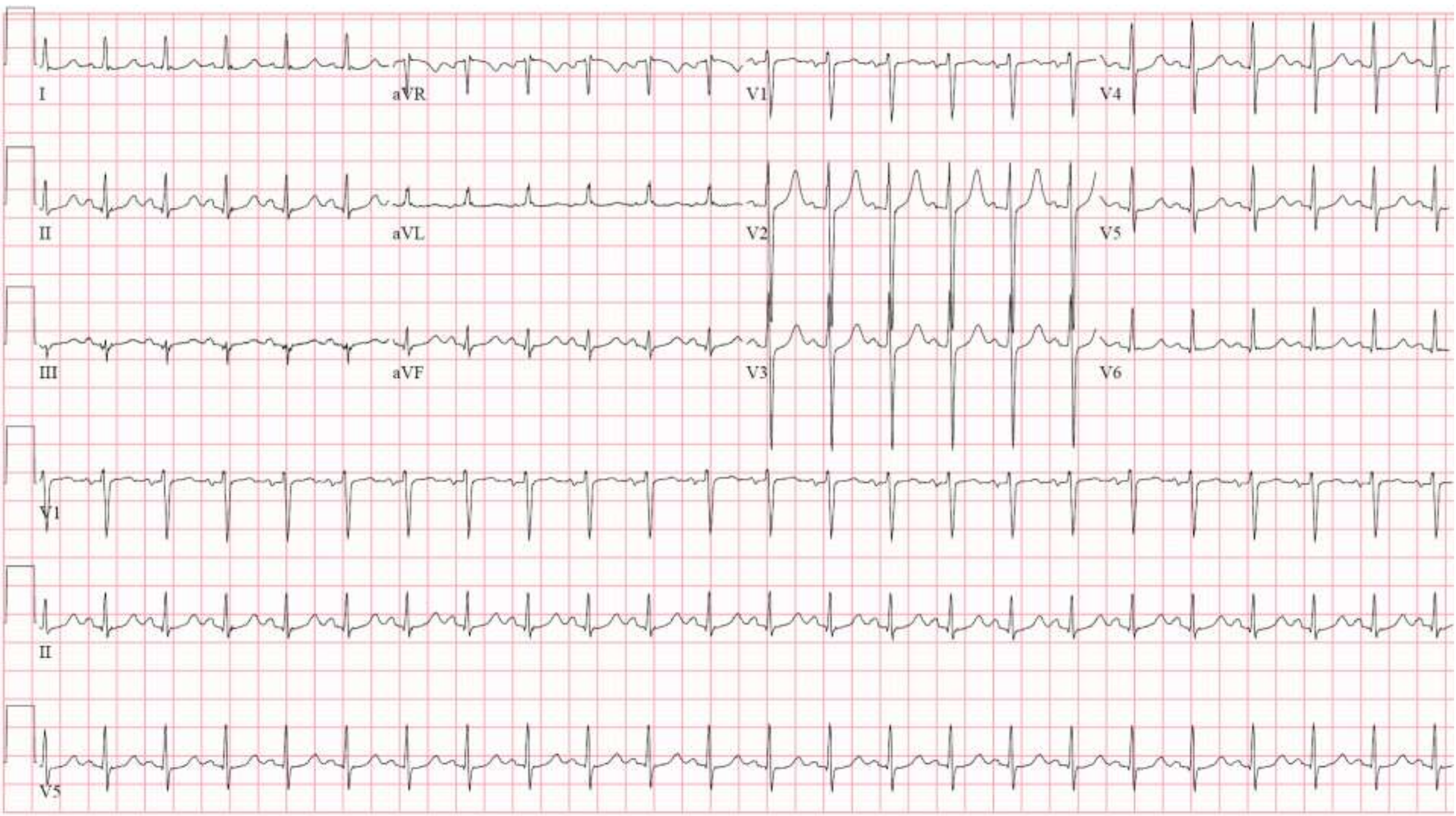
Sinus Bradycardia



Sinus Tachycardia



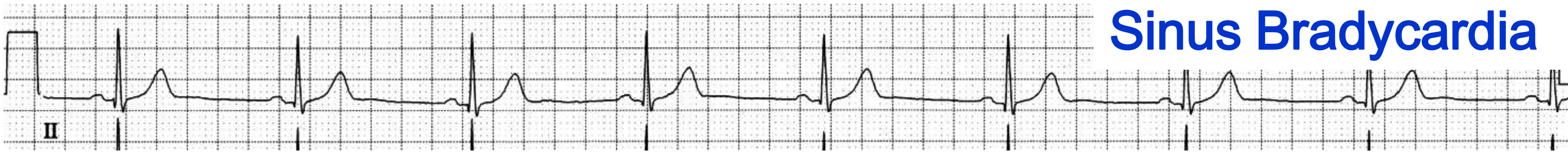
Sinus Tachycardia



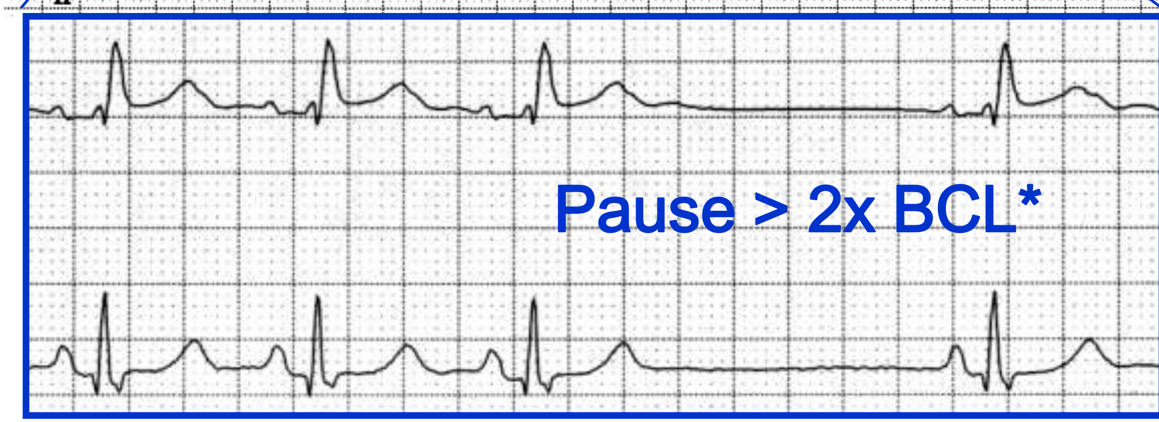
Sinus Dysrhythmias

Sinus Tachycardia

Sinus Bradycardia

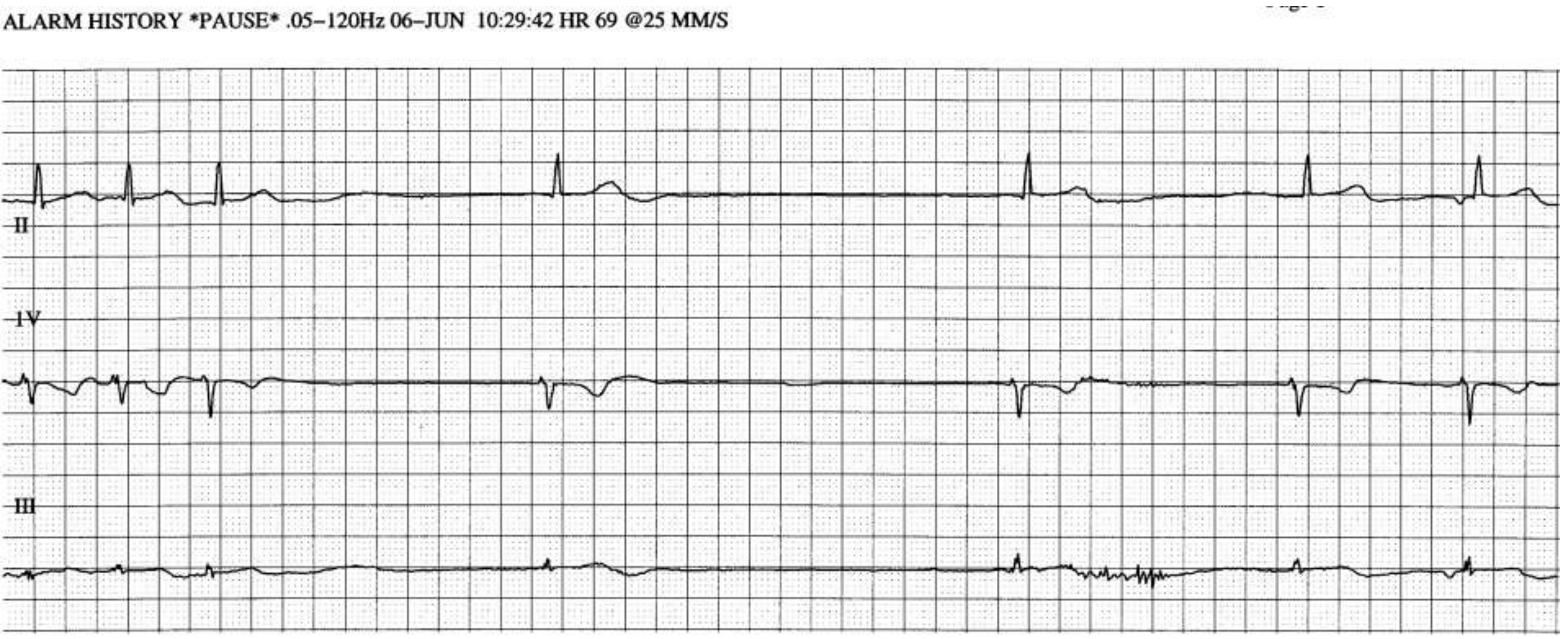


Sinus Pause



*BCL - basic cycle length

Sinus pause after tachycardia



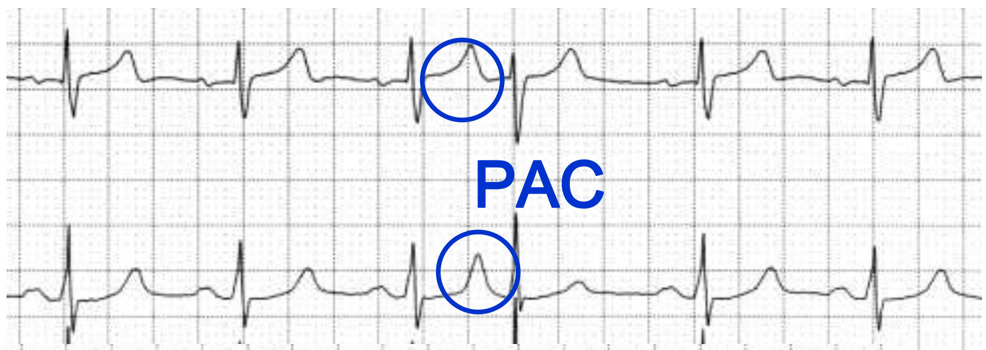
Atrial Rhythms

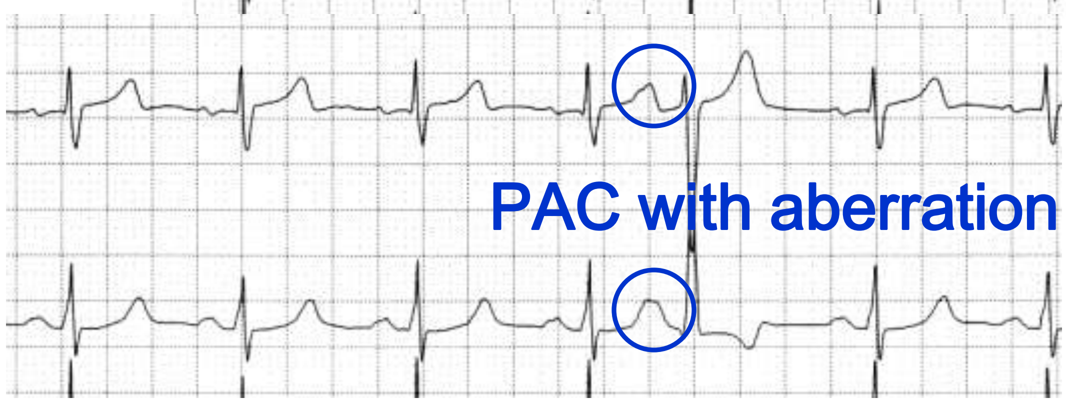
- PAC - early different P wave… look for it! … It disturbs the regularity of the rhythm
  - Normal, aberrant, or no QRS complex
- Ectopic atrial rhythm - like NSR, but abnormal P wave axis and shape
- Atrial tachycardia - like atrial rhythm, but >100 beats/min
- Wandering atrial pacemaker - gradual

Atrial Rhythms

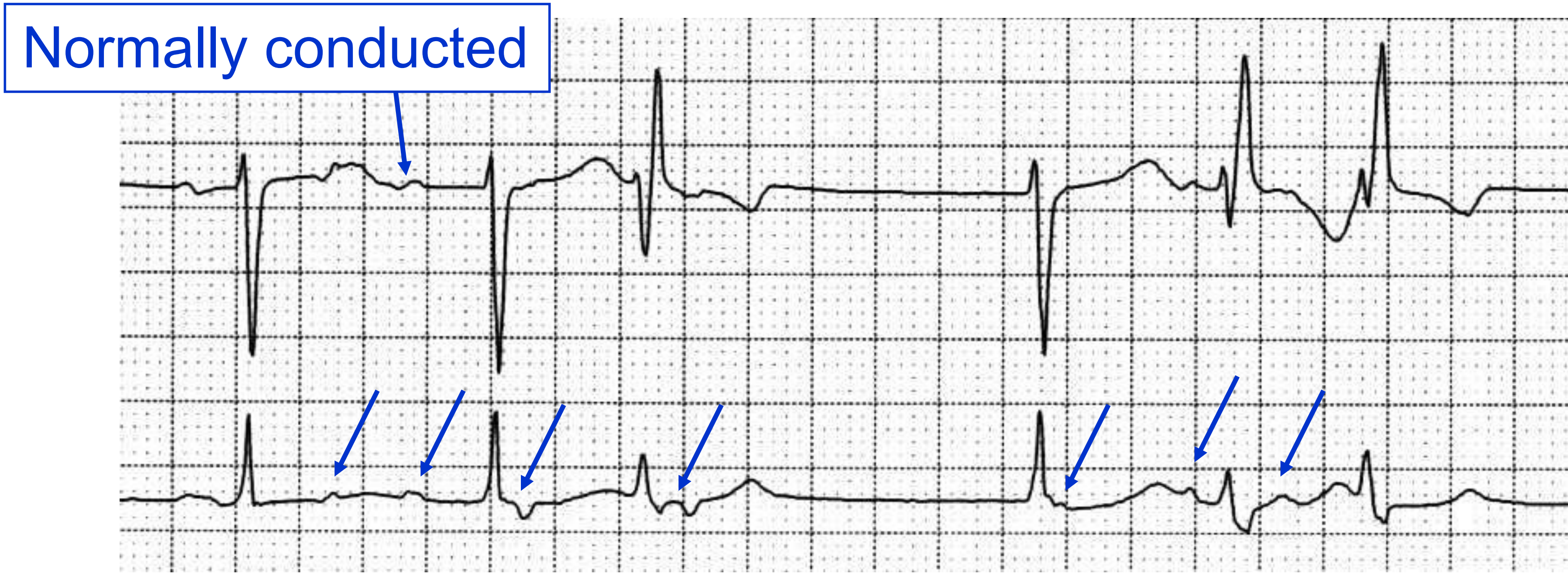
Early different P wave, may hide in ST segment or T wave (only a small distortion of the wave from baseline)

Atrial Rhythms

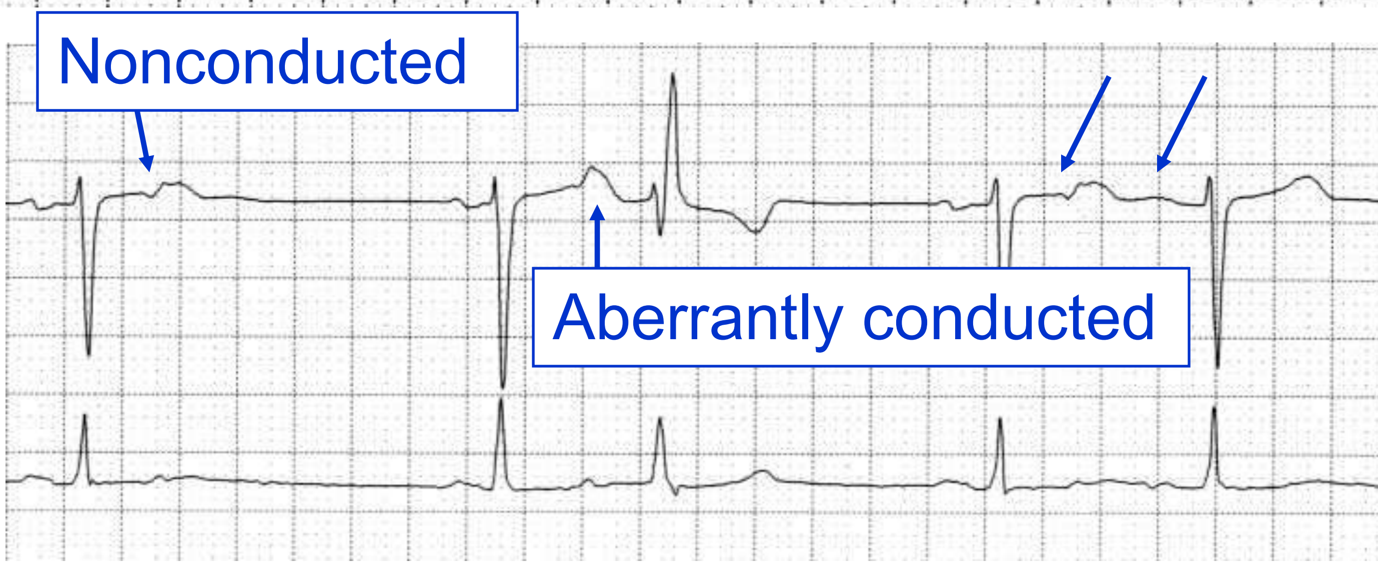




PACs can have 3 results:

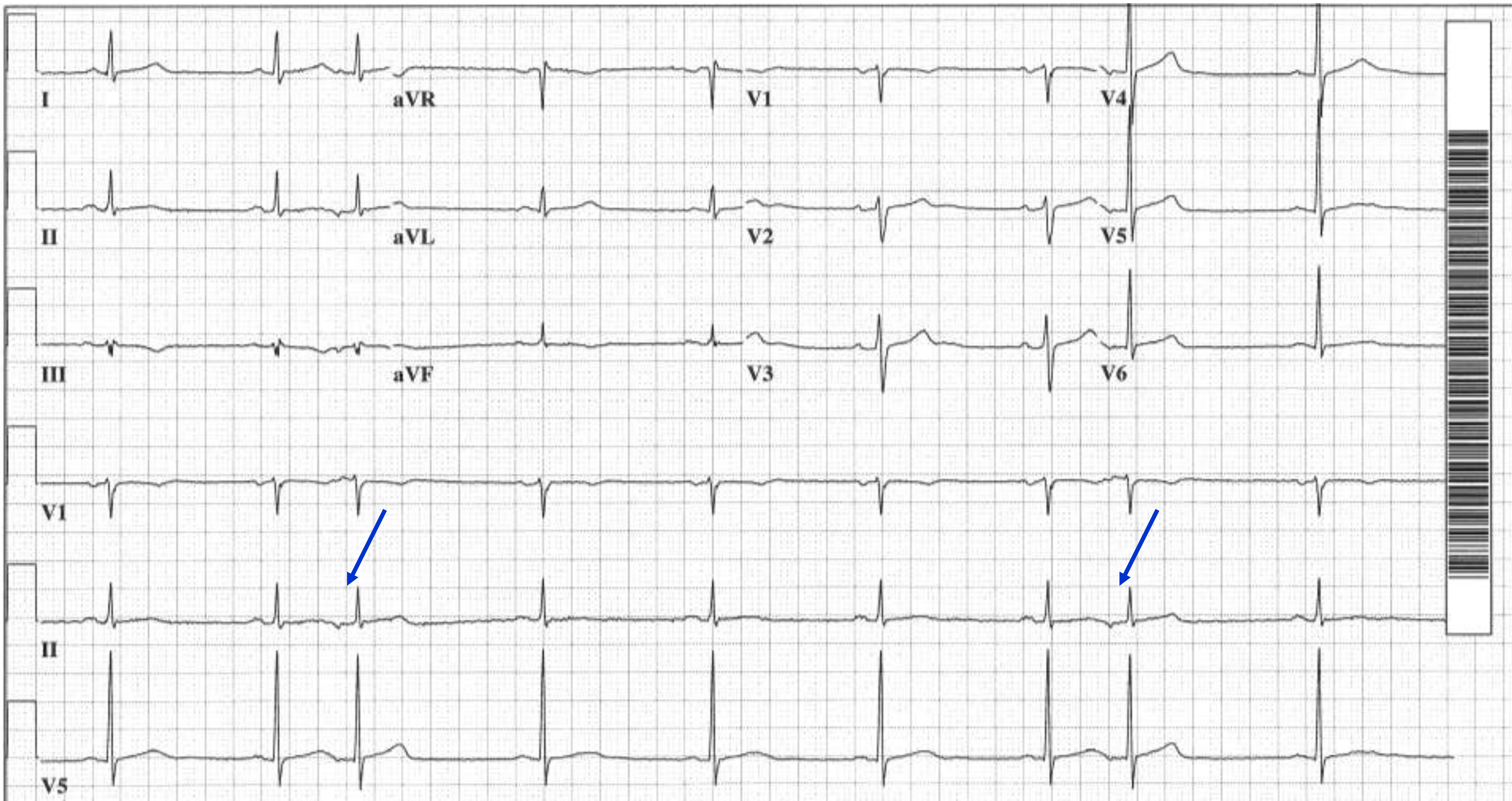


PAC - early different P wave!



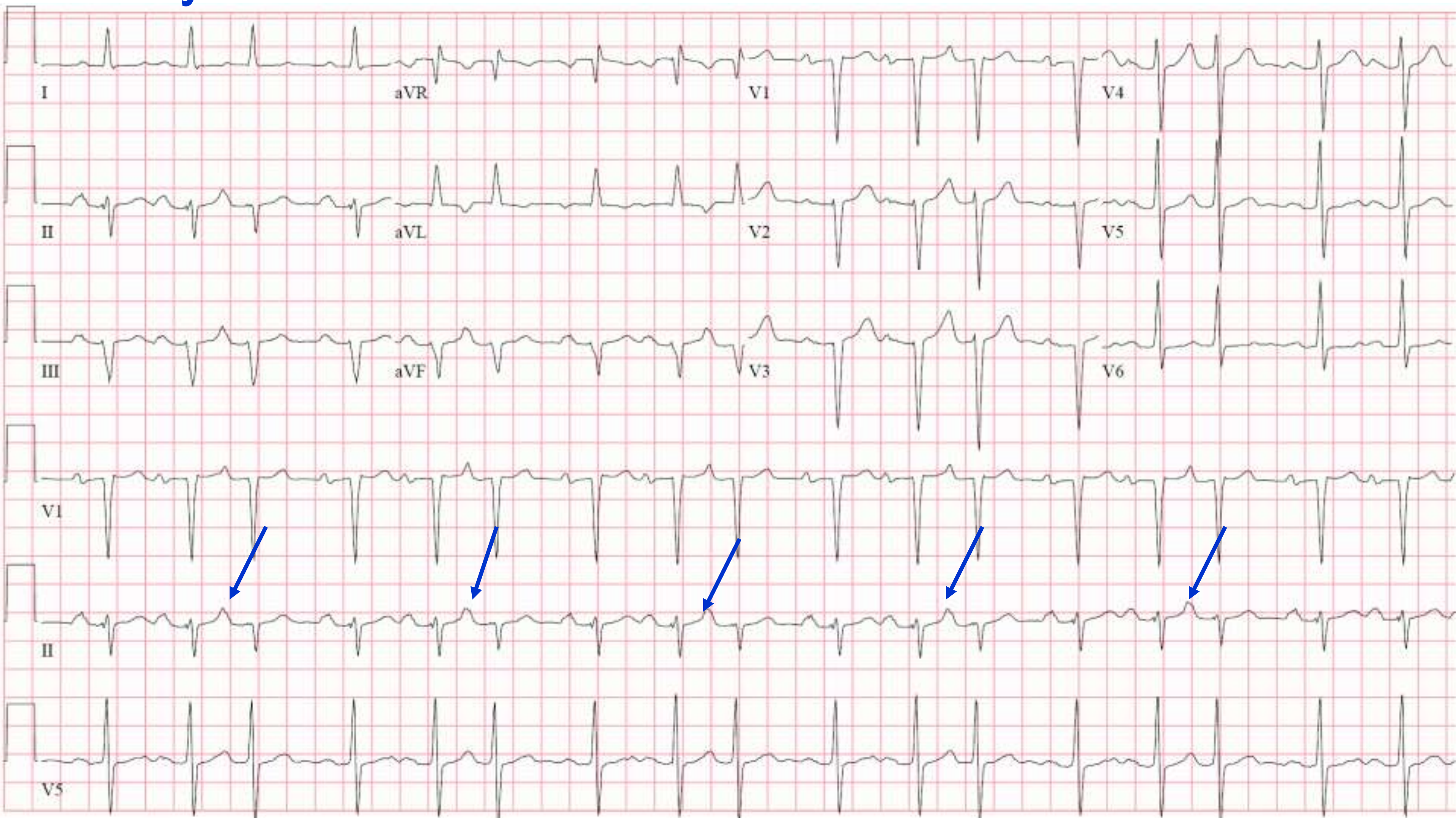
Premature atrial complexes (PACs)

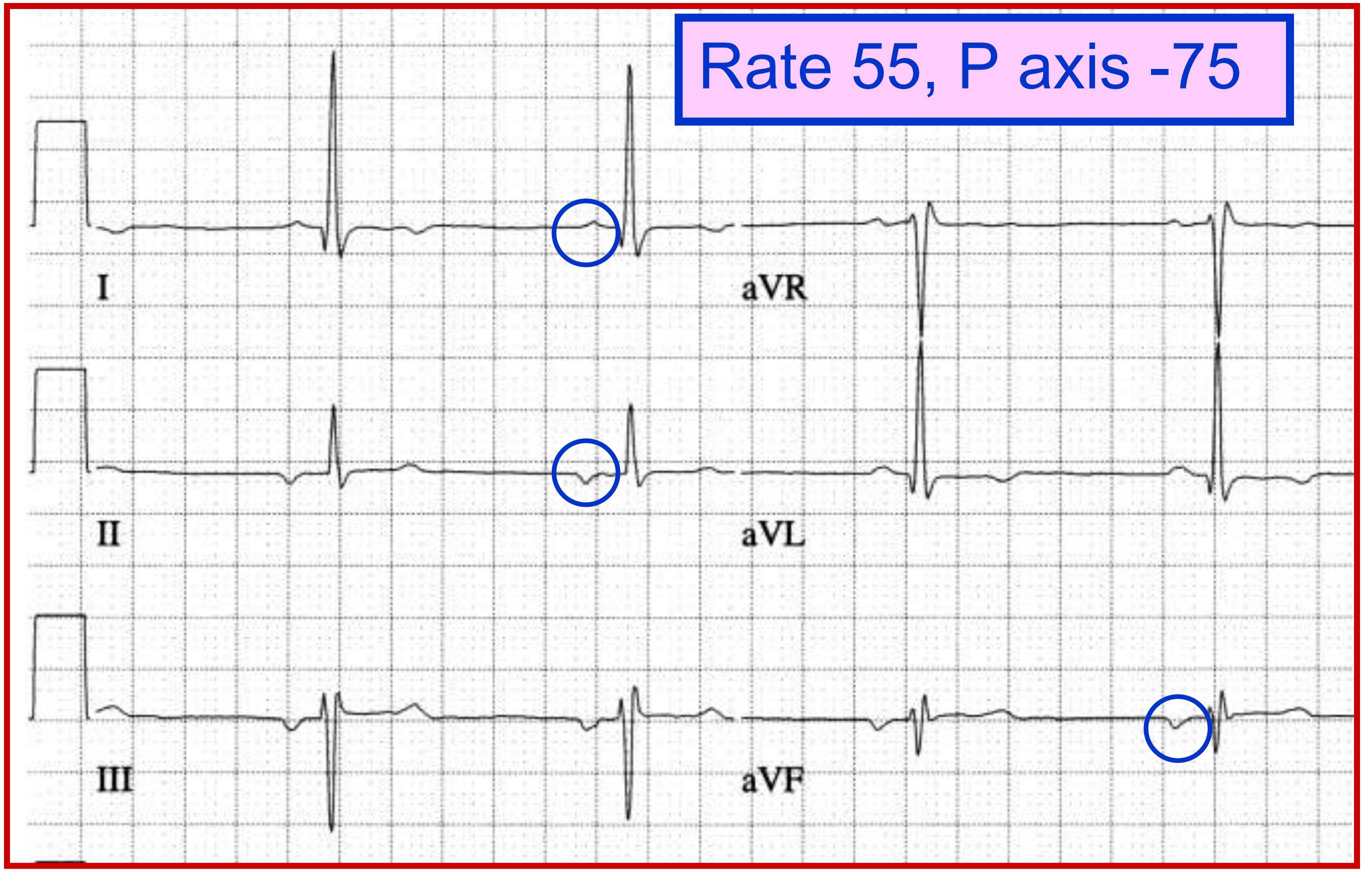
PAC – early different P wave!



Premature atrial complexes (PACs)

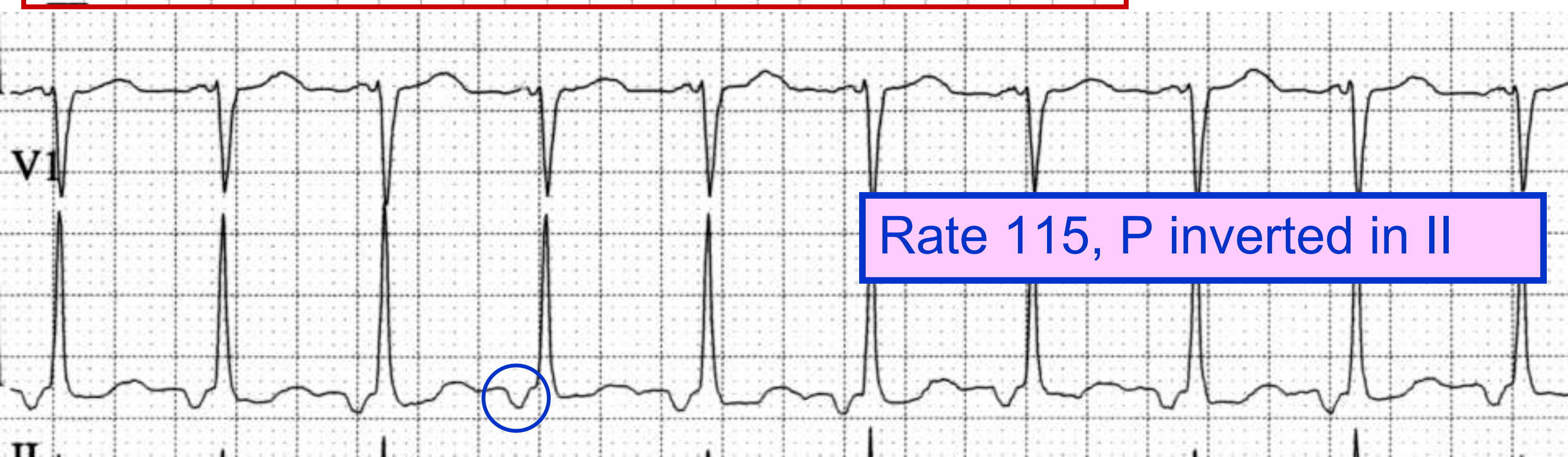
PAC – early different P wave; here atrial trigeminy, The early P wave distorts the T wave





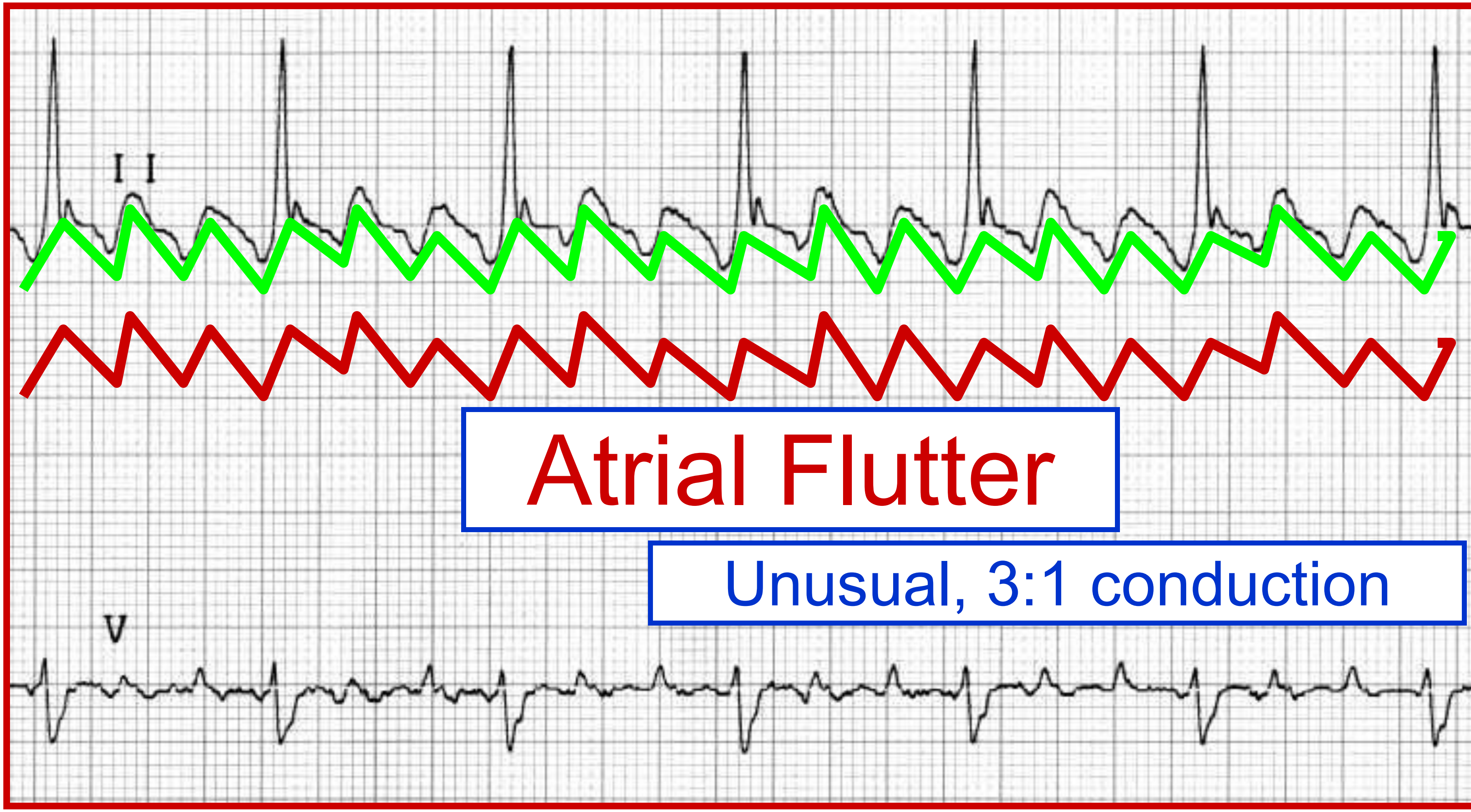
Ectopic Atrial Rhythm

Ectopic Atrial Tachycardia



Atrial Flutter

- Organized reentry in the atrium at rate of 250-350 waves/min, consistent
- Waves best in II, III, and aVF, sawtooth
- Ventricular response
  – may be 2:1 AV conduction, regular at 150 beats/min
  – may be variable
  – may alternate 2:1 and 4:1 conduction



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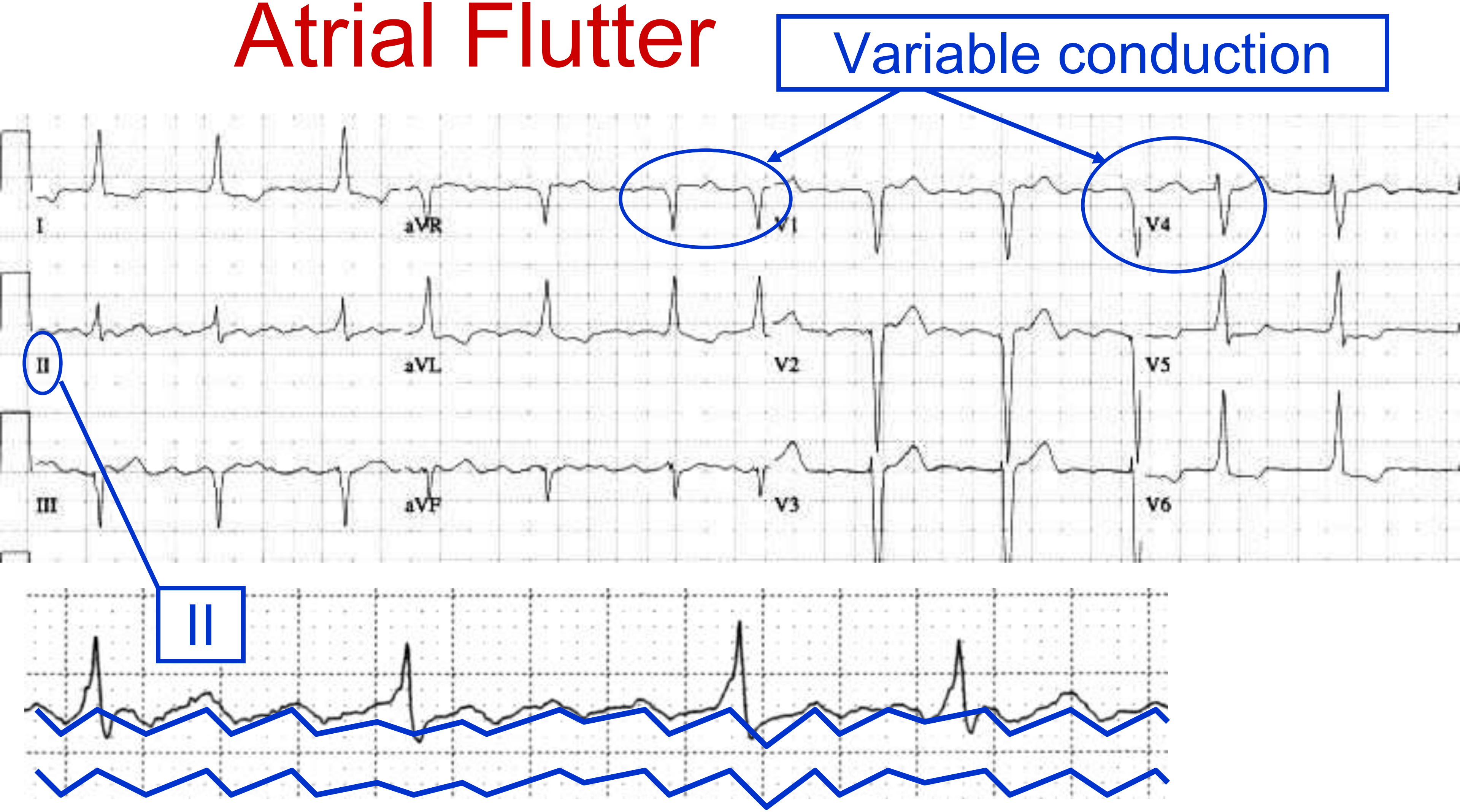
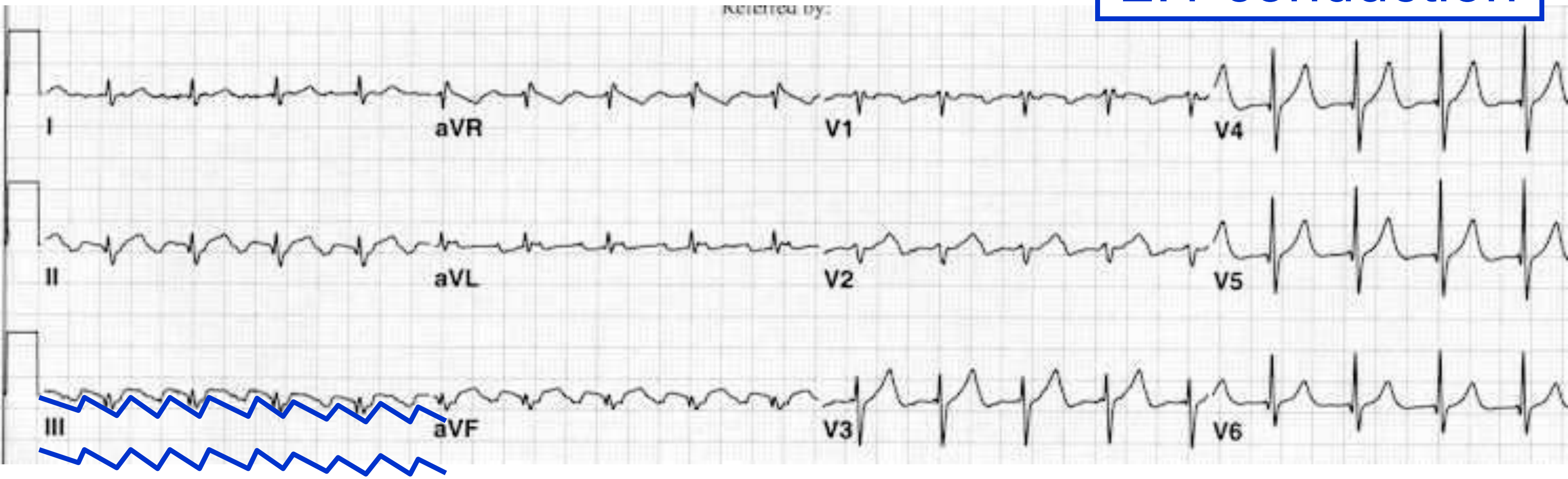
Atrial Flutter



Atrial Flutter

2:1 conduction



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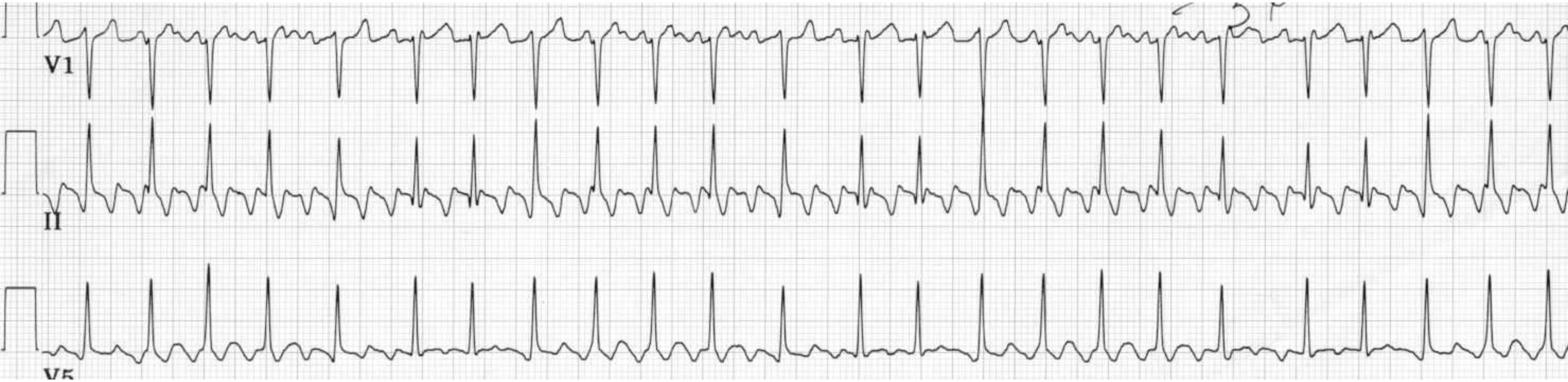
  - may be variable
  - may alternate 2:1 and 4:1 conduction

Atrial Flutter

Classic sawtooth in II

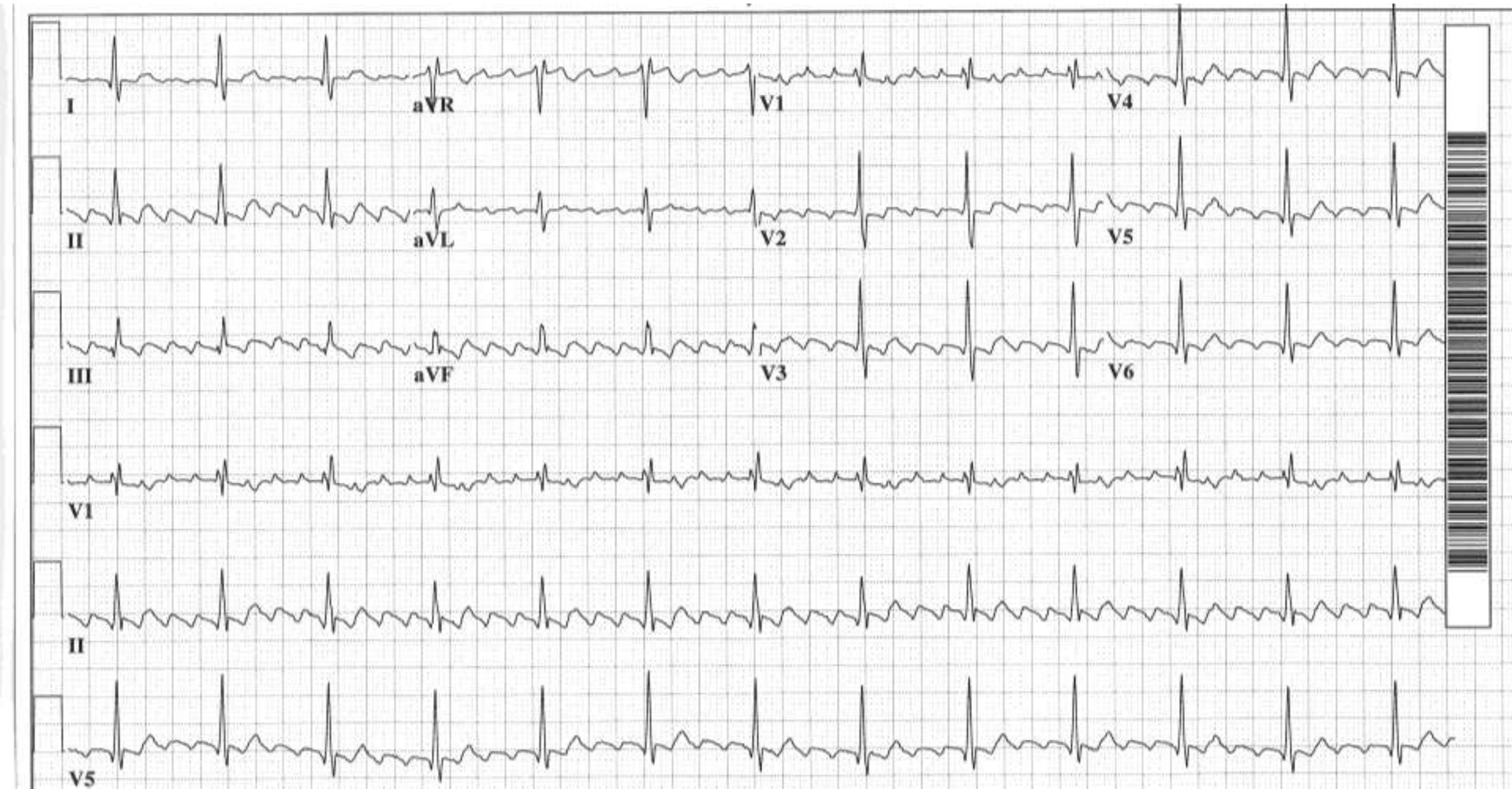
Variable conduction



Atrial Flutter

Classic sawtooth in II, III, and aVF

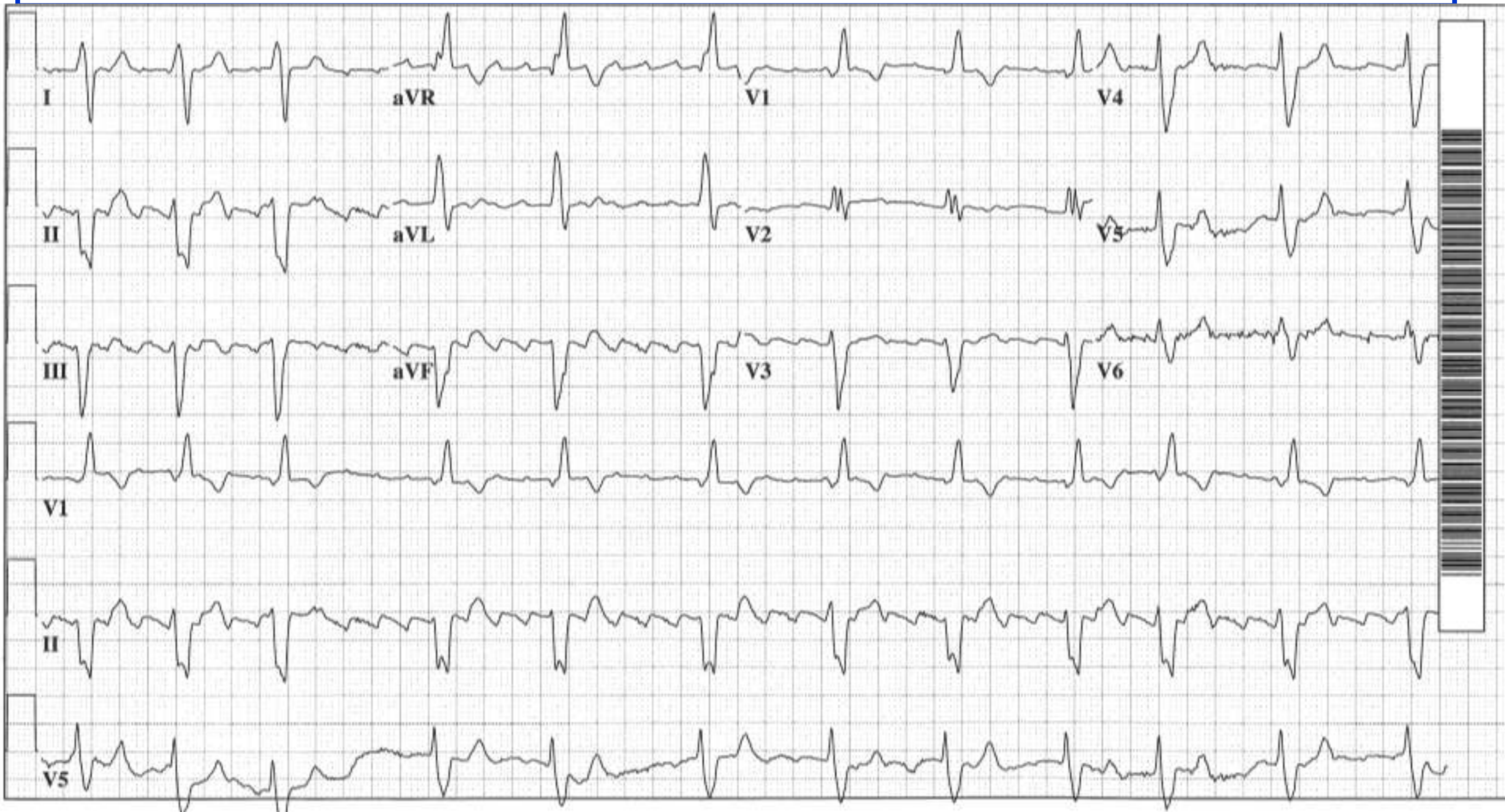
Atrial rate about 310, ventricular rate about 78, 4:1 conduction



Atrial Flutter

Classic sawtooth in II, III, and aVF

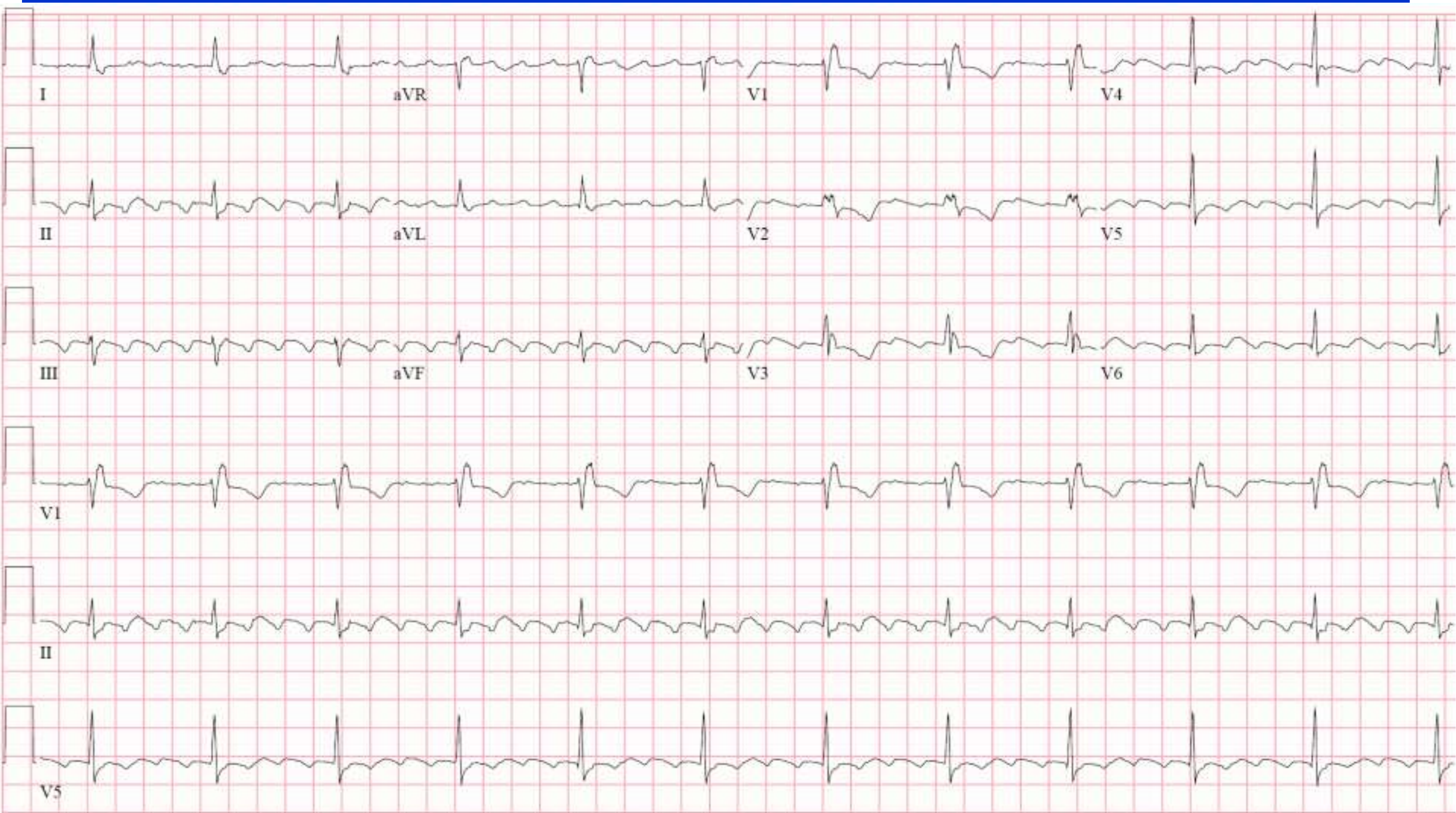
Flutter can have variable ventricular response and the QRS can be abnormal



Atrial Flutter

Classic sawtooth in II, III, and aVF

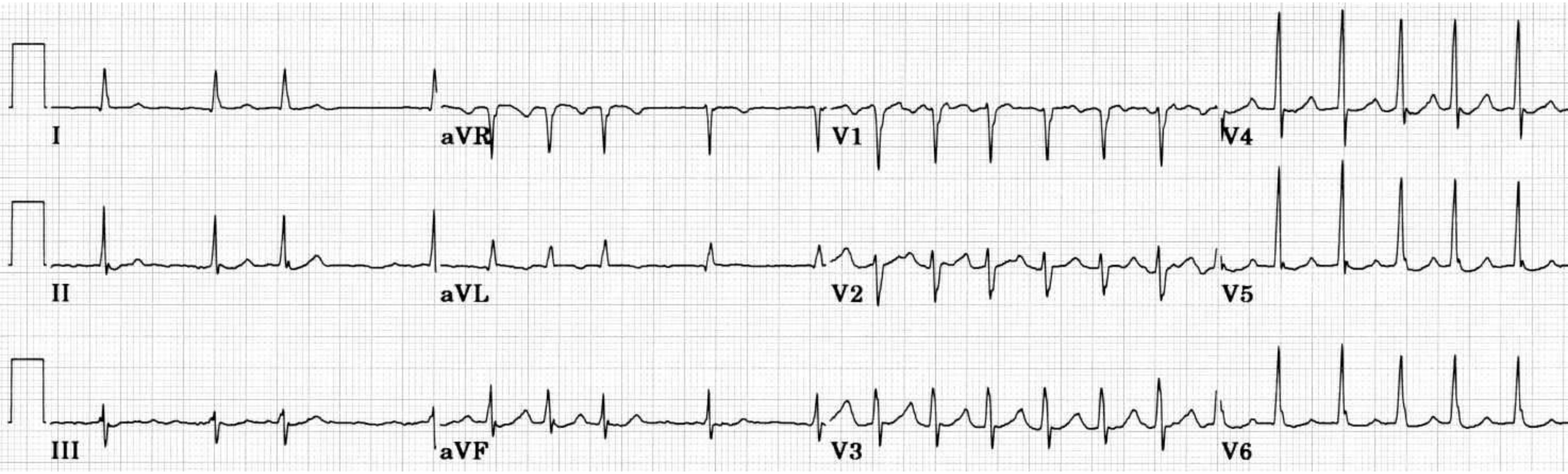
Here, atrial flutter with 4:1 conduction and RBBB too



Atrial Fibrillation

- Disorganized atrial rhythm, faster than 350
- Usually best in V1
- Moderate ventricular response is 70-110 beats/min
- Irregularly irregular (no pattern) RR interval
- If regular RR interval, then the ventricle is beating on its own

Atrial Fibrillation



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Atrial Fibrillation

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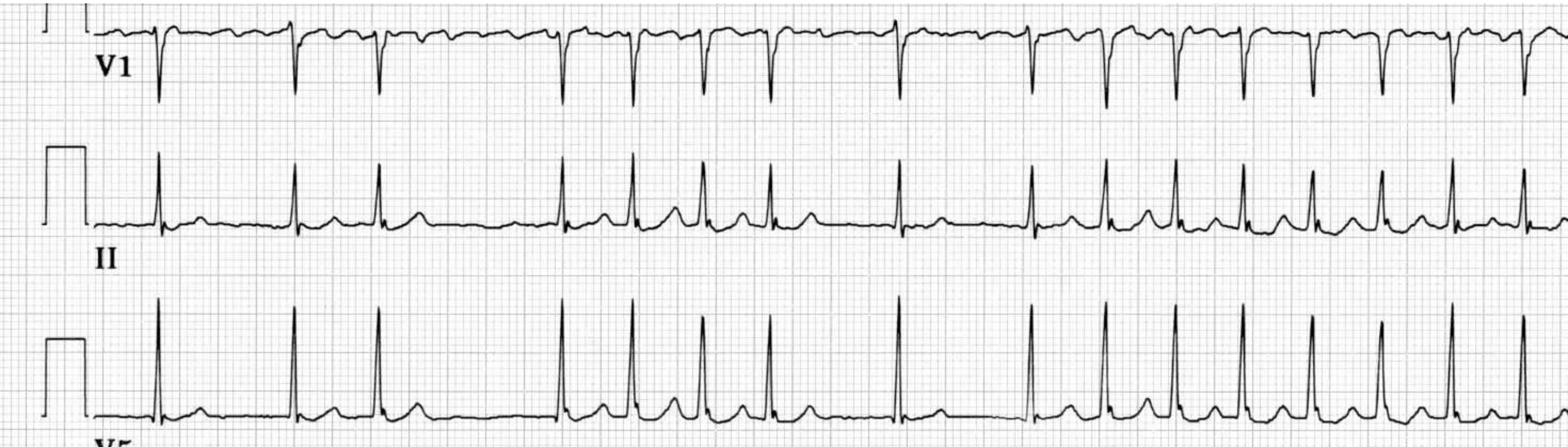
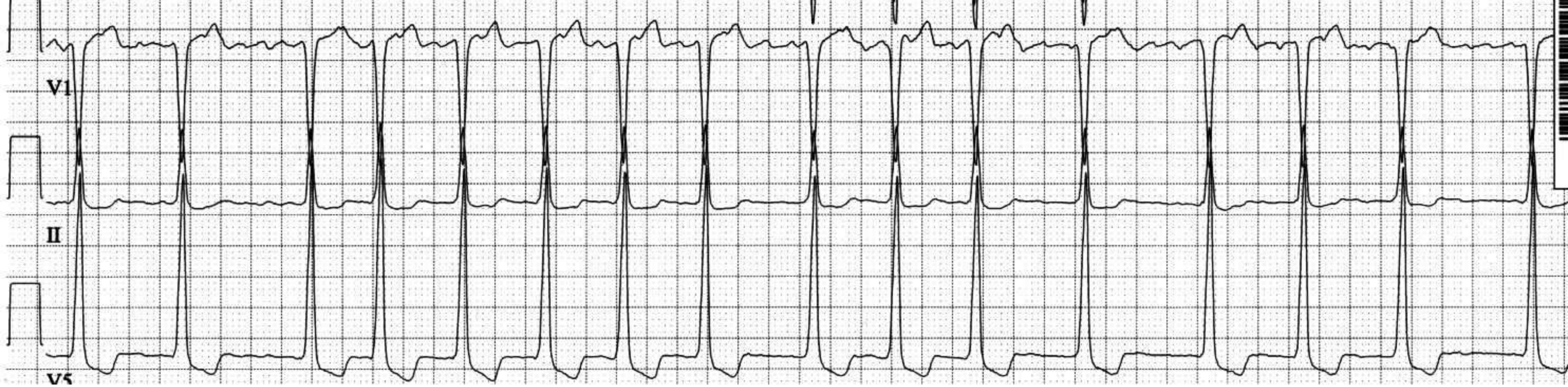
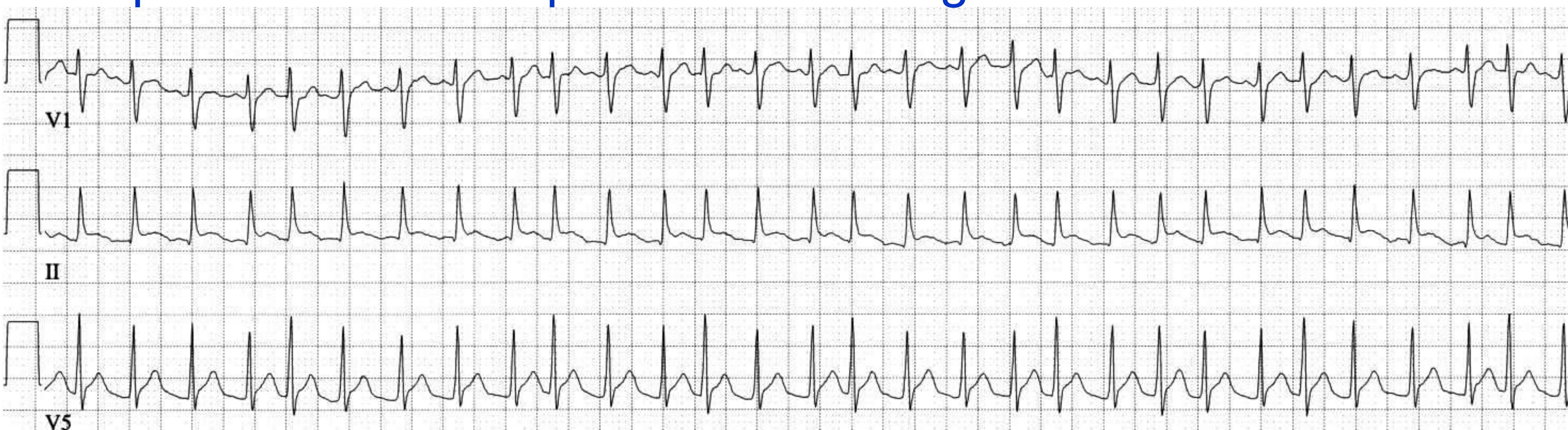


Atrial Flutter vs. Fibrillation

	Atrial Flutter	**Atrial Fibrillation**
Best leads	II, III, aVF	V_1
Atrial rhythm	Regular	Irregular
Atrial rate	220-340	Faster
Ventricular Response	Often a pattern of 2:1 or 4:1 or alternating or 3:1, occasionally irregular	Always irregularly irregular unless complete AV block

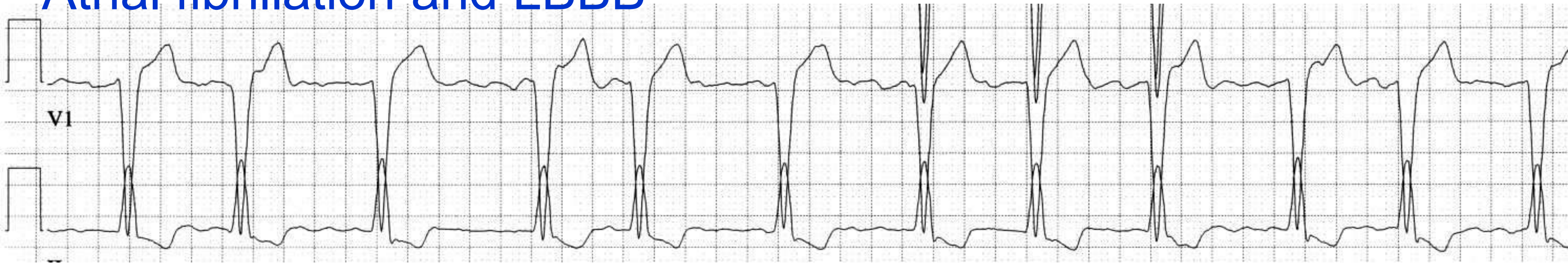


A rapid ventricular response is less irregular **Atrial Fibrillation**



Atrial Fibrillation

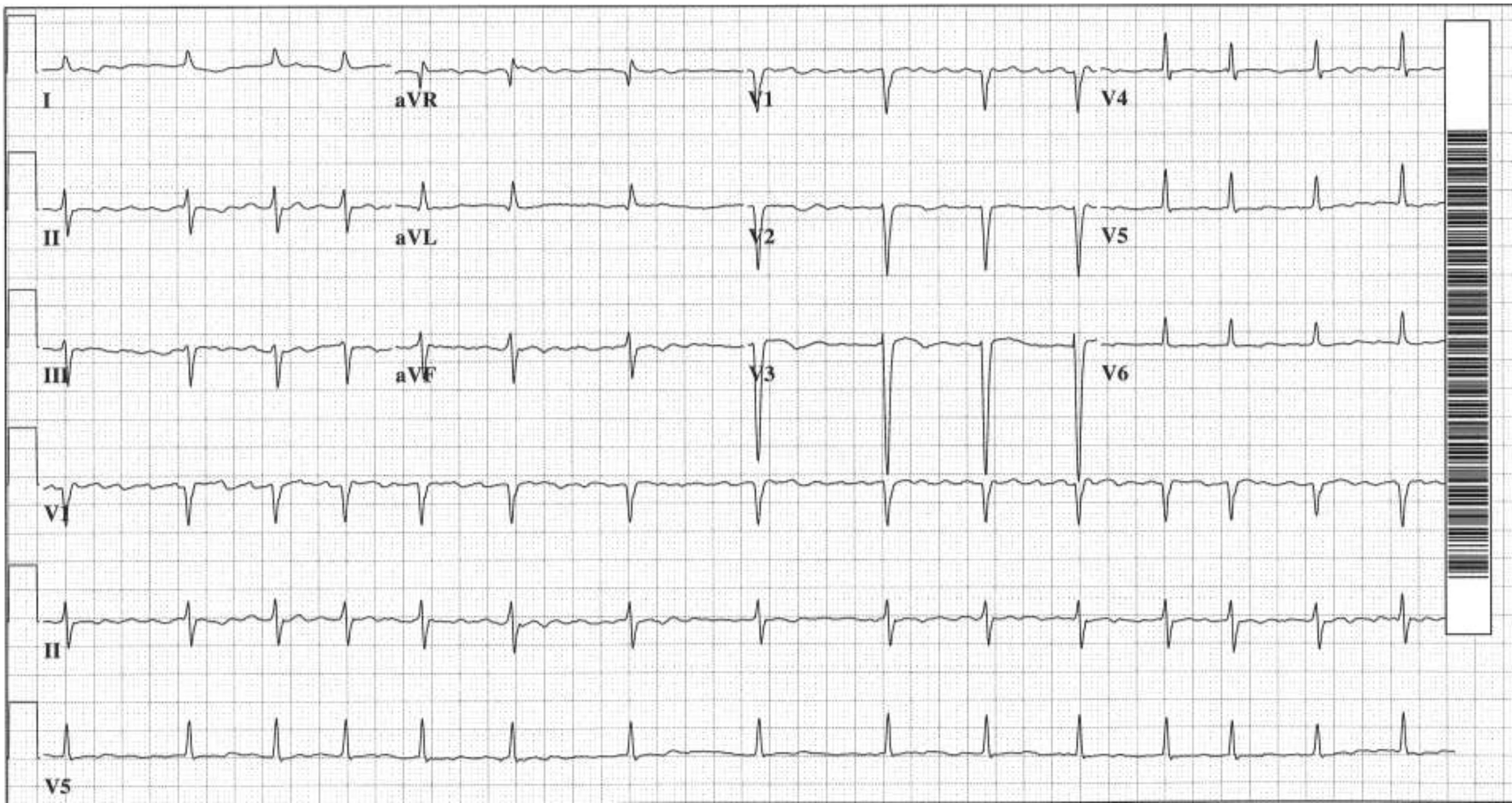
Atrial fibrillation and LBBB



Atrial fibrillation and RBBB

Atrial fibrillation can occur in patients with bundle branch block

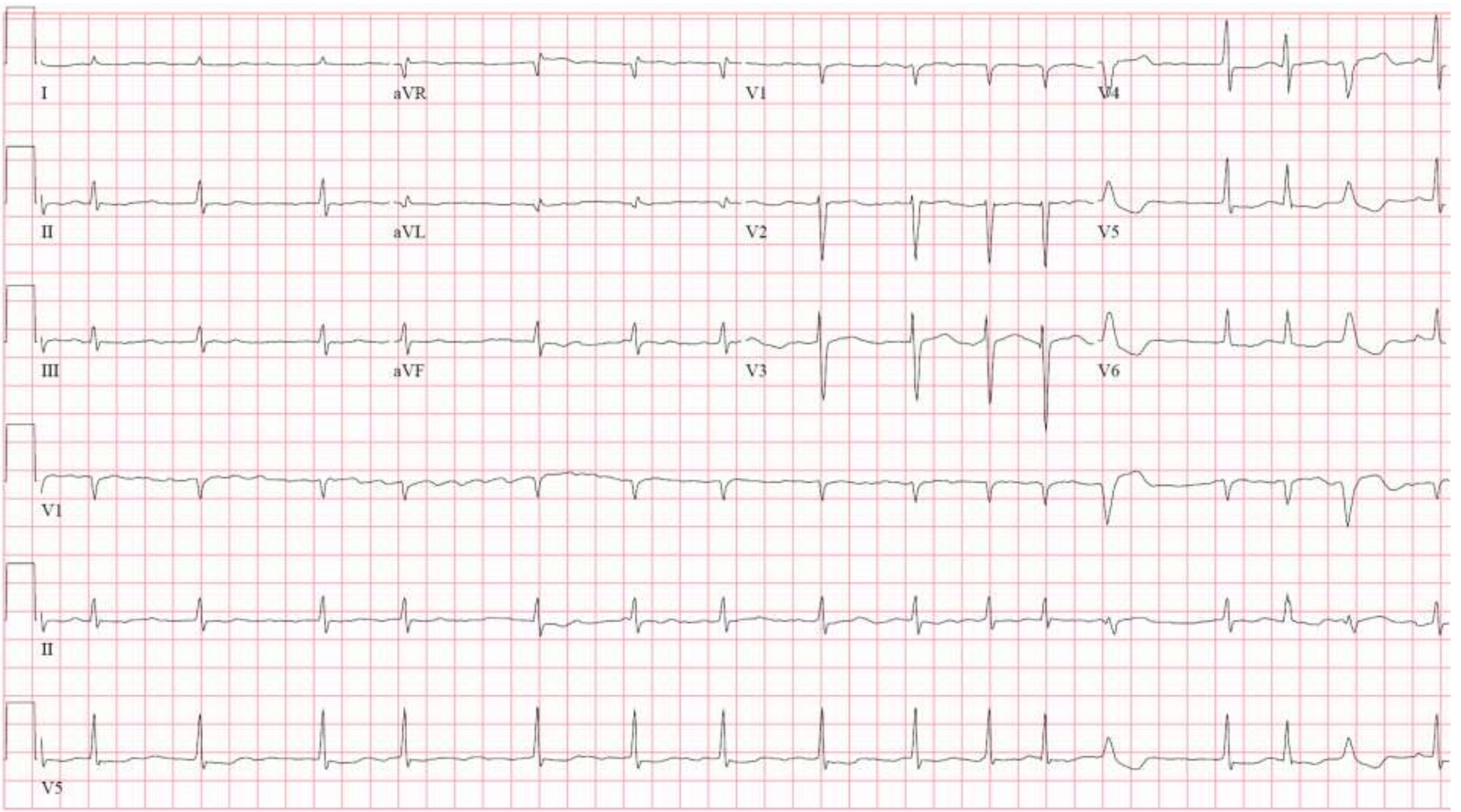
Atrial Fibrillation



Atrial Fibrillation

Afib and rapid ventricular response (RVR) is less irregular than with slower response

Atrial Fibrillation



Multifocal Atrial Tachycardia

- Variable P morphology and PR interval and P-P interval, not gradual or progressive
- Rate over 100 beats/min
- Often indicates severe end-stage cardiac or pulmonary disease

Multifocal Atrial Tachycardia

Multifocal atrial tachycardia (MAT) is usually irregularly irregular, similar to Afib, but there are real and distinct P waves

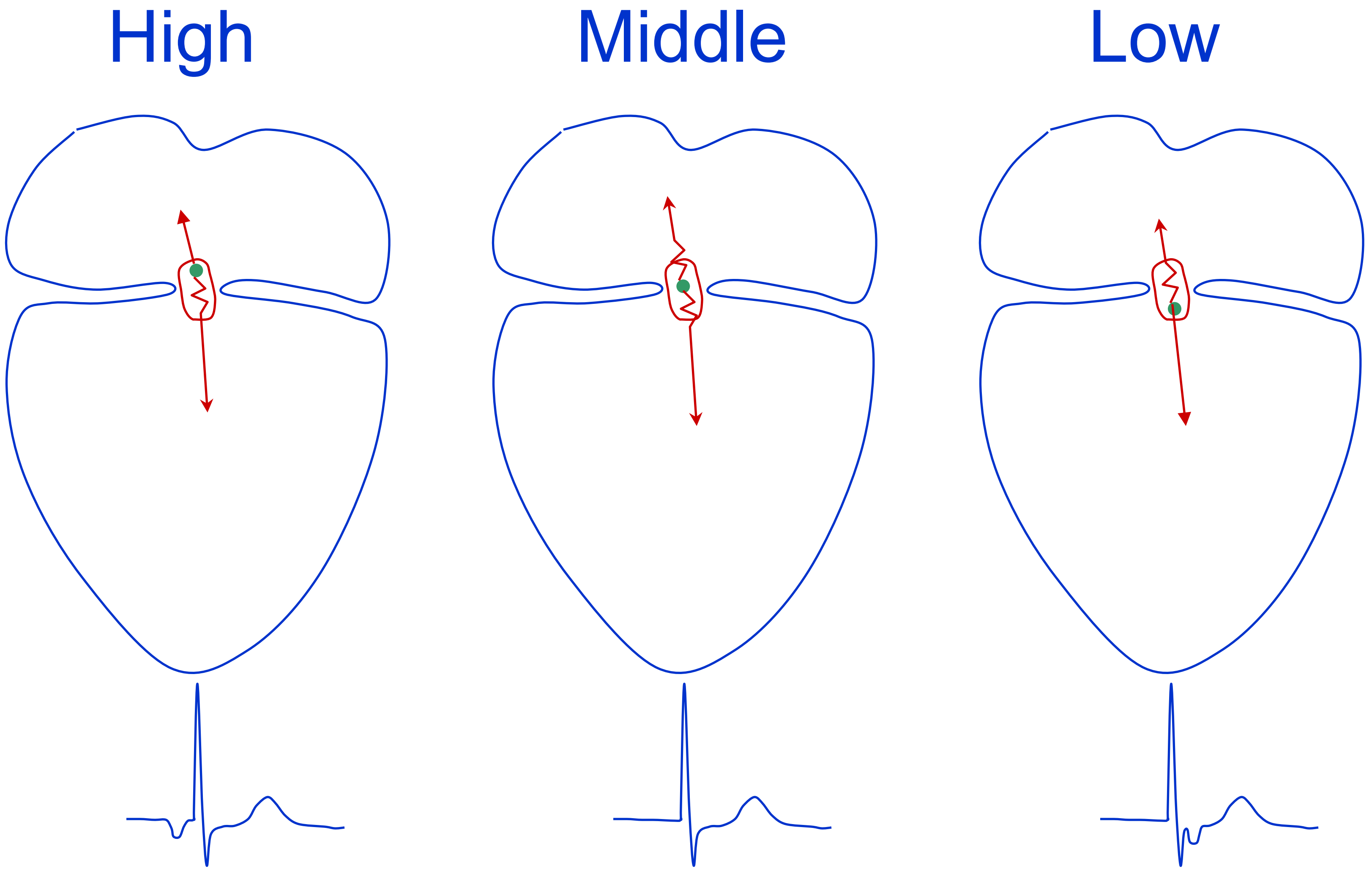
AV Junctional Beats

- P wave, if seen, left axis deviation
  - inverted in II, III, and aVF
  - called “retrograde P wave”
- PR interval is short
  - <0.11 sec
  - P may be in the QRS complex
  - P may occur immediately after QRS (R-P interval <0.20 sec)

Where in the AV Junction?

- No matter where, the PR interval will be short and the P wave if seen will be inverted
- High in the AV junction – P precedes QRS, PR interval short
- Middle of AV junction – P within QRS, not seen
- Low in the AV junction – P follows QRS

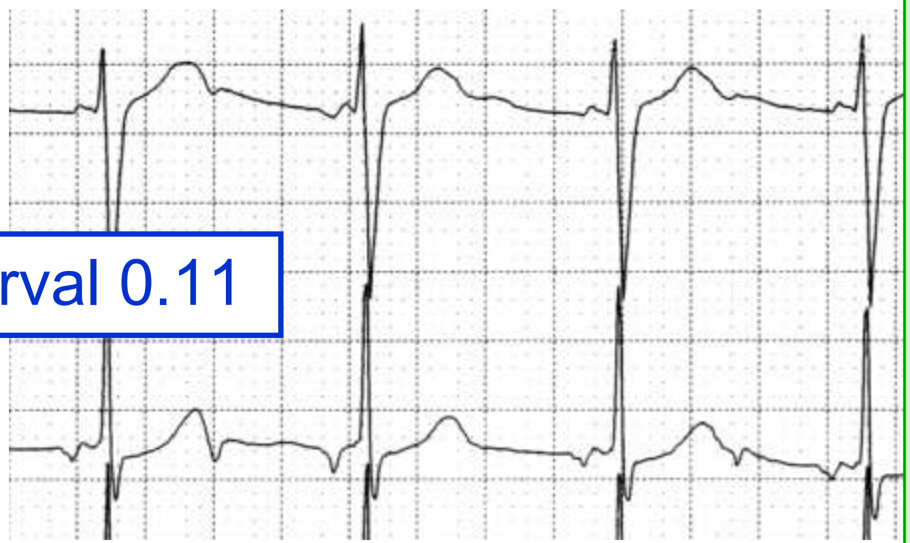
AV Junctional Beats



Junctional Rhythms

- Junctional escape rhythm - very regular, rate 40-50 beats/min
- Accelerated junctional rhythm - rate usually about 70-130 beats/min
- Junctional escape complex - junctional beat which occurs after a pause
- Junctional premature complex - junctional beat which occurs early (before next expected beat)

Junctional Rhythms



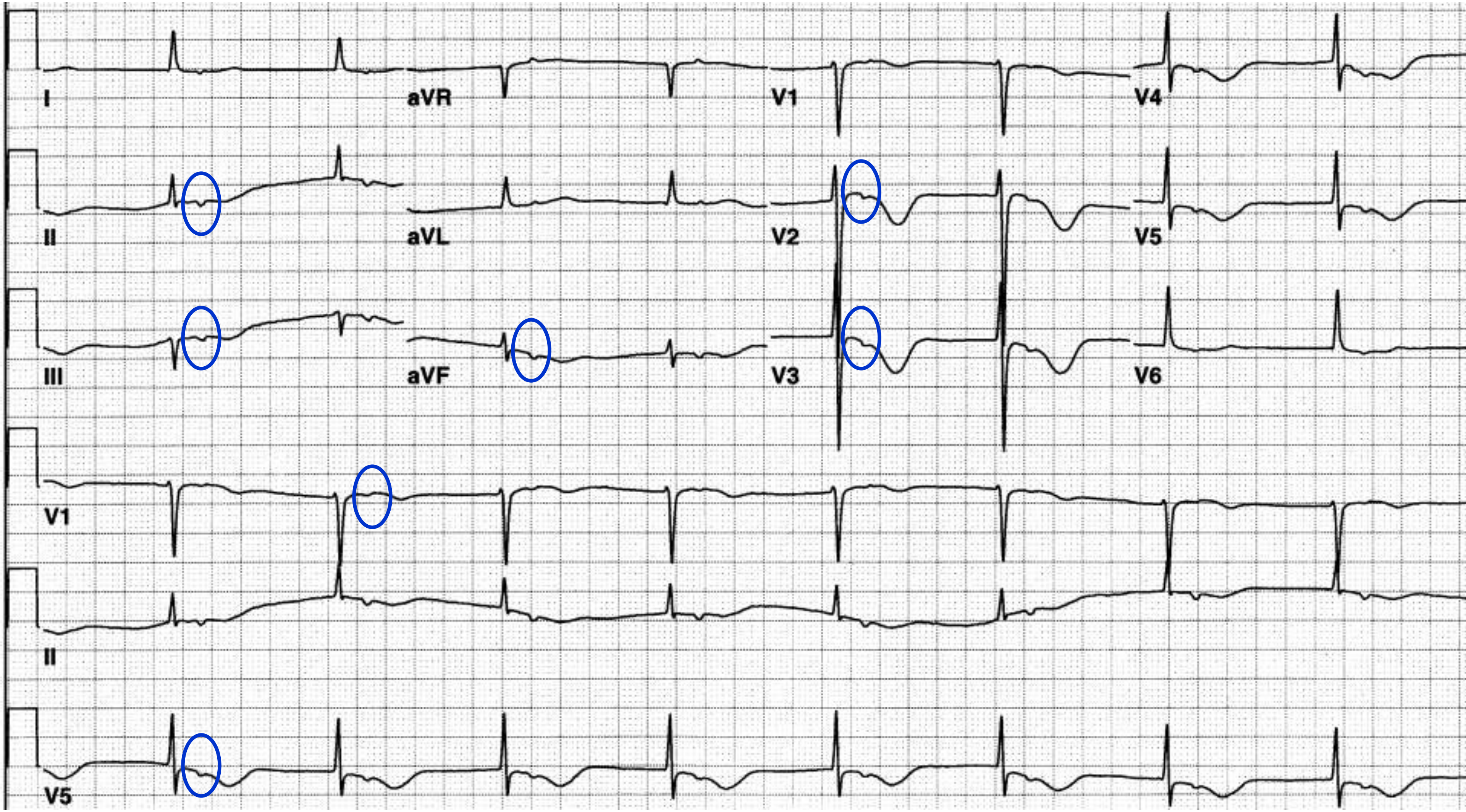
P wave, if seen

- Left axis deviation
  - inverted in II, III, and aVF
  - called “retrograde P wave”

PR interval is short

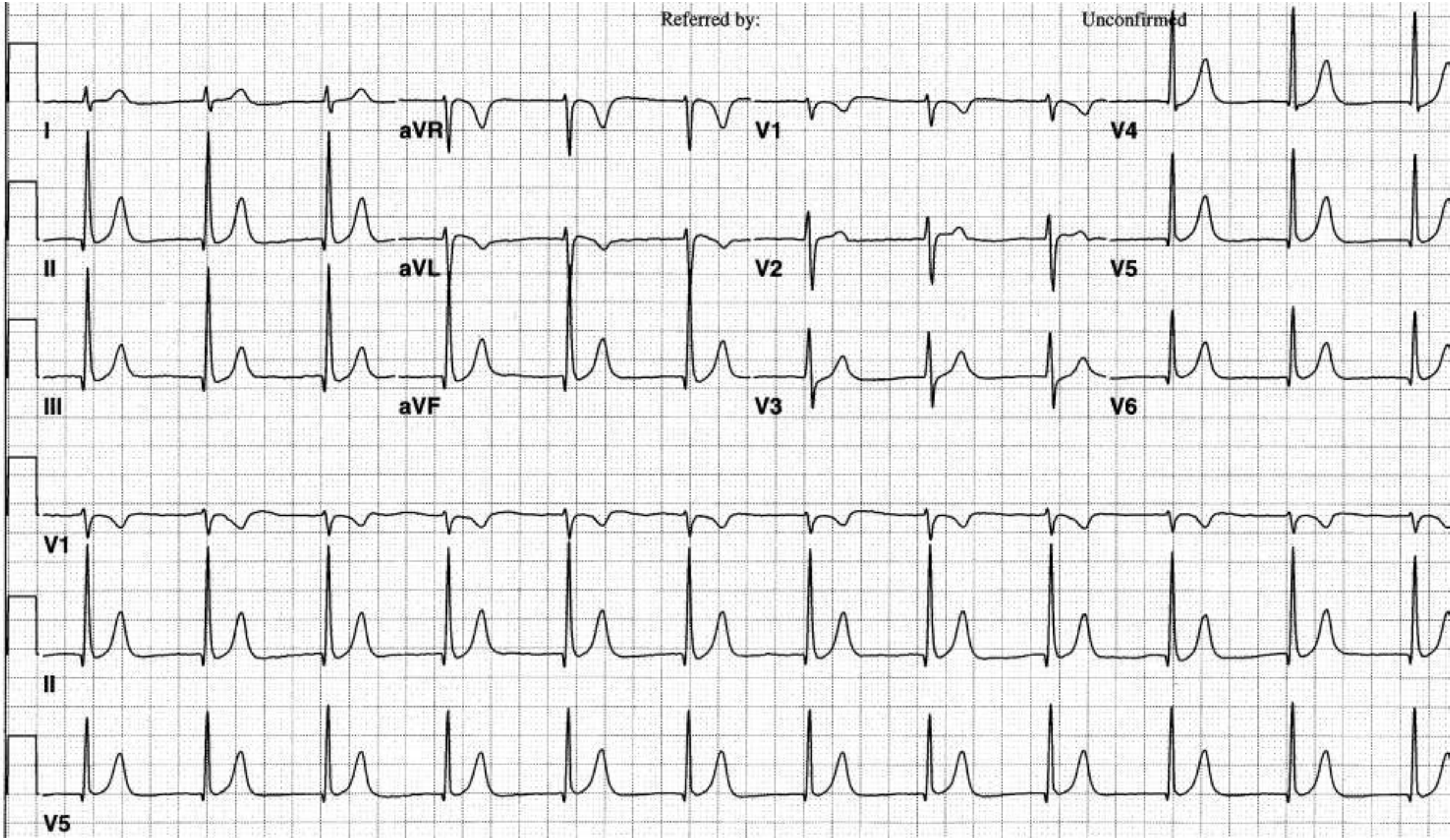
- <0.11 sec
- P may be in the QRS
- P may be immediately after QRS (R-P interval <0.20 sec)

Junctional Rhythms



The P wave FOLLOWS the QRS. Potassium 2.6. Also long QT interval.

Accelerated Junctional Rhythm

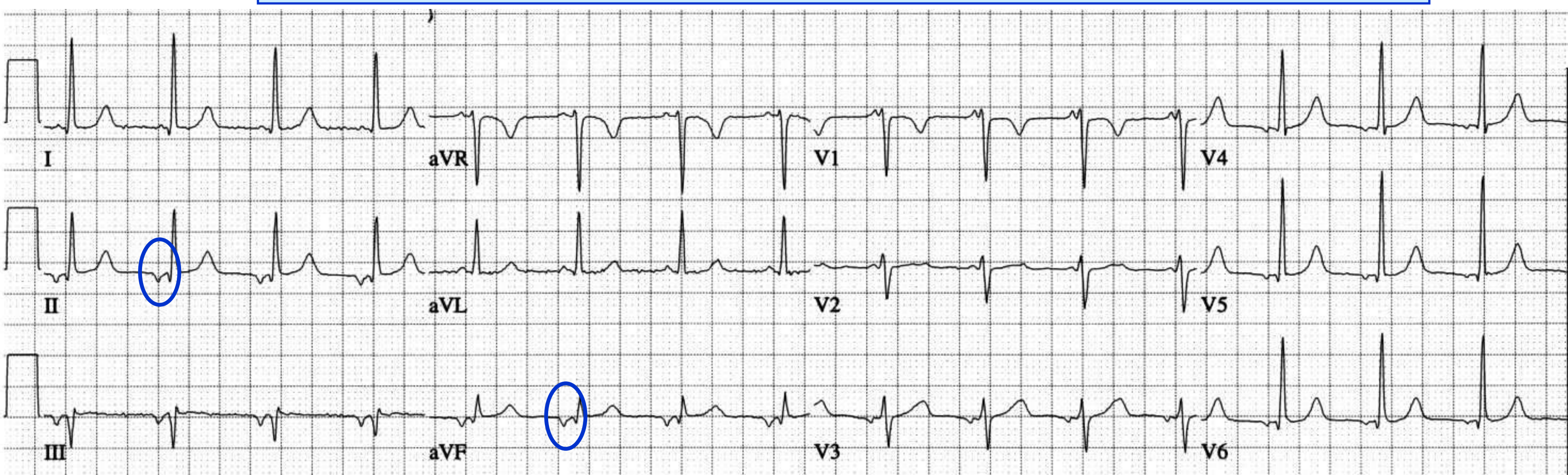


The P wave is not seen. ICU patient with OD.

Junctional Rhythms

Sinus - Nonconducted PAC – Junctional escape beat

Accelerated Junctional Rhythm: short PR and retrograde P wave



Supraventricular Tachycardia

Rate 140 to 220

Regular rhythm, normal QRS, same as baseline

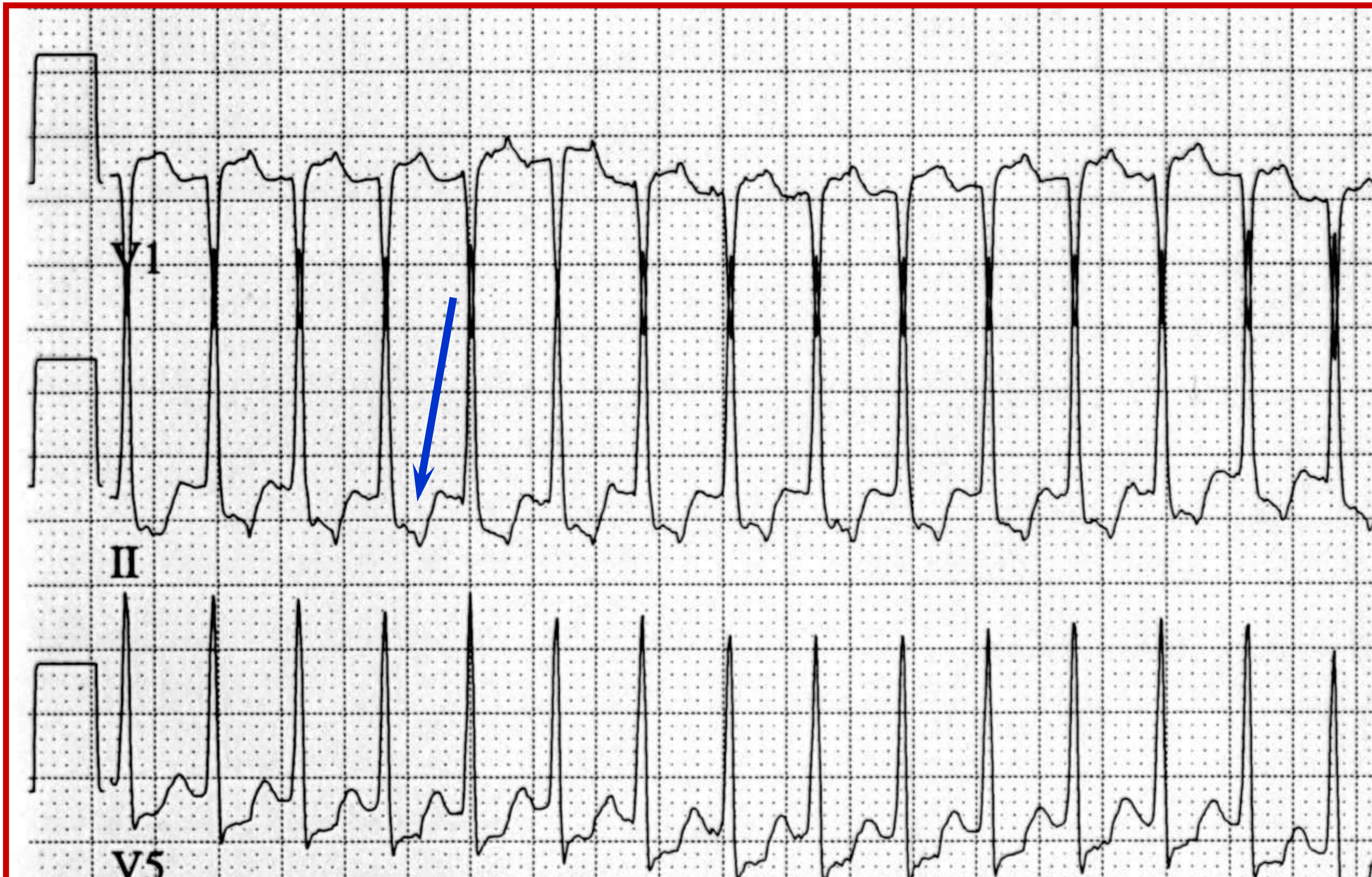
No sinus P wave present

Often unable to determine specific mechanism of tachycardia

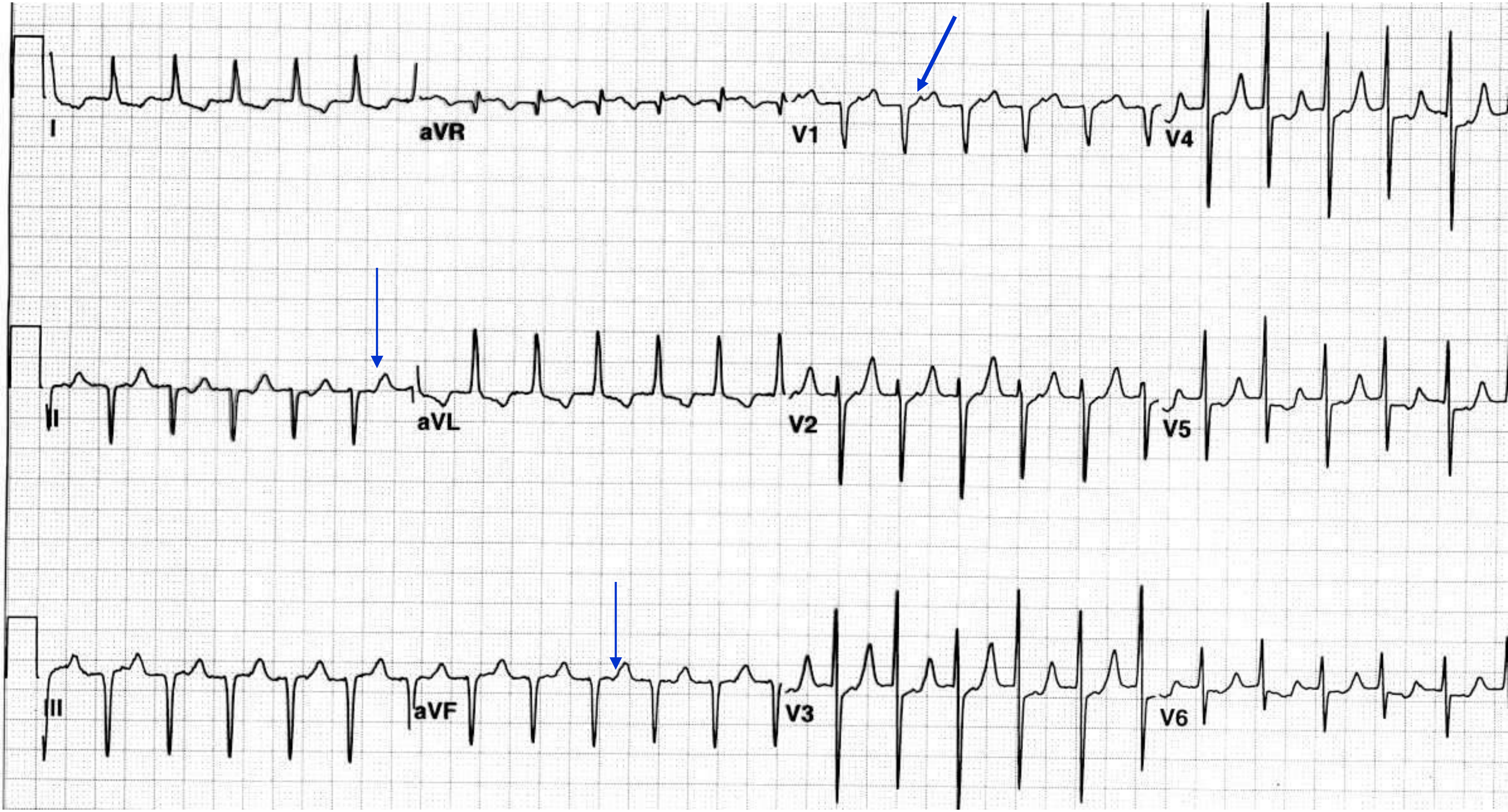
AVNRT-
A-V Nodal Reentrant Tachycardia

- Most common form of paroxysmal supraventricular tachycardia
- Onset and termination are abrupt
- Rate usually 140-220 beats/min
- P waves retrograde
- Common type - slow antegrade - short RP
- Uncommon type - fast antegrade - long RP

Supraventricular Tachycardia



Supraventricular Tachycardia



RATE 150, RP interval 0.12 sec, P axis -90 degrees

Supraventricular Tachycardia

RATE 168, RP interval ???, P wave axis ???

AVRT - Atrioventricular Reciprocating Tachycardia

- Accessory pathway of WPW (Kent bundle) always required
- rates 140-250 beats/min

Orthodromic		Antidromic
antegrade	down AV node	*retrograde*
retrograde	up the Kent bundle	*antegrade*
narrow,	normal QRS	*wide*
common	occurrence	*uncommon*

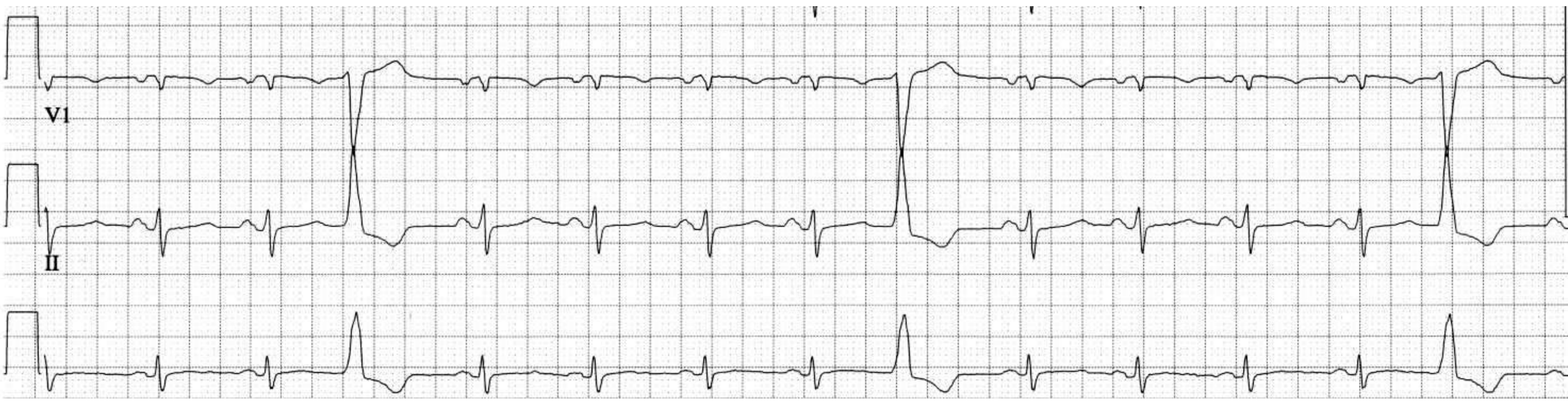
Ventricular Rhythms

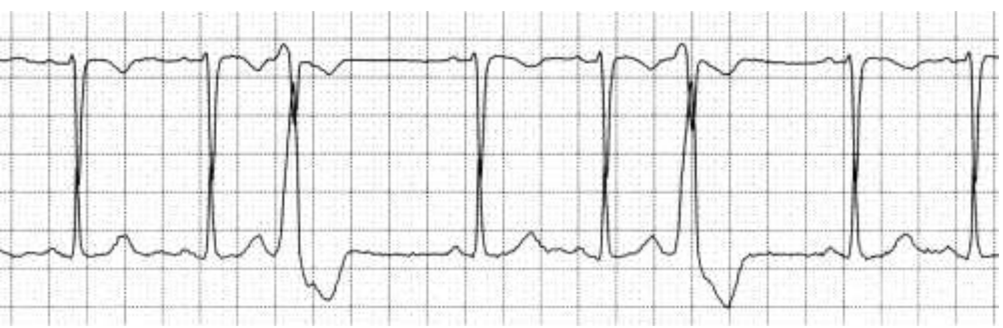
- Ventricular beat
  - No preceding premature P wave
  - QRS complex wide and different, >0.12 sec
  - May have a following P wave
- PVC - premature ventricular complex - early different QRS
- Ventricular escape rhythm - series of ventricular beats at rate of 30-40 beats/min

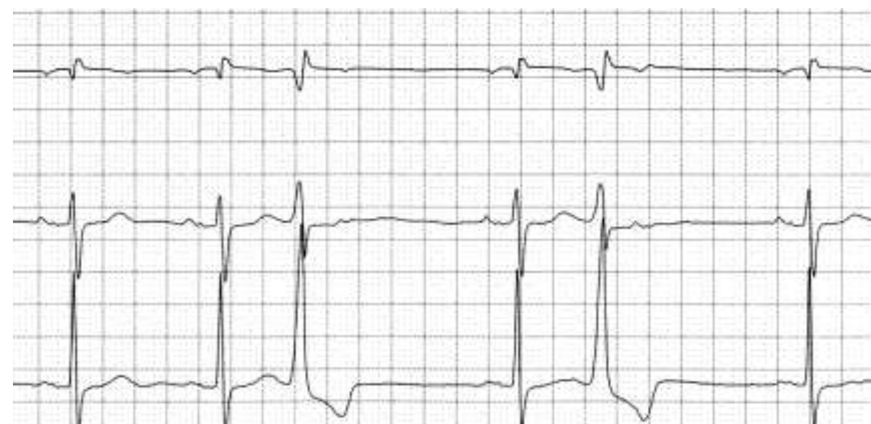
The PVC
Premature Ventricular Complex

- Compensatory pause
  - usual
  - retrograde conduction through AV node doesn't reset SA node
- No pause or interruption: "interpolated" PVC
- Couplet - 2 PVC's in a row
- Quadrigeminy - every 4th beat a PVC
- Trigeminy - every 3rd beat a PVC
- Bigeminy - every 2nd beat a PVC
- Unifocal - all alike
- Multifocal - all not alike

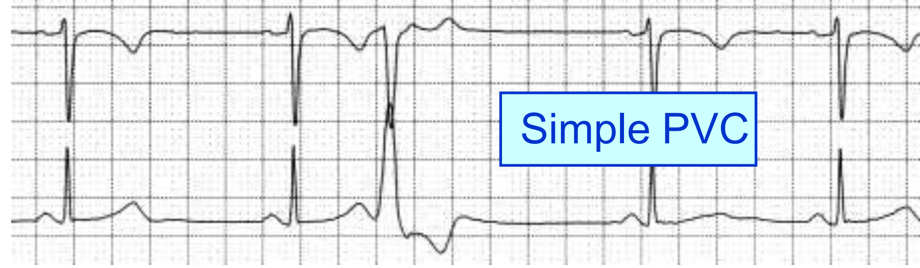
PVC’s



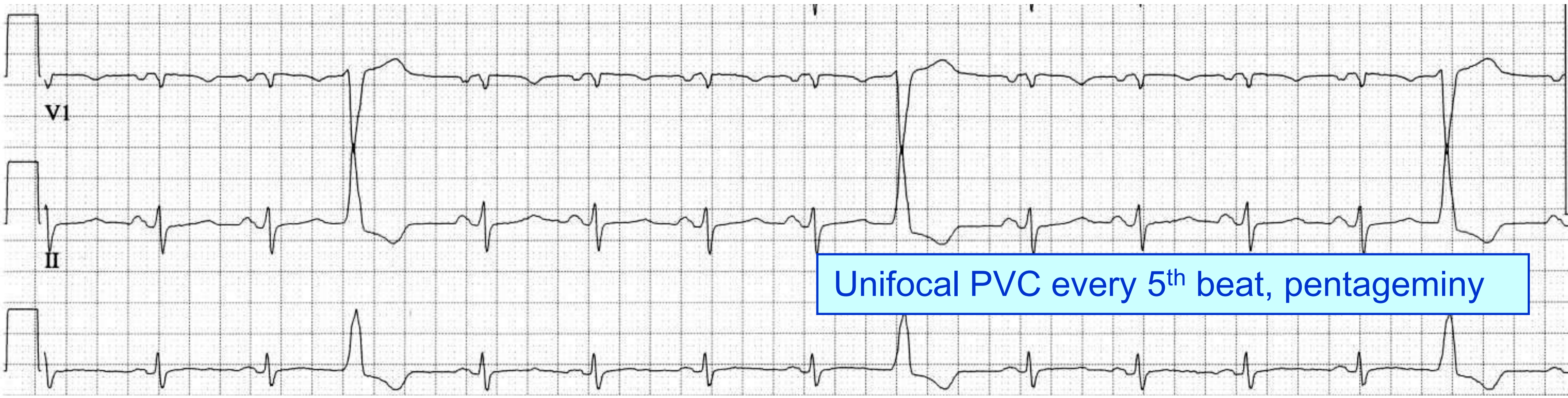




PVC's

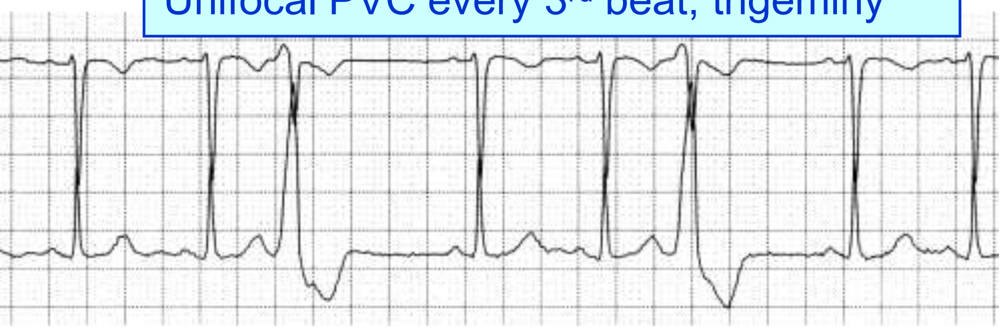


Simple PVC

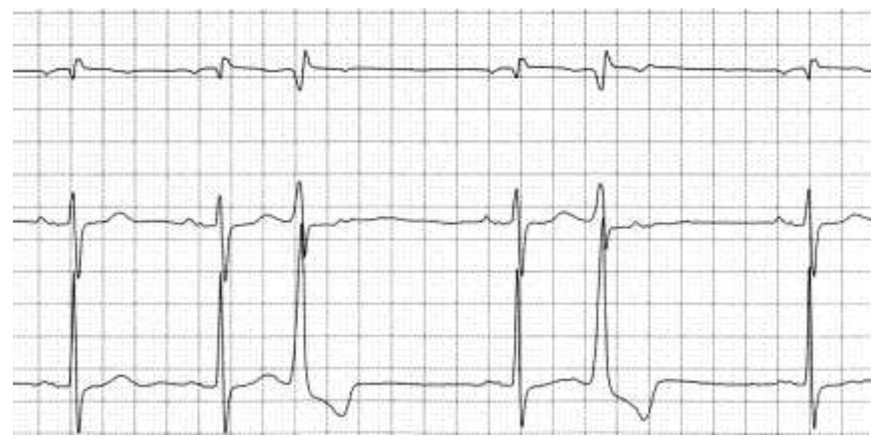


Unifocal PVC every 5th beat, pentageminy

Unifocal PVC every 3rd beat, trigeminy

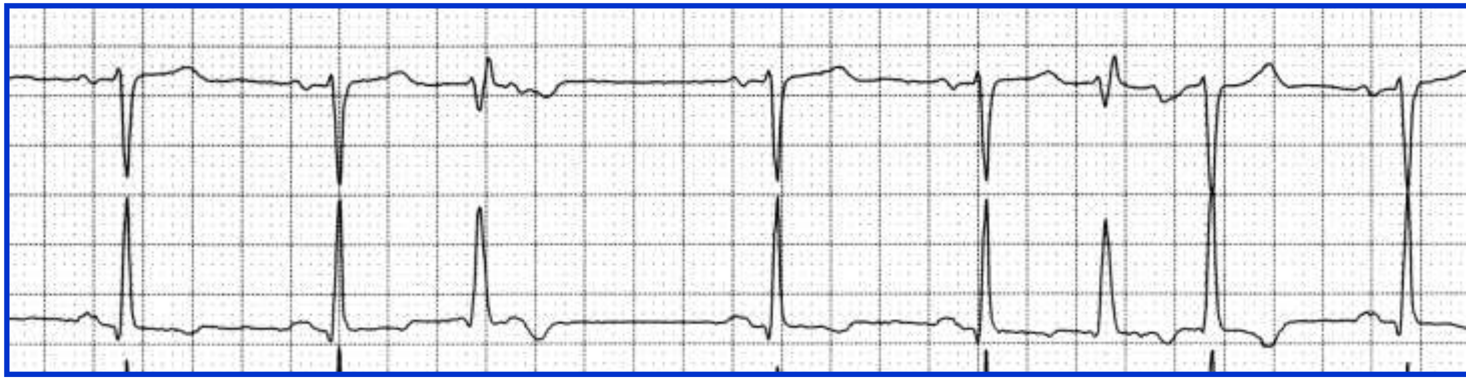


Multifocal PVC

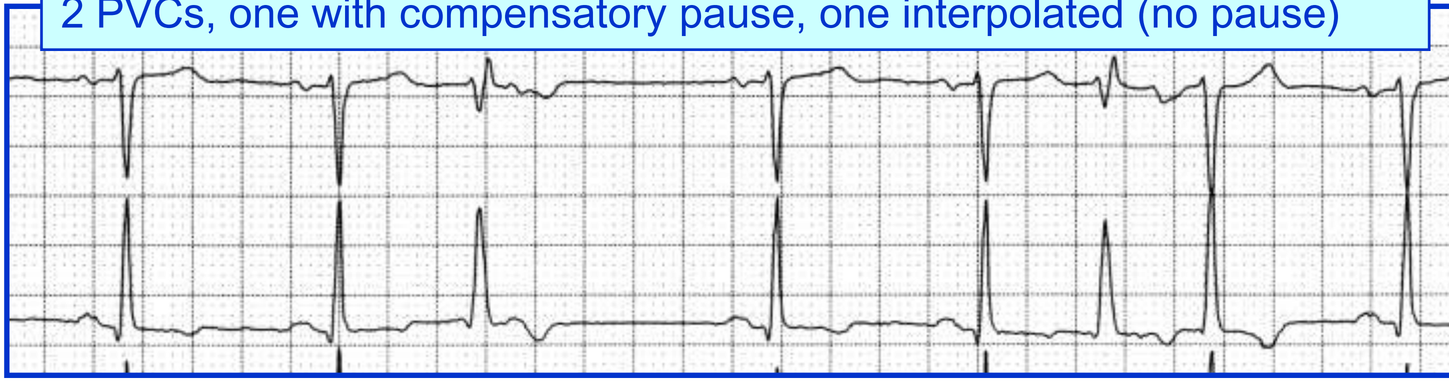


Unifocal PVC

PVC's



PVC’s



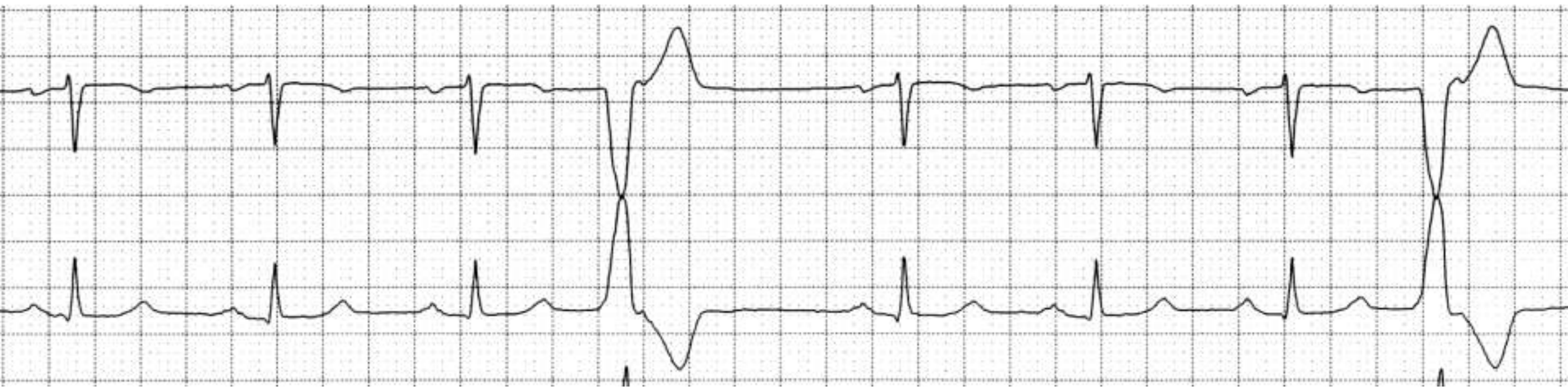
2 PVCs, one with compensatory pause, one interpolated (no pause)

Unifocal PVC every 2nd beat, bigeminy

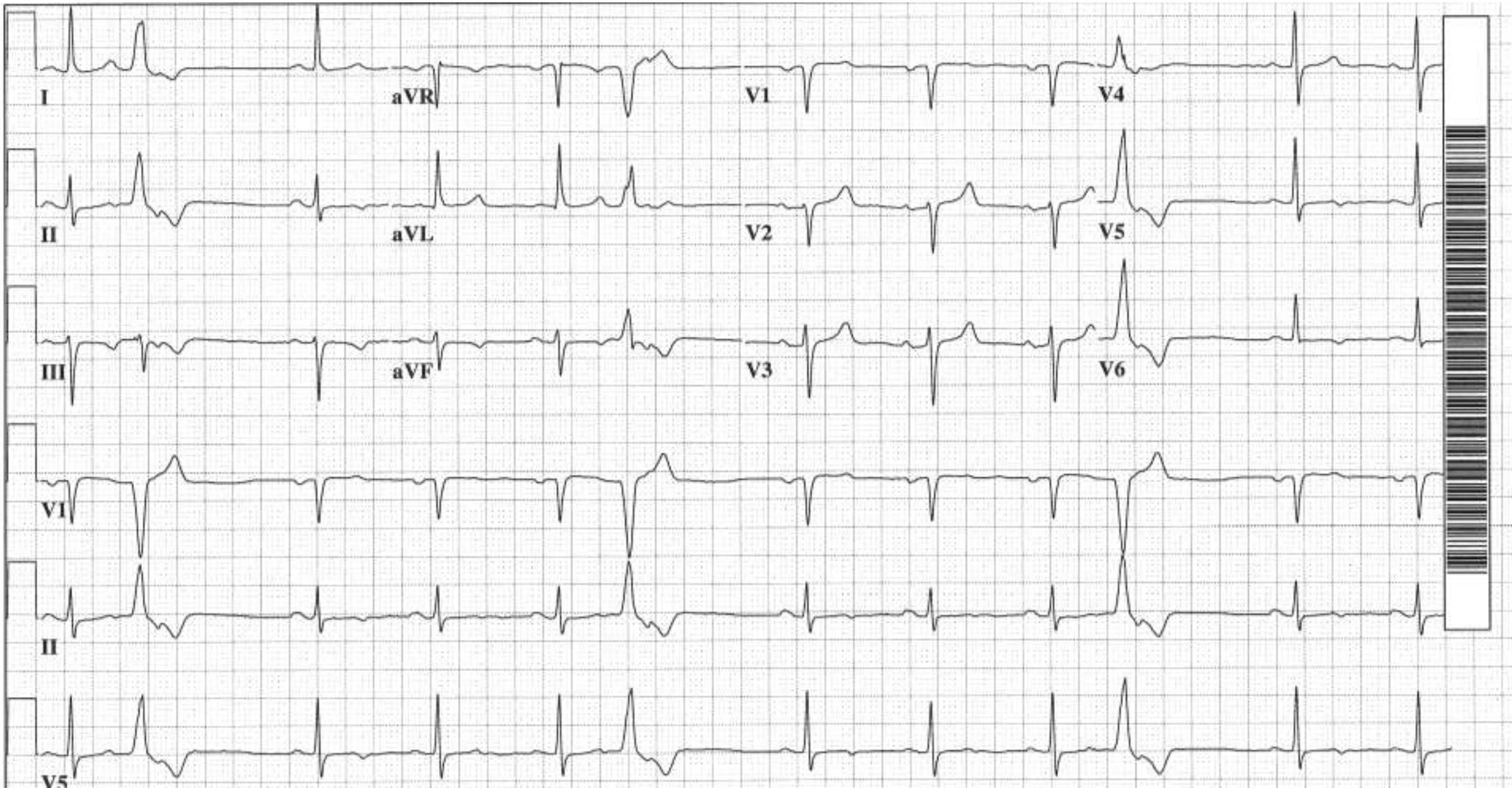
Multifocal couplet

Multifocal couplet

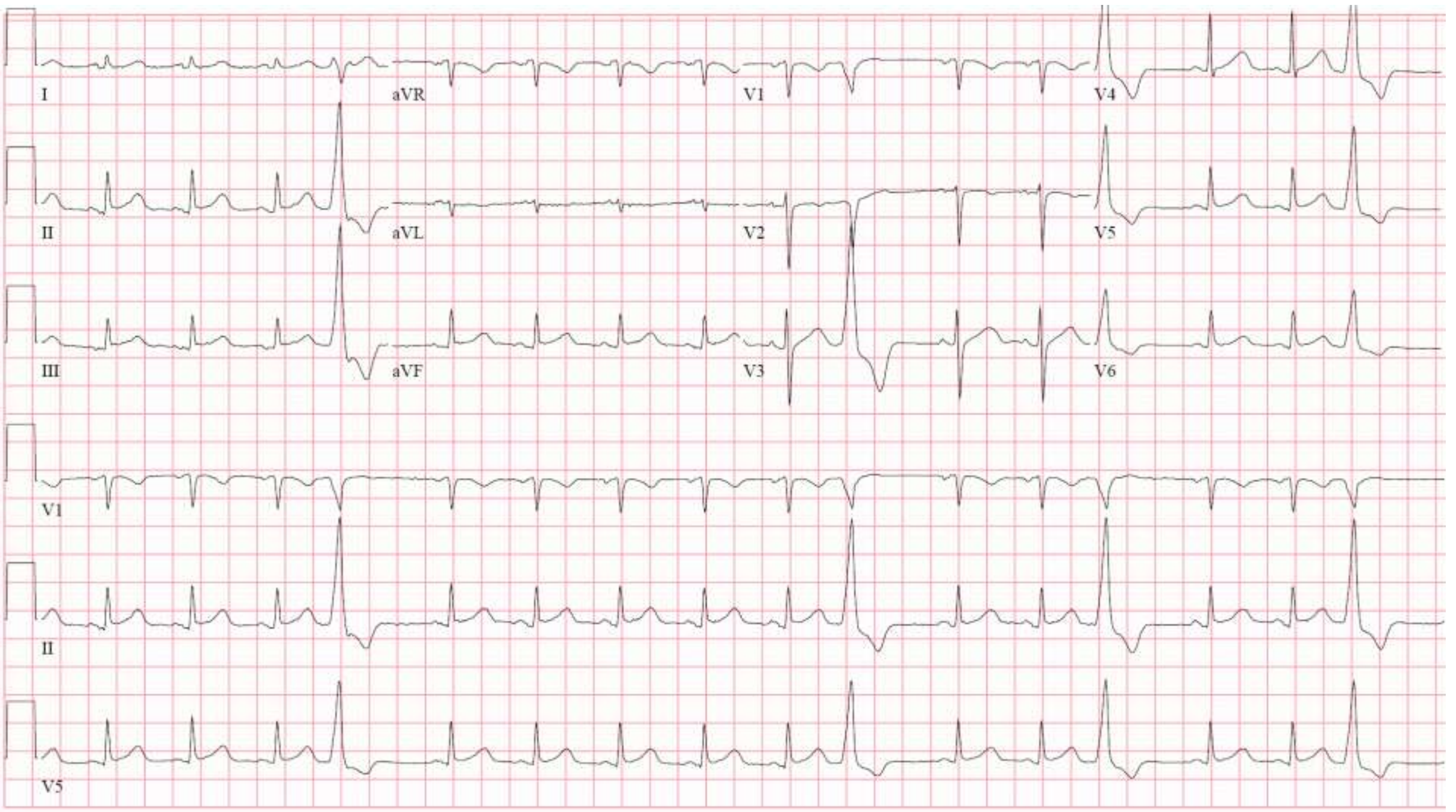
Unifocal Ventricular Quadrigeminy



PVCs



PVCs



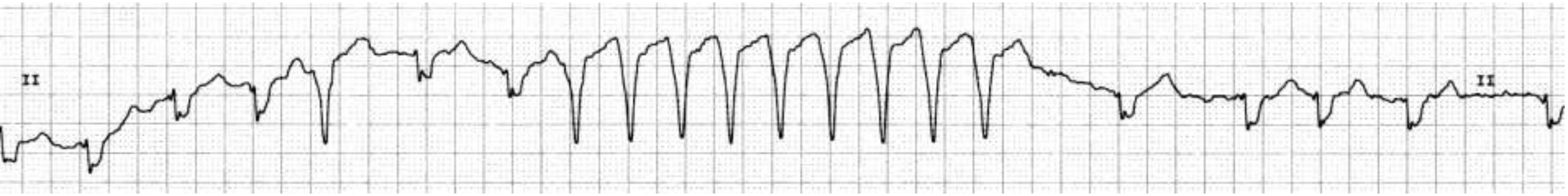
Ventricular Rhythms

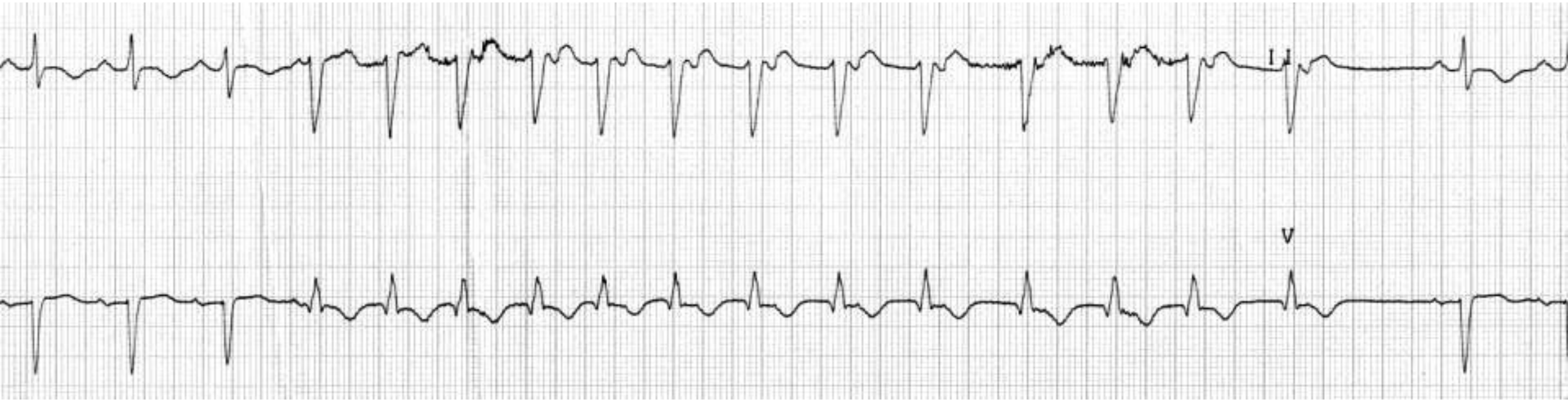
- 3 PVC’s in a row - triplet or short burst of Ventricular tachycardia
- Nonsustained ventricular tachycardia - less than 30 sec
- Sustained ventricular tachycardia - more than 30 sec
- Rate usually 140-200

Ventricular Tachycardia

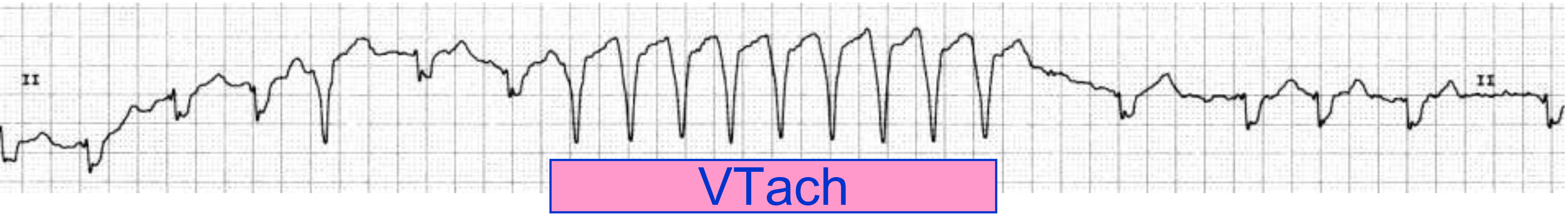
- Rate < 110 = accelerated idioventricular rhythm
- Abrupt onset and termination
- Monomorphic - all beats look alike
- Polymorphic - all beats don't look alike, no gradual change
- Torsades de pointes - turning of the points, gradual change from beat to beat

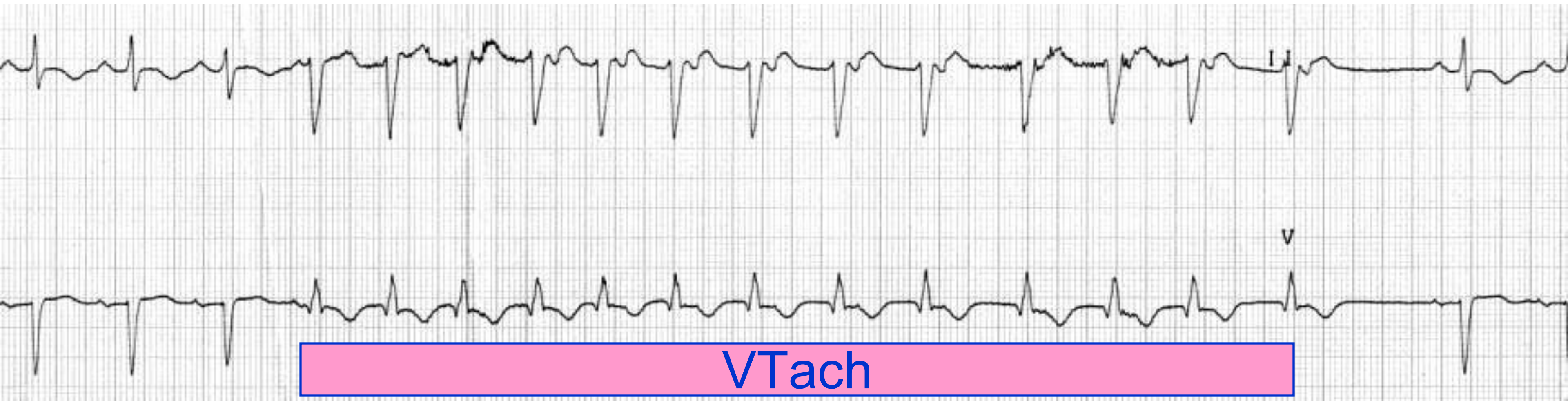
Nonsustained Ventricular Tachycardia



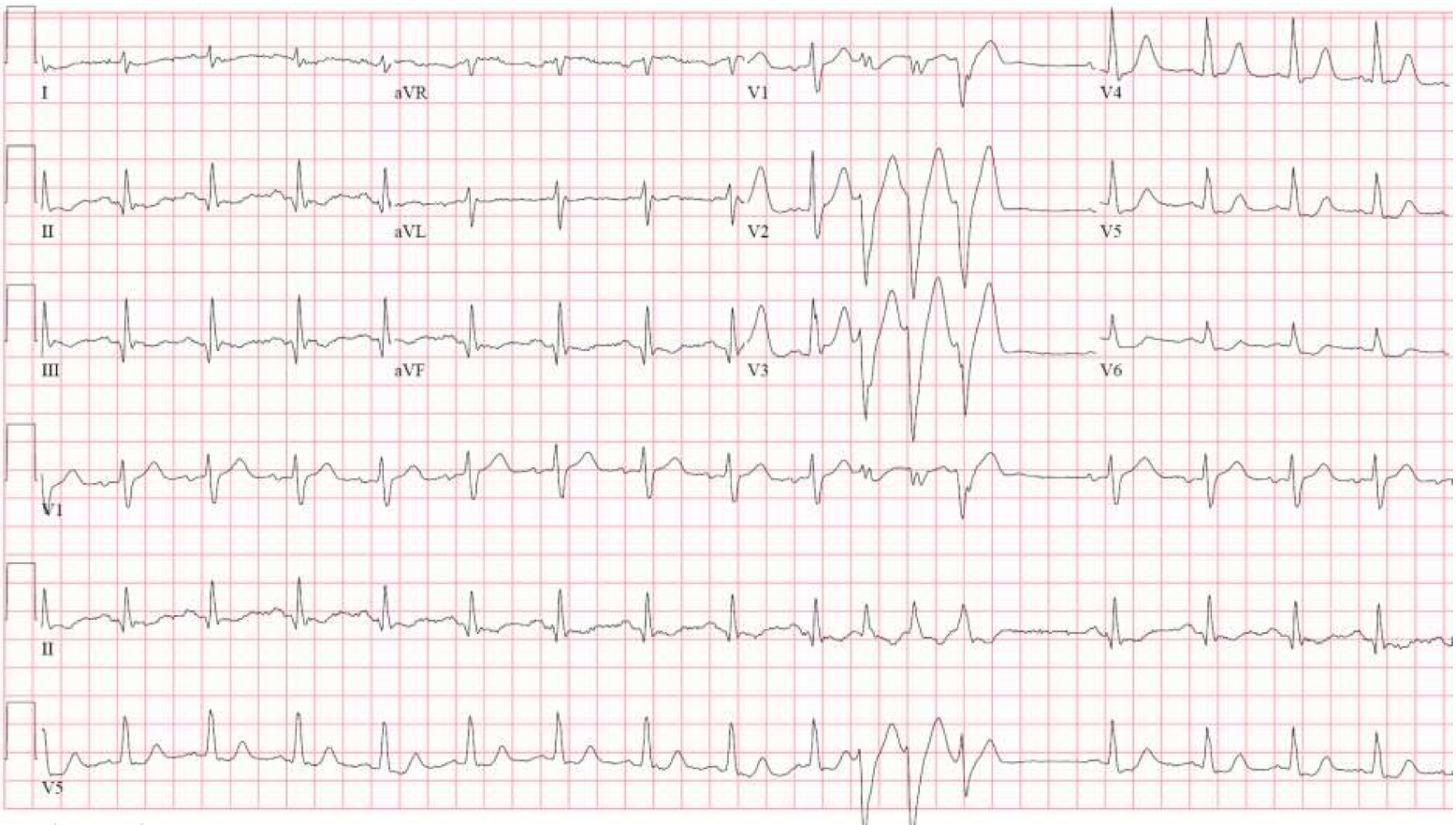


Nonsustained Ventricular Tachycardia

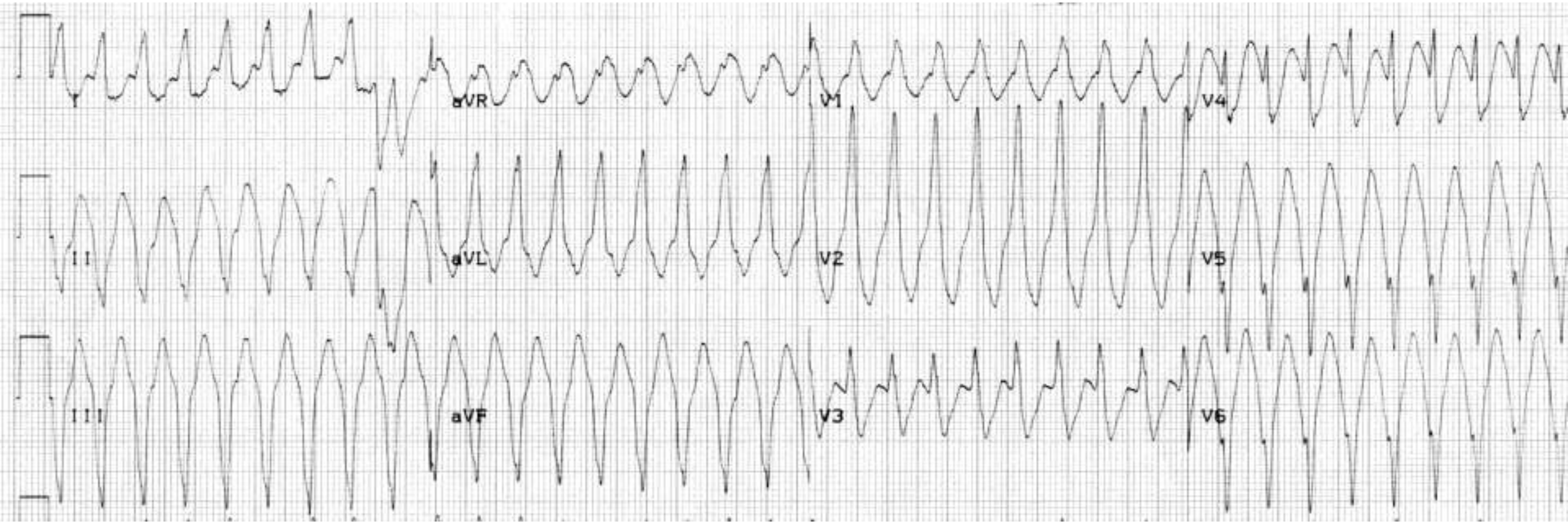




Nonsustained Ventricular Tachycardia

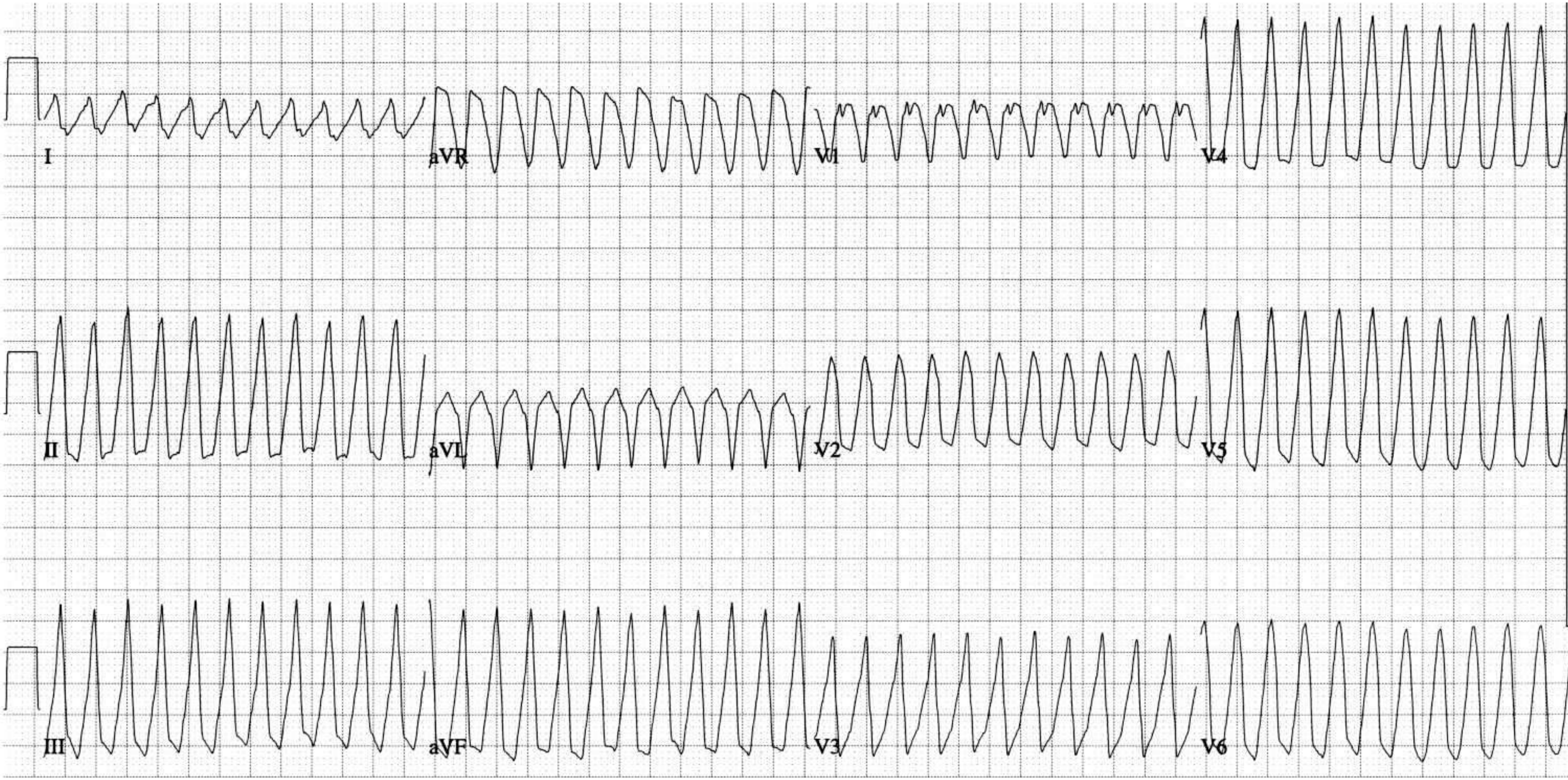


Sustained Ventricular Tachycardia



41 year-old man with DCM and normal coronary arteries

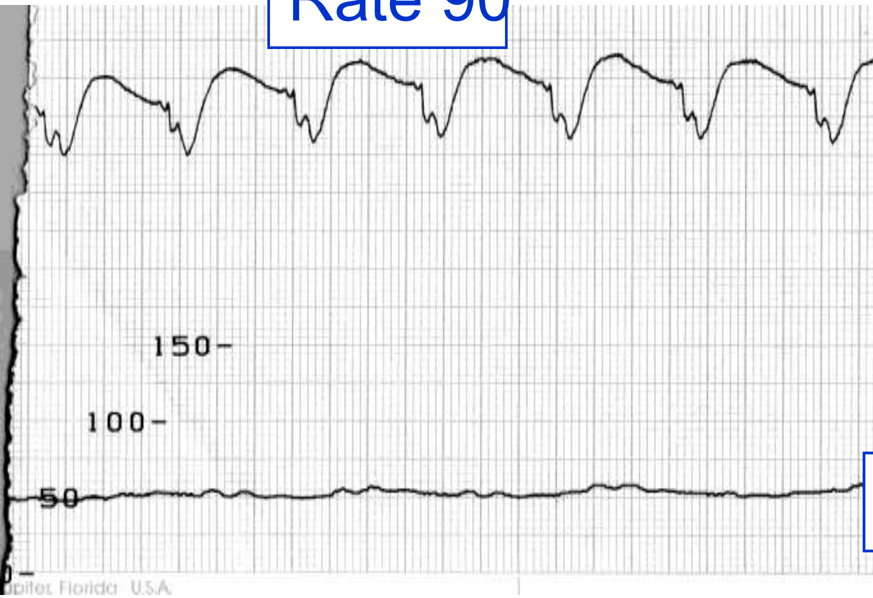
Wide Complex Tachycardia



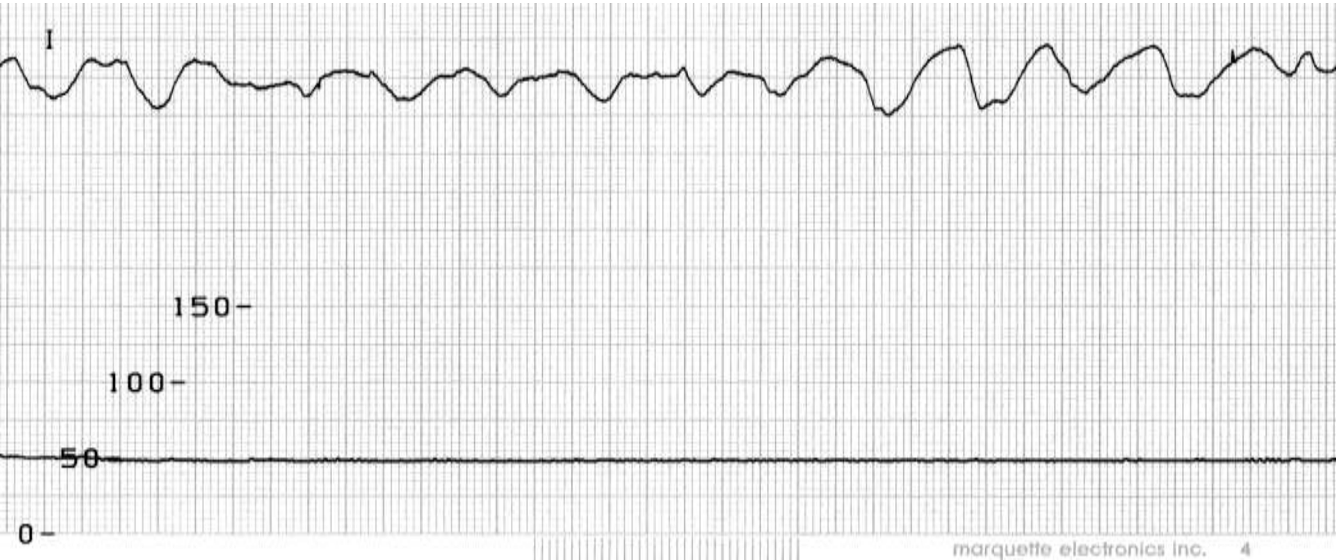
Patient with Tetralogy of Fallot, received ICD

Degeneration of Ventricular Rhythm

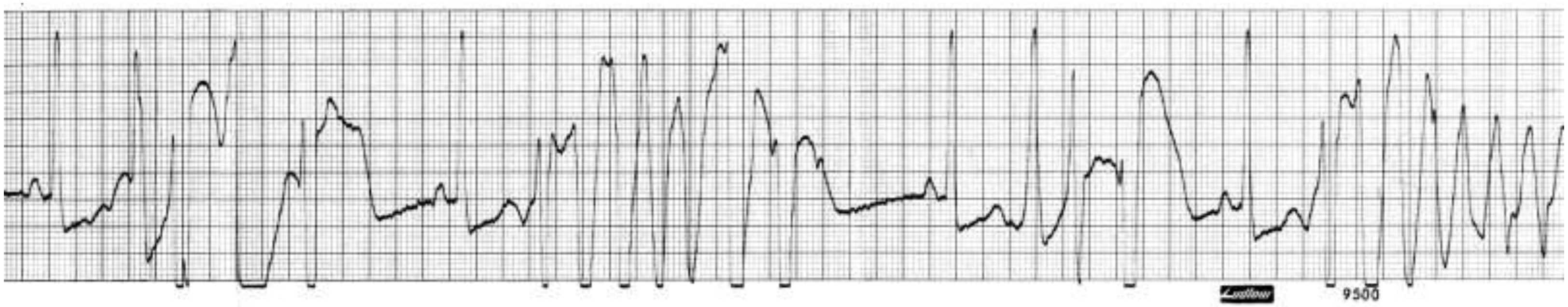
Rate 90

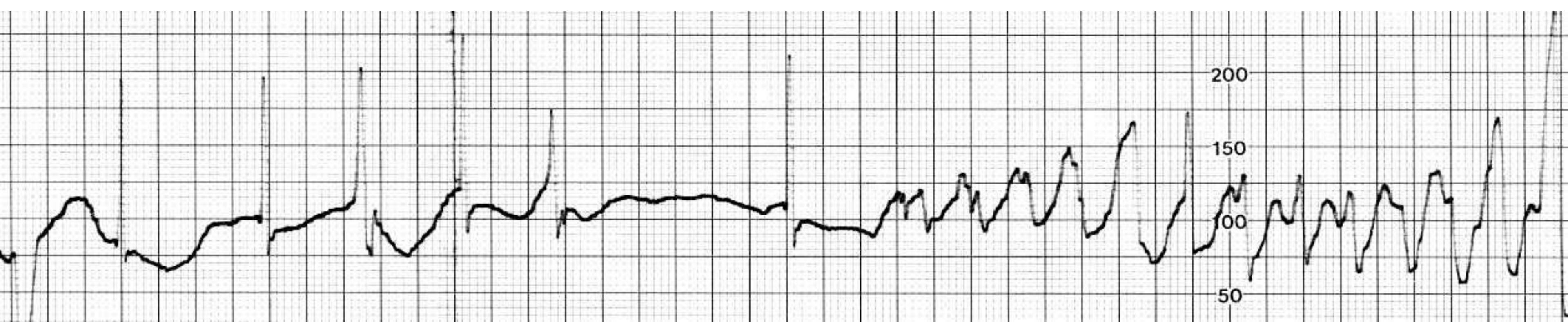


Minimal pulse pressure



Ventricular Tachycardia Torsade

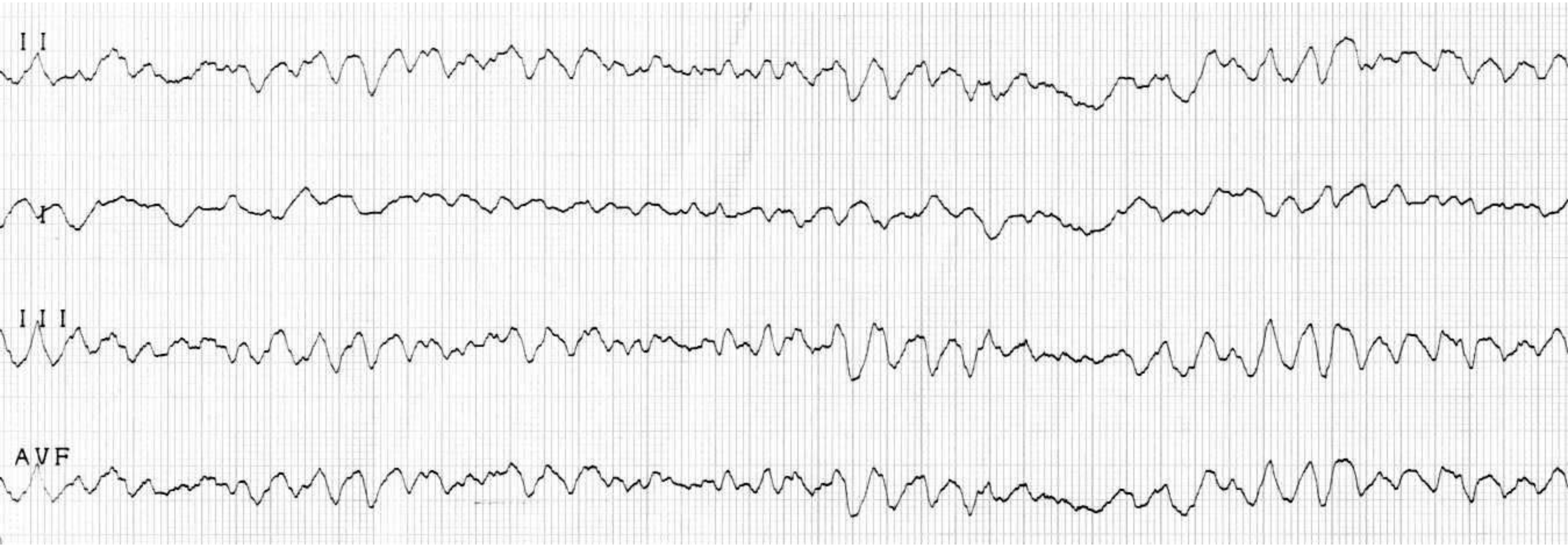




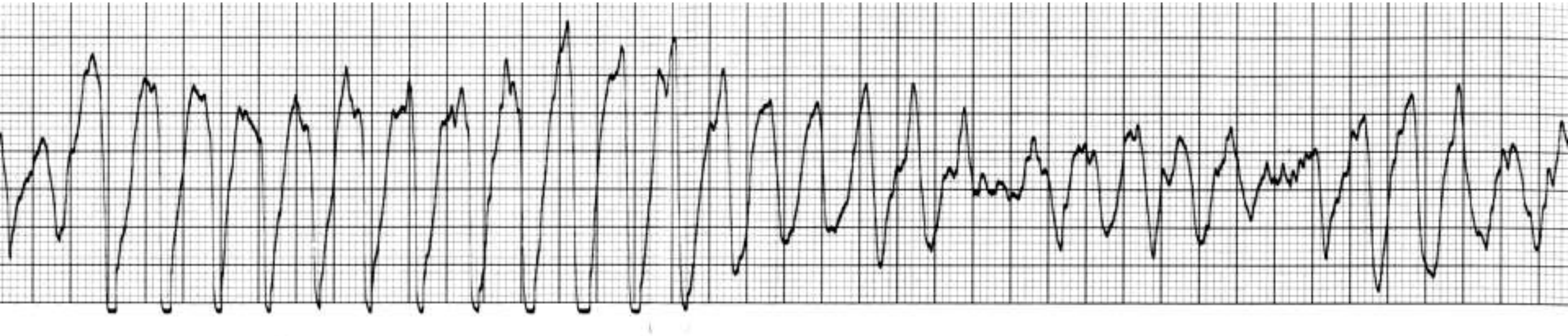
Ventricular fibrillation

- Ventricular flutter - regular, like ventricular tachycardia, but cannot distinguish individual QRS complex
- Ventricular fibrillation - irregular, chaotic, deflections vary in amplitude and contour, without distinct P or QRS or T wave, with rate of undulations from 150-500/min

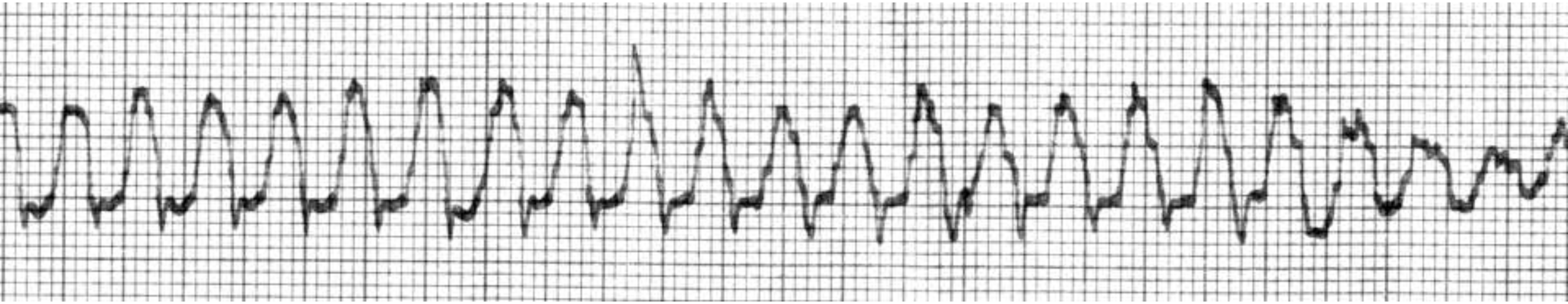
Ventricular Fibrillation

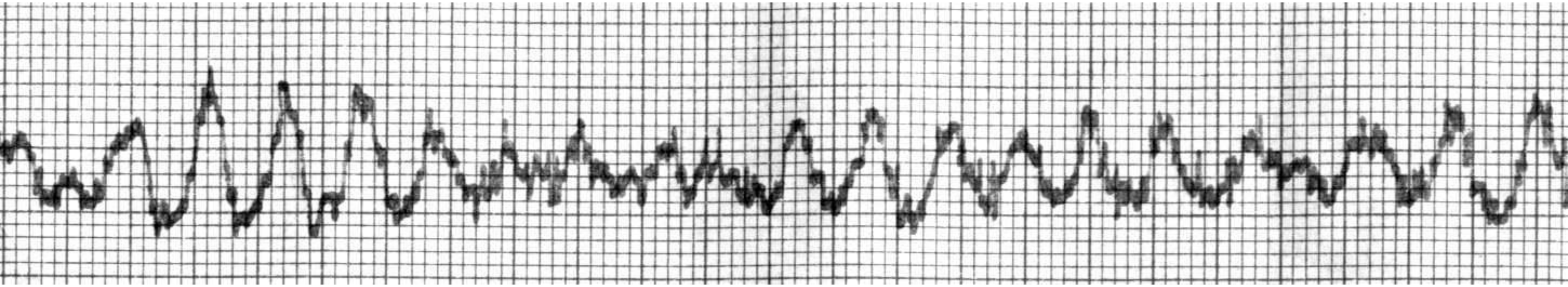


Torsades

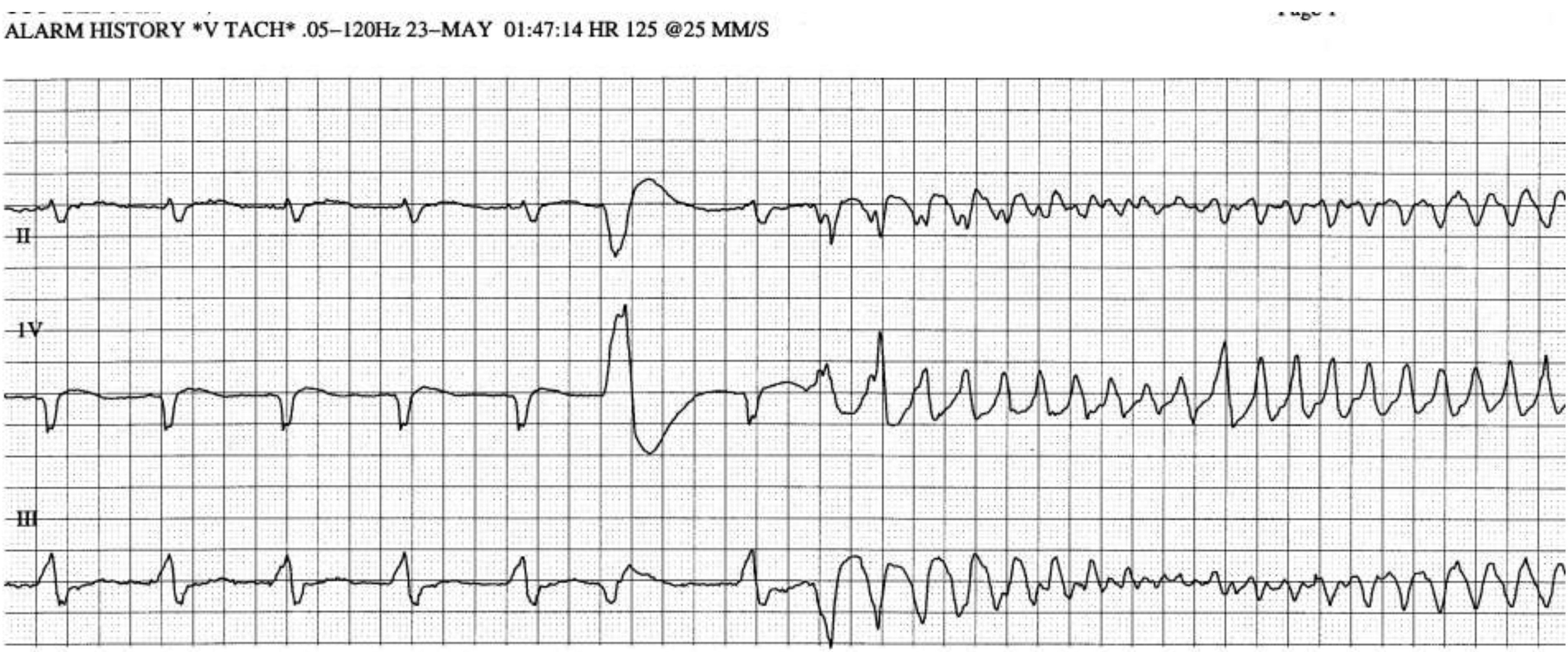


Ventricular Fibrillation

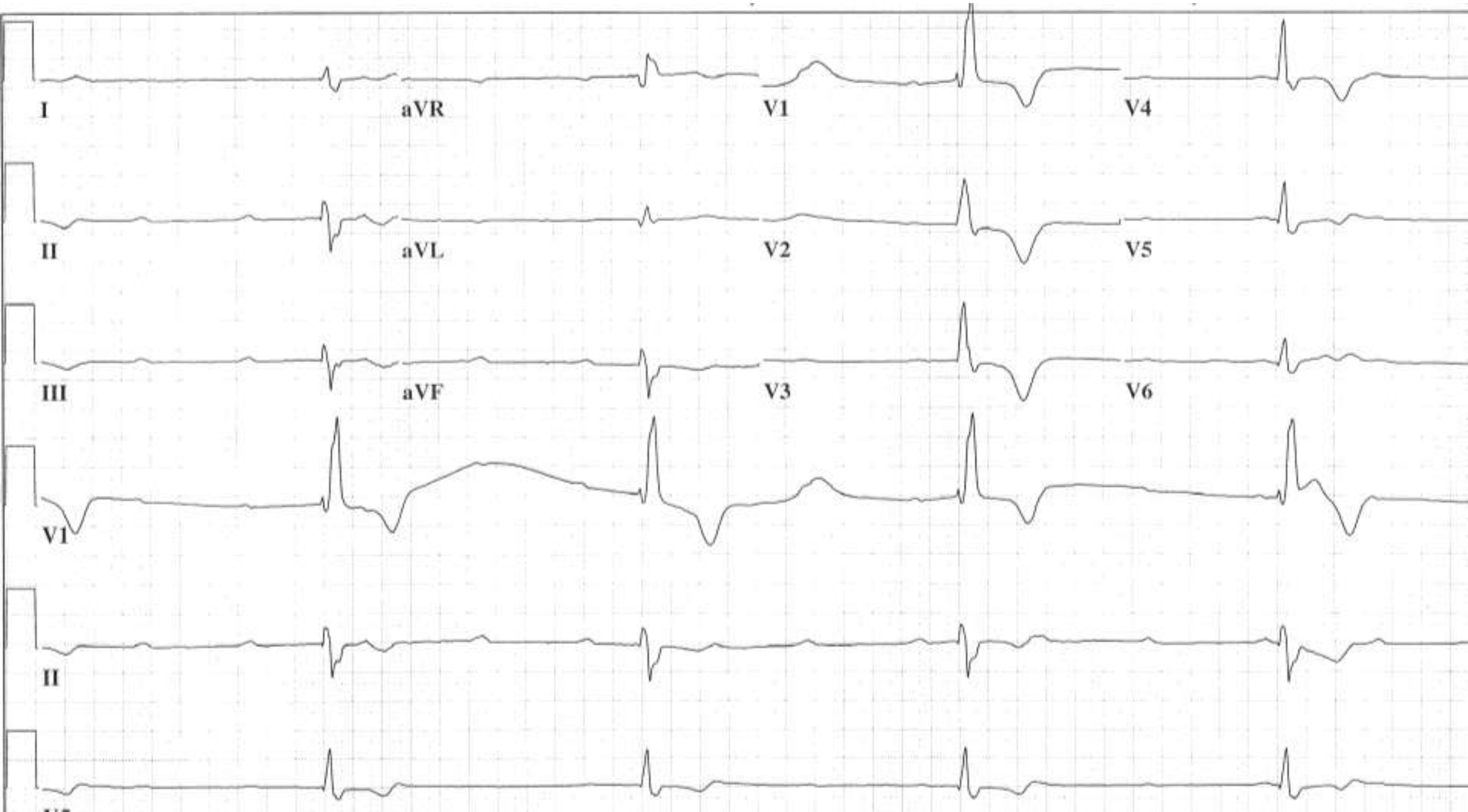




Ventricular Fibrillation

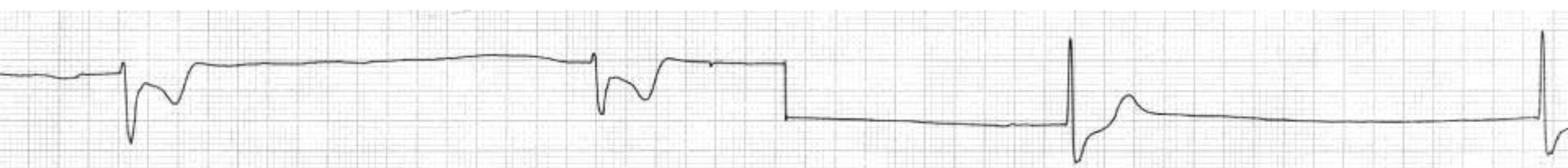


Ventricular escape rhythm



Agonal Rhythms

Lead II Lead aVL



Lead V2 Lead V5

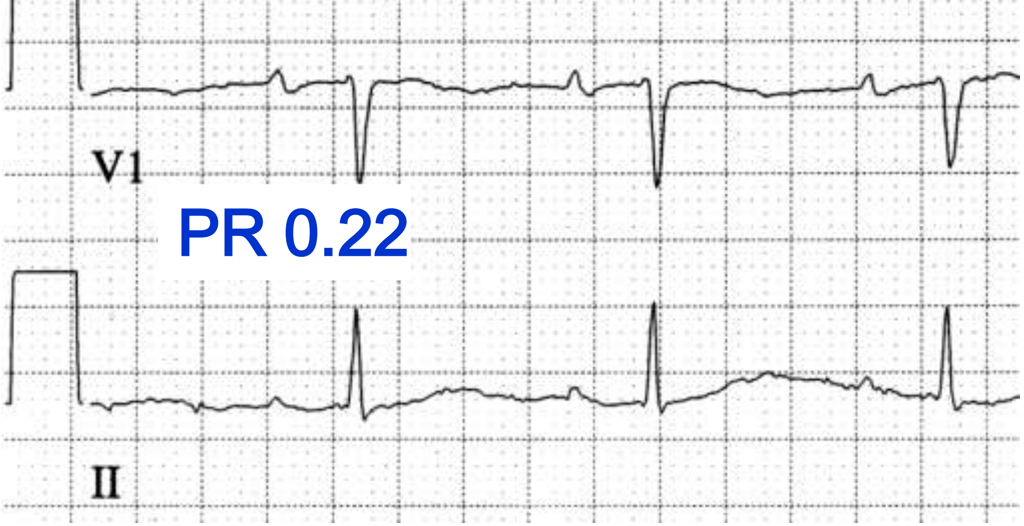
Summary of Beat Morphology

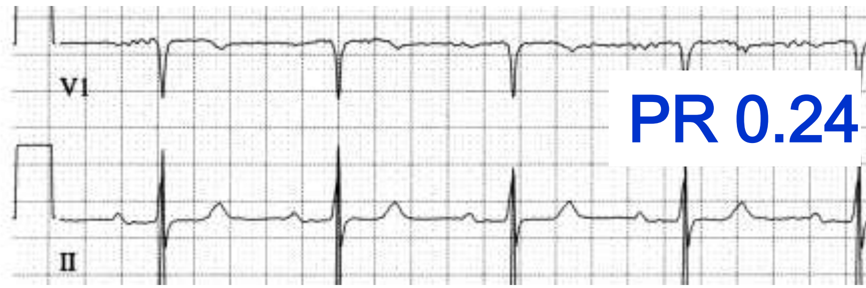
Type of Beat	P wave	PR interval	QRS complex
Sinus	Normal	Normal	Normal
Atrial	Abnormal	Normal	Usually normal
Junctional	Retrograde	Short	Usually normal
Ventricular	None	None	Wide

Degrees of AV Block

Degree	**Which Conduct**	**PR interval**	**RR interval**
First	All	Constant and long	Regular
Second (Wenckebach) (Mobitz I)	Some	Variable, pattern	Grouped beats
Second (2:1)	Some	Constant	Regular
Second (Mobitz II)	Some	Constant	Irregular, multiples
Third (Complete)	None	Variable, random	Regular

First Degree AV Block

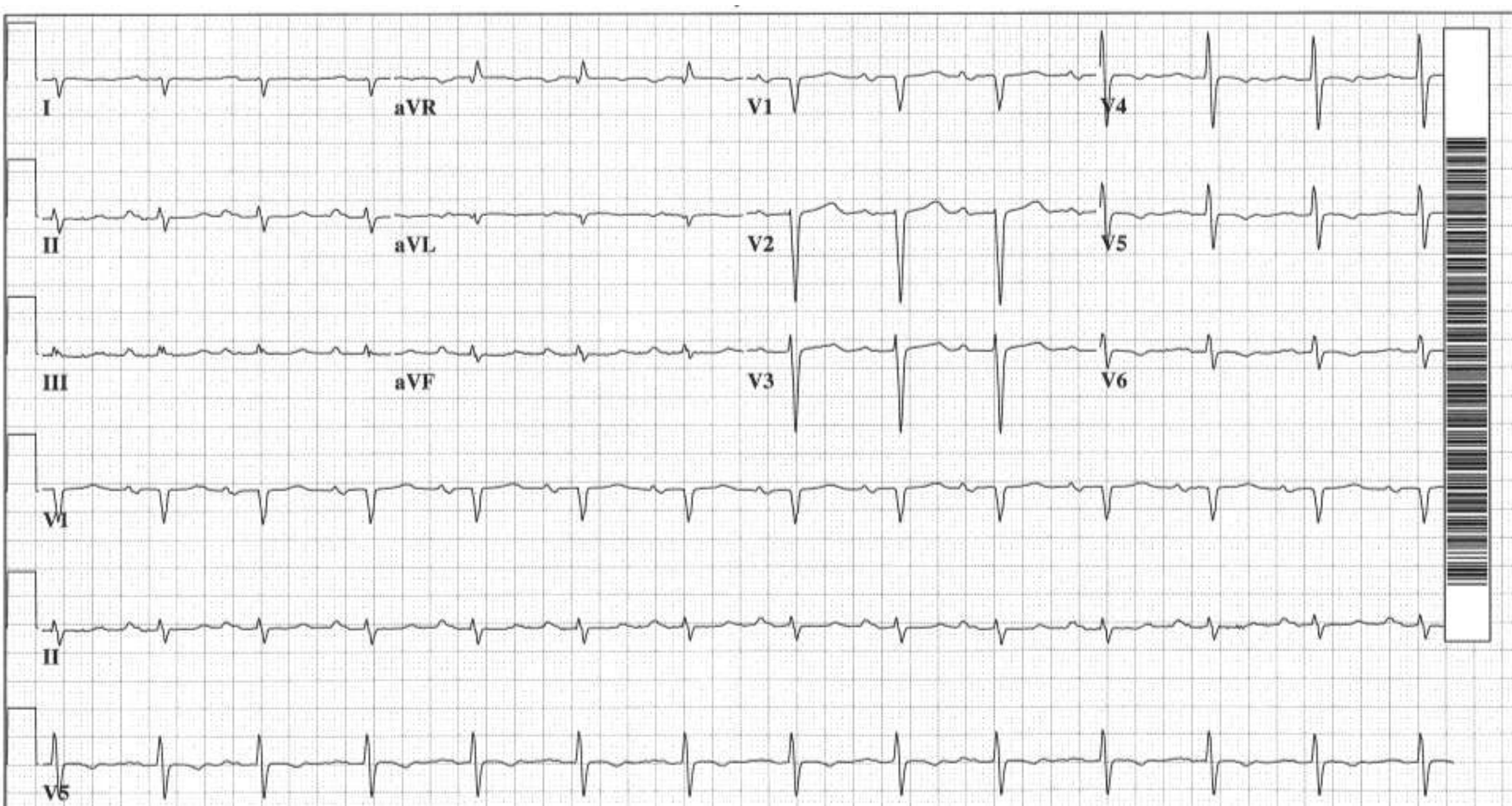




PR interval
Constant
and
Long

First Degree AV Block

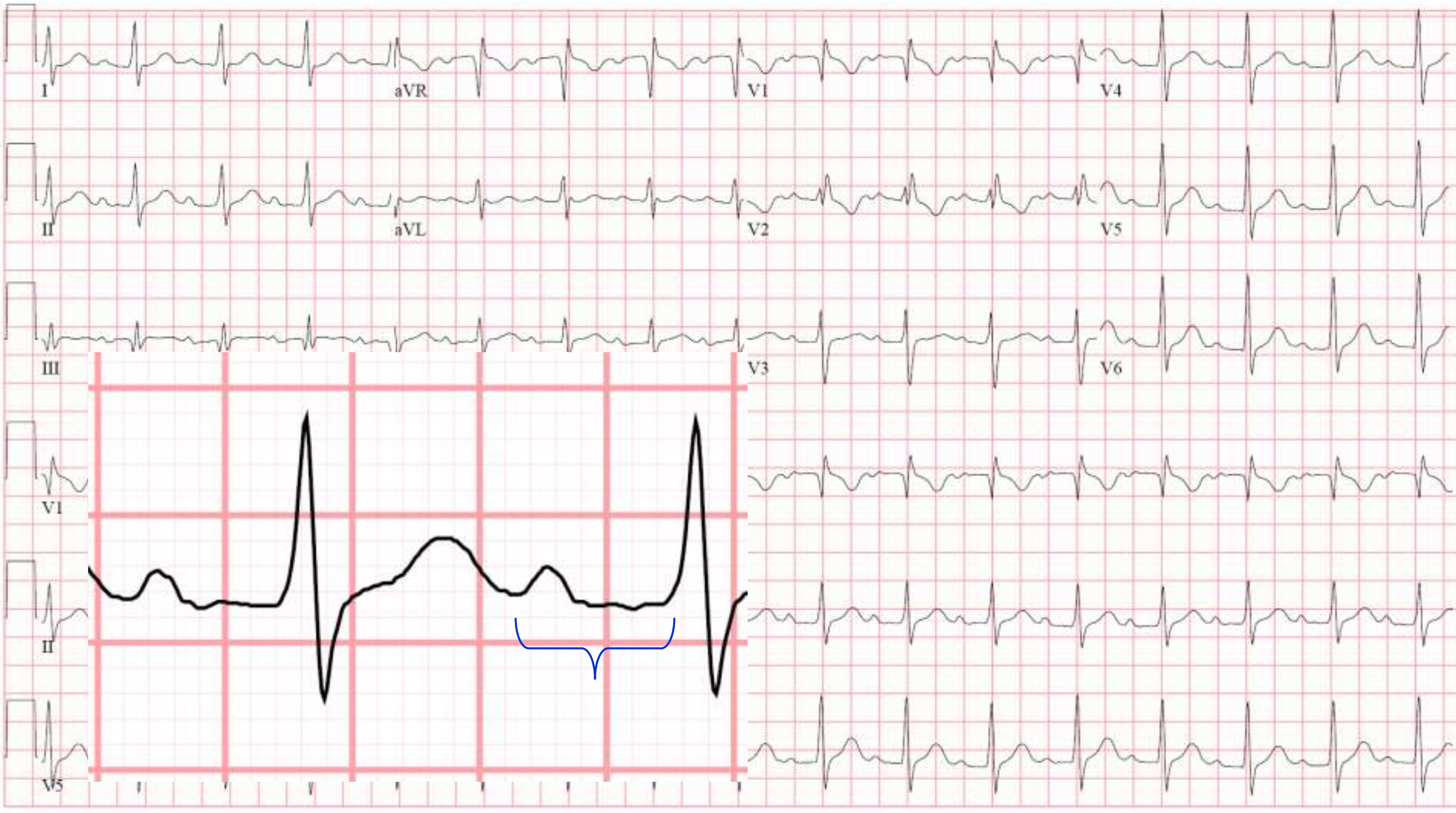
PR 0.24 **PR interval Constant and Long**



PR 0.24

First Degree AV Block

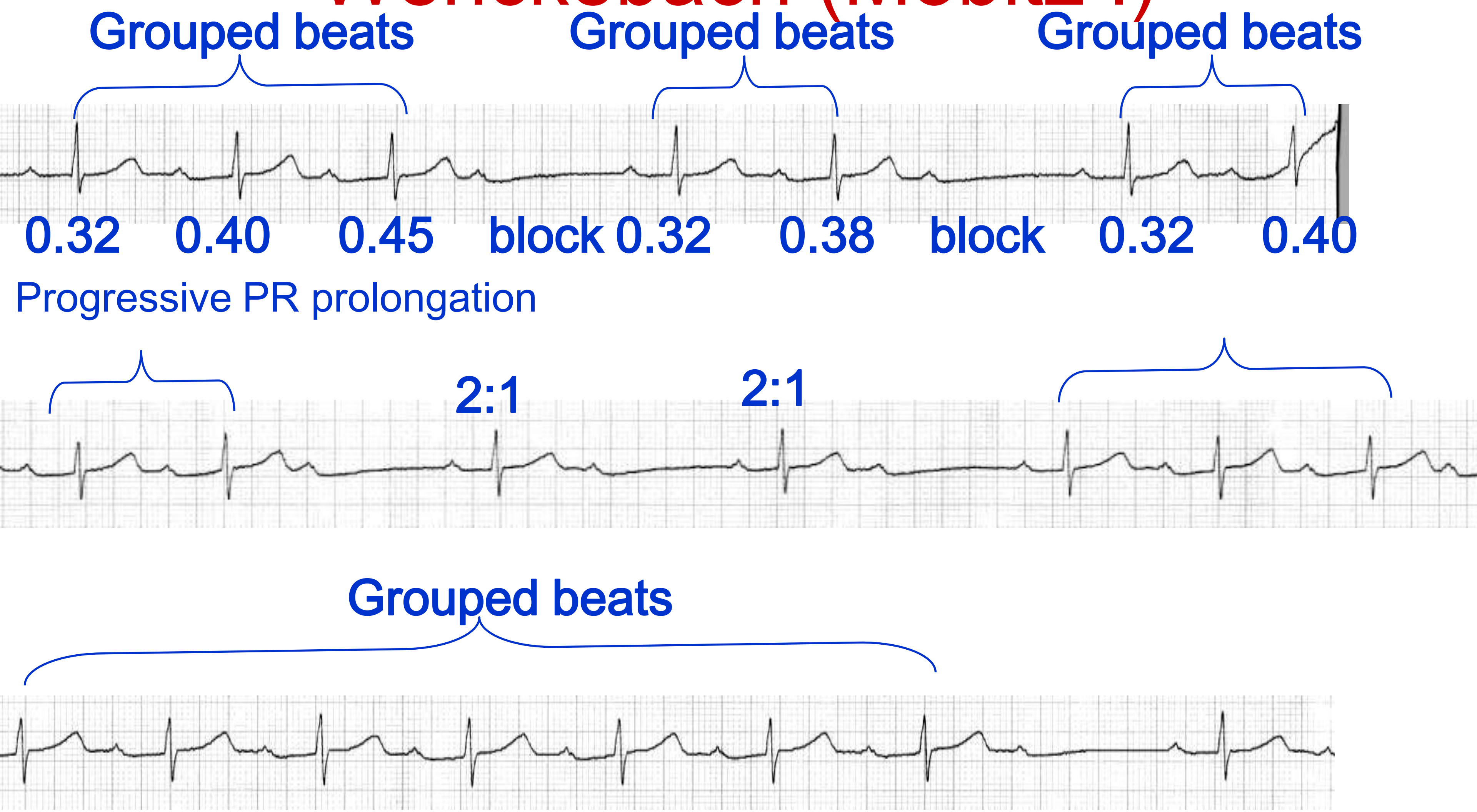
PR interval Constant and Long



Second Degree AV Block, Wenckebach (Mobitz I)

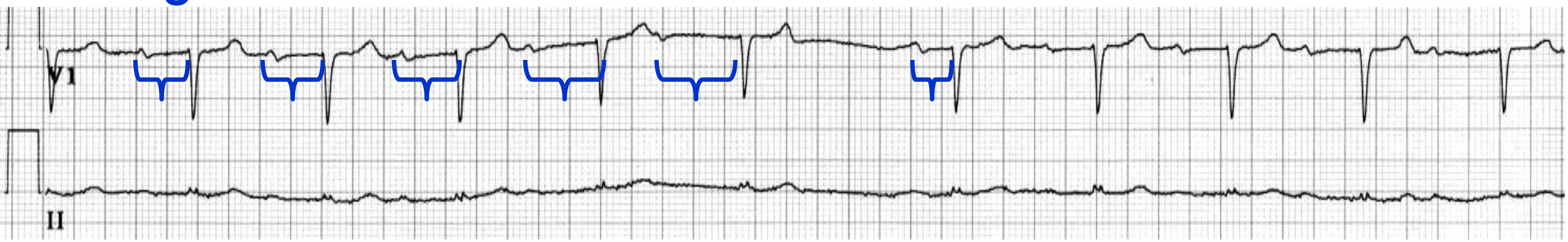
- Some beats don't conduct, so more P's than QRS's
- Progressive Prolongation of the PR interval for the conducted beats
  - increment of prolongation actually decreases
  - progressive shortening of the RR interval
- After pause is shortest PR interval
  - may be a junctional or ventricular escape beat

Second Degree AV Block, Wenckebach (Mobitz I)

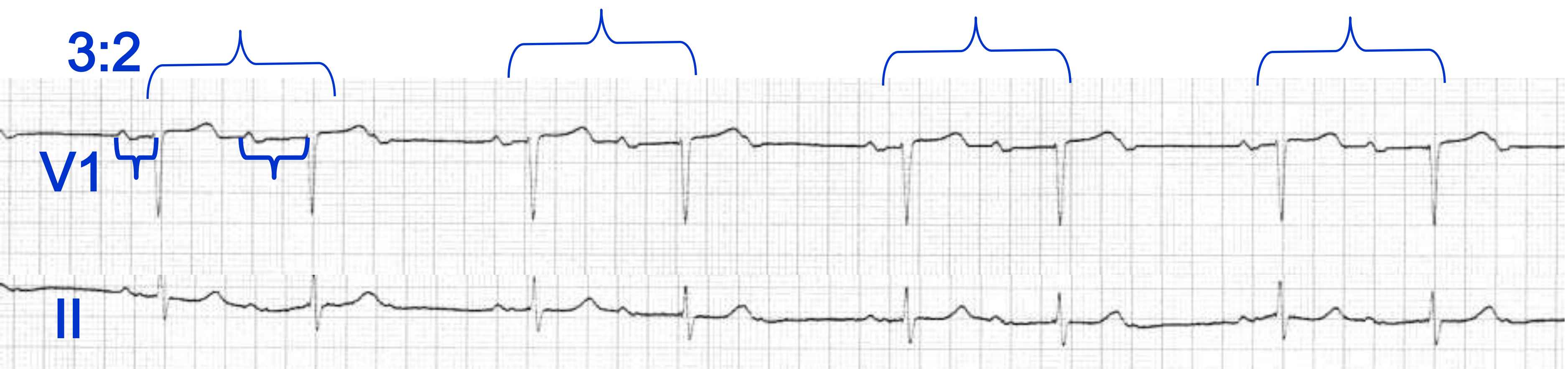


Second Degree AV Block, Wenckebach (Mobitz I)

Low grade block

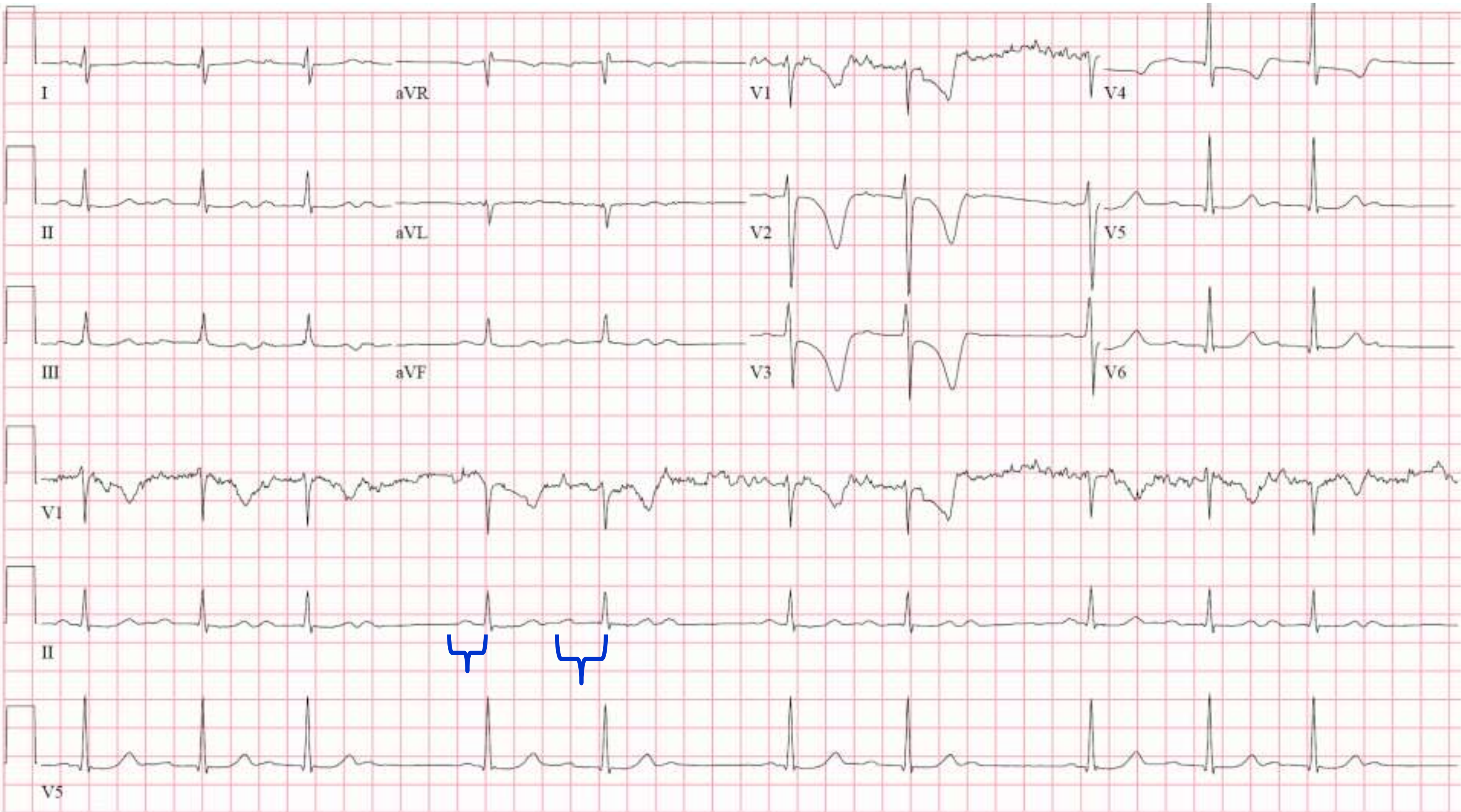


3:2



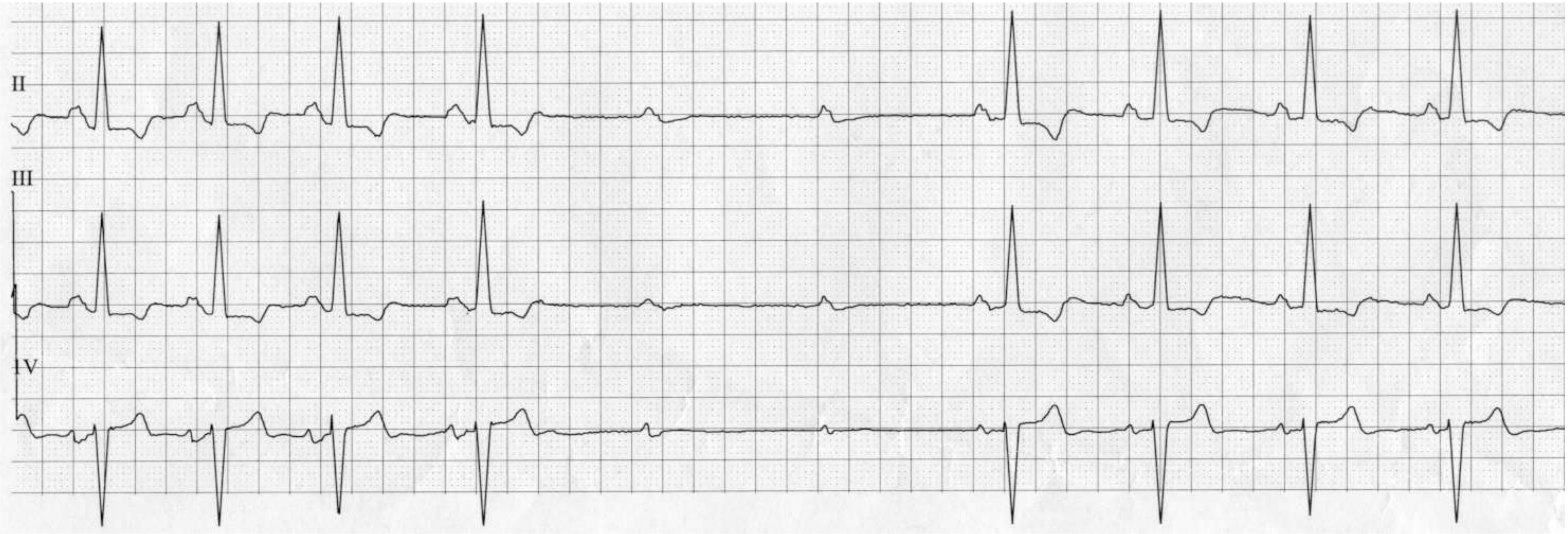
Non-simultaneous

Second Degree AV Block, Wenckebach (Mobitz I)



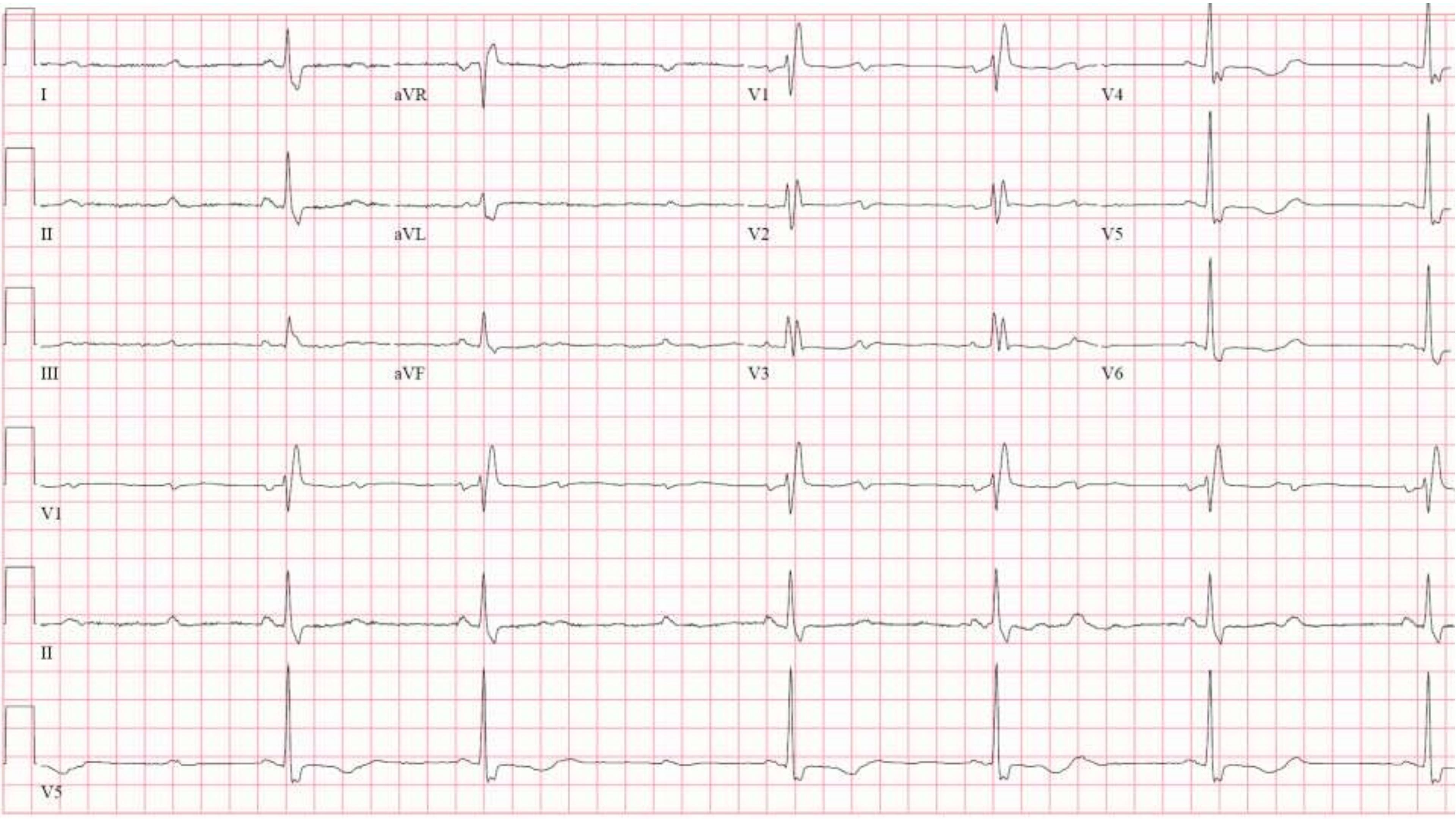
Second Degree AV Block, Mobitz II

PR interval constant for conducted beats



Second Degree AV Block, Mobitz II

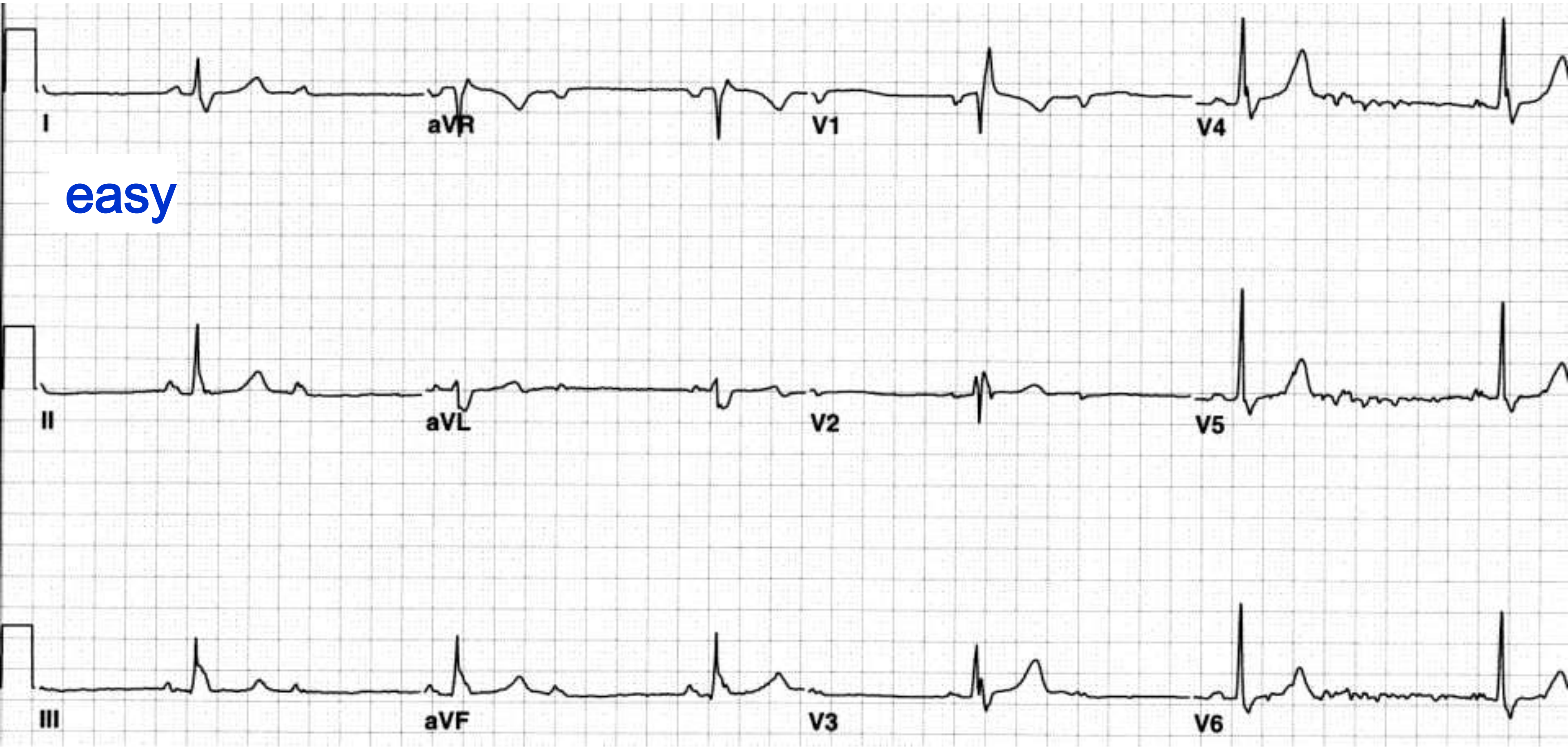
PR interval constant for conducted beats



Second Degree AV block, 2:1

- Can be either mechanism of Wenckebach or mechanism of Mobitz II, can't tell
  - if QRS is wide, could be either
  - if QRS is narrow, usually is Wenckebach
- Can be tricky to diagnose, must find the nonconducted P waves (otherwise the mistaken diagnosis will be mere bradycardia)

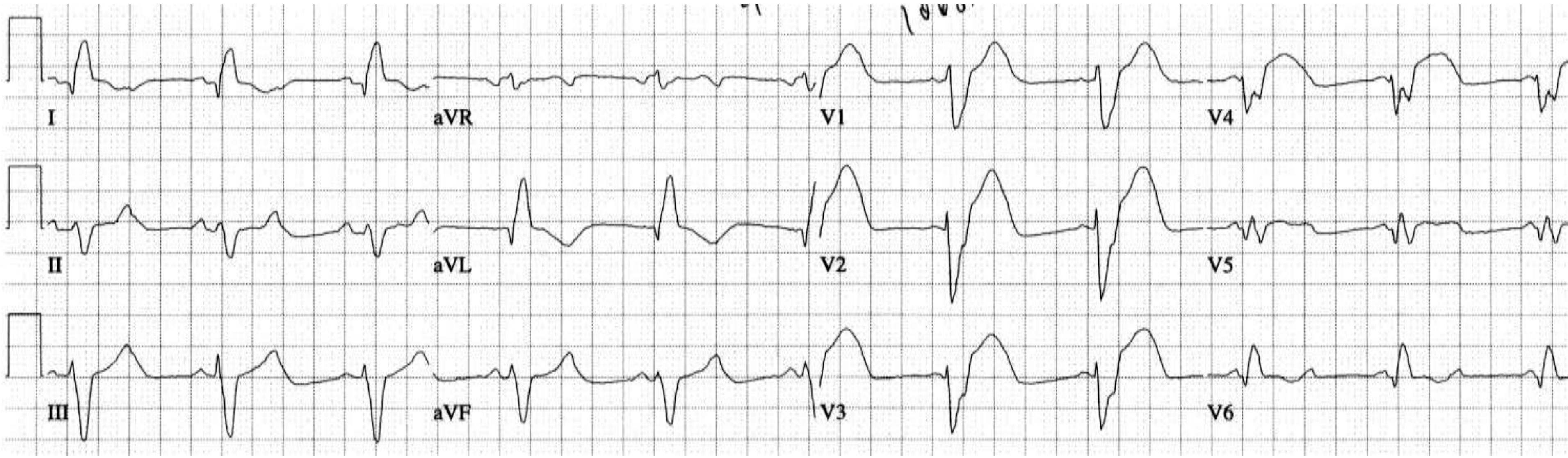
Second Degree AV block, 2:1



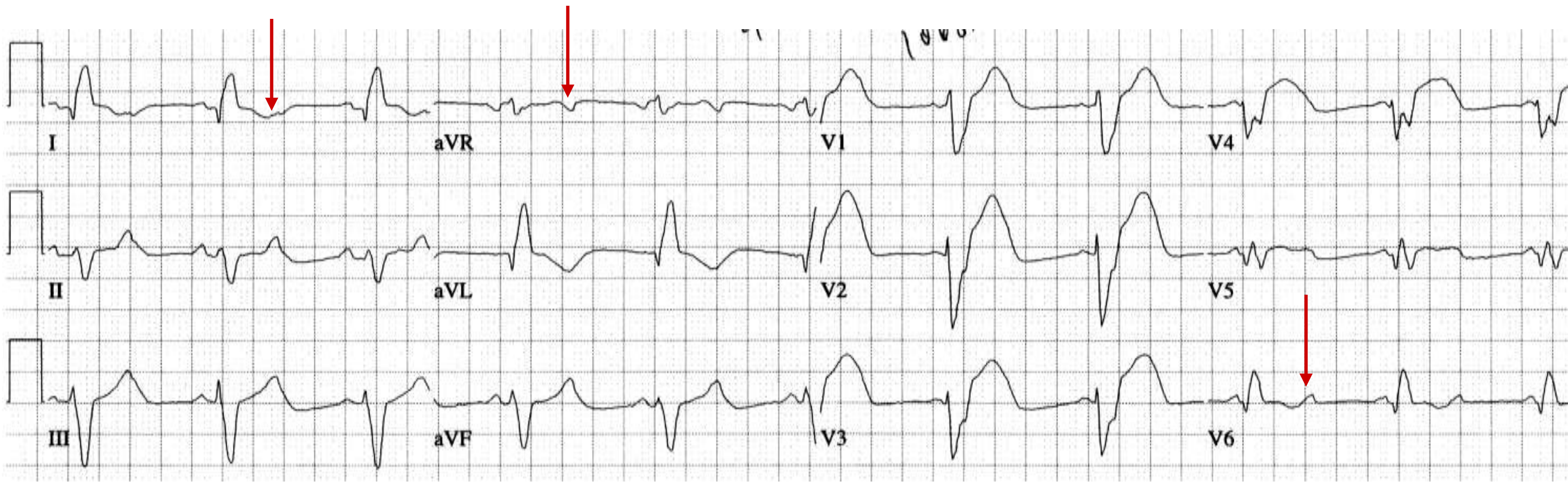
Second Degree AV block, 2:1

Task: find the nonconducted P wave.

Second Degree AV block, 2:1



Second Degree AV block, 2:1

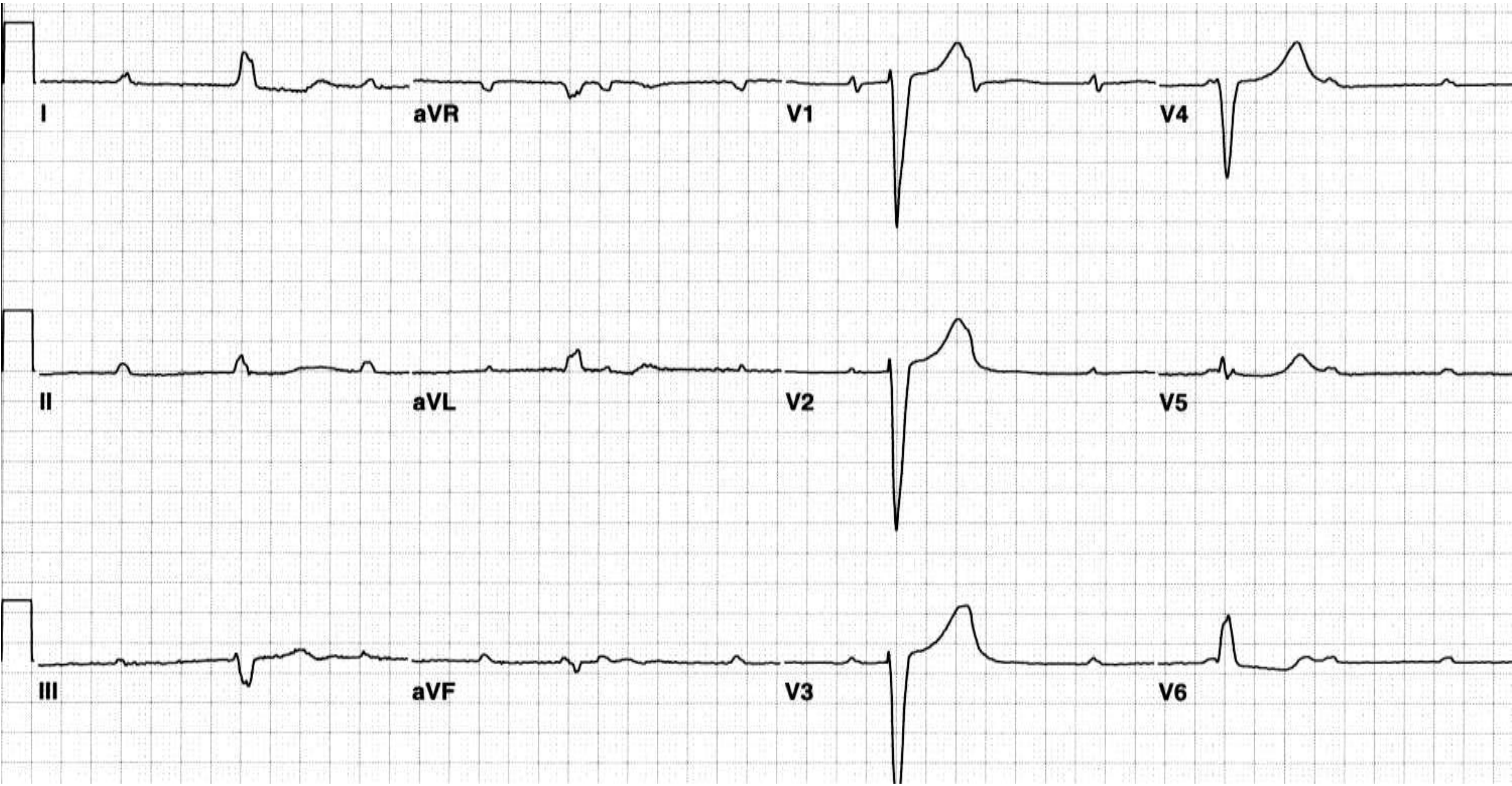


- Not so easy… could misdiagnose as NSR rate 64.
- But actually is sinus tachycardia at rate of 128 (patient is likely sick) with 2:1 block.
- The extra P waves are best seen at the 3 red arrows, and are same shape and axis as the sinus P waves.
- Wide QRS indicates disease below the bundle of His: IVCD

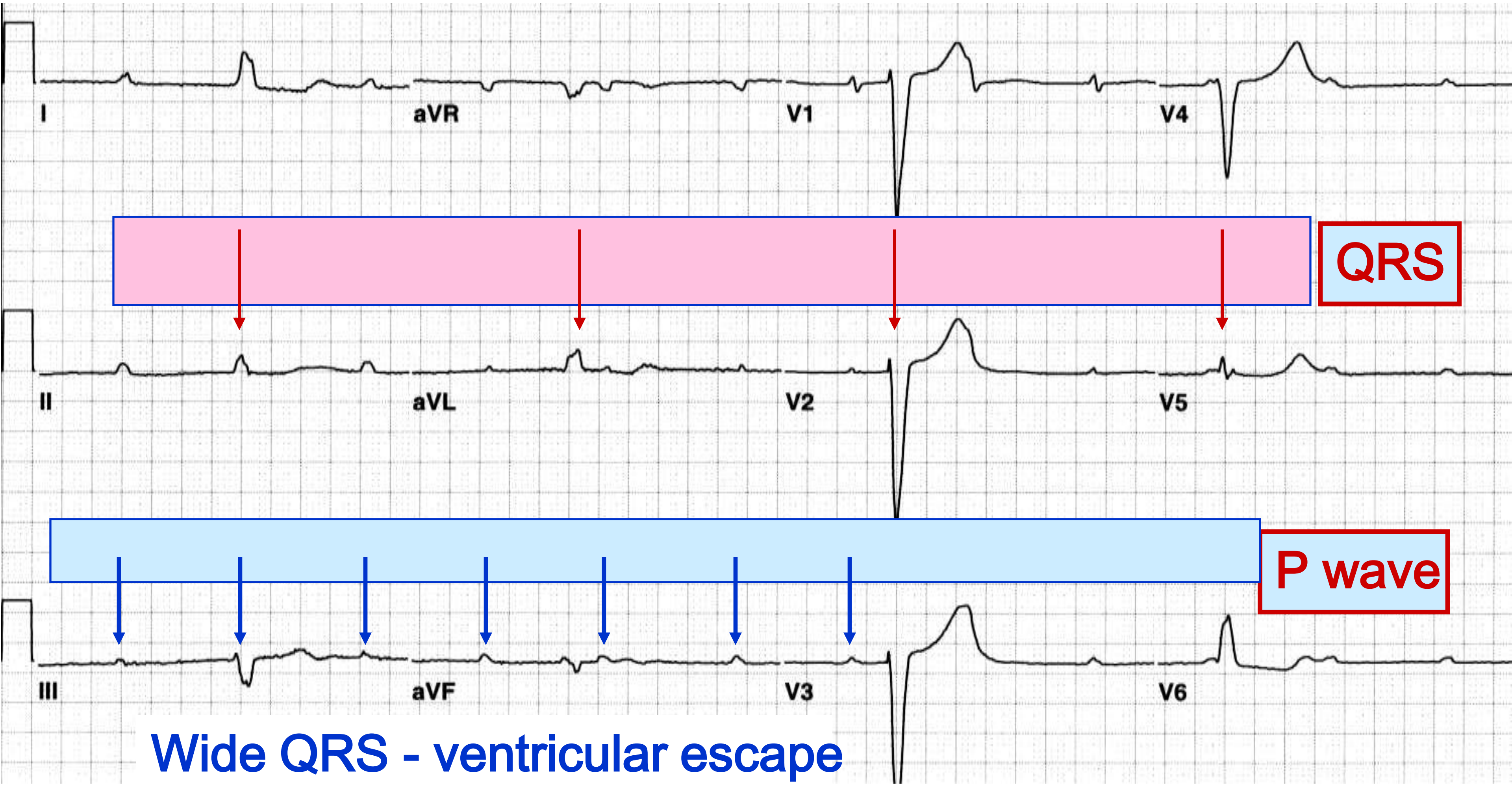
Third Degree AV block (Complete Heart Block)

- No atrial activity conducts to the ventricle
- Atrial rate faster than ventricular rate
- No relationship between P and QRS
    - PR interval is random
    - PR interval may at first glance seem to have a pattern
- Ventricular rhythm is independent, either junctional or ventricular escape rhythm
    - Regular ventricular rhythm, even in AFib

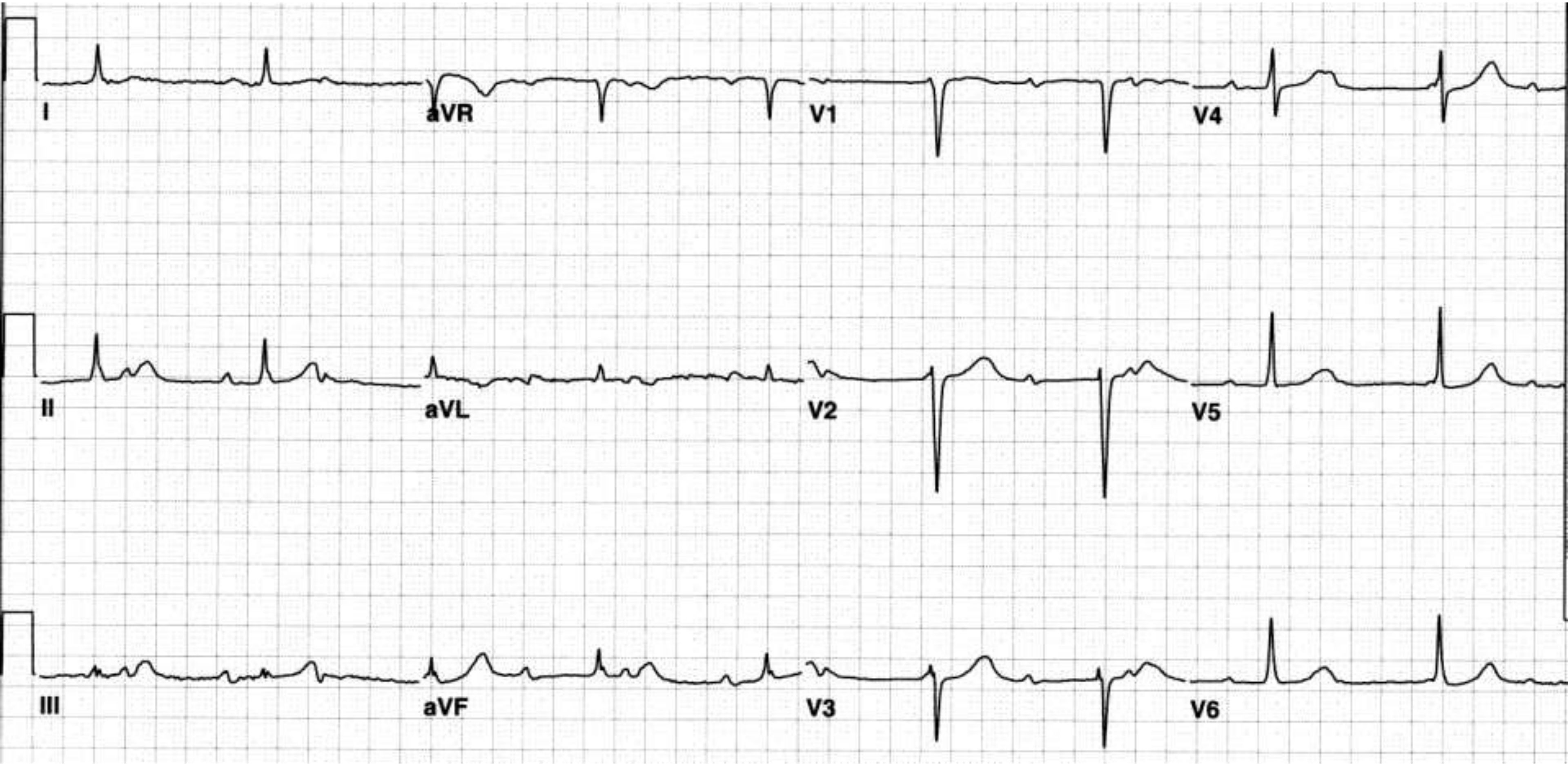
Third Degree AV block (Complete Heart Block)



Third Degree AV block (Complete Heart Block)



Third Degree AV block (Complete Heart Block)

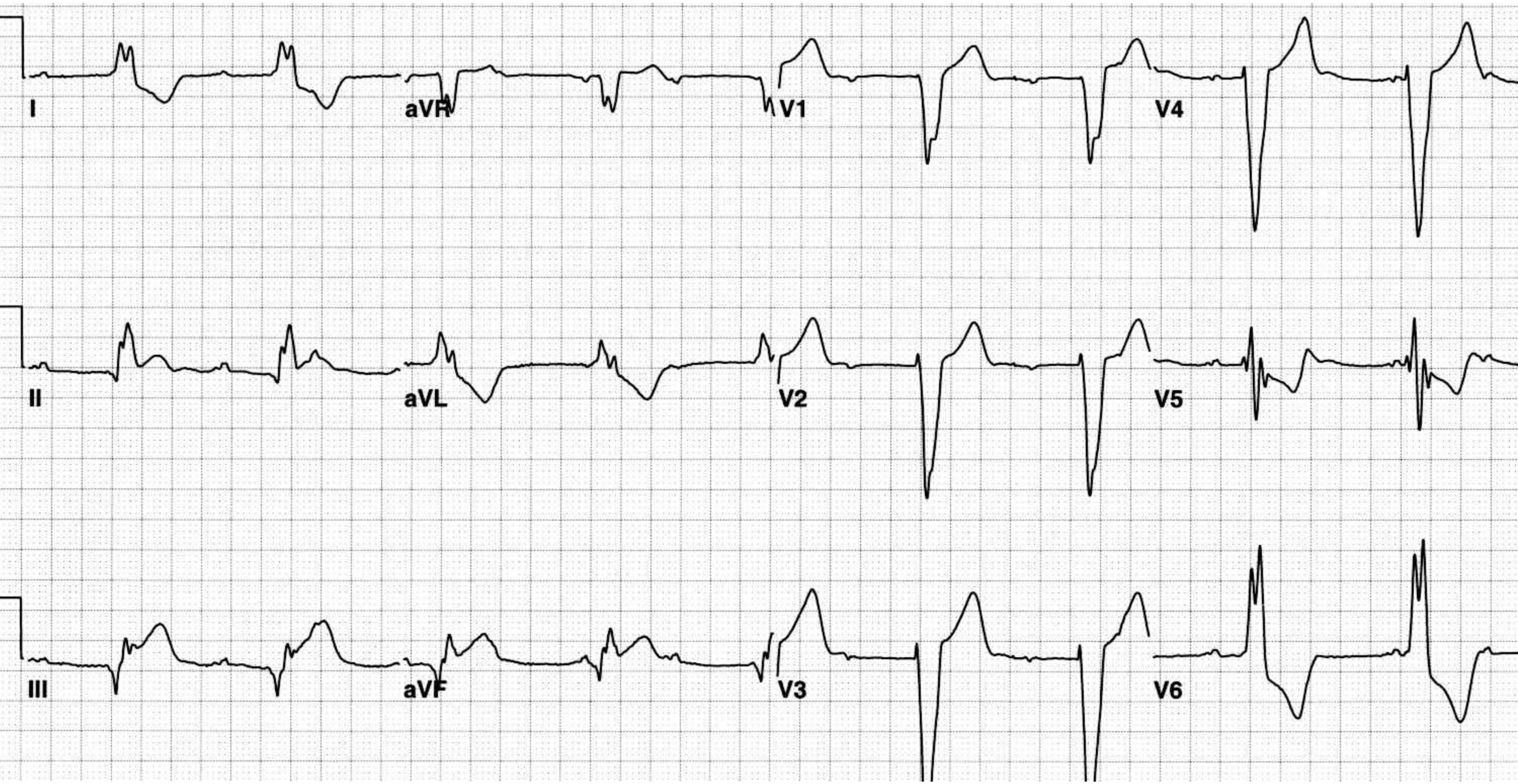


Third Degree AV block (Complete Heart Block)

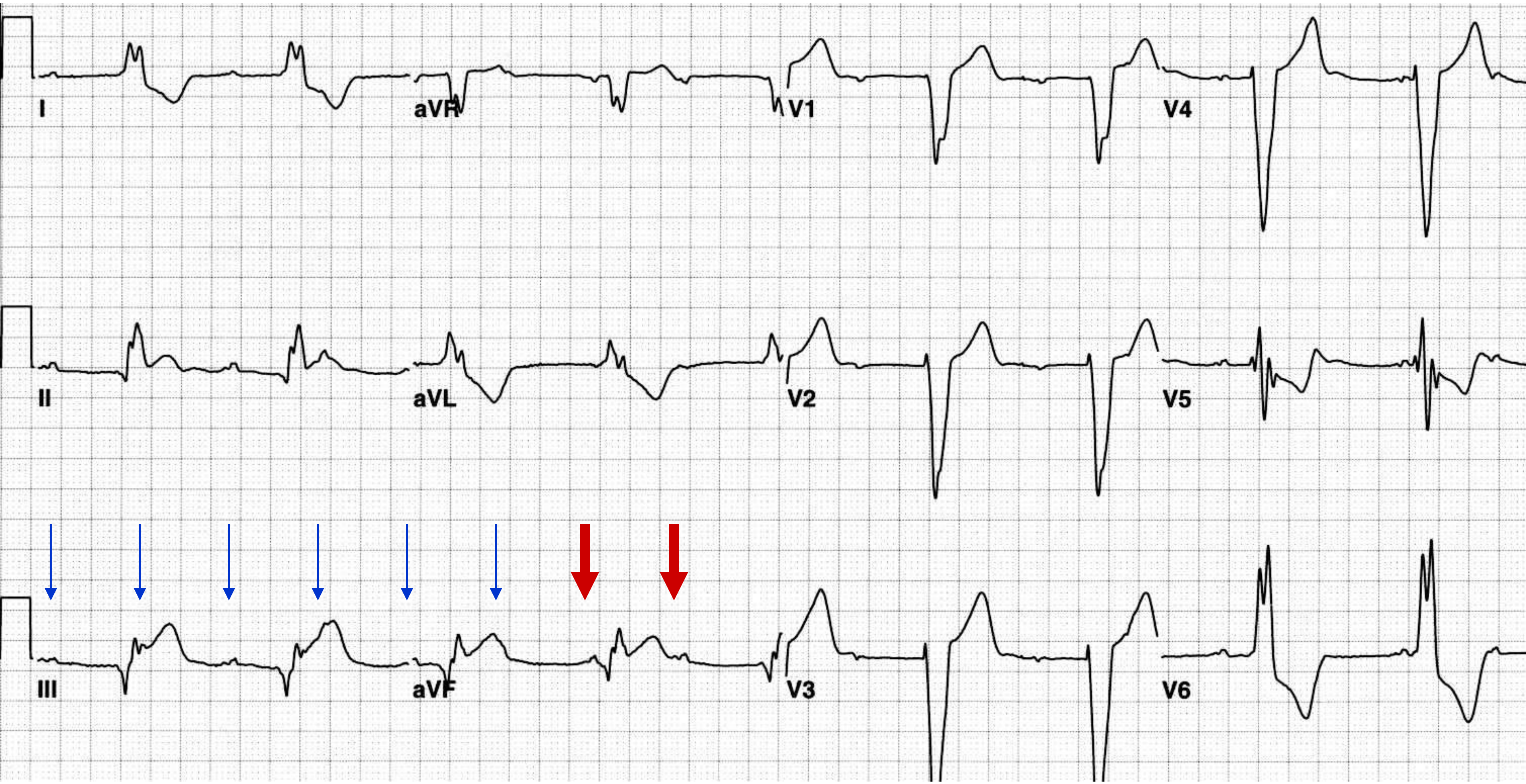
Narrow QRS - junctional escape

Red arrow: P simultaneous with QRS

Third Degree AV block (Complete Heart Block)



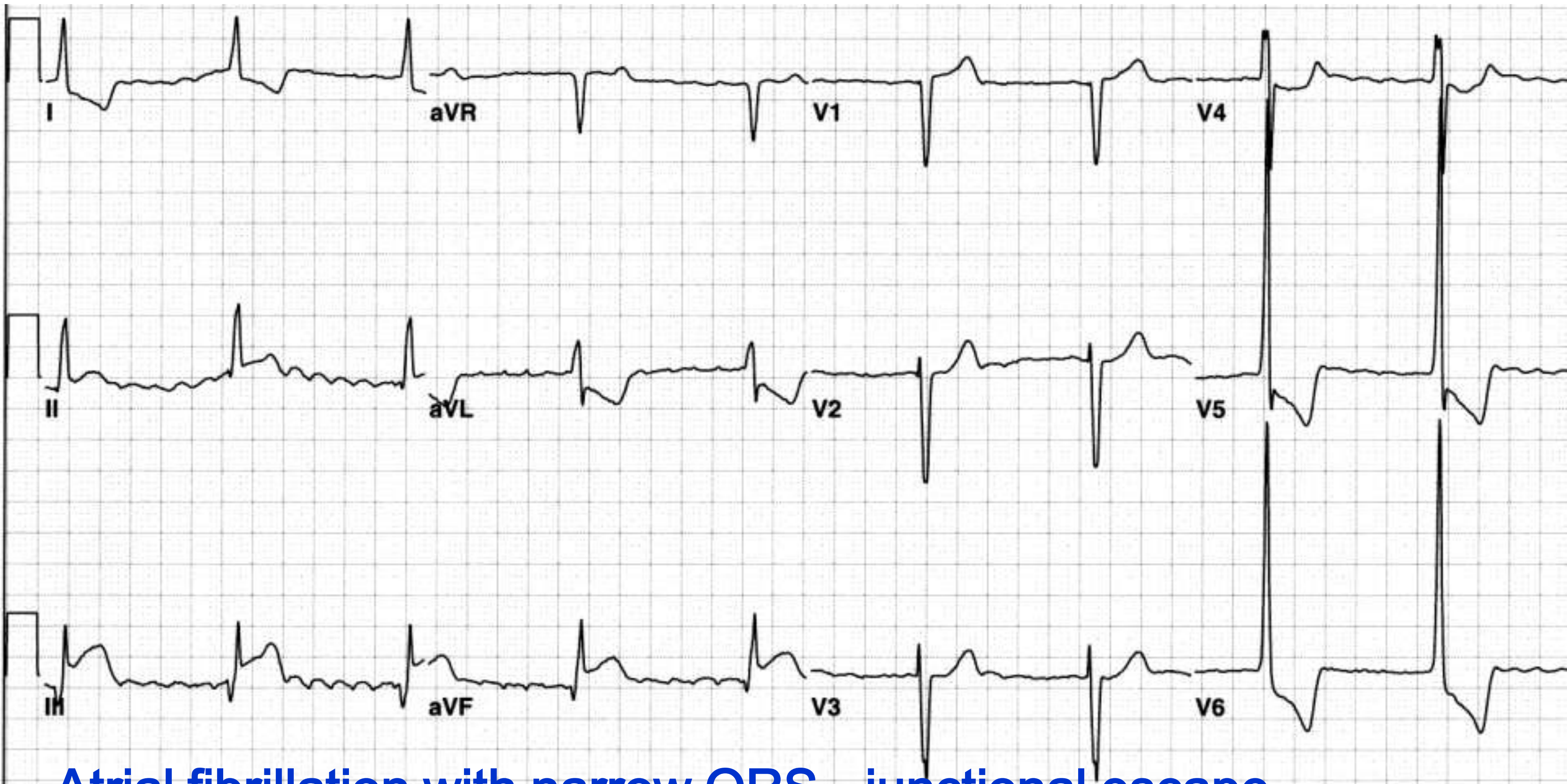
Third Degree AV block



Wide QRS (LBBB pattern) - ventricular escape.
Acute inferior injury pattern!

Sinus tachycardia, rate 100

Third Degree AV block

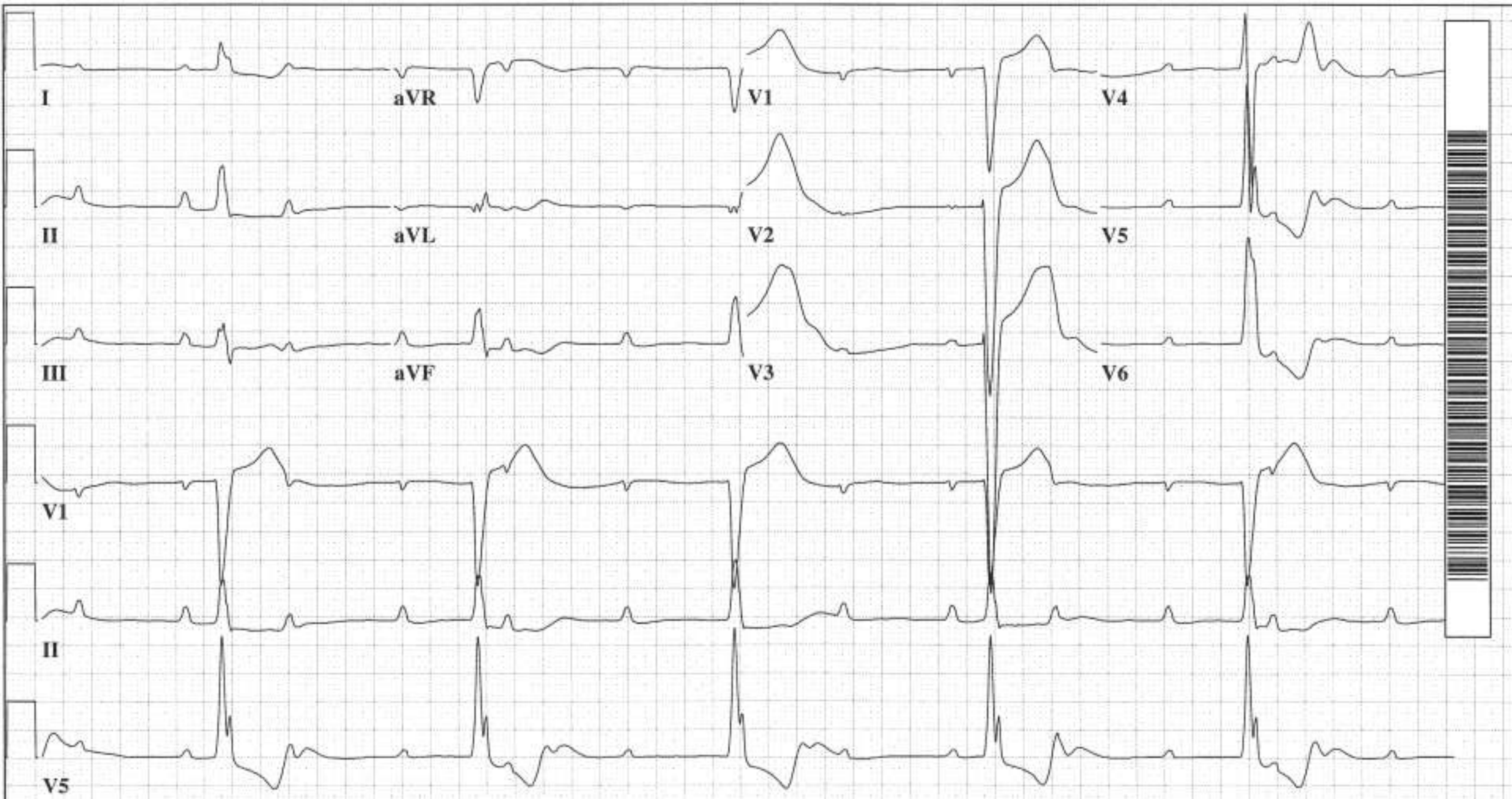


Atrial fibrillation with narrow QRS - junctional escape.

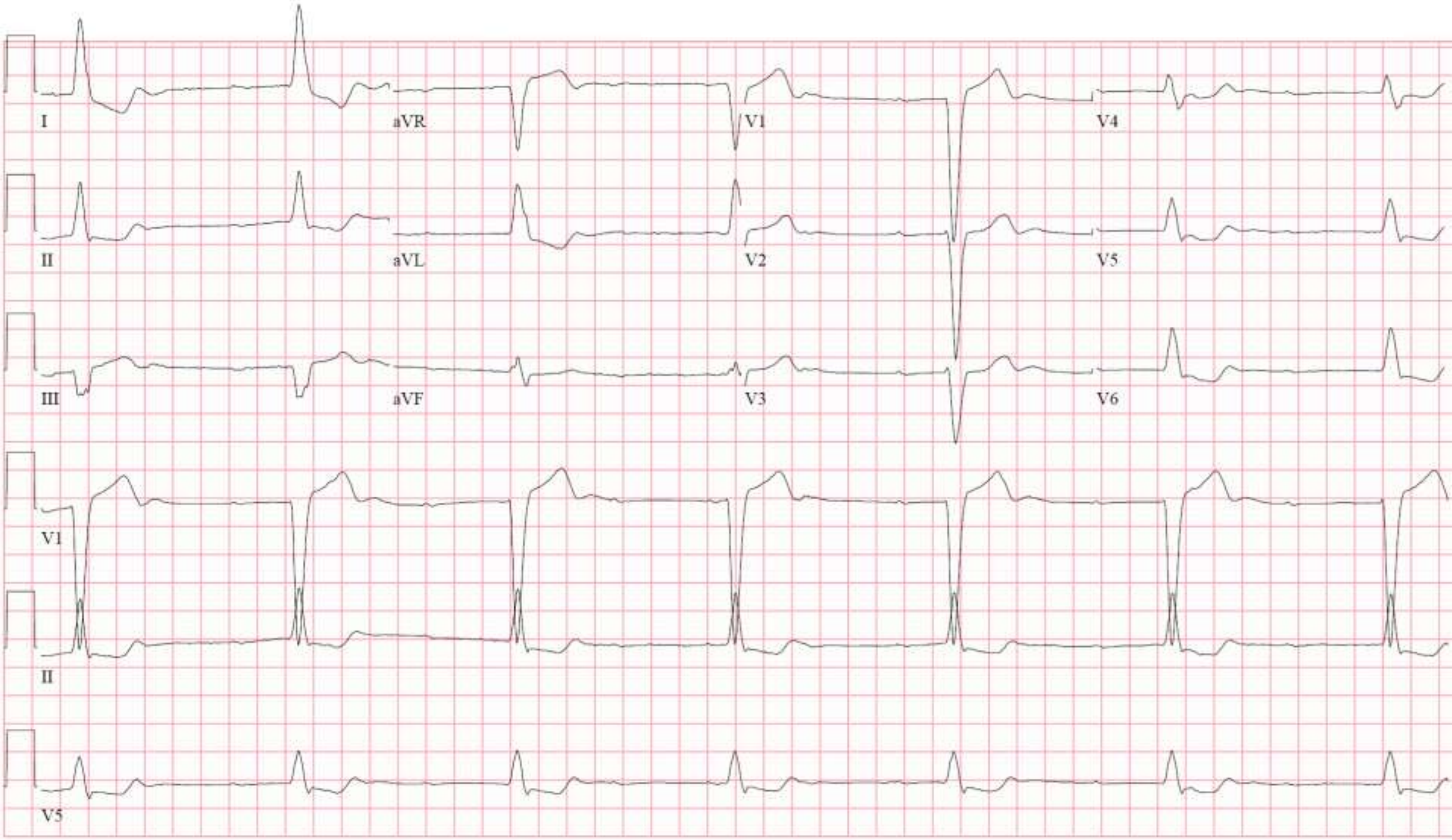
Acute inferior injury pattern! ST elevation in II, III, and aVF

When atrial fibrillation has a regular ventricular response, the AV node is not conducting

Third Degree AV block



Third Degree AV block

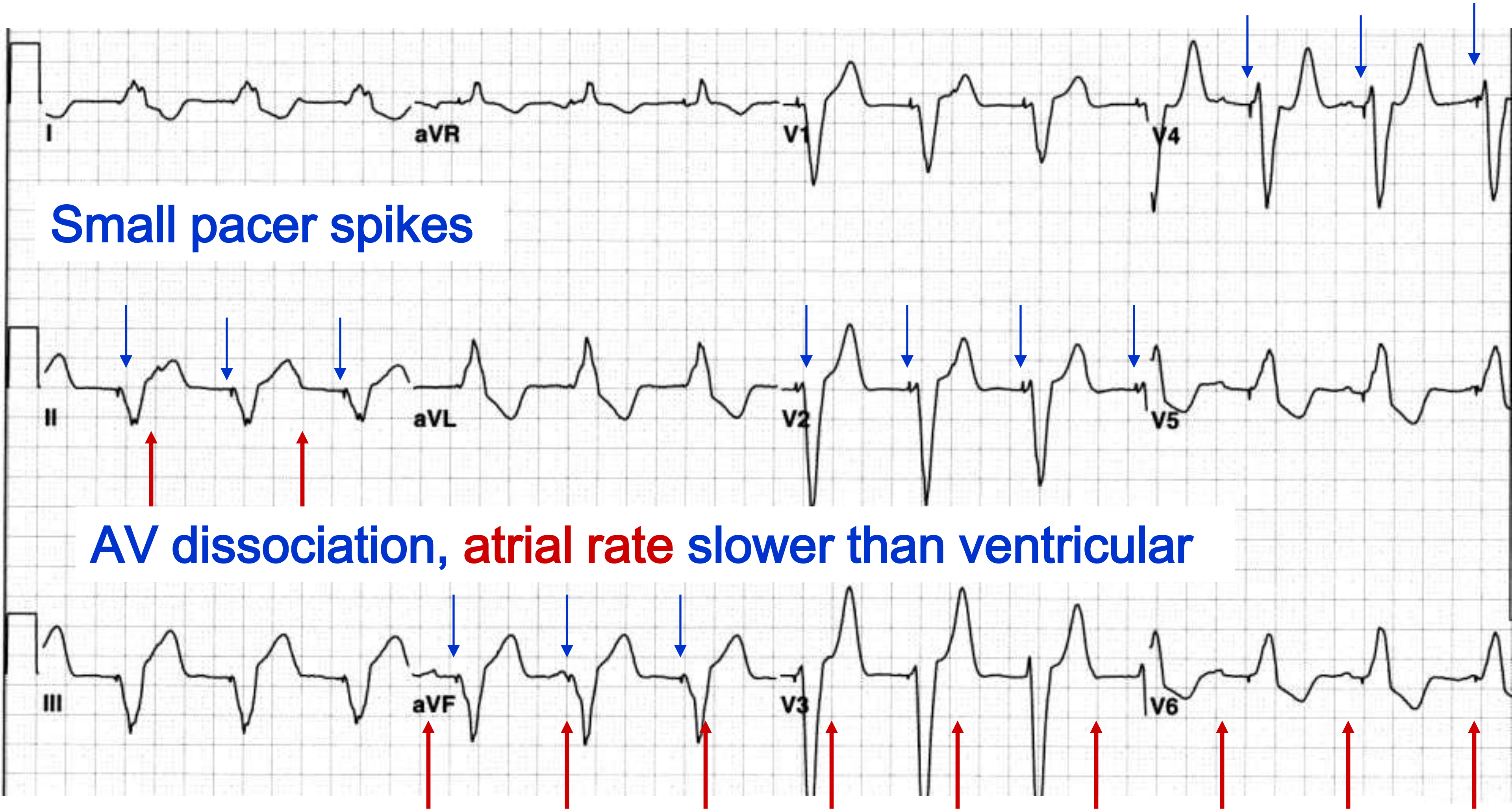


Pacemaker ECG

- Artificial Pacemakers generate an electric voltage of generally less than 1 msec - ECG appears unnaturally short and spikey
- Pacer <u>spike</u> can be in atrium or ventricle or both. (Spike indicates the pacemaker fires)
- <u>Capture</u>: pacer spike precedes a P or a QRS
- <u>Sense</u>: no pacer spike shortly after a P or a QRS

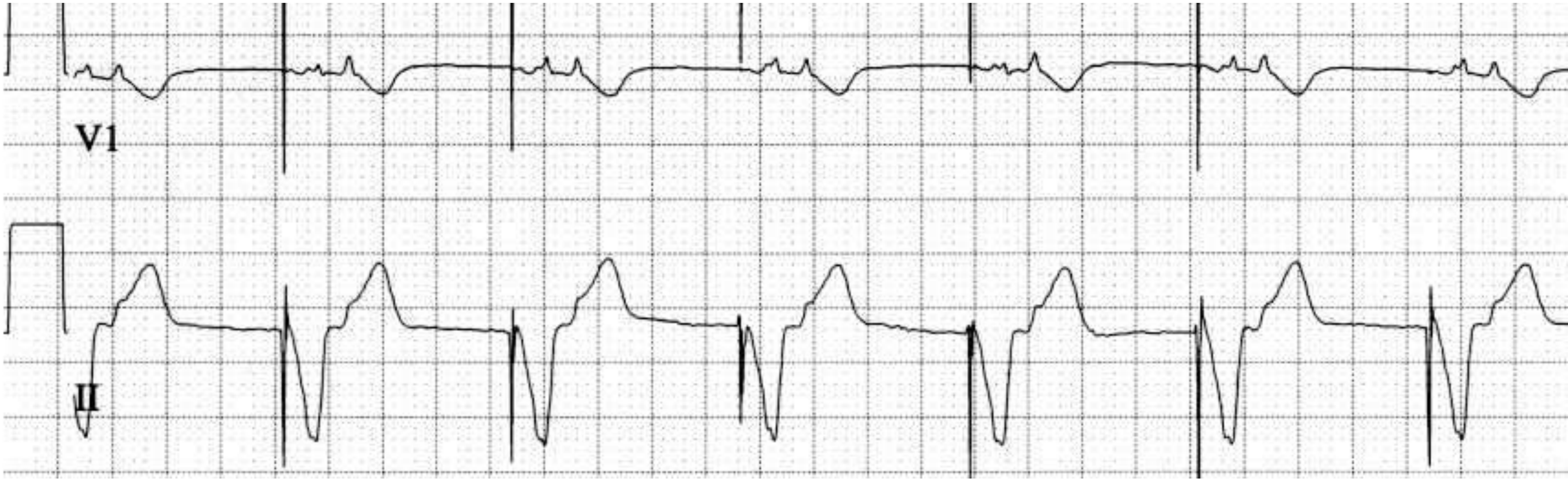
Pacemaker ECG

Pacemaker ECG

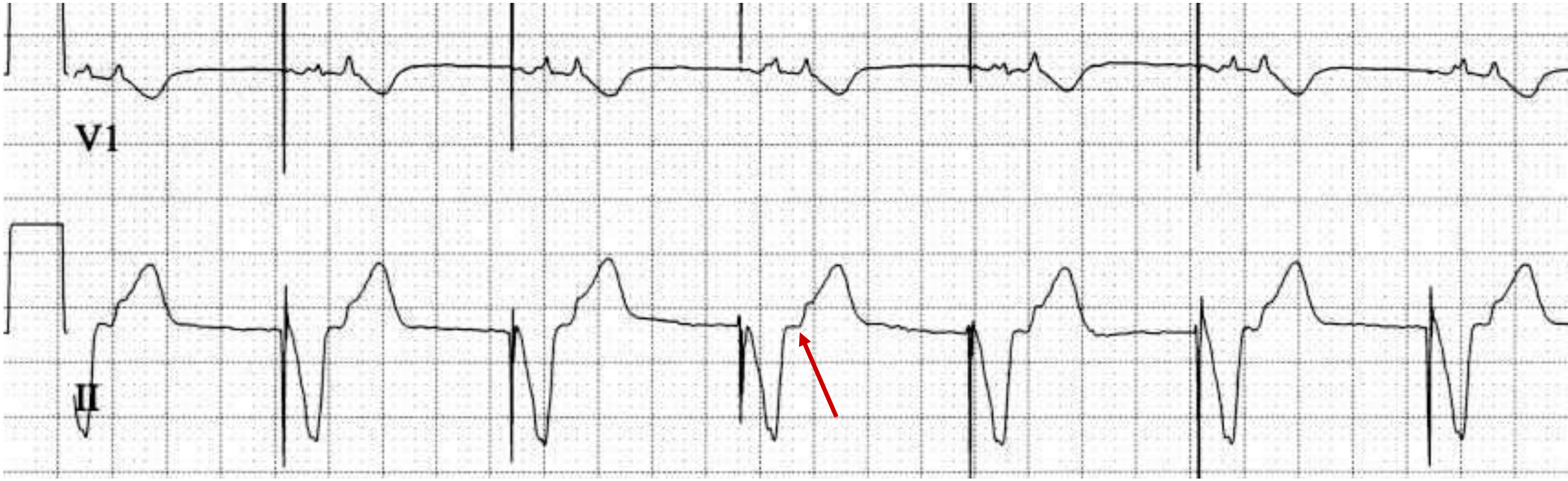


LBBB and left axis deviation is typical pattern for transvenous pacemaker tip at RV apex

Pacemaker ECG

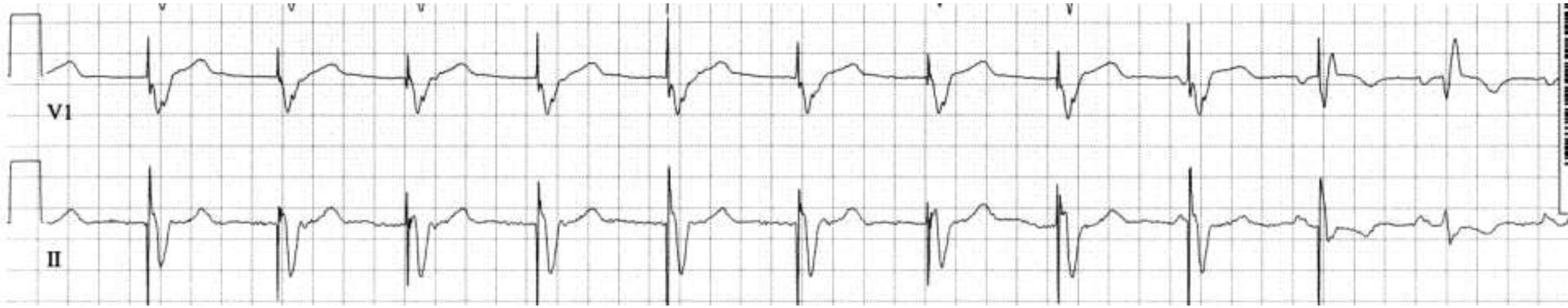


Pacemaker ECG



Note:
Spike before each QRS
No P before any QRS
Hidden P at end of QRS, best seen in II
Ventricular pacemaker, 100% capture, with 1:1 retrograde conduction (VA conduction)

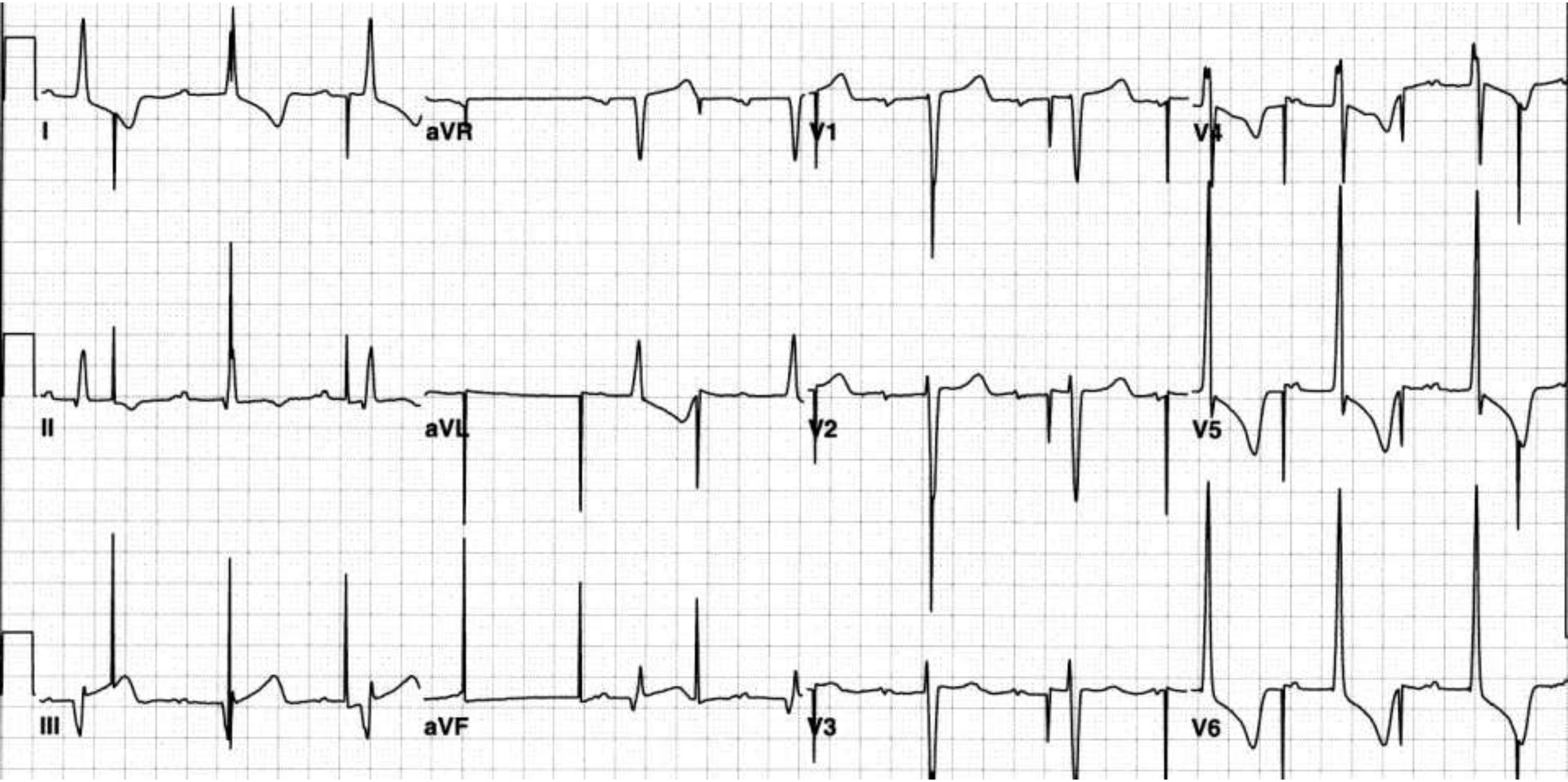
Pacemaker ECG



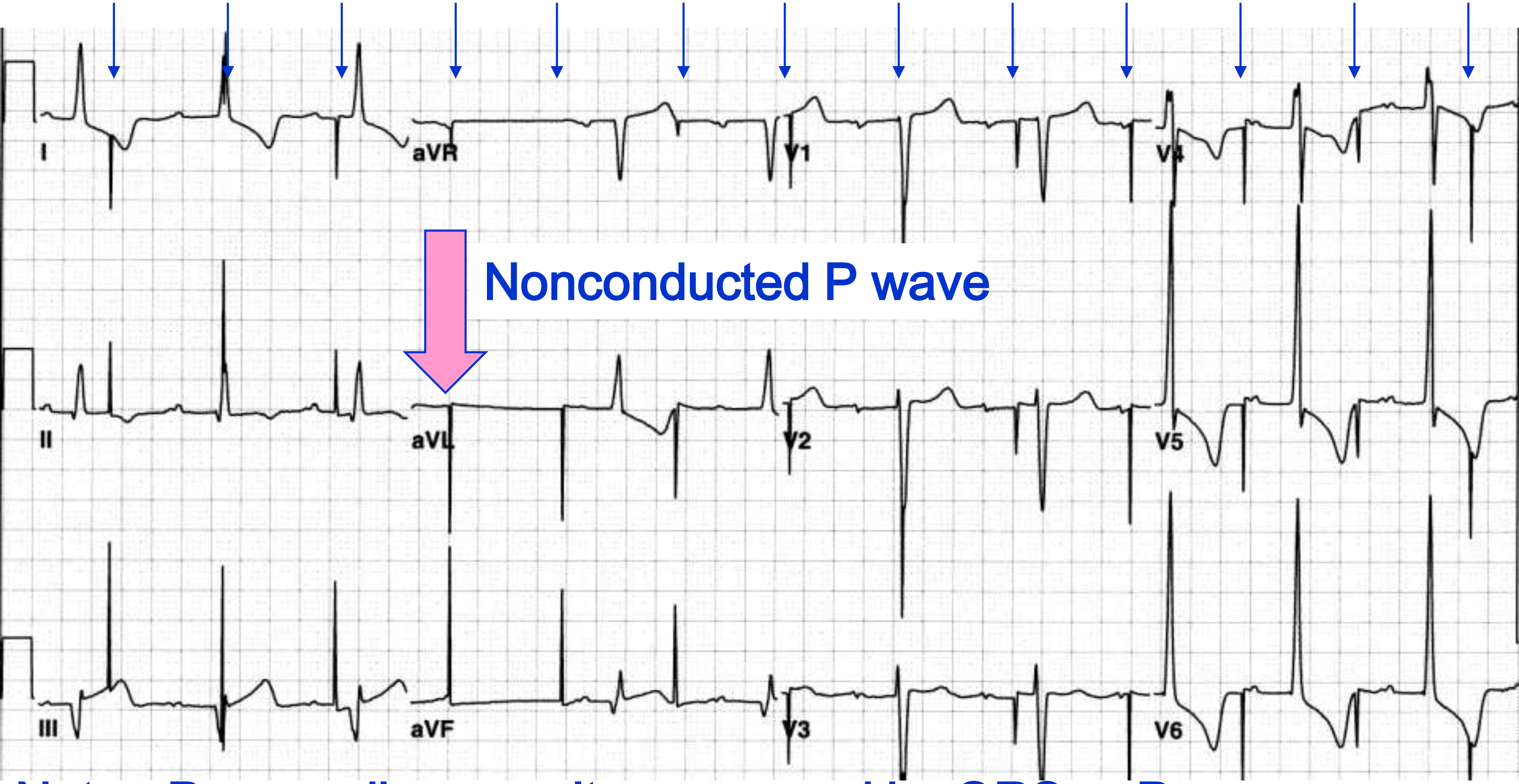
Pacemaker ECG

Note:
All QRS initiated by large pacer spike except the last.
Last paced beat is a fusion beat.
Blue arrows show P waves

Pacemaker ECG

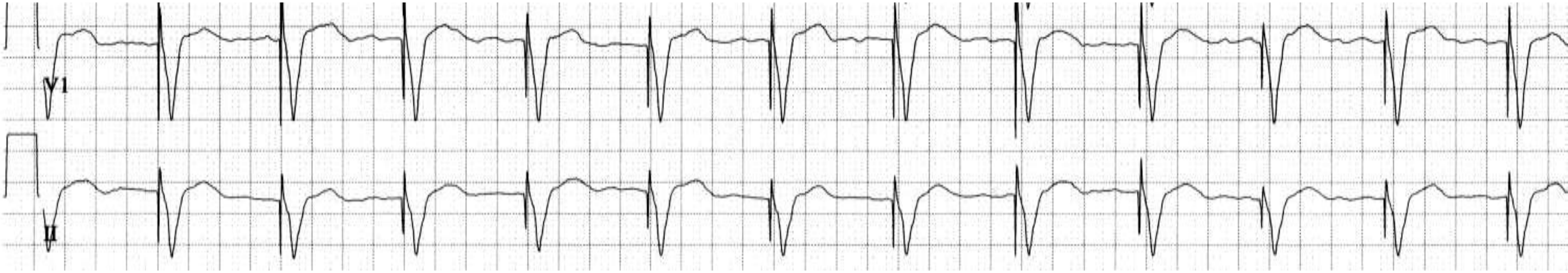


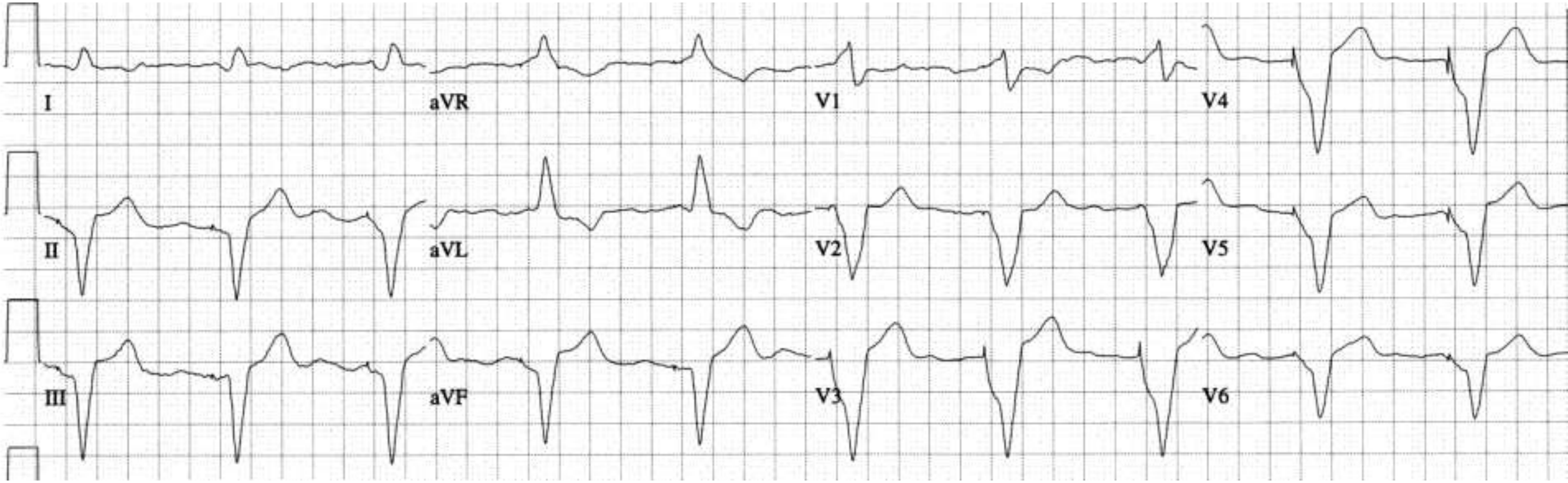
Pacemaker ECG



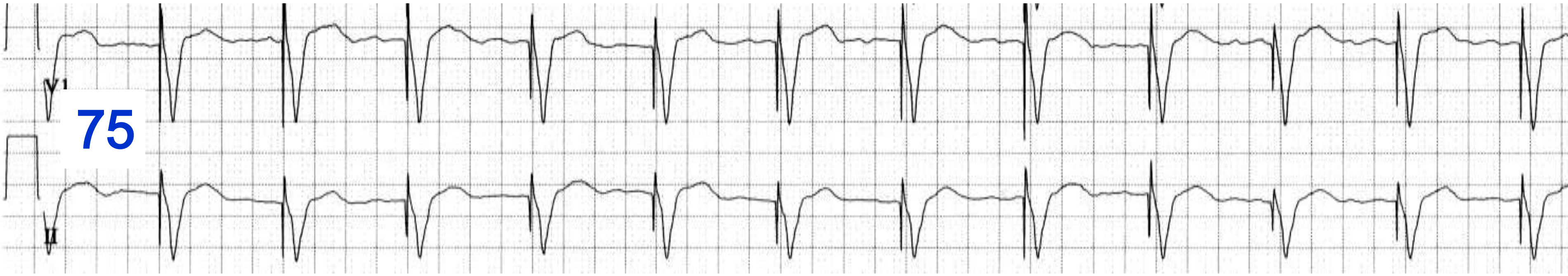
Note: Pacer spikes aren't suppressed by QRS or P waves
Pacer spikes aren't followed by QRS or P waves
Native: NSR rate 65, FAV, IMI recent LVH, Wenckebach

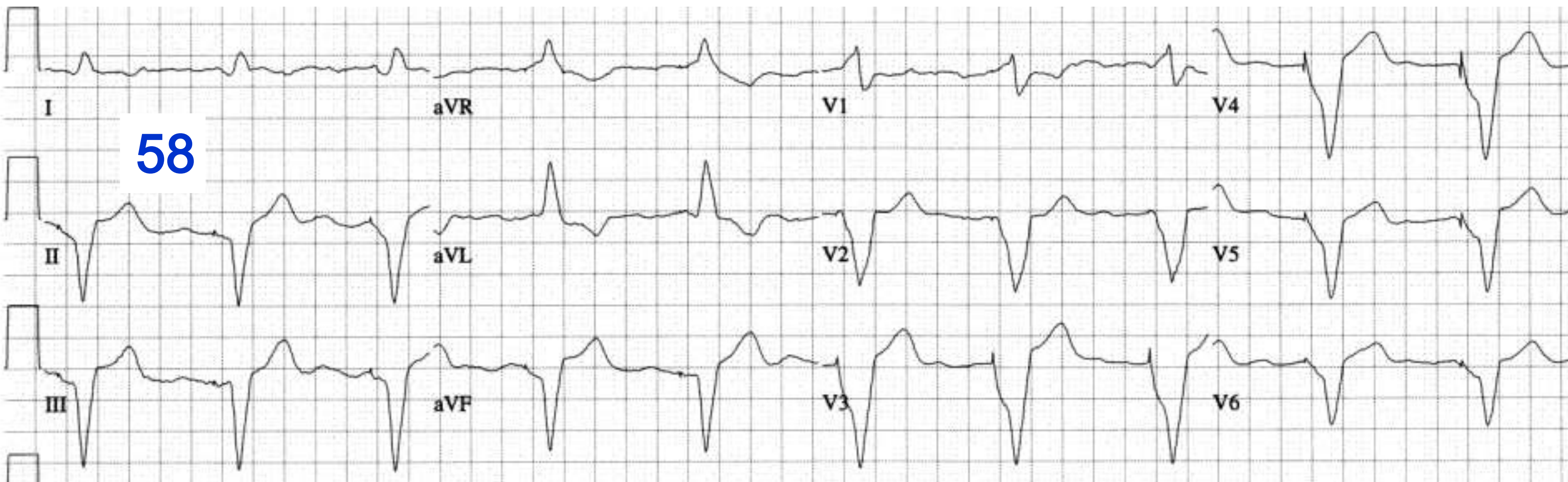
Pacemaker ECG





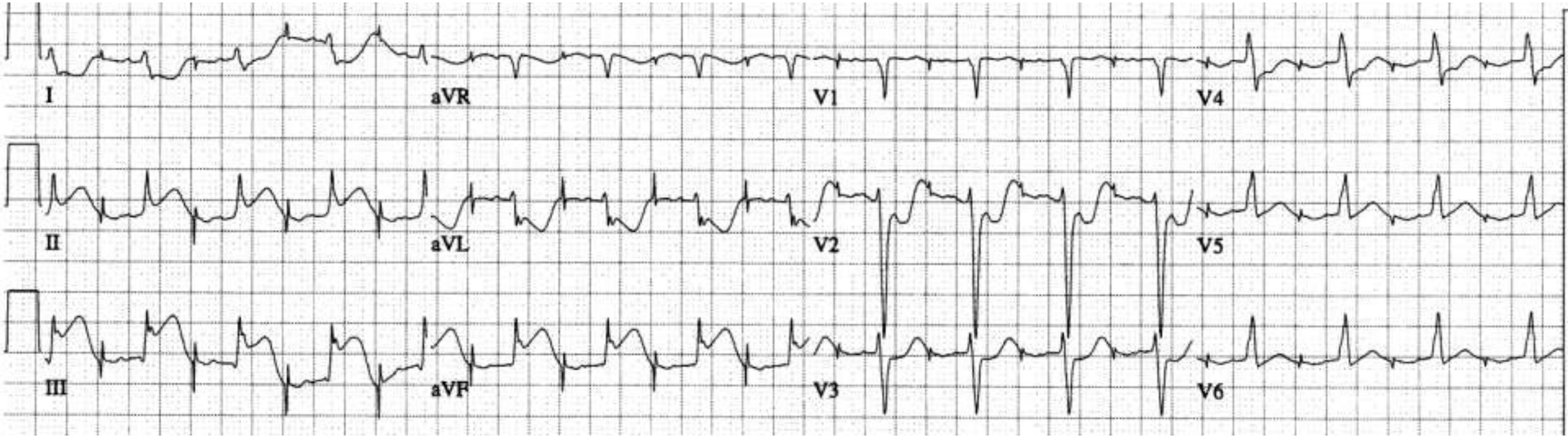
Pacemaker ECG





Note: Both patients have atrial fibrillation without AV conduction

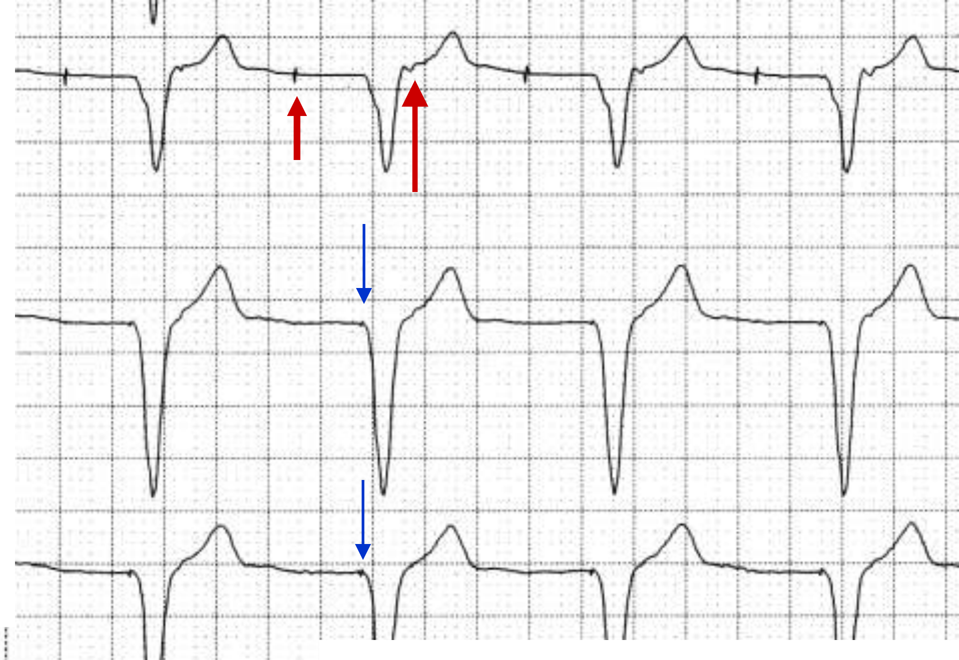
Pacemaker ECG



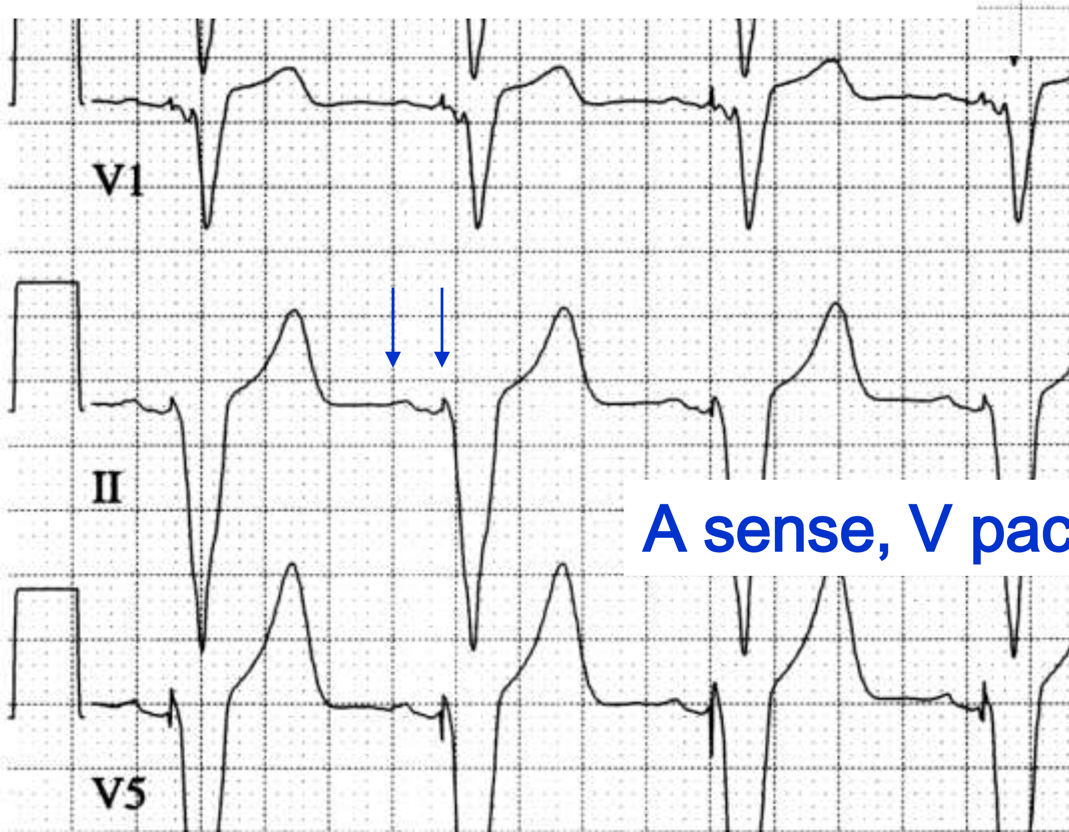
Note:

- Pacer spike followed by P wave - Atrial pacemaker
- Atrial pacer rate is fast at 100 bpm
- Prolonged constant PR interval - First degree AV block
- ST elevation in II, III and F, inferior transmural injury
- Reciprocal change in I and L
- ST depression in V2, posterior injury

Pacemaker ECG



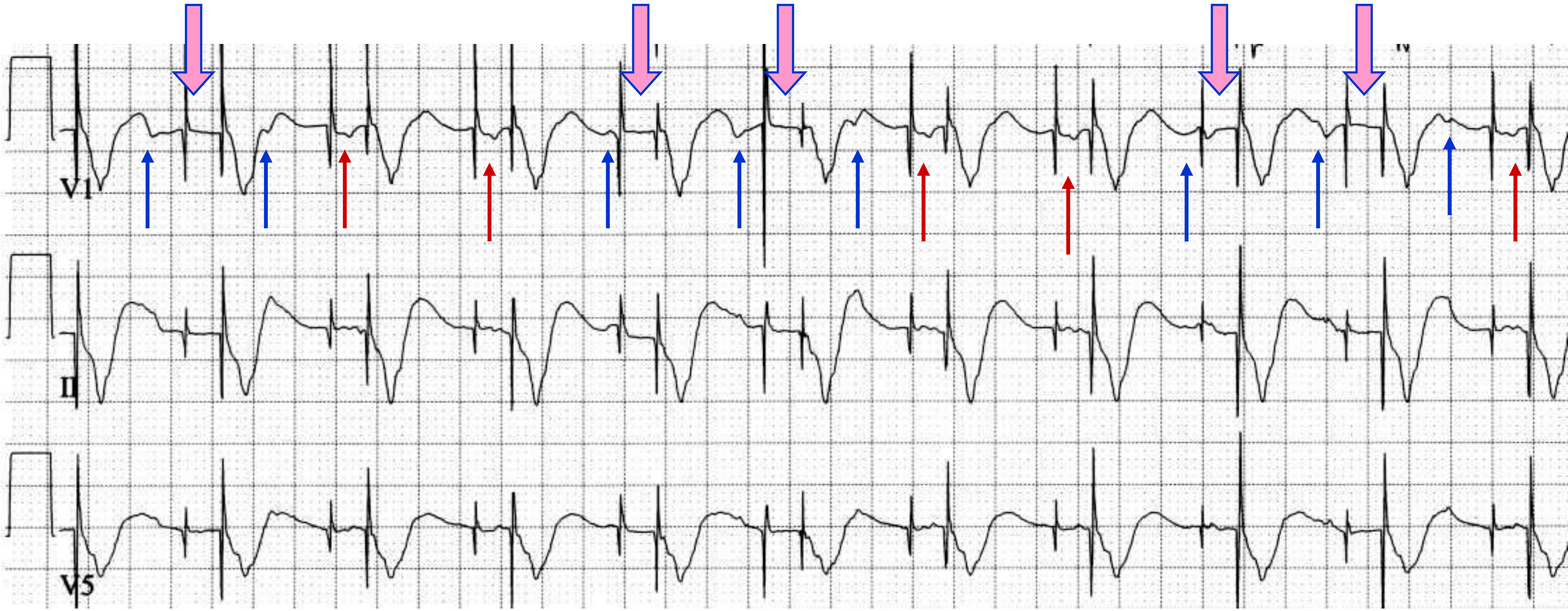
A pace, noncapture
V pace, capture
retrograde A wave



A sense, V pace

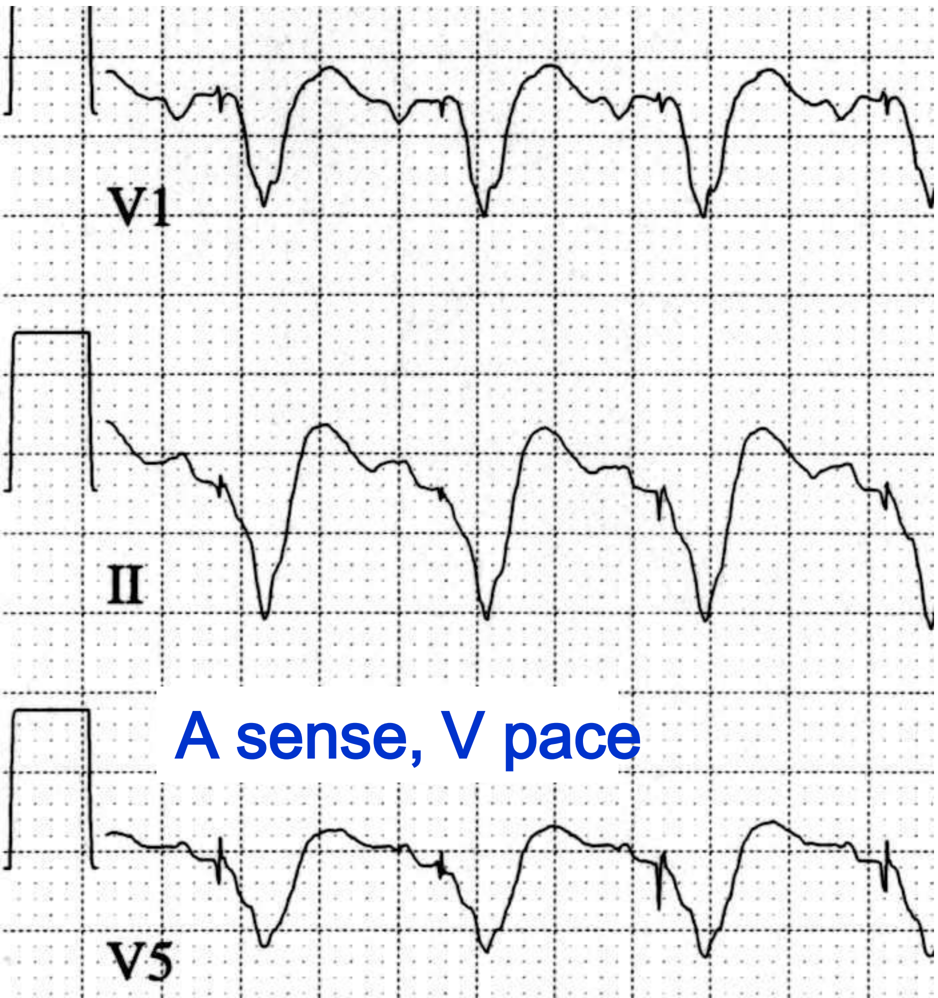
Pacemaker ECG

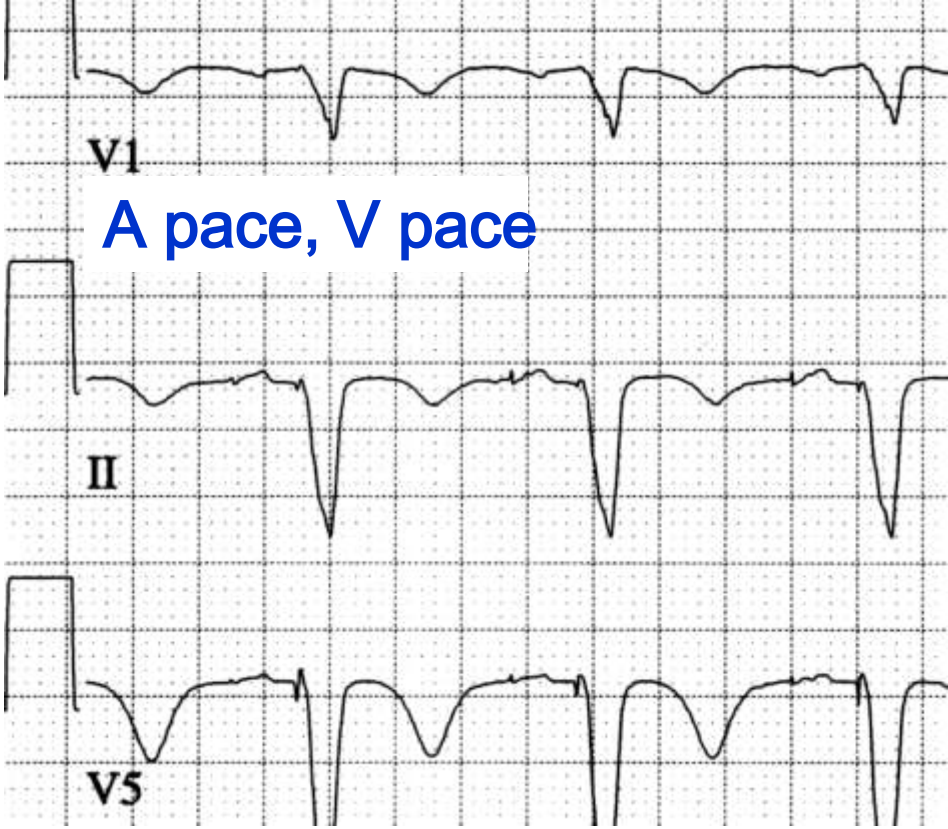
Nonconducted atrial spikes due to refractory atrium



Red arrow - conducted atrial spikes
Blue arrow - native P waves

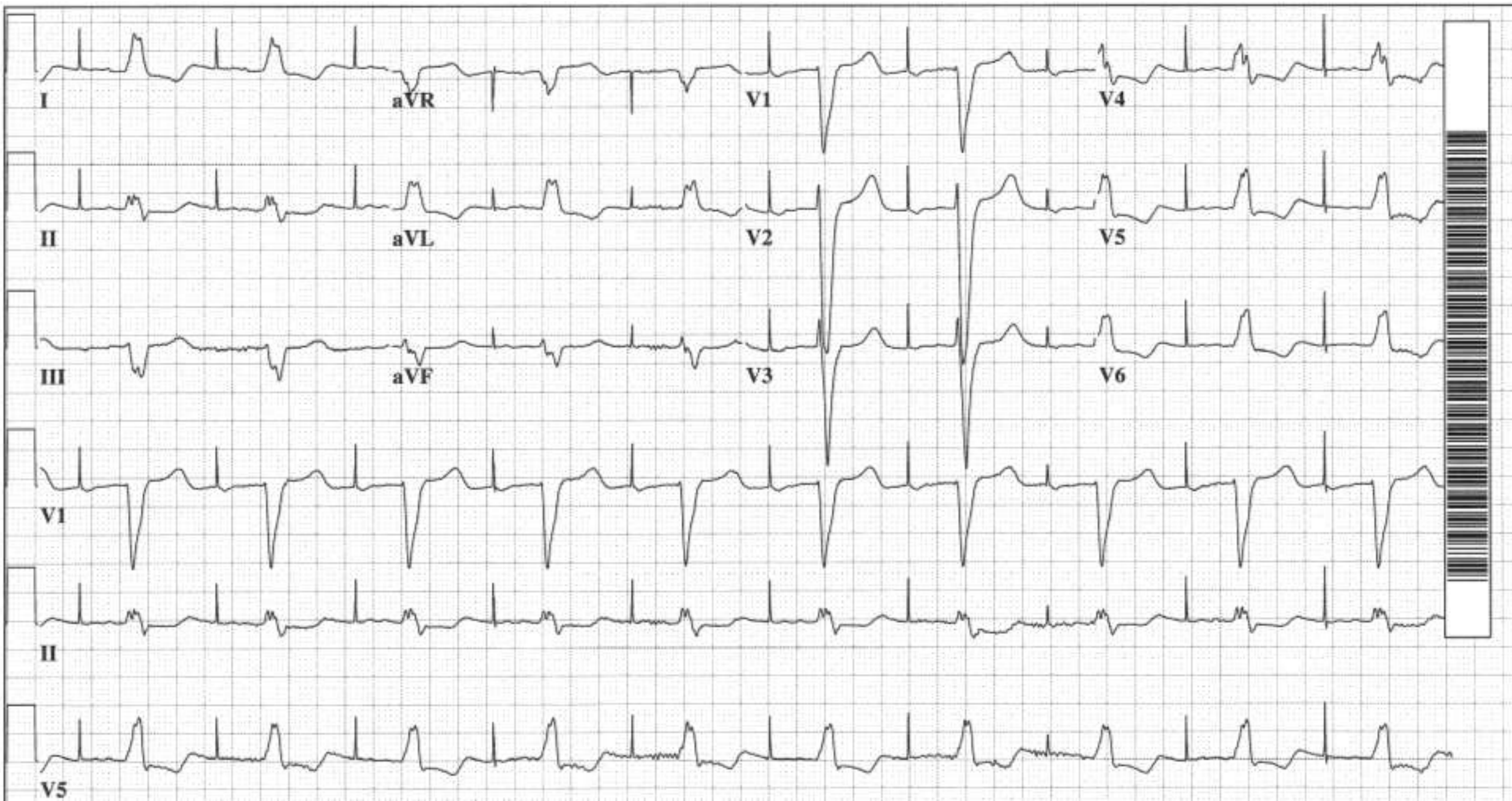
Pacemaker ECG





Pacemaker ECG

A pace, V sense



Pacemaker ECG

V pace (retrograde P wave)