Adult Hospital Medicine Boot Camp

Nashville, TN

Basics of 12-Lead ECG Interpretation

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Objectives

- Analyze the basic ECG components required to assess pathology to include, heart rate, rhythm, axis, and intervals.
- Develop a simple method that will allow you to consistently assess unknown ECGs for common pathologies.
- Identify the common variances within normal ECGs.
- Interpret normal ECGs, Bundle branch blocks and Fascicular Blocks, LV Hypertrophy, and Myocardial infarctions using specific diagnostic criteria.

Disclosure Statement

- No association or financial arrangement with any vendor or pharmaceutical company.

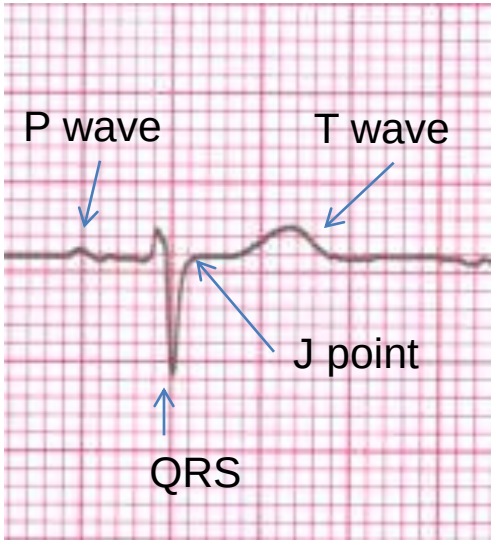
Basic Assumption

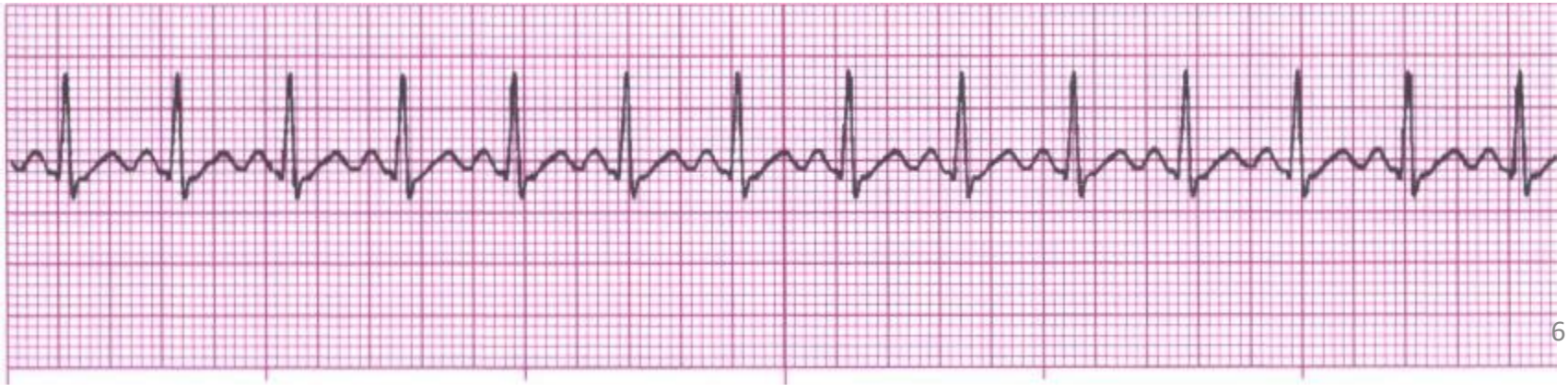
- I assume that you do not know or remember much about ECGs.

First Things First

- Coming from a Primary Care Perspective
- Evaluate an ECG the same way each time
- Develop a system to accomplish this process
- Force yourself to practice
- Art of Interpreting ECGs

Waveforms

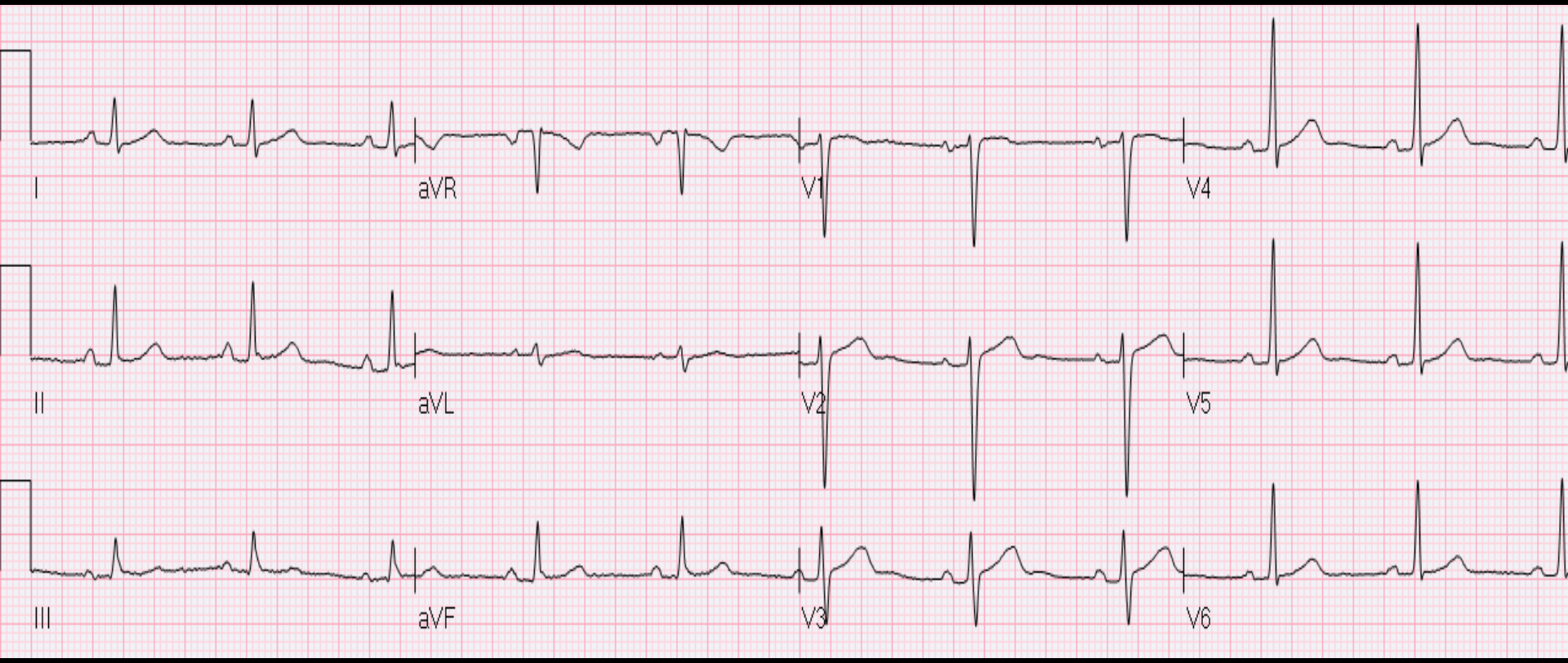




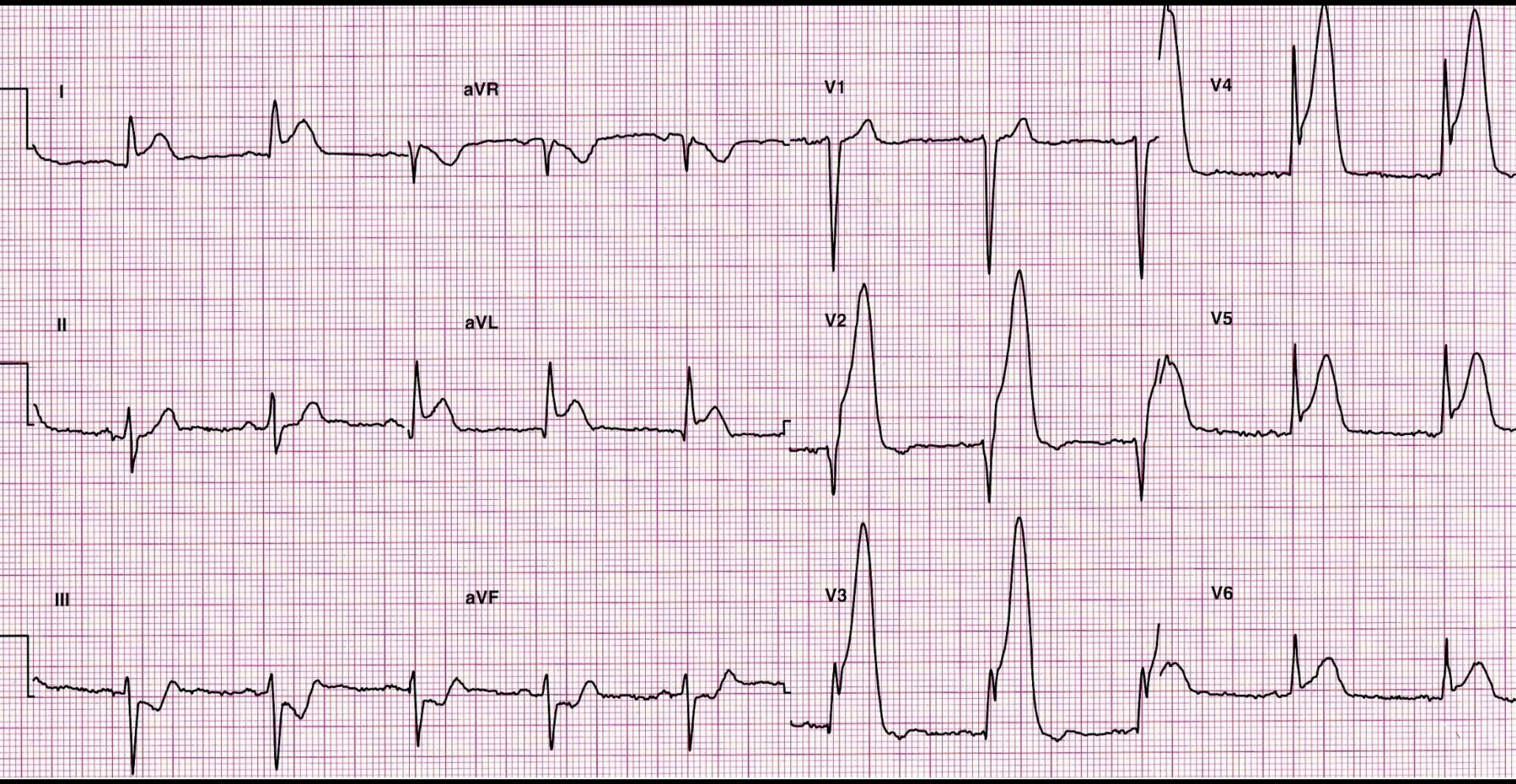
One Method

- **Gestalt or general impression**
- Determine the Heart Rate
- Determine the Rhythm
- Measure the Longest Interval in the Limb Leads
- Determine the Axis
- Assess the R-Wave Progression

Gestalt: Normal



Gestalt: Abnormal



One Method

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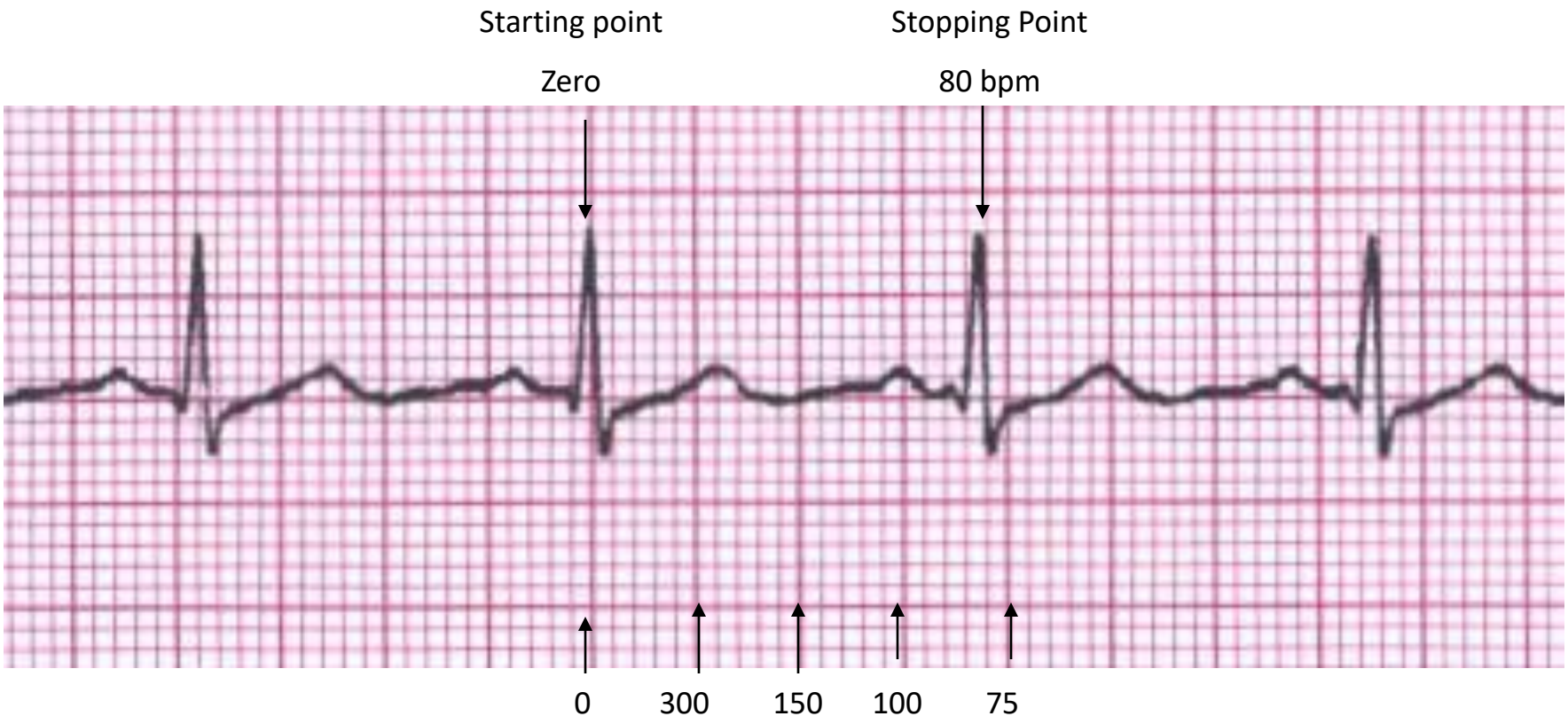
Computer 12-Lead ECG Header

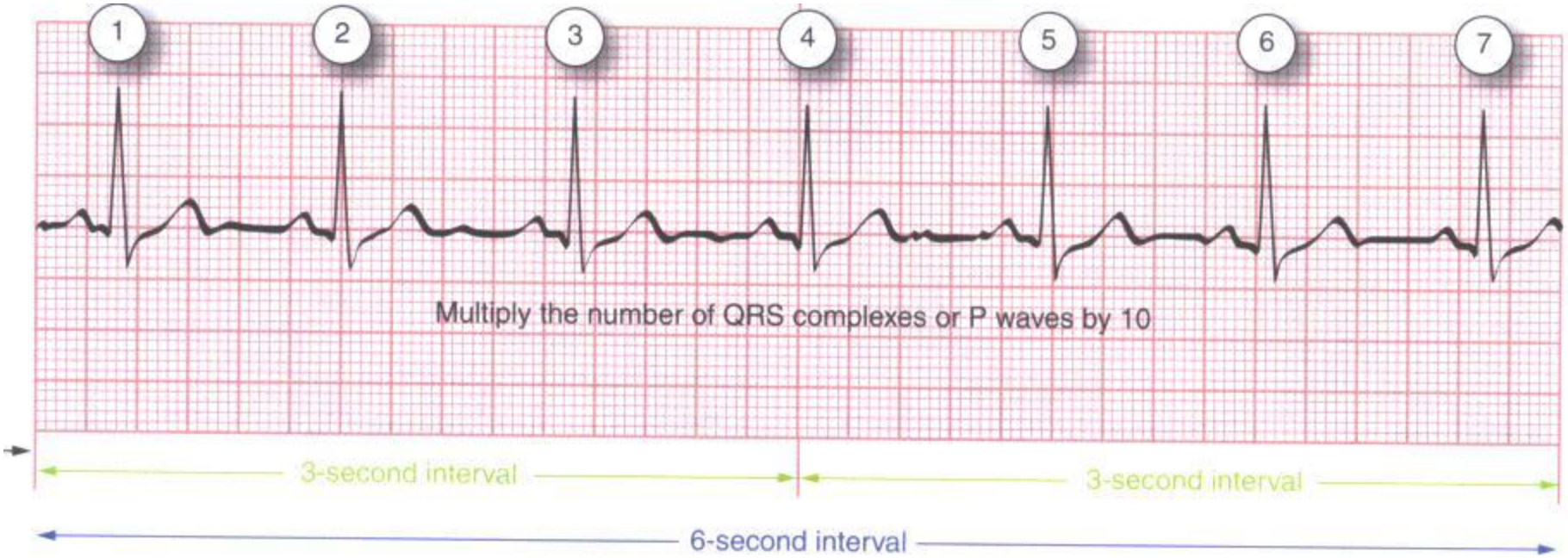
05–SEP–1960 (42 yr)		Vent. rate	73	BPM
Female	Caucasian	PR interval	174	ms
		QRS duration	90	ms
Room:T2		QT/QTc	370/407	ms
Loc:9	Option:14	P–R–T axes	36 78	102

Normal sinus rhythm
Anterolateral infarct , new
Inferior injury pattern
*** ** ** ** * ACUTE MI ** ** **
Abnormal ECG
When compared with ECG of 25–FEE
PR interval has decreased
Acute Anterior infarct is now Present

Heart Rate Determination



Heart Rate for Irregular Rhythms



Rhythm Determination

Is the distance between one QRS complex the same as the others?

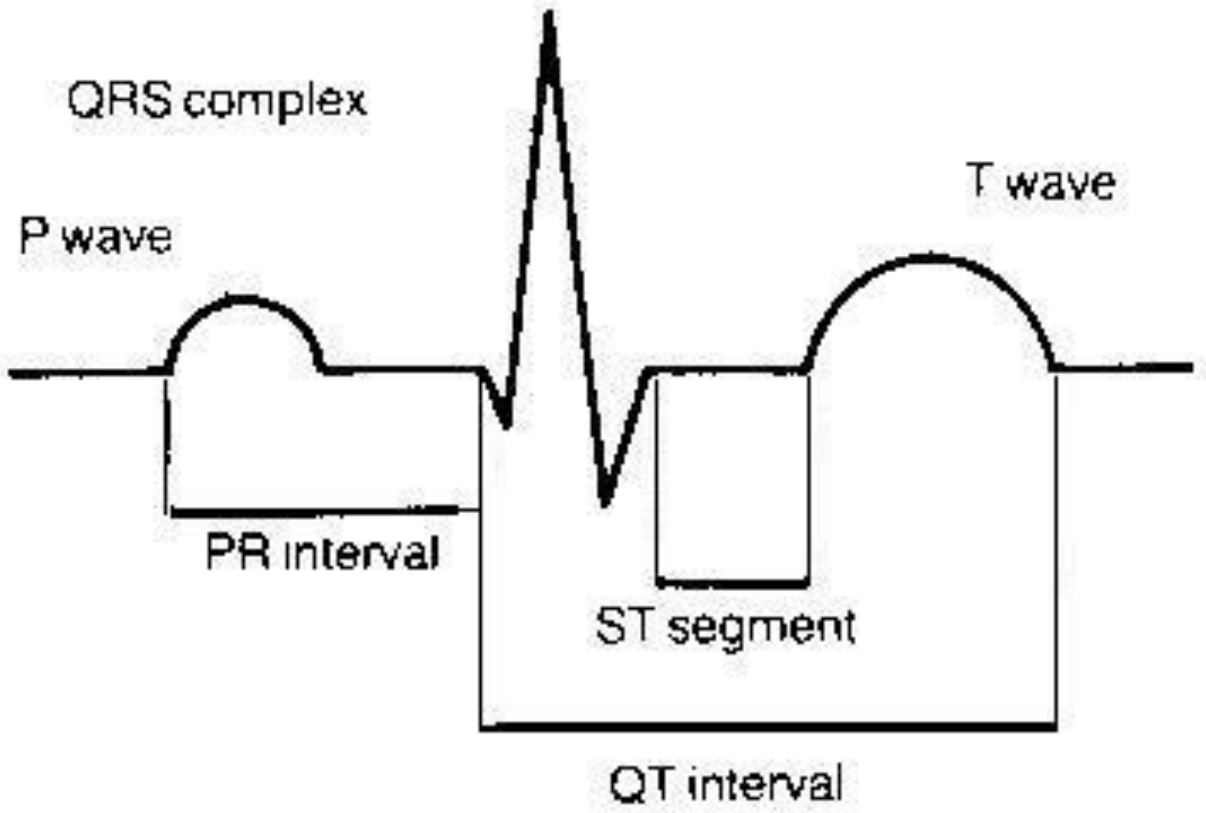
If yes, rhythm is considered Regular.

If no, rhythm is considered Irregular.

One Method

- Gestalt or general impression
- Determine the Heart Rate
- Determine the Rhythm
- **Measure the Longest Interval in the Limb Leads**
- Determine the Axis
- Assess the R-Wave Progression

PR, QRS, QT Intervals



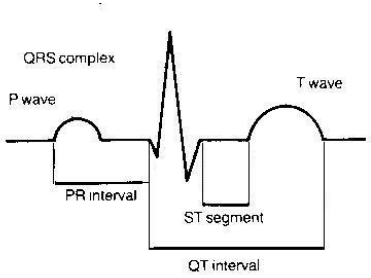
PR Normal: 120 – 200 ms

QRS Normal: < 120 ms

QT Normal: Heart rate dependent:

PR Interval

- Measure from start of P wave to start of QRS
- Best measured in limb lead II
- Conduction through the AV node
- Normal:
  - 120 ms to 200 ms
  - 3 to 5 boxes

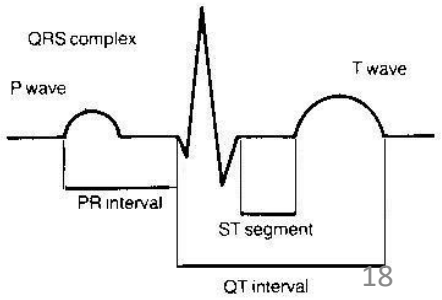


- Short PR Interval
  - Pre-excitation synd.
    - WPW, LGL
  - PACs
- Long PR Interval
- Lots of causes, don't really care about cause
- Refer to as: "First Degree AV Block"

QRS Interval

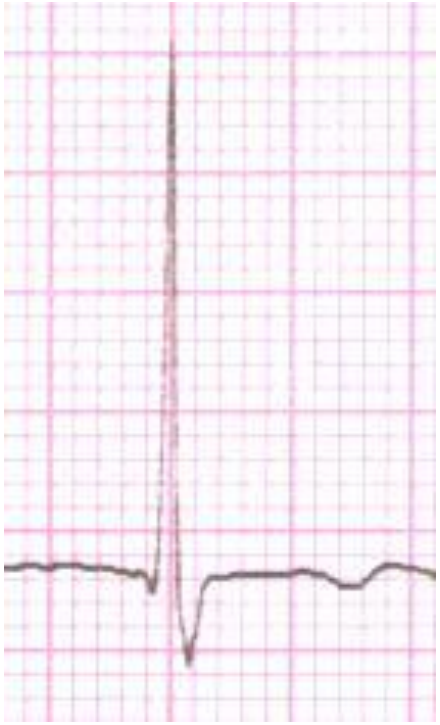
- Beginning of QRS to the end (J-point)
- Normal: < 120 ms (less than 3 boxes)
- Use the Limb Lead with longest QRS to measure

- Causes of Prolonged QRS interval:
  - Bundle Branch Blocks, IVCD, WPW, LVH, RVH,
  - Rhythm: ventricular tach, PVCs, idoventricular rhythm



QT Interval

- Measures a complete ventricular cycle
    - From beginning of ventricular depolarization to ventricular repolarization
- Measure from start of QRS to end of T-wave
- Normal is defined based on heart rate
    - HR of 60 = 400 ms; HR of 100 = 320 ms
- Simple rule:
  - The QT is probably prolonged if it exceeds more than HALF of the R-R interval.
  - Rule works well as long as HR is not excessive

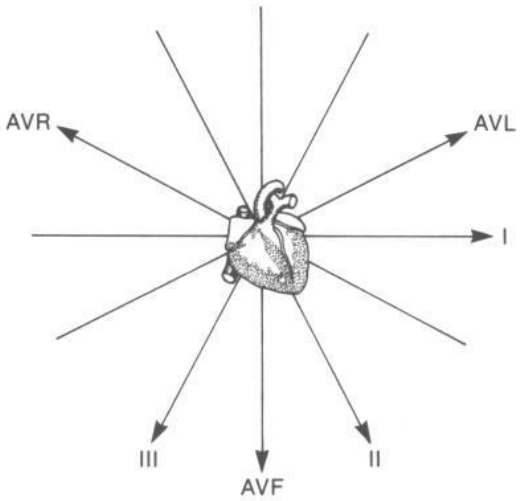


One Method

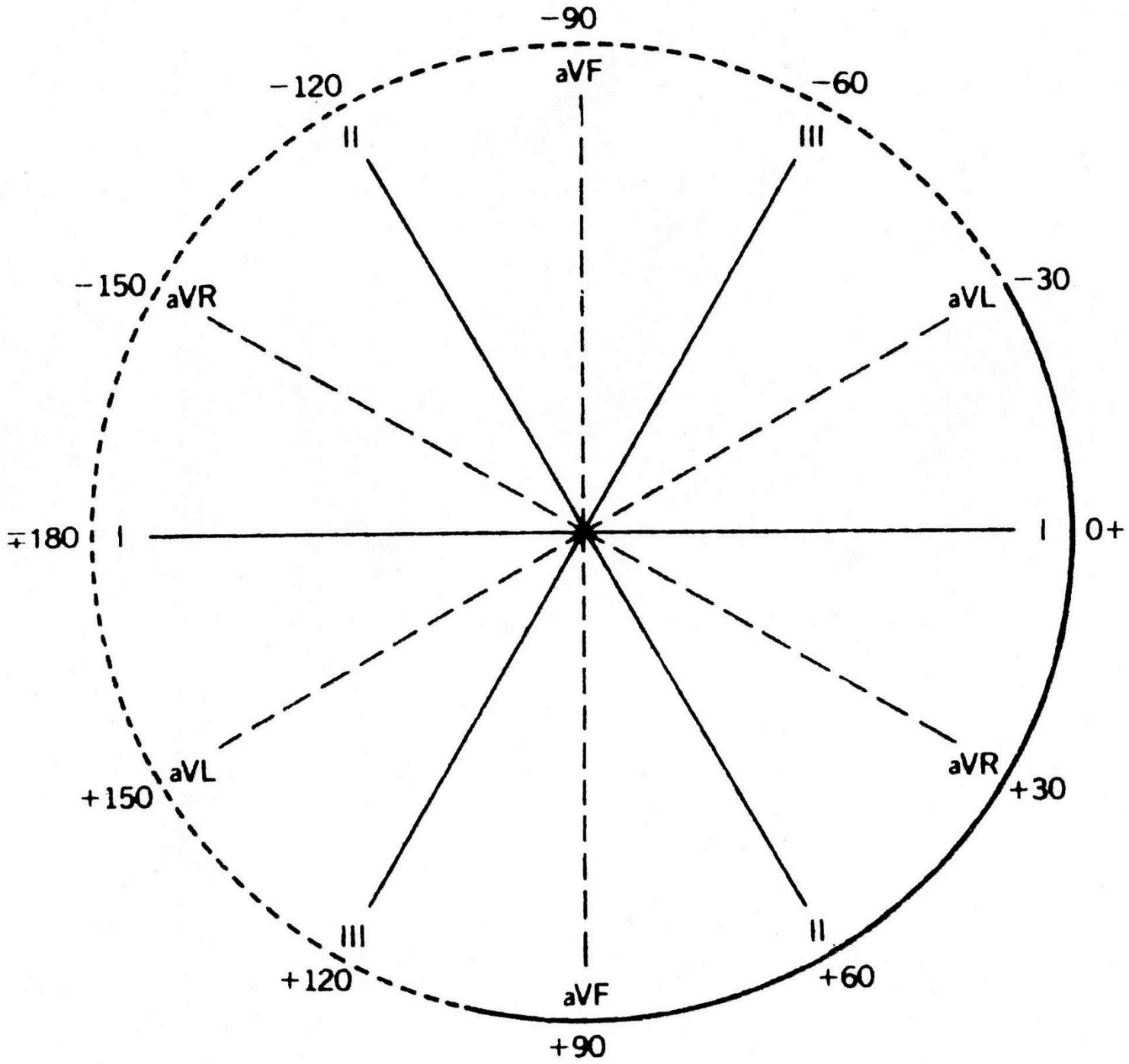
- Gestalt or general impression
- Determine the Heart Rate
- Determine the Rhythm
- Measure the Longest Interval in the Limb Leads
- **Determine the Axis**
- Assess the R-Wave Progression

Axis Determination

- Based on the frontal plane (limb leads)
- Ballpark estimates are usually fine, rarely necessary to have specific degrees noted
- Utilize the Quadrant Method
  - Based on two limb leads: I and aVF
  - Normal is based on quadrant



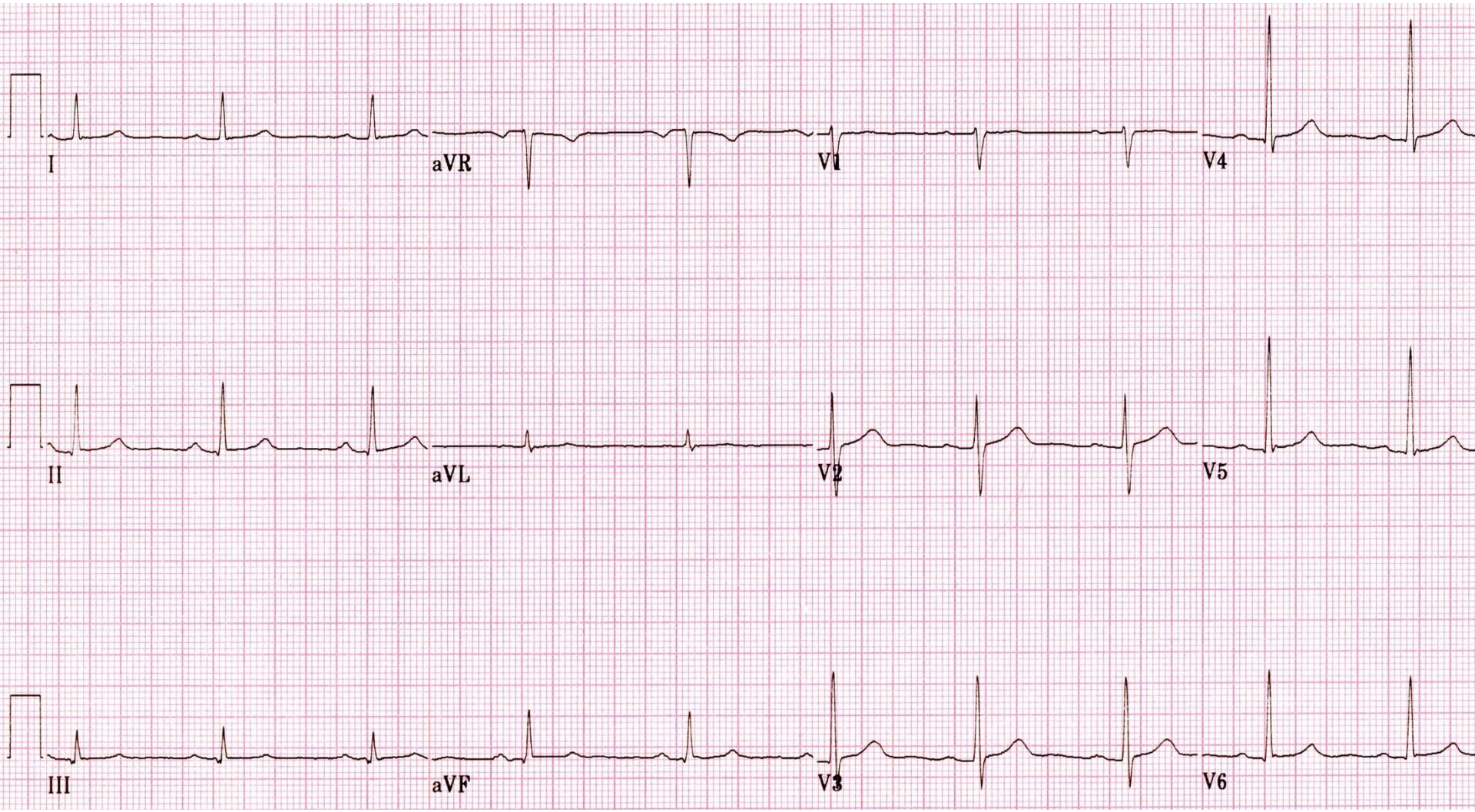
Lead Placements


−90
aVF
−120
II
−60
III
−150
aVR
−30
aVL
±180
I
I
0+
aVL
+150
aVR
+30
III
II
+120
+60
aVF
+90

Quadrant Method

- From the ECG, looking at Limb Lead I, determine the net deflection of the QRS complex (Positive, Negative, equal)
- Plot this on your axis diagram
- Next, from the ECG, looking at Limb Lead aVF, determine the net deflection of the QRS complex (Positive, Negative, equal)
- Plot this on your axis diagram

- Where the areas cross over, this is the quadrant in which the axis lies.


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

Axis Pathology

- Left Axis Deviation
  - Left Bundle Branch Block
  - Left Ventricular Hypertrophy
  - Inferior Wall MI
  - Left Anterior Fascicular Block
- Right Axis Deviation
  - Right Bundle Branch Block
  - Right Ventricular Hypertrophy
  - High Lateral Wall MI
  - Left Posterior Fascicular Block

One Method

- Gestalt or general impression
- Determine the Heart Rate
- Determine the Rhythm
- Measure the Longest Interval in the Limb Leads
- Determine the Axis
- **Assess the R-Wave Progression**

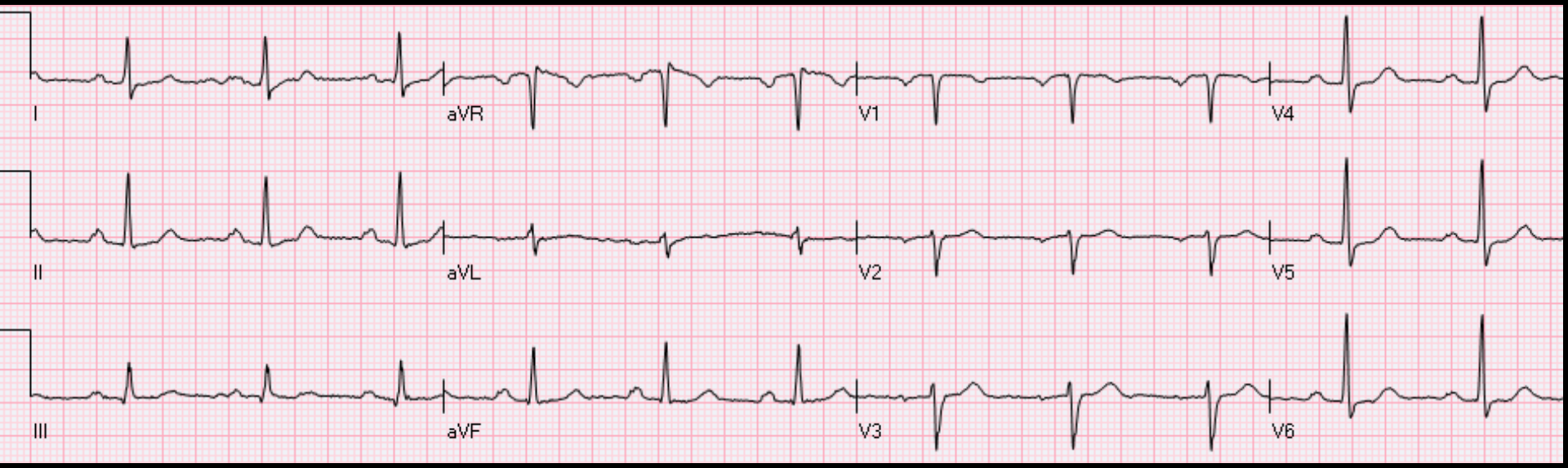
R-wave Progression

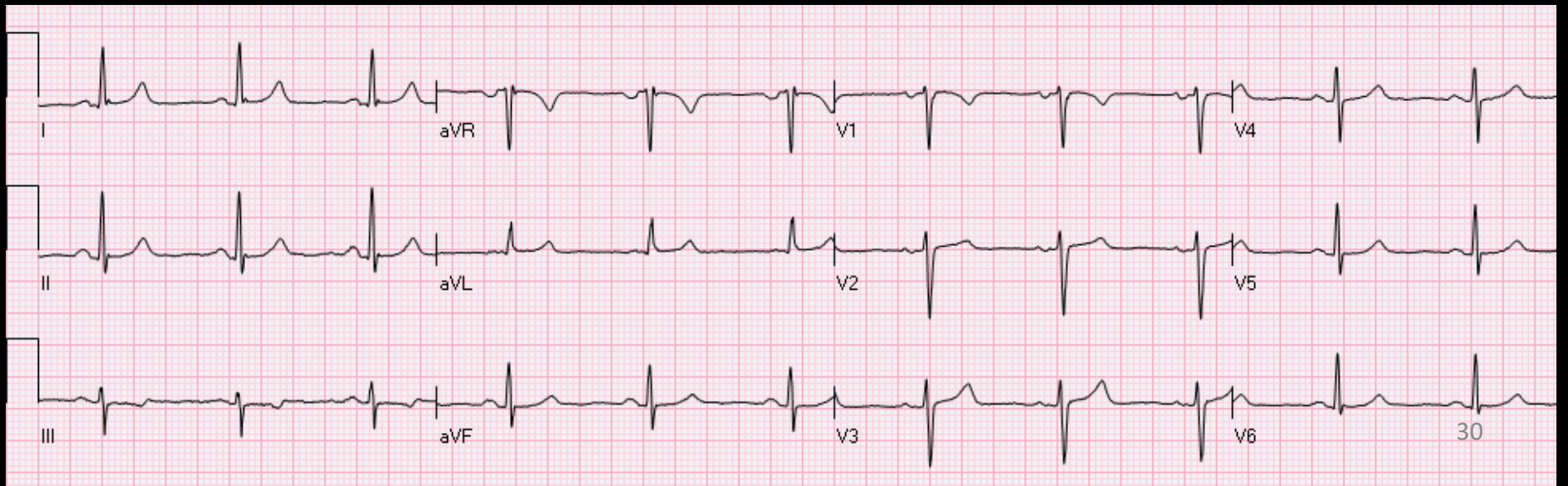
- Precordial Chest leads V1 – V6
- R wave progresses from V1 through V6
- Descriptive term only, does not imply pathology
- Terminology:
  - Normal, early transition, late transition
- Causes:
  - LVH, RVH, MI, Conduction defects, normal variants, lead misplacement….

R-wave Progression

Start small (V1) Get big (V6). Transition occurs at V3, V4, or between V3 & V4.

R-Wave Progression





What Next

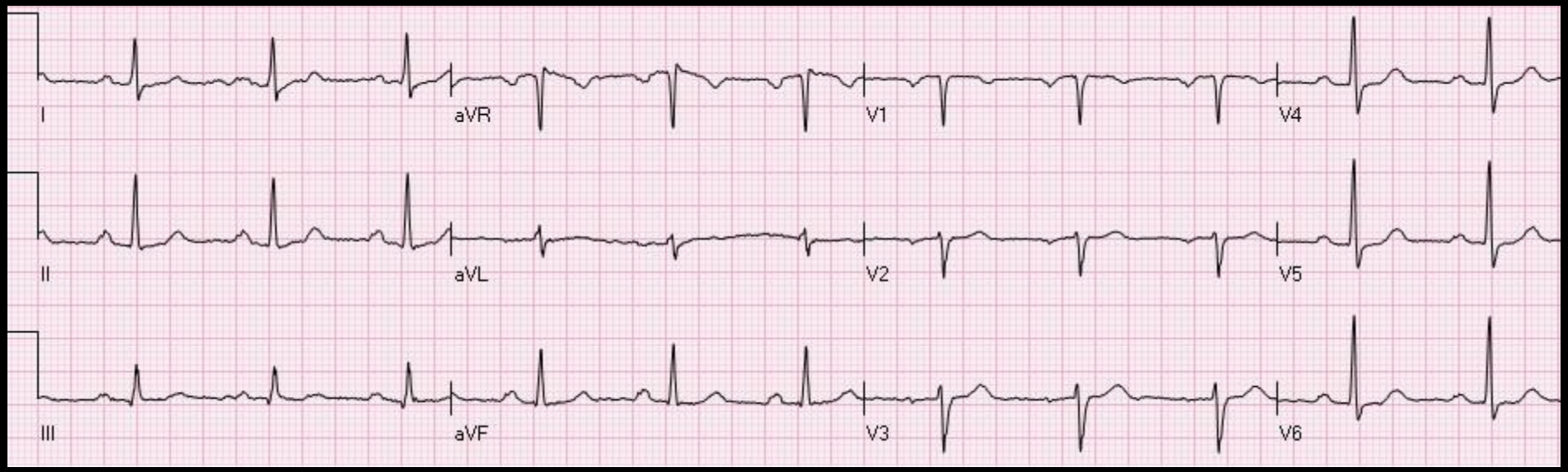
- For each ECG lead, note the following:
  - Location and morphology of P-waves
  - QRS pattern (presence of Q-waves)
  - ST Segment (elevation or depression)
  - T wave changes

  Review all leads except aVR.

Normal ECG:
The 12-lead ECG morphology for a normal individual is not always uniform. A number of constitutional variables can substantially alter a normal ECG, including sex, age, height, race and anatomic position of the heart within the chest. Lead placement, variations in technique and different machines can also distort a normal ECG.

<u>Helpful Criteria:</u>
* P-waves upright in I, II, V2-V6
* T-waves upright in I, II, V3-V6, Inverted in aVR
Variable in III, aVL, aVF, V4-V6

* Small Q-waves normal in I, aVL, V4-V6
* Deep Q-waves (QS) normal in aVR, and occasionally seen in leads III and V_1

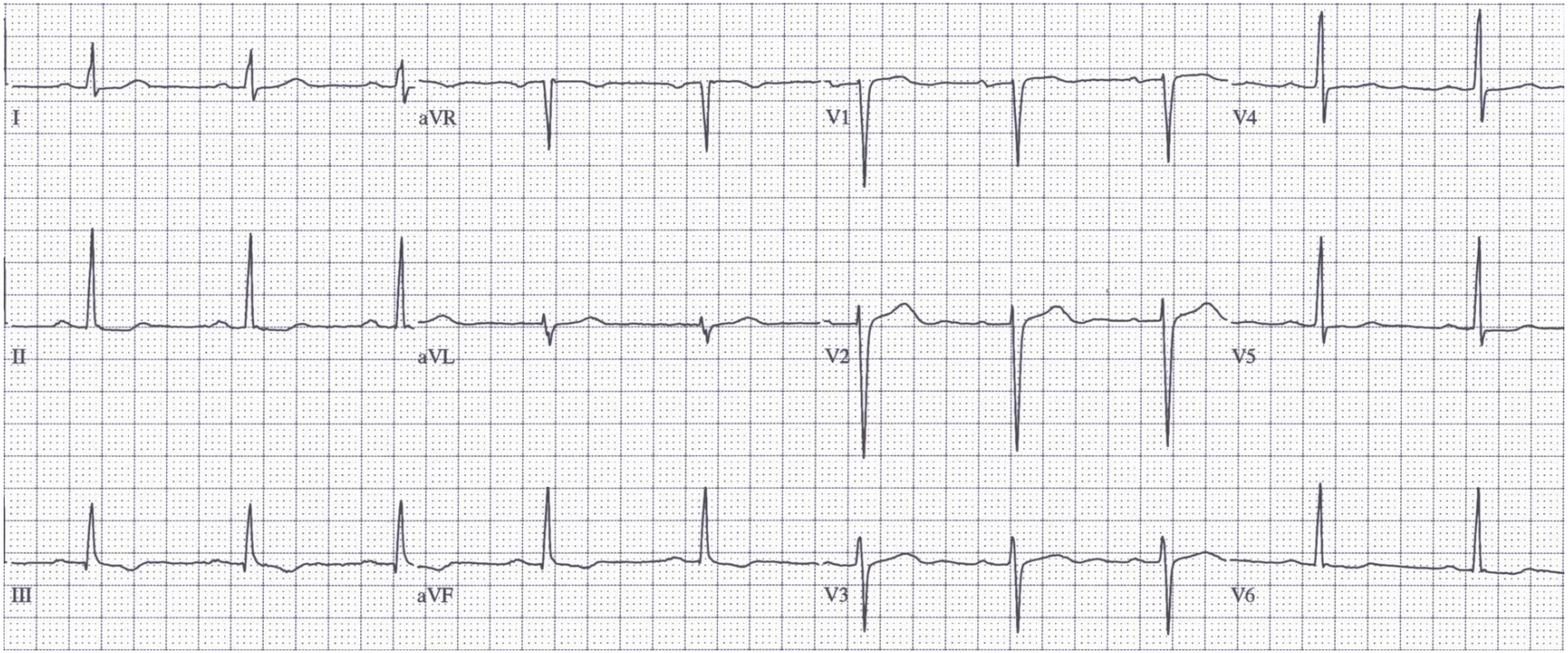


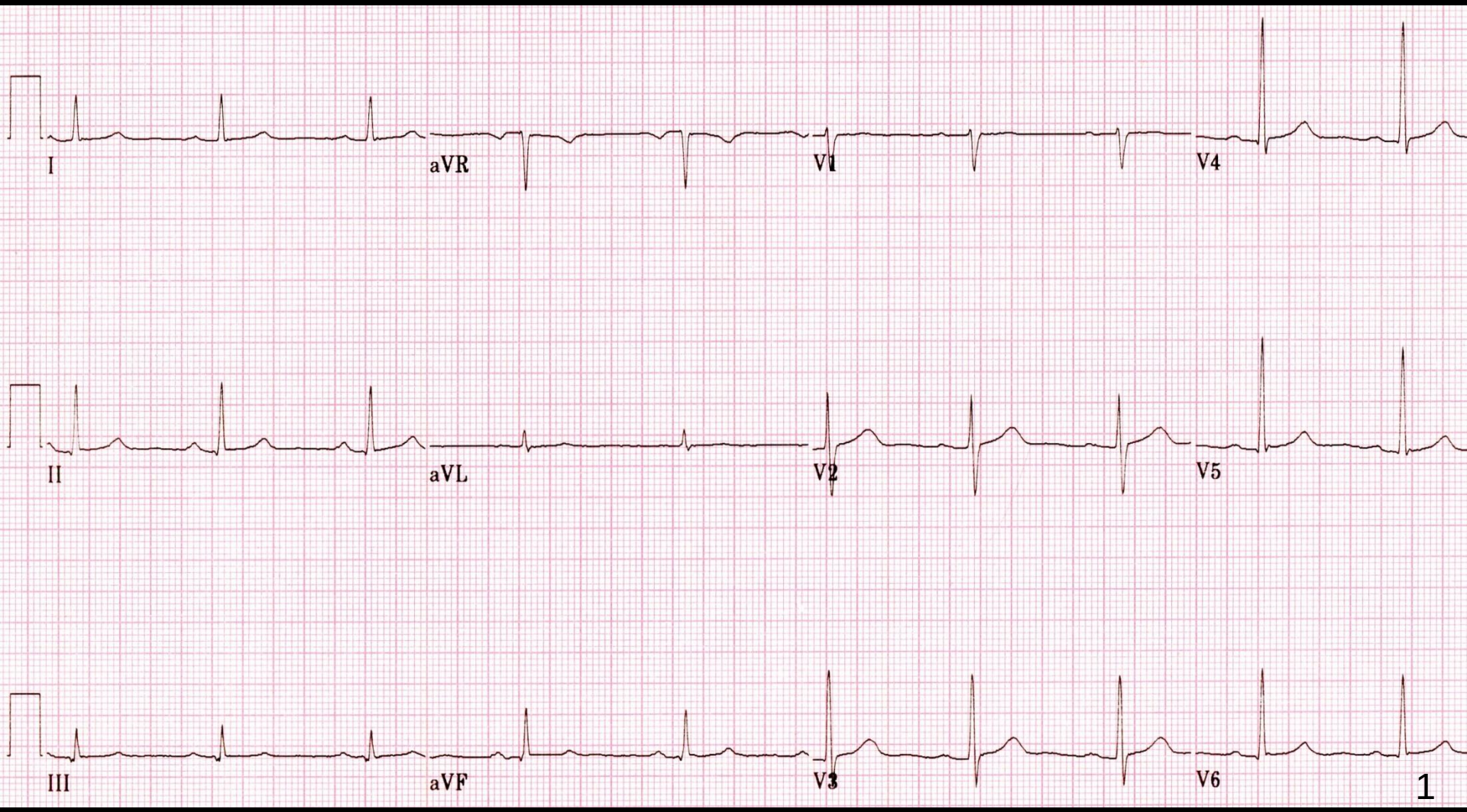
Helpful Criteria:

* P-waves upright in I, II, V2-V6
* T-waves upright in I, II, V3-V6, Inverted in aVR
  Variable in III, aVL, aVF, V4-V6

- Small Q-waves normal in I, aVL, V4-V6
- Deep Q-waves (QS) normal in aVR and occasionally seen in leads III and V1

Let's Practice





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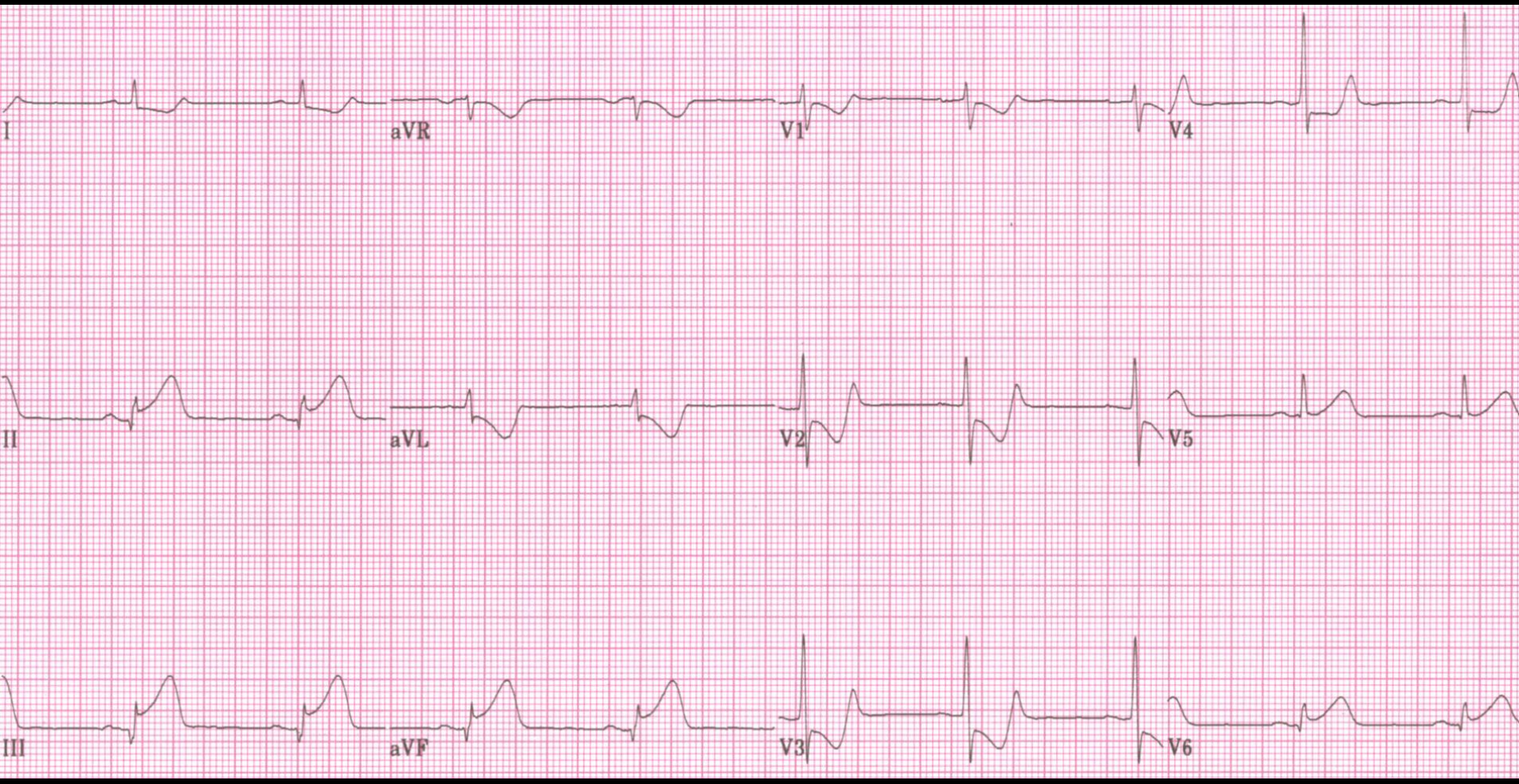
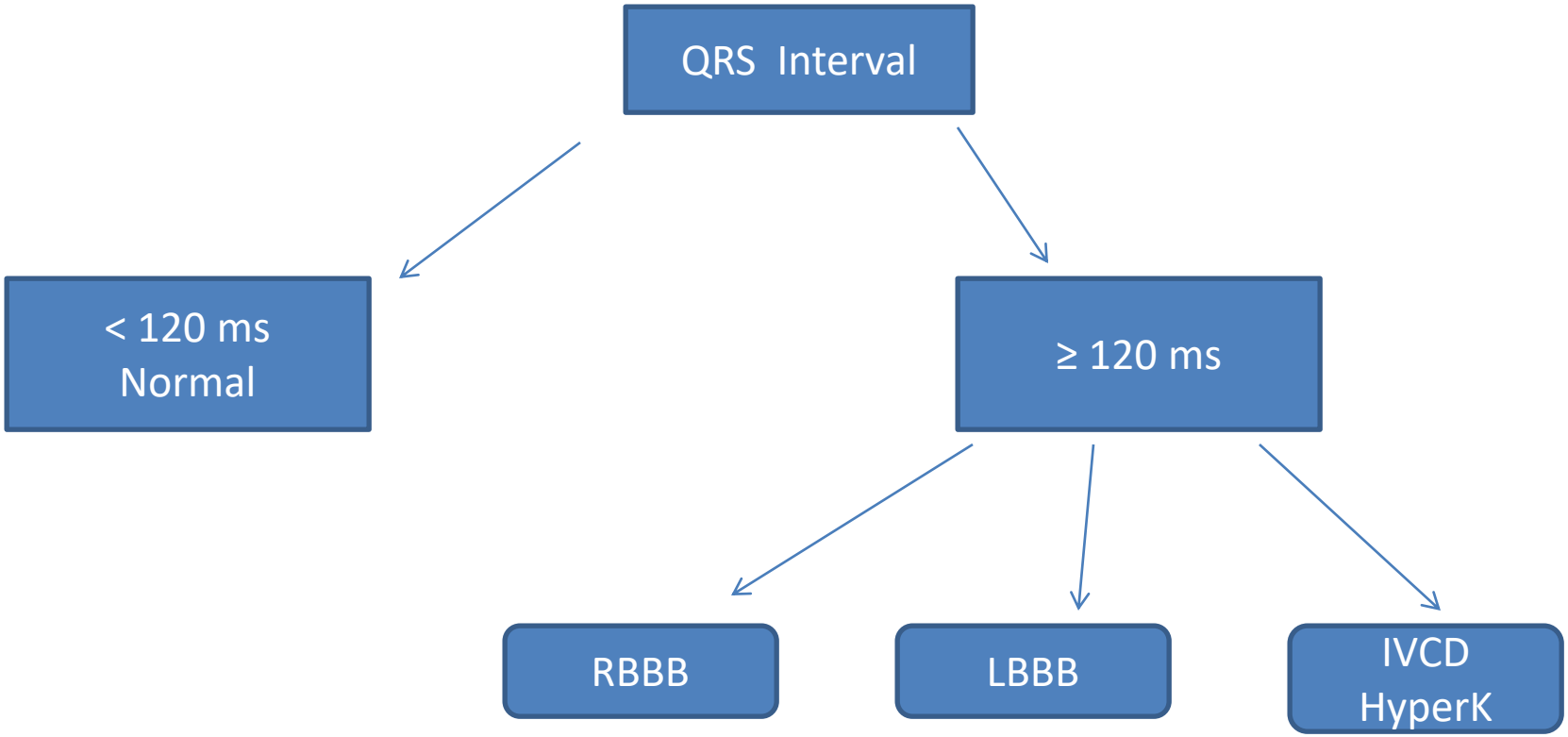

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

Bundle Branch Blocks

Simplified Diff. Wide-QRS Complex



Differential for Wide-QRS Complex

- Hyperkalemia
- Ventricular tachycardia
- Idioventricular rhythm, including heart block
- Drug effects and overdose (esp. tricyclics)
- Wolff-Parkinson-White
- Bundle Branch Blocks and Idioventricular conduction delays (IVCD)
- Ventricular premature contractions
- Aberrantly conducted complexes
    - In order of descending mortality

Do I have a Bundle Branch Block?

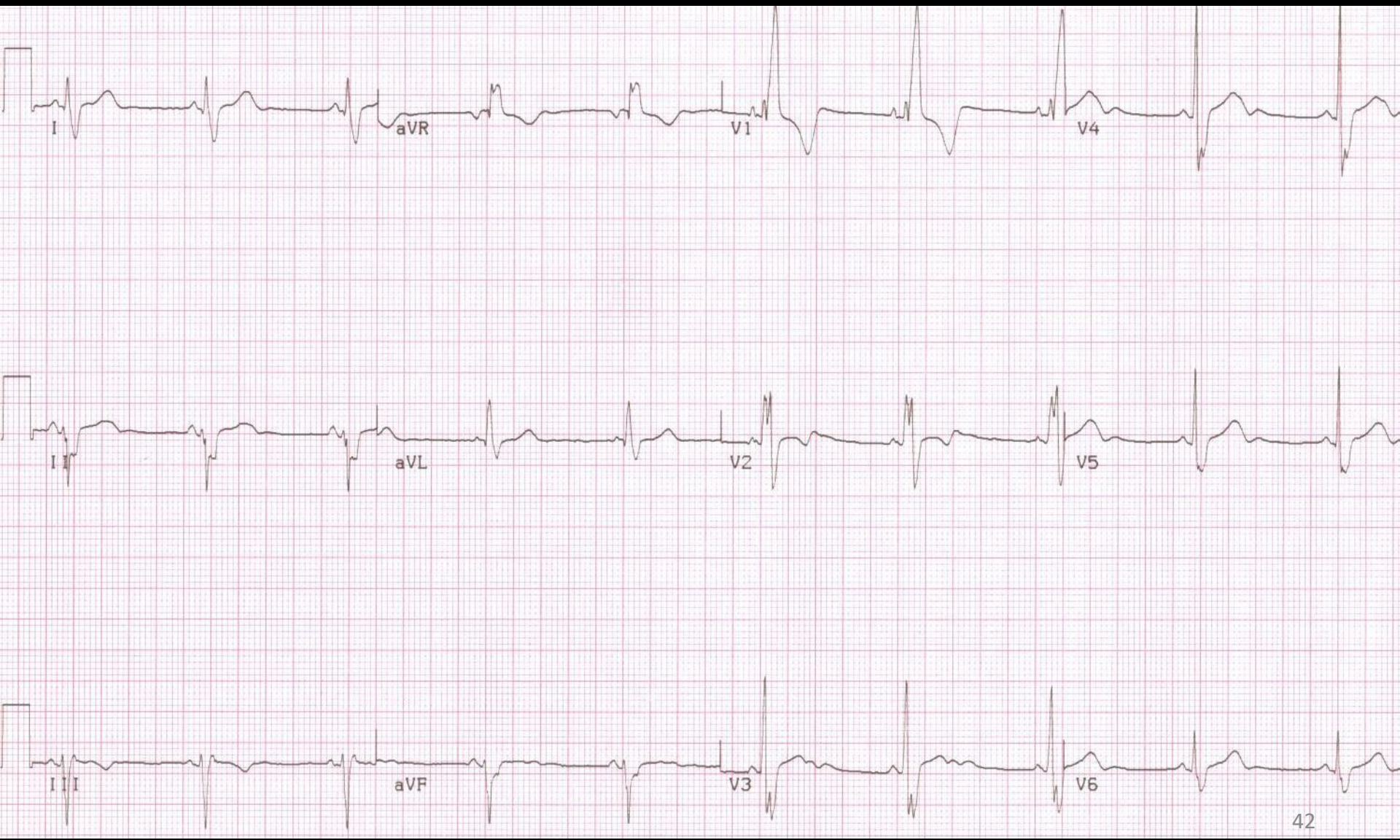
- Diagnostic criteria
  - Width of the QRS complex
    - ≥ 120 ms is Always abnormal
  - If QRS is < 120 ms, NOT a BBB

Right Bundle Branch Block

- Diagnostic criteria:
  - QRS ≥ 120 ms
  - Axis is RAD or Normal (can be LAD with LAFB)
  - rSR' pattern V_1 - V_2
  - Slurred S-wave in I and V_6
  - NSSTT changes in V_1 & V_2

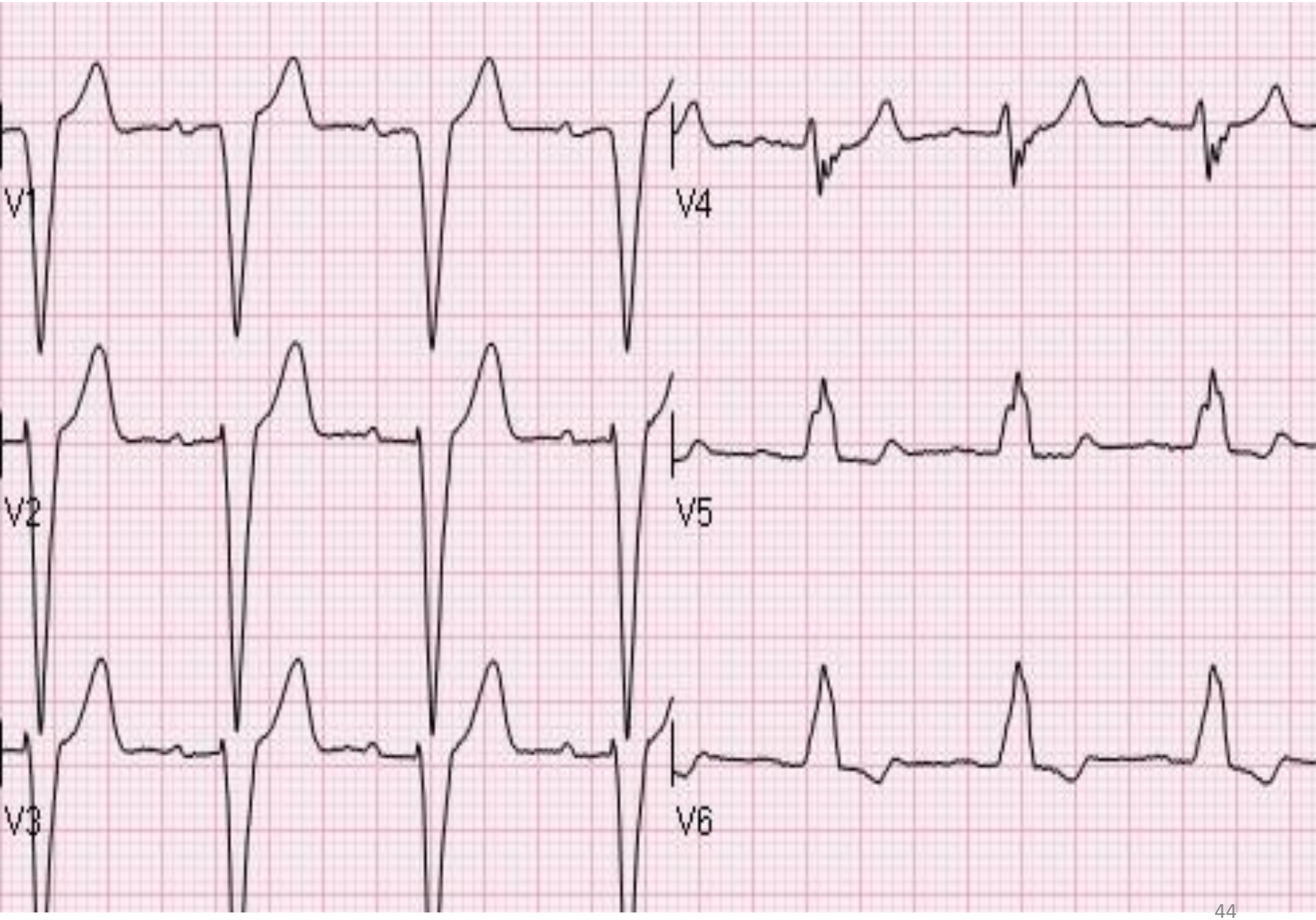
  (Non-specific ST-T wave changes)

RBBB

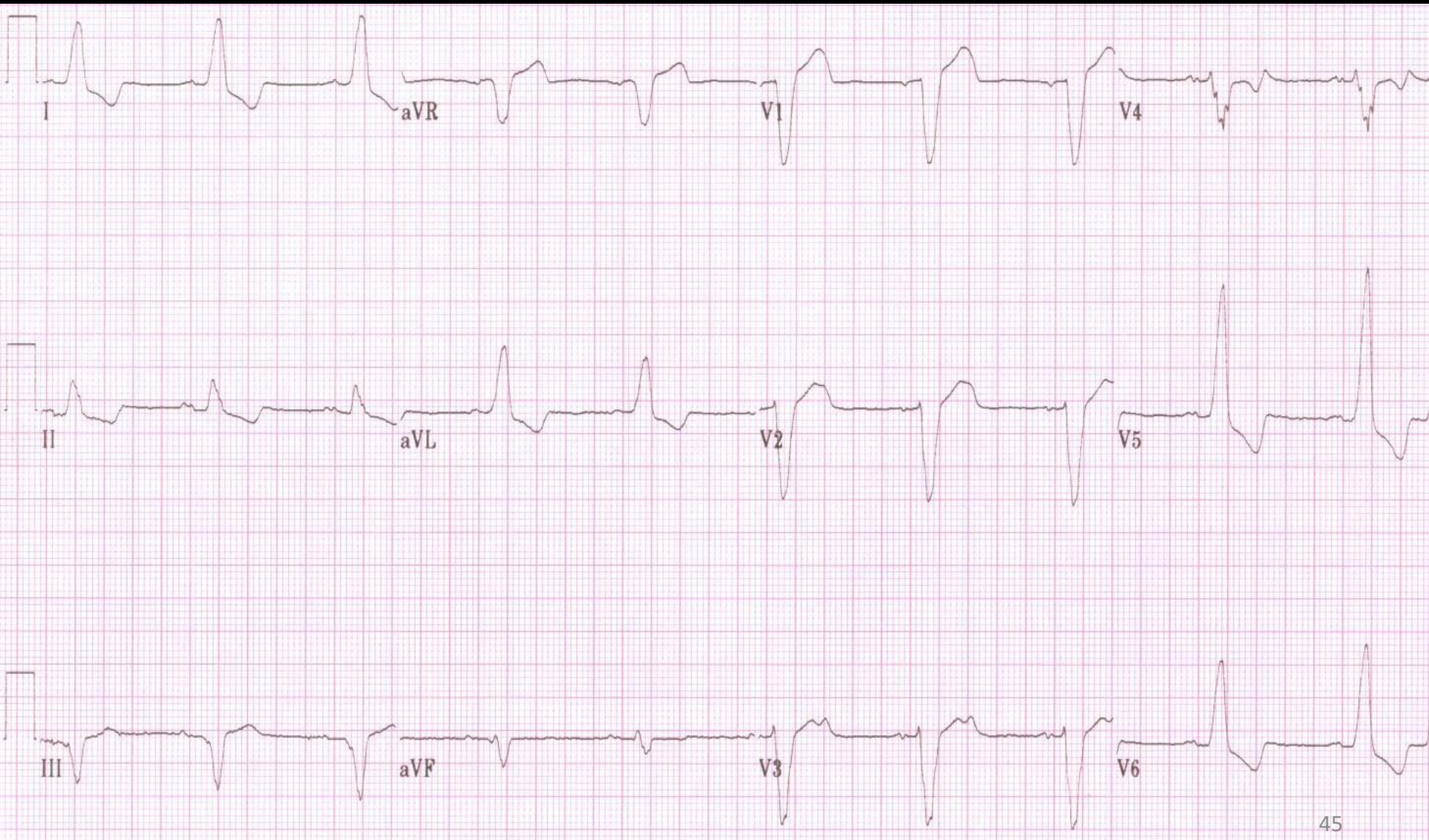


Left Bundle Branch Block

- Diagnostic criteria:
  - QRS ≥ 120 ms
  - Axis is Normal or LAD
  - Wide monomorphic S-waves in V_1 – V_4
  - Wide monomorphic R-wave in I and V_6
  - NSSTT changes in most leads


V1
V4
V2
V5
V3
V6

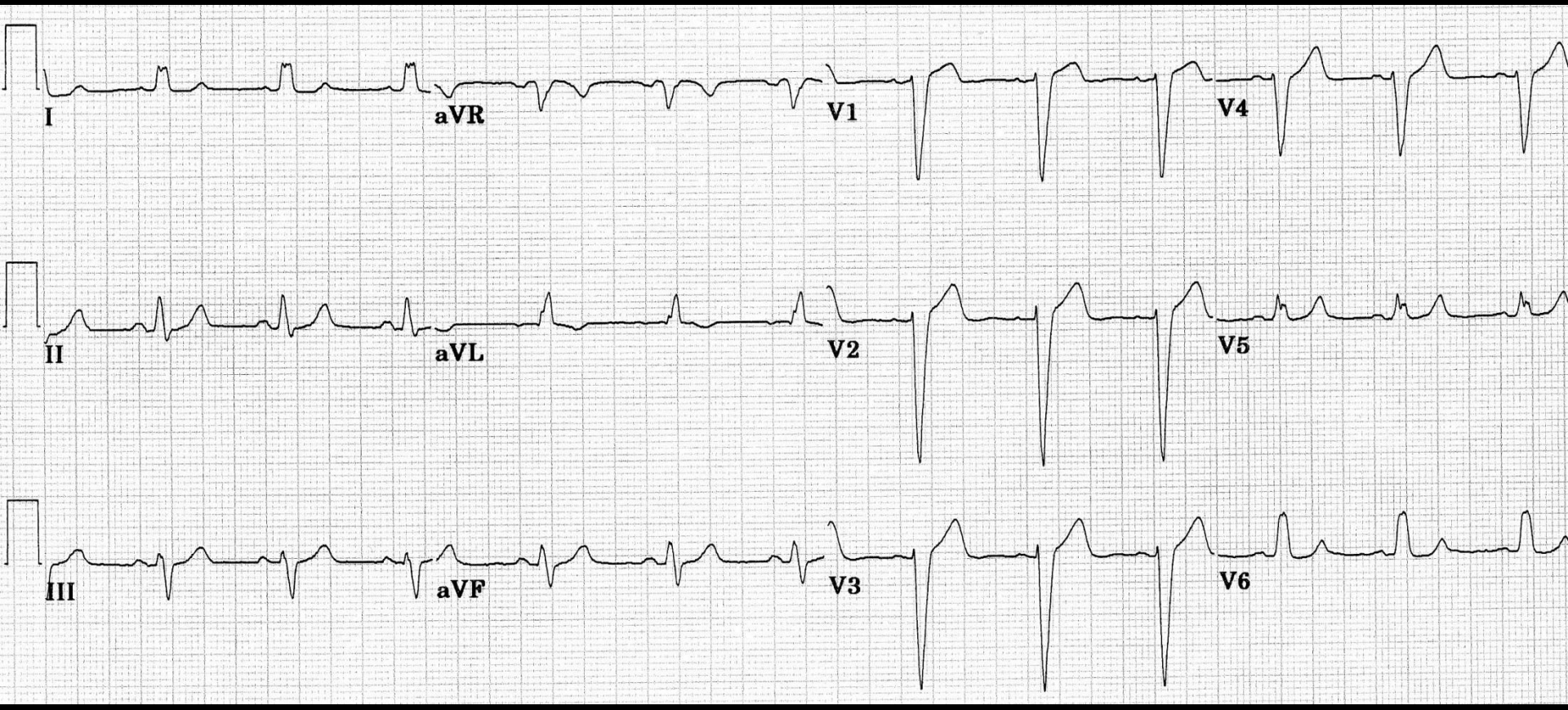
LBBB

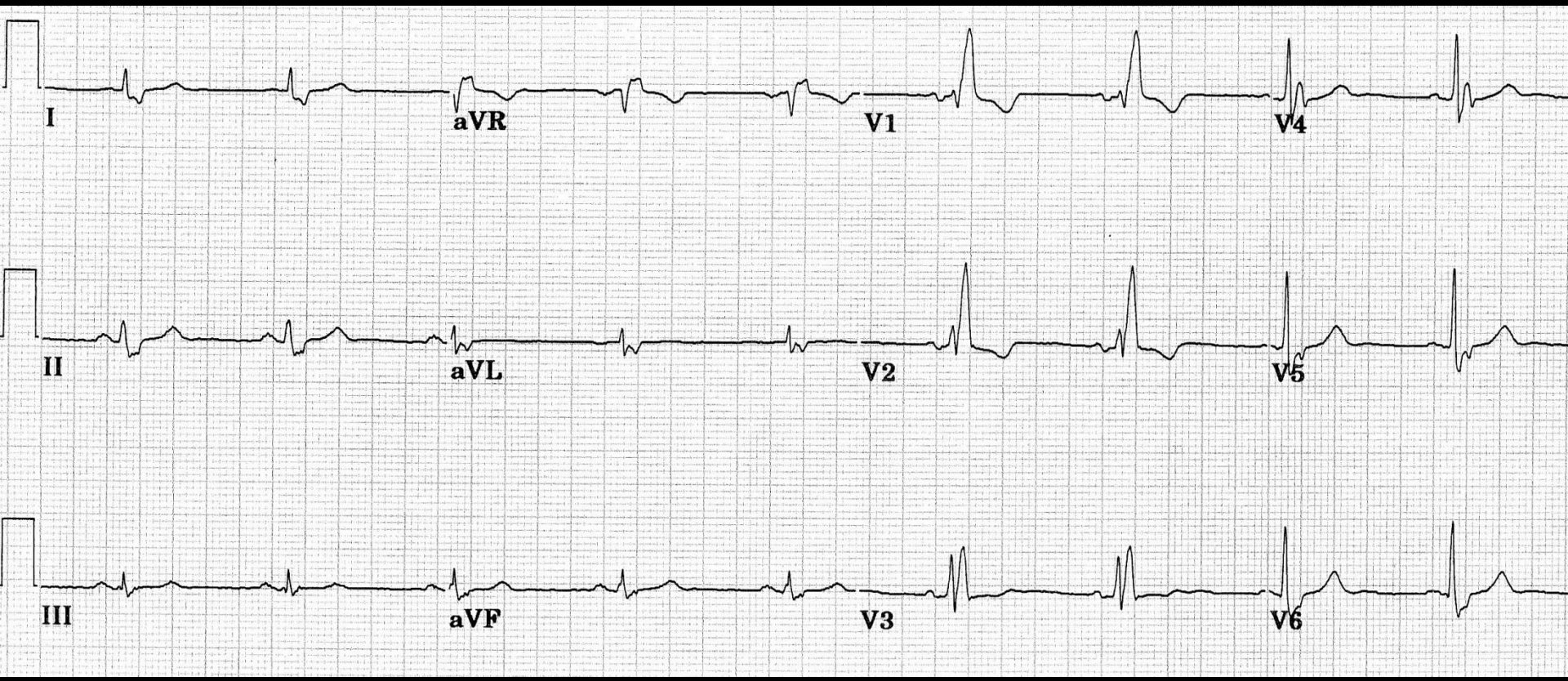


How do I Differentiate between Left and Right BBB?

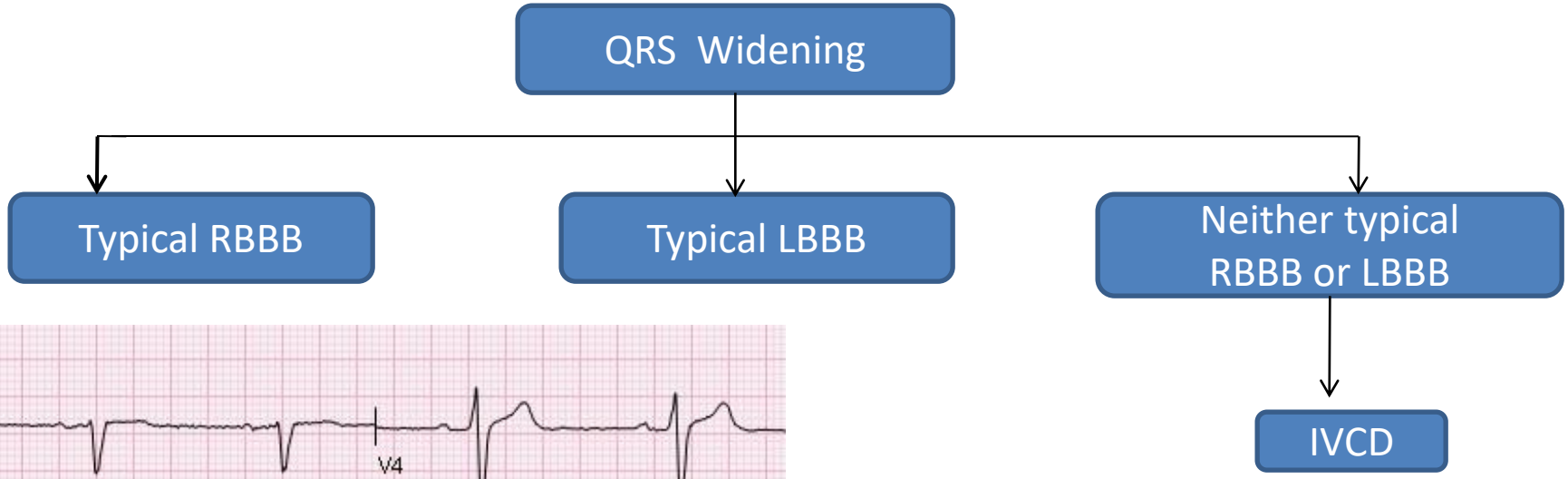
- RBBB
  - QRS ≥ 120 ms
  - Axis is RAD or Normal (can be LAD with LAFB)
  - rSR' pattern V_1 - V_2
  - Slurred S-wave in I and V_6
  - NSSTT changes in V_1 & V_2
- LBBB
  - QRS ≥ 120 ms
  - Axis is Normal or LAD
  - Wide monomorphic S-waves in V_1 – V_4
  - Wide monomorphic R-wave in I and V_6
  - NSSTT changes in most leads

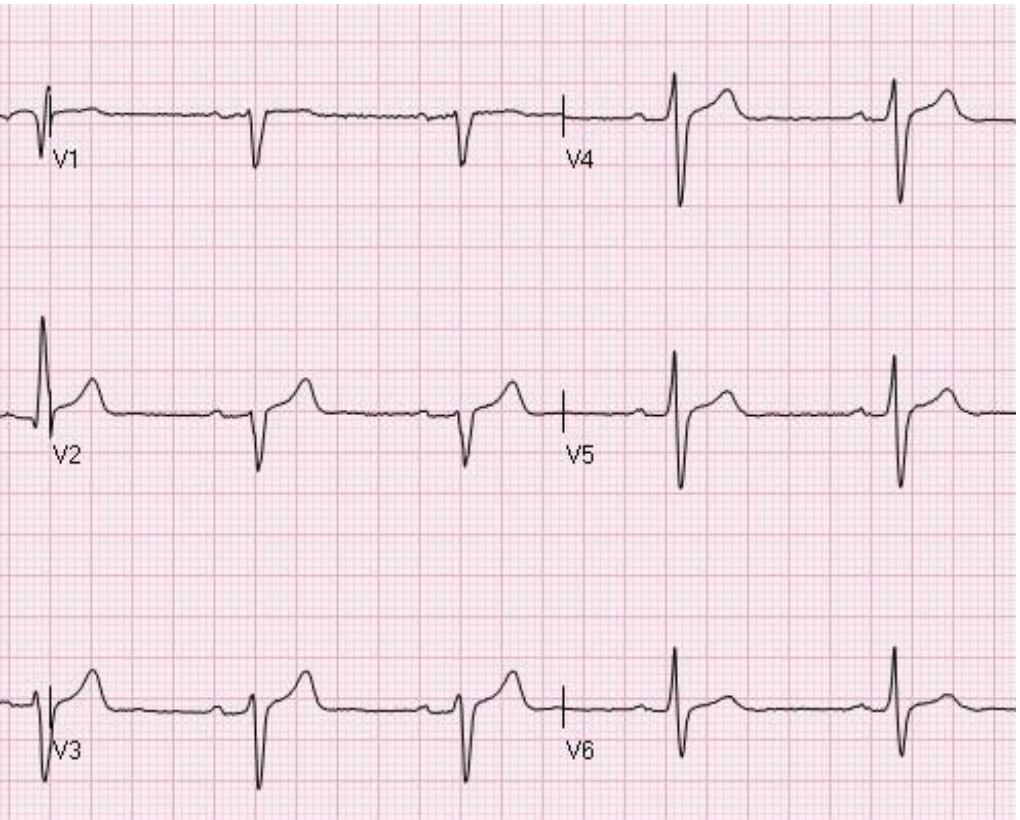
Let's Practice

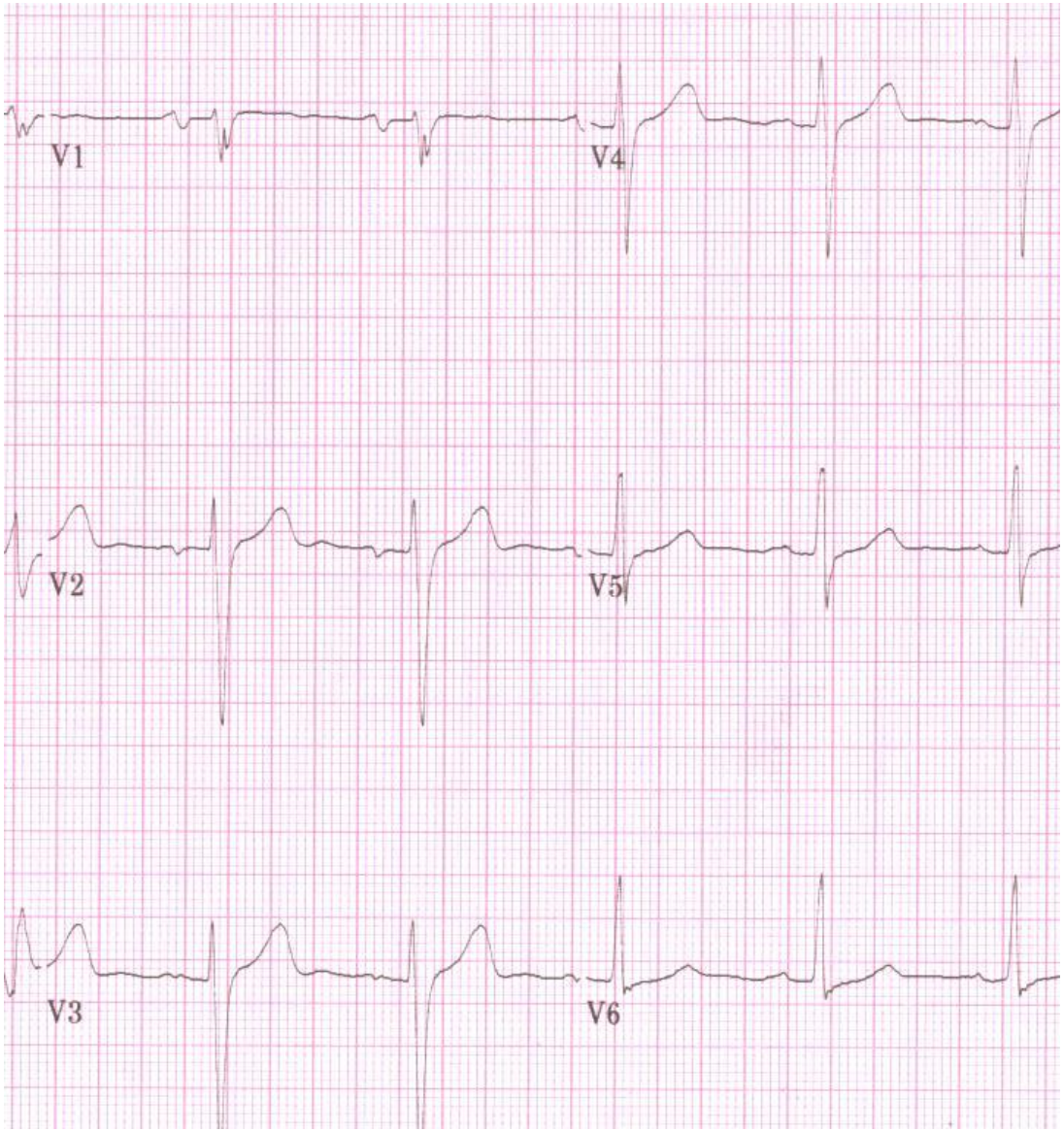

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

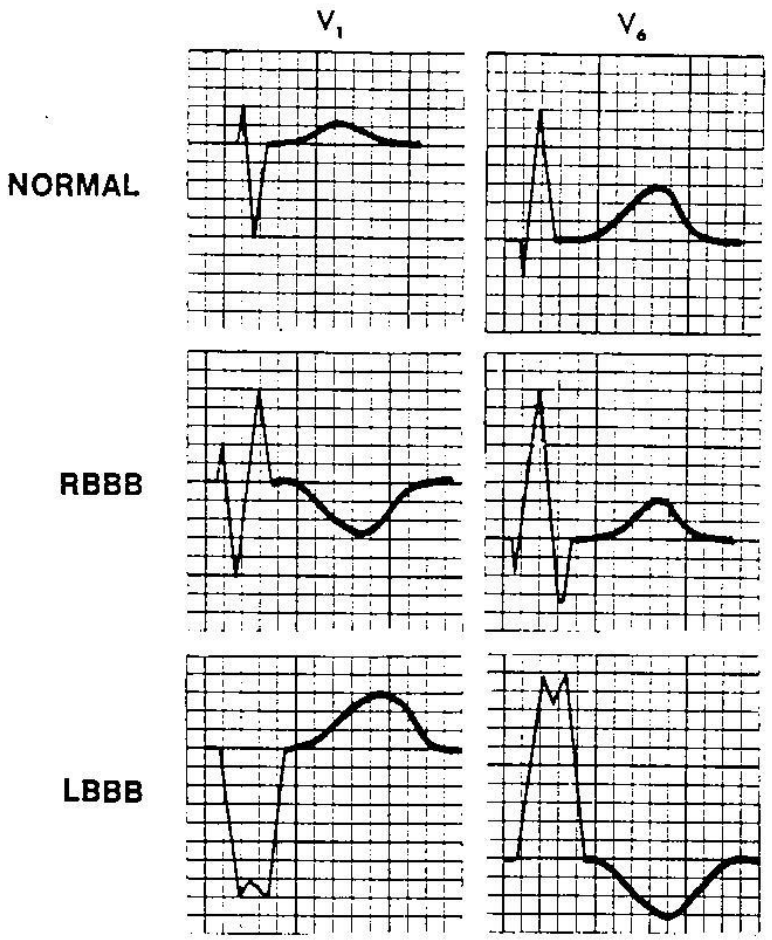

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6

Intraventricular Conduction Delay






V1
V4
V2
V5
V3
V6


V1
V6
NORMAL
RBBB
LBBB

Fascicular Blocks

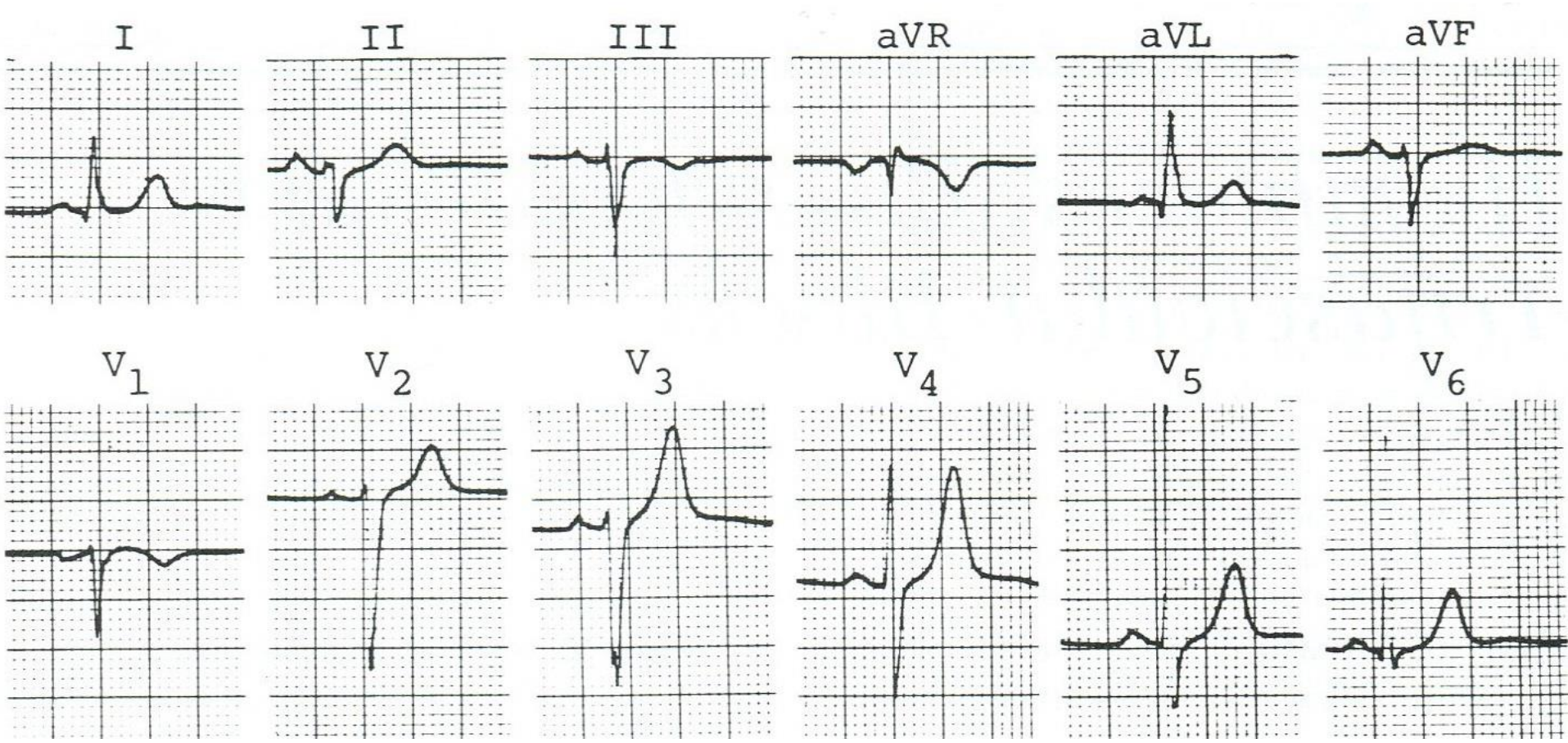
Pathology

- Disruption of the Left Ventricular conduction system, resulting in the ventricles being innervated asynchronously and abnormally. Results in altered vectors produced by the ventricle.

Left Anterior Fascicular Block

- ECG Criteria:
  - Axis ≥ 45°
  - No other cause of axis deviation present
  - Normal QRS duration (100 – 110 ms)
  - Small Q in lead I, small R in lead III (q1r3 pattern)

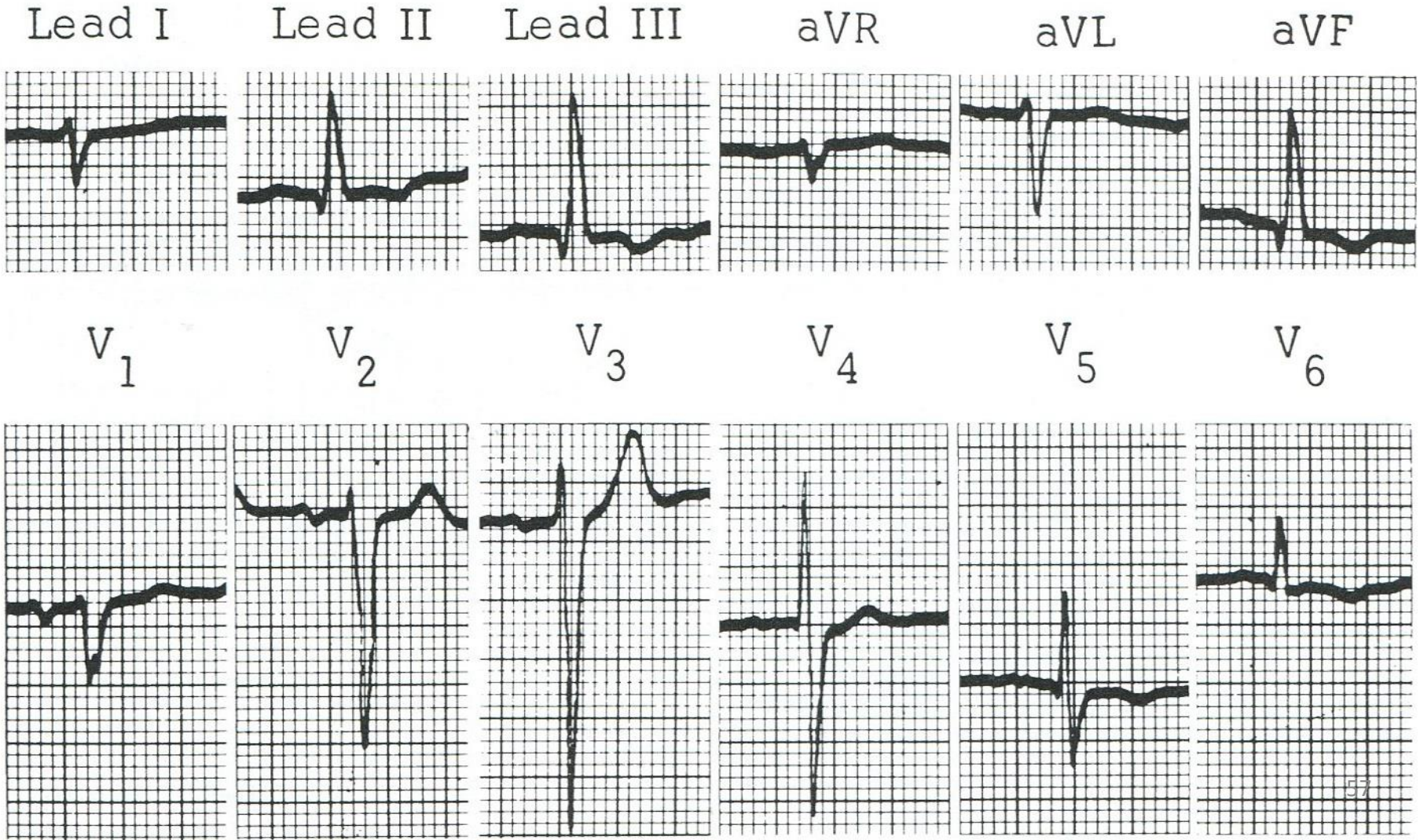
Left Anterior Fascicular Block



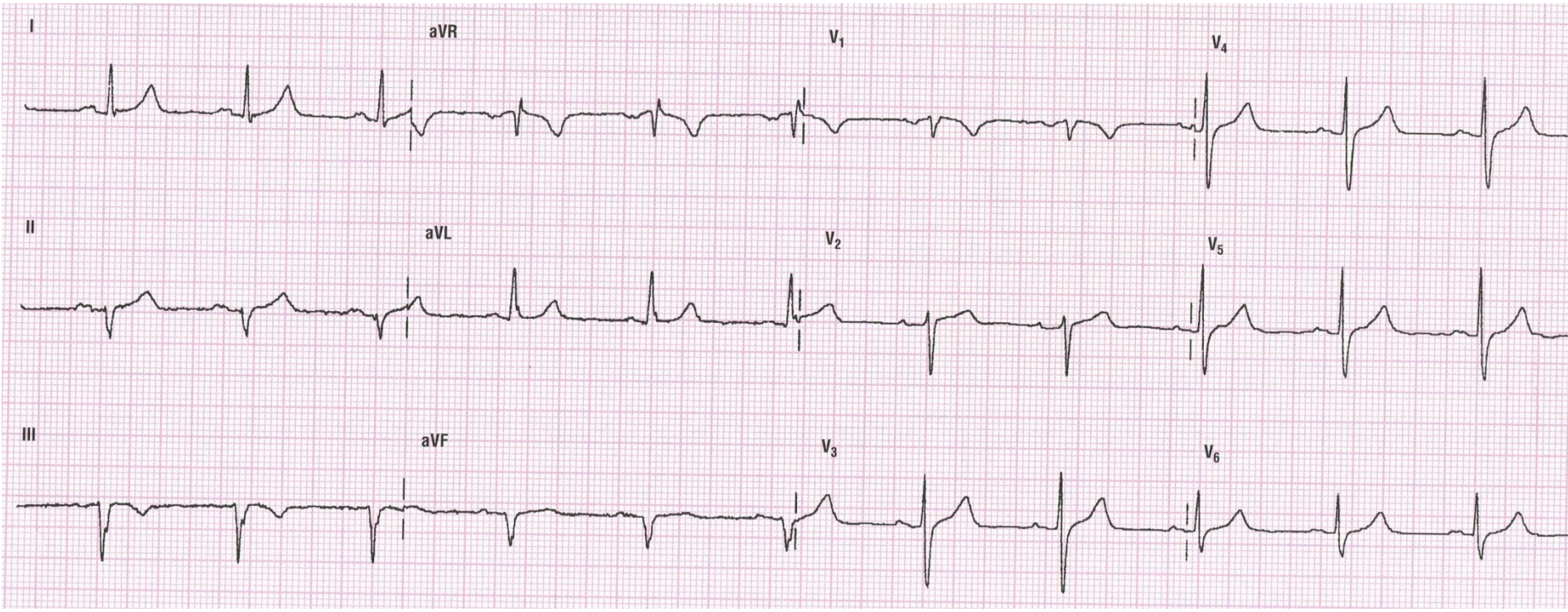
Left Posterior Fascicular Block

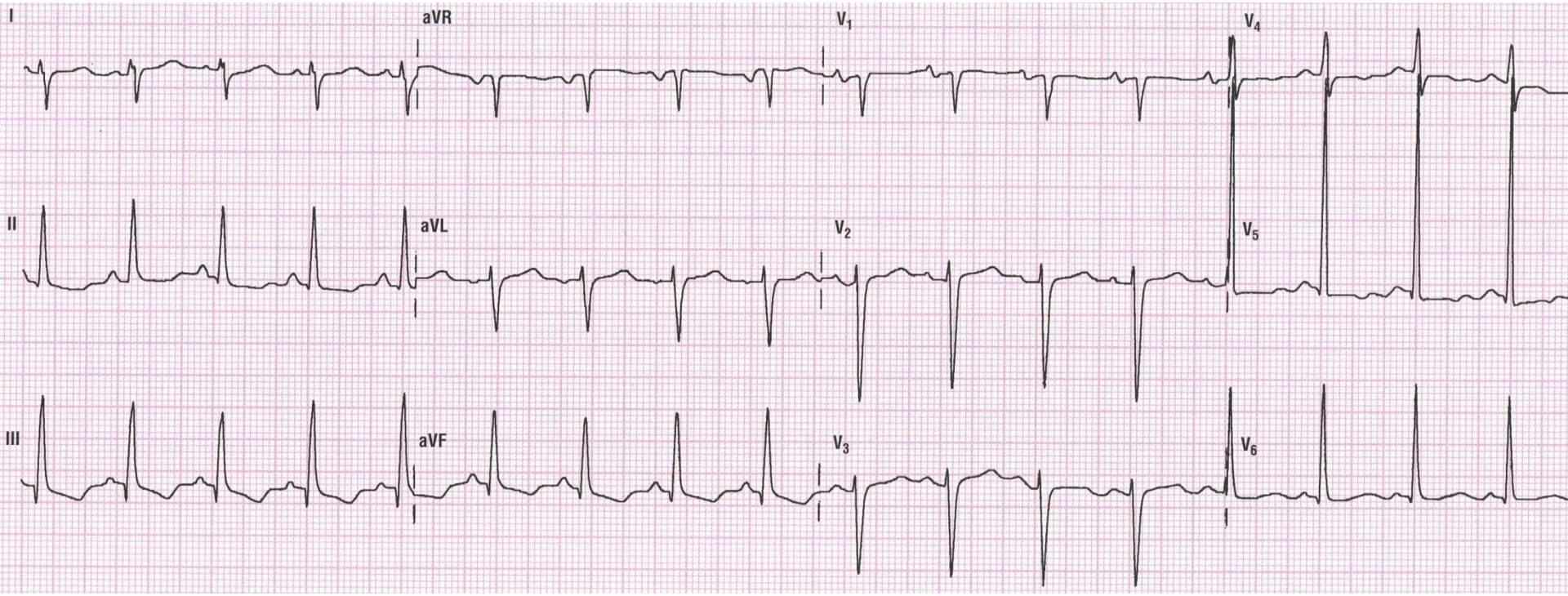
- ECG Criteria:
  - Axis ≥ 100°
  - No other cause of axis deviation present
  - Normal QRS duration (100 – 110 ms)
  - Small R in lead I, small Q in lead III (r1q3 pattern)

Left Posterior Fascicular Block



Let's Practice





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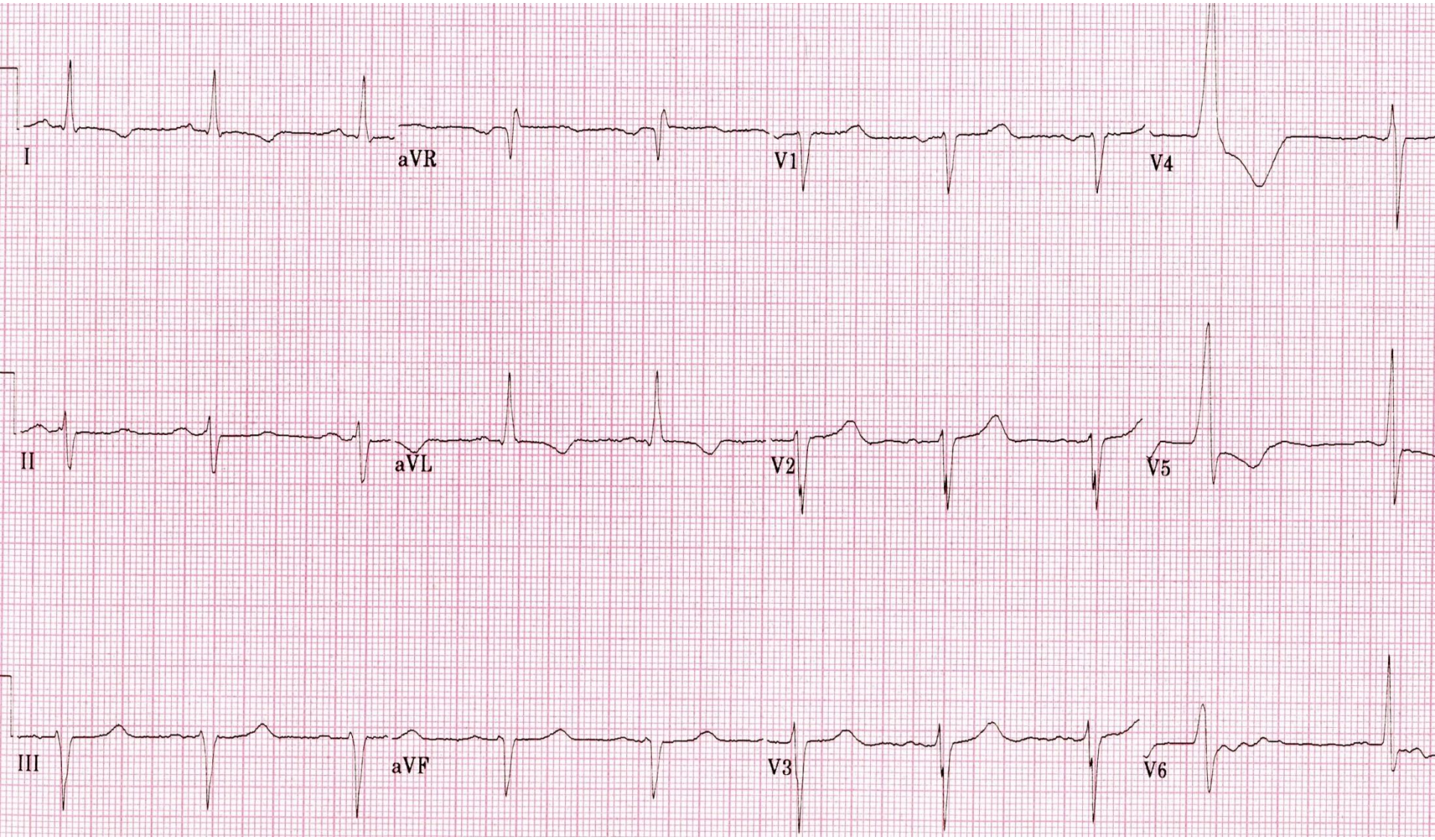

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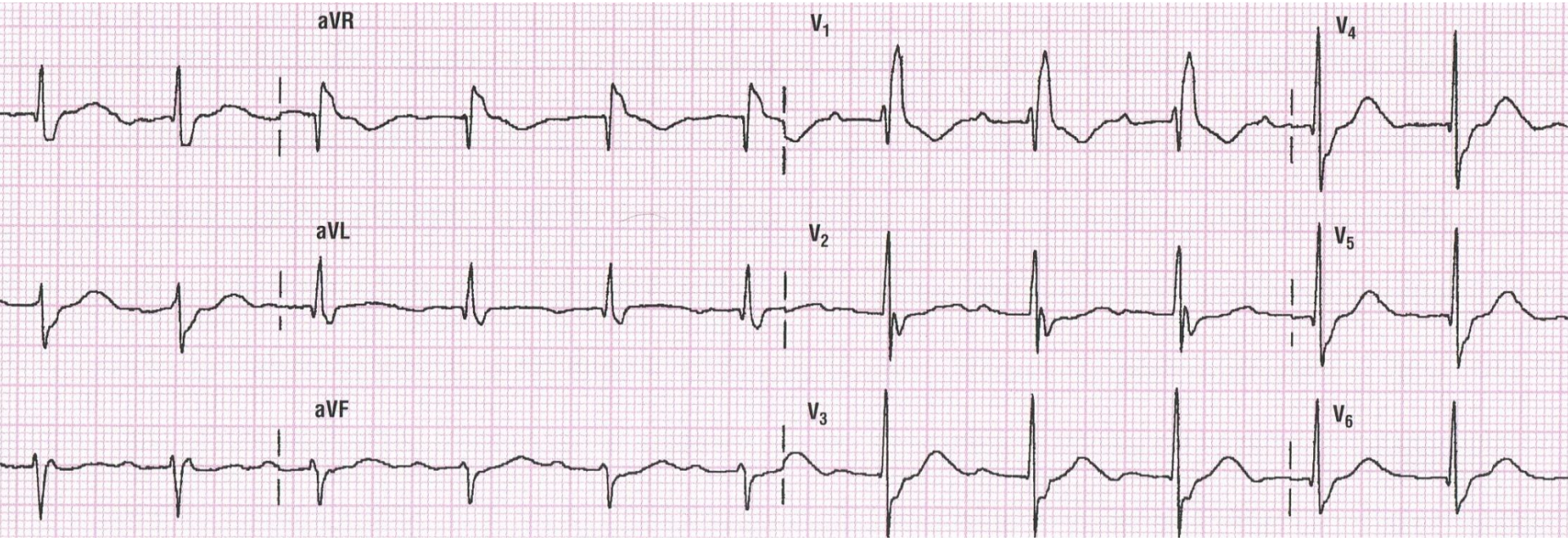
Bifascicular Blocks

- Involves RBBB with either LAFB or LPFB
- RBBB with LAFB is very common and stable
- RBBB with LPFB is also more common than LPFB by itself and is more unstable
- The RBBB is the dominant ECG finding, associated with an axis deviation


aVR
V1
V4
aVL
V2
V5
aVF
V3
V6

LEFT VENTRICULAR HYPERTROPHY

Left Ventricular Hypertrophy

- Area that causes confusion
- Multiple criteria exists for diagnosis
- Limited sensitivity using ECG (60%) at best
- Diagnosis is enhanced by clinical correlation

Left Ventricular Hypertrophy

- 30% of ED patients with CP
- Variable ECG criteria
- Age cut off

LVH ECG Computerized Algorithms Criteria

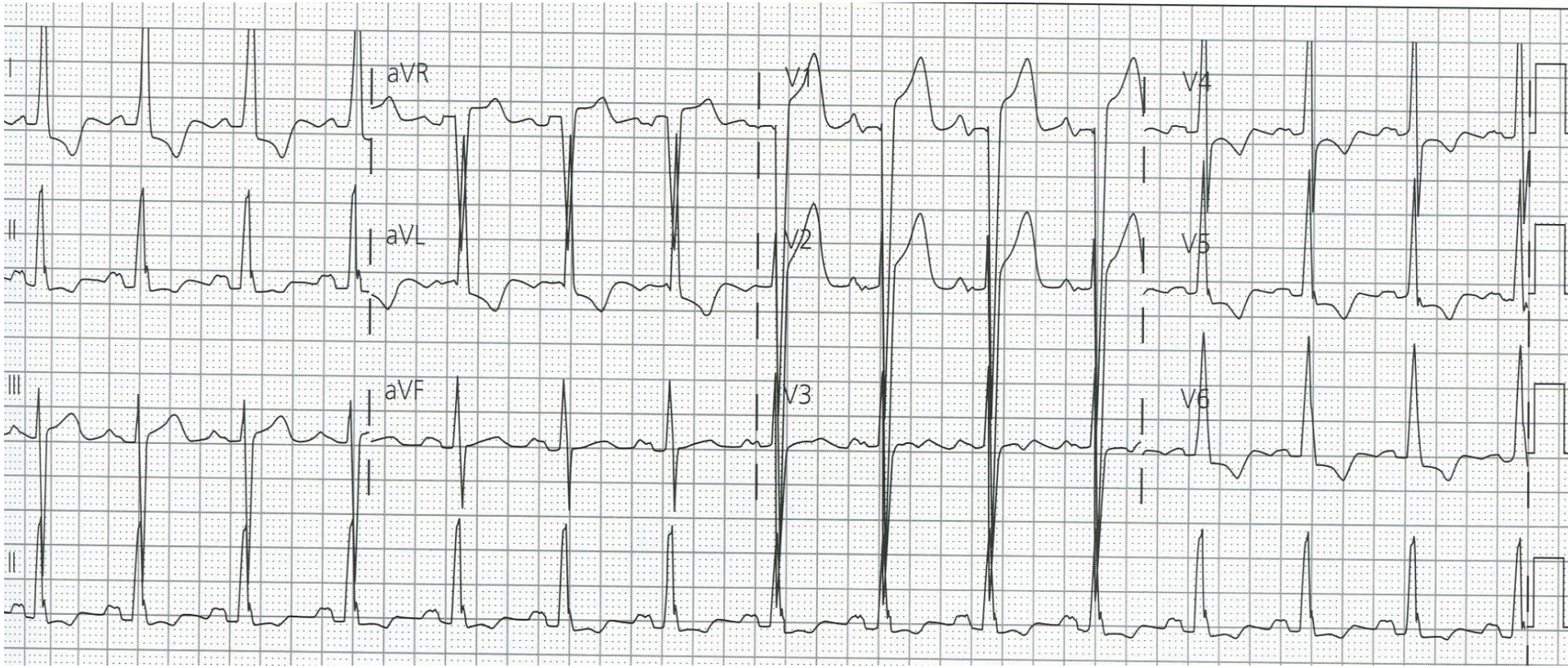
1. QRS < 120 ms, and one or more of the following
2. R wave in lead I + S wave in lead III > 25 mm
3. R wave in aVL > 11 mm
4. R wave in aVF > 20 mm
5. S wave in aVR > 14 mm
6. R wave in V5 or V6 > 26 mm
7. R wave in V5 or V6 + S wave in V1 > 35 mm

Simple LVH Rule

Rule of 35

The amplitude of the S wave in V1 or V2 plus the amplitude of the R wave in V5 or V6 > 35 mm, in a patient of age > 35

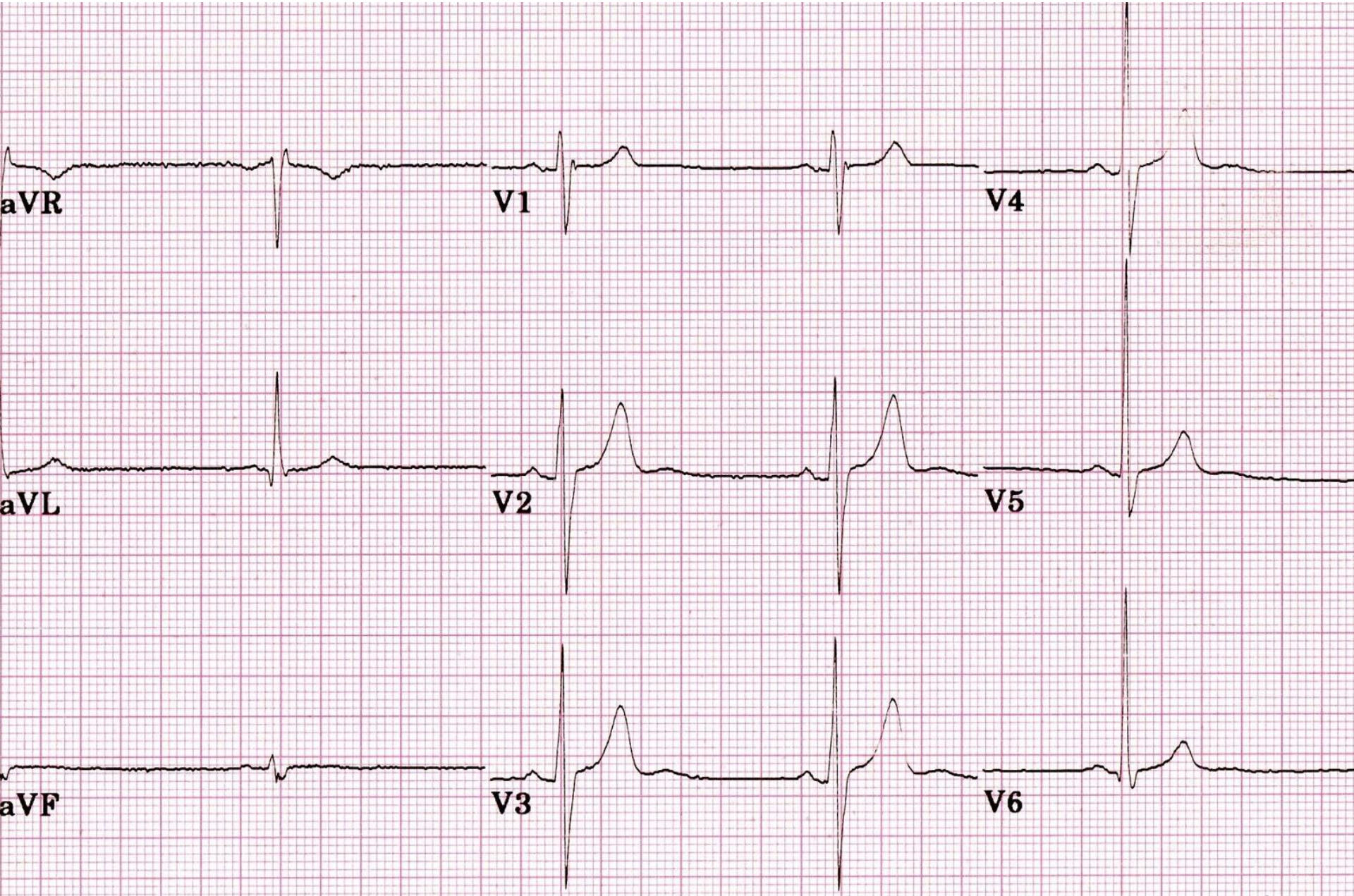
Left Ventricular Hypertrophy



LVH Simplified Criteria

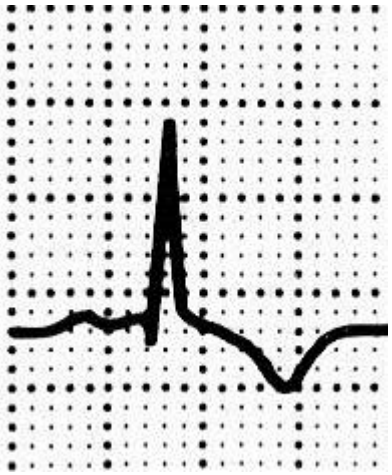
- 1. Deepest S wave in Lead V1 or V2 plus
  Tallest R wave in lead V5 or V6 ≥ 35
- 2. R wave in lead aVL ≥ 12
- 3. Patient ≥ 35 years old
- 4. “Strain” pattern present

Adapted from Sokolow-Lyon criteria.

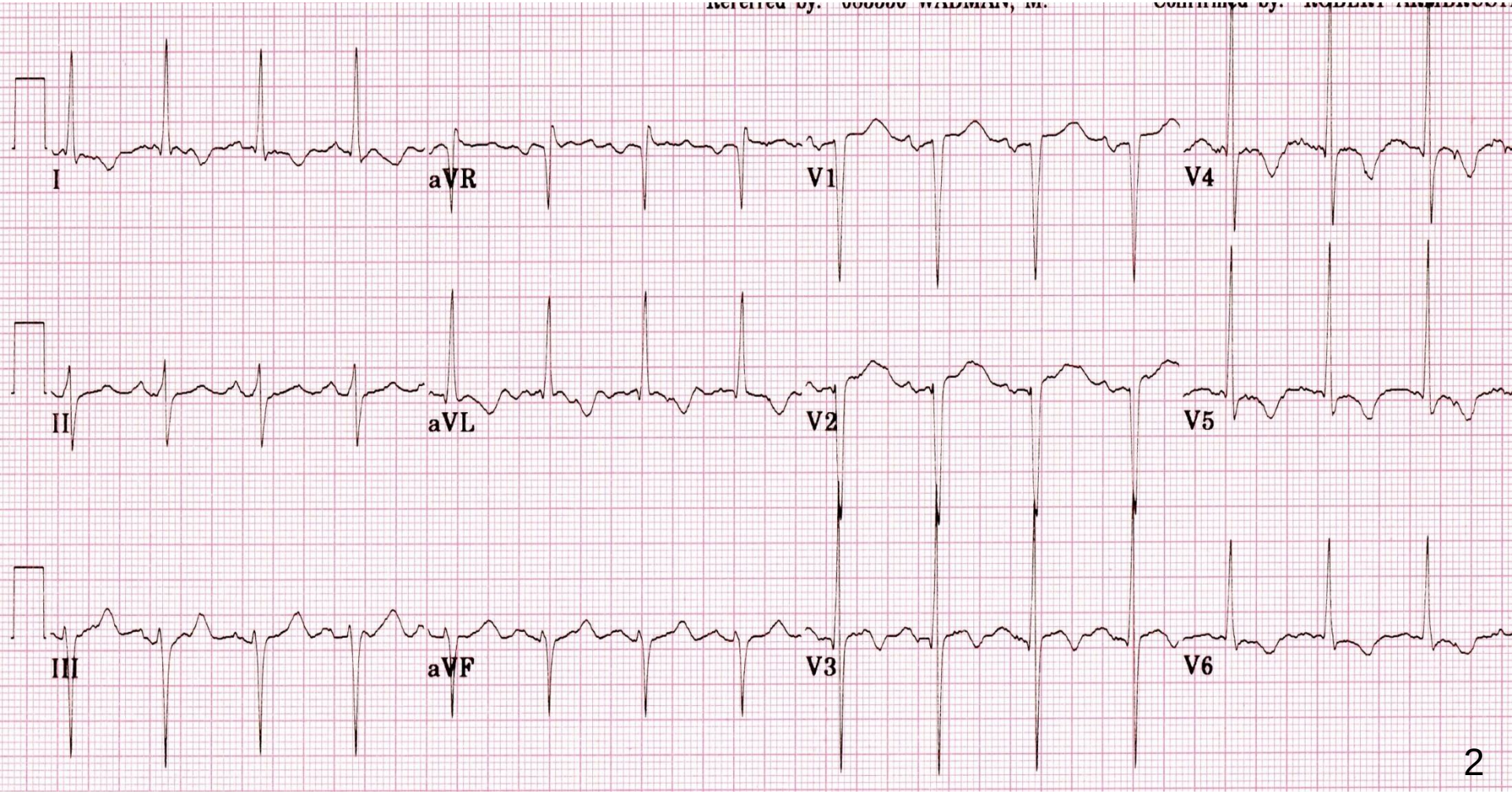

aVR
V1
V4
aVL
V2
V5
aVF
V3
V6

Strain Pattern

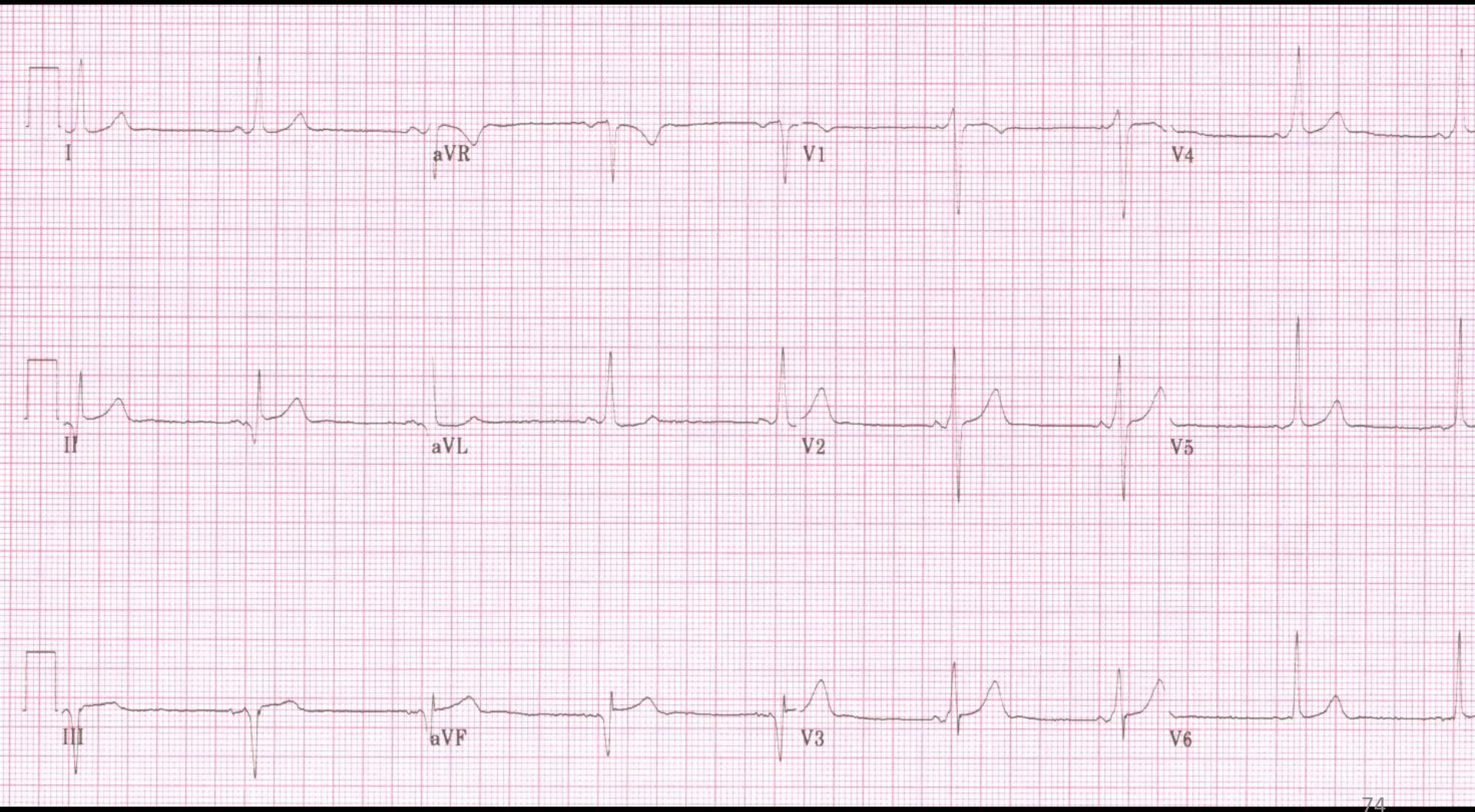
- Strain pattern shows asymmetric ST segment depression and T wave inversion
- ST segment manifests a slow downward decline with a much more rapid return to baseline.



Let's Practice

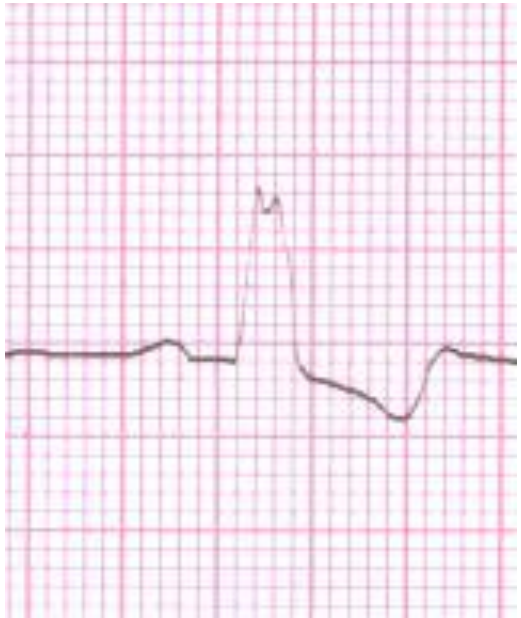

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
2

WPW

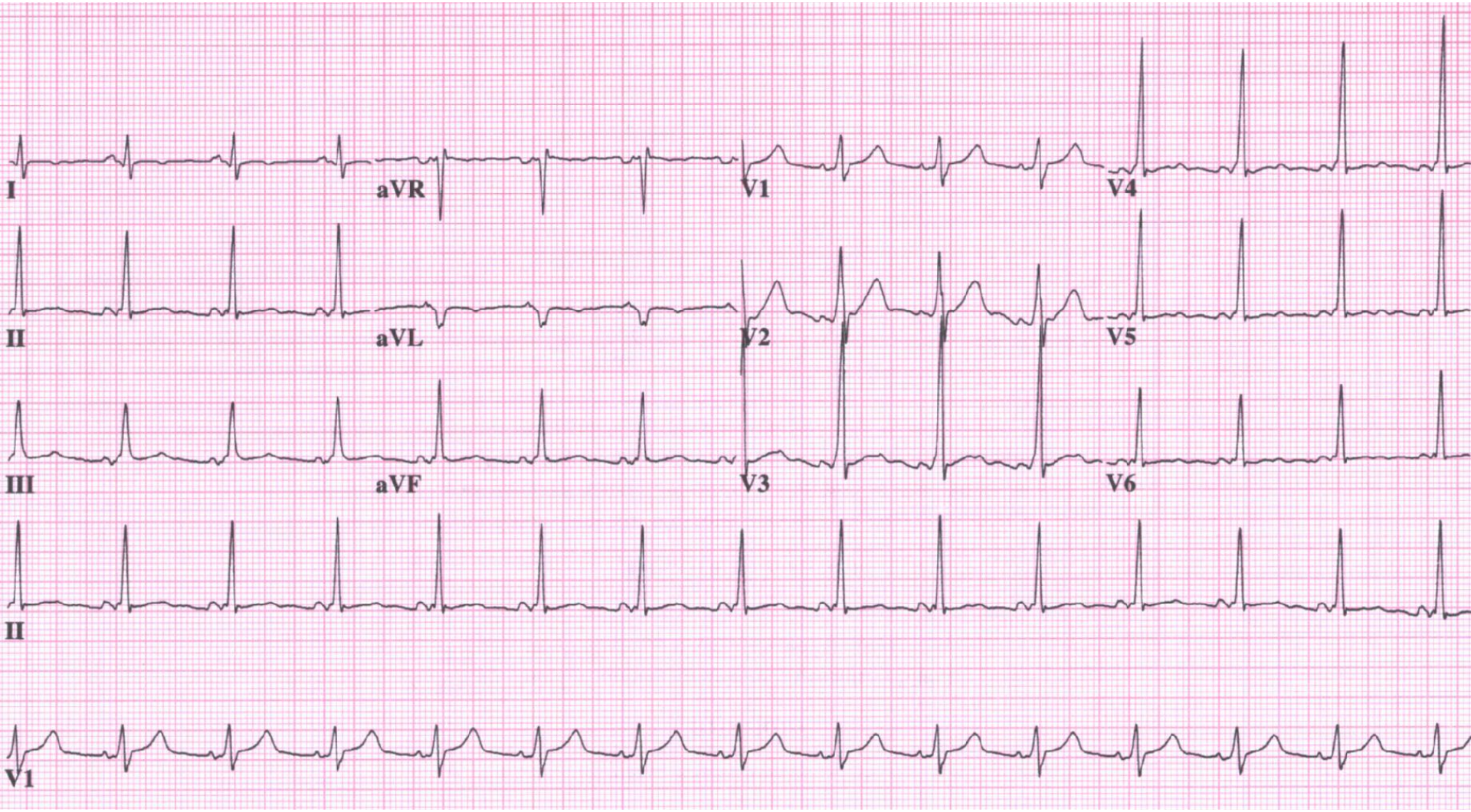


WPW Exception

- Diagnostic criteria for WPW
  - PR interval < 120 ms with a normal looking P-wave
  - Wide QRS complex: 110 ms or greater
  - Presence of “delta-wave” (initial slurring or QRS)
  - Secondary ST-T changes




V6

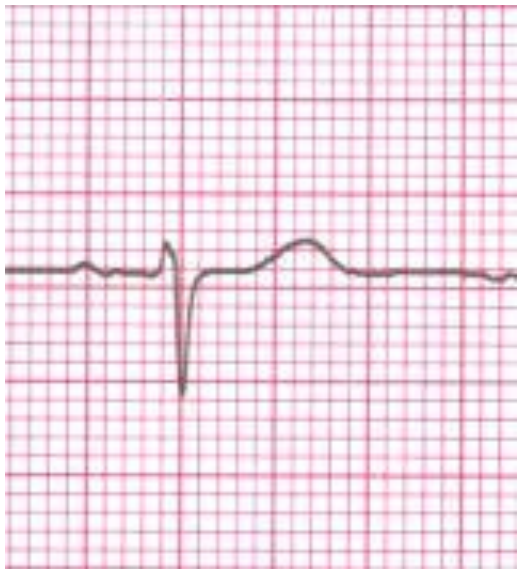

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
V1

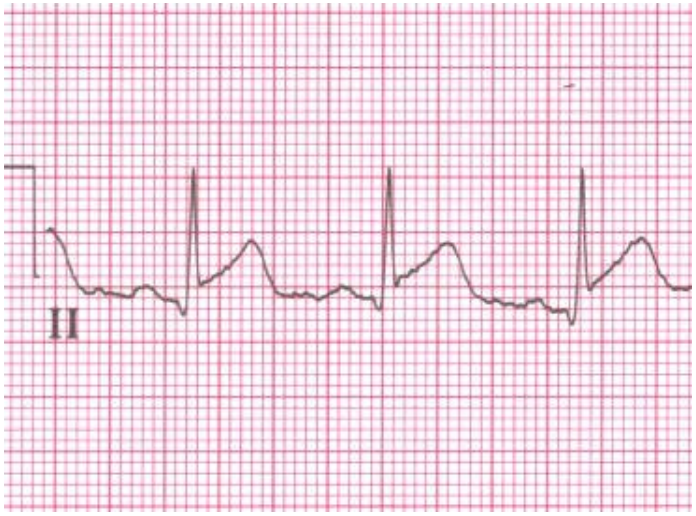
MYOCARDIAL INFARCTION

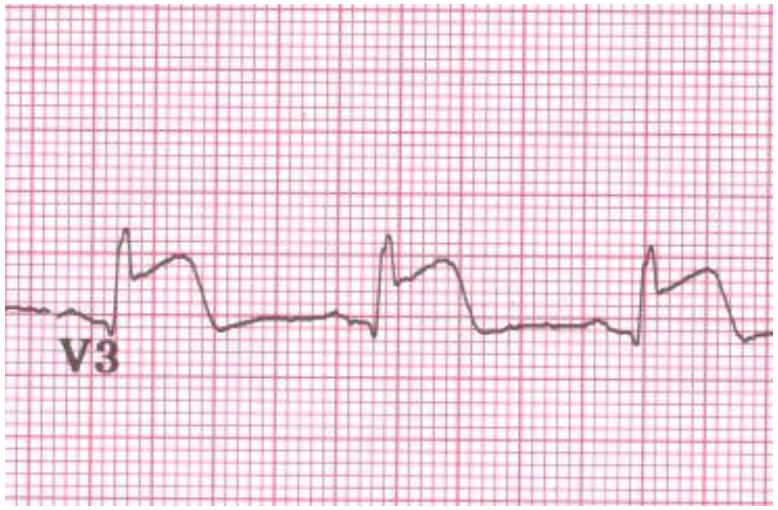
Myocardial Infarction

- Area fraught with interpretation issues
- Will focus only on STEMI (ST elevation MI)
- A normal ECG does NOT necessarily rule out an impending MI
- If available, review old ECGs
- Evaluate the entire 12-lead ECG

ST Segment





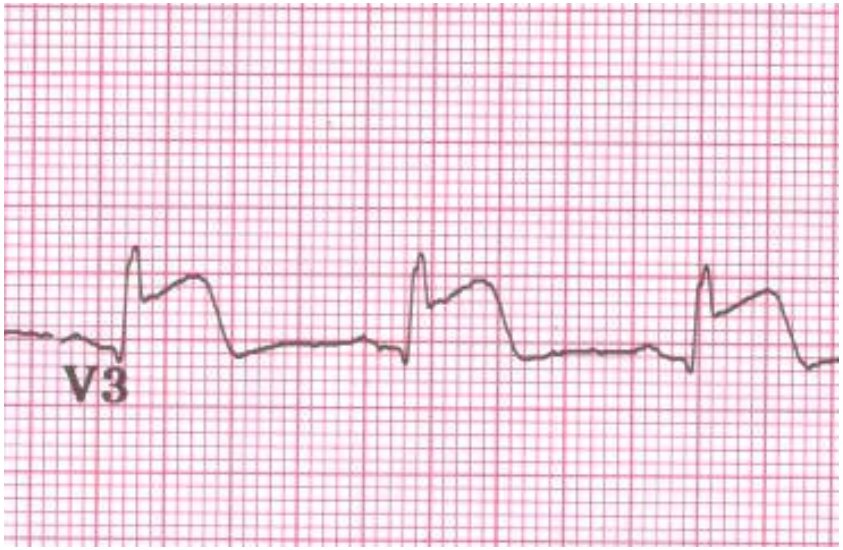


Key Criteria for Diagnosis

- Ischemia
  - ST segment depression (2 mm or greater)
  - T-wave inversion (symmetrical)
- Differentiate from NSTEMI

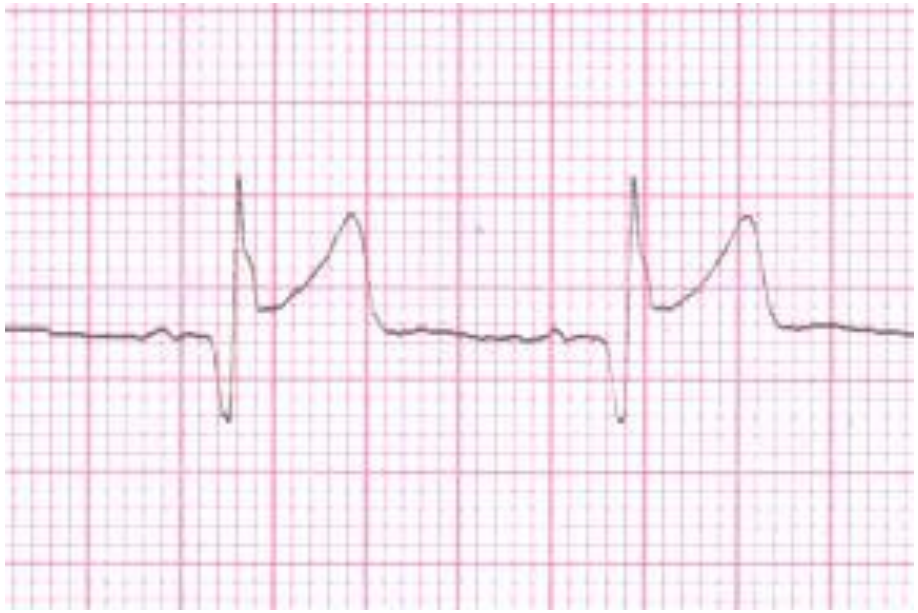
Key Criteria for Diagnosis

- Injury Pattern
  - ST segment elevation (1 mm or greater)
  - T-wave peaks initially then inverts later



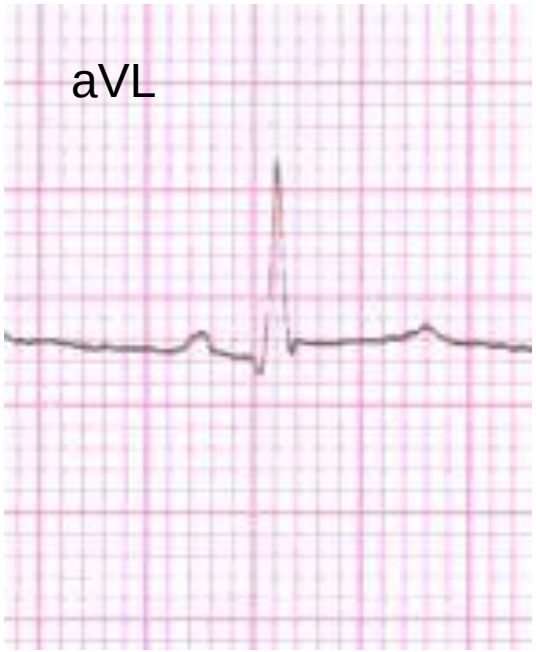
Key Criteria for Diagnosis

- Infarction Pattern
  - Presence of Significant Q-waves
    - Defined as:
    - 1) Q-wave that is 1/4 total height of QRS
    - 2) Wider than 40 ms



Insignificant Q-waves

- Do not meet the criteria for significance
- Typically found in following leads:
  - Leads I, aVL, $V_4 – V_6$ (Septal Q-waves)



Other Important Information

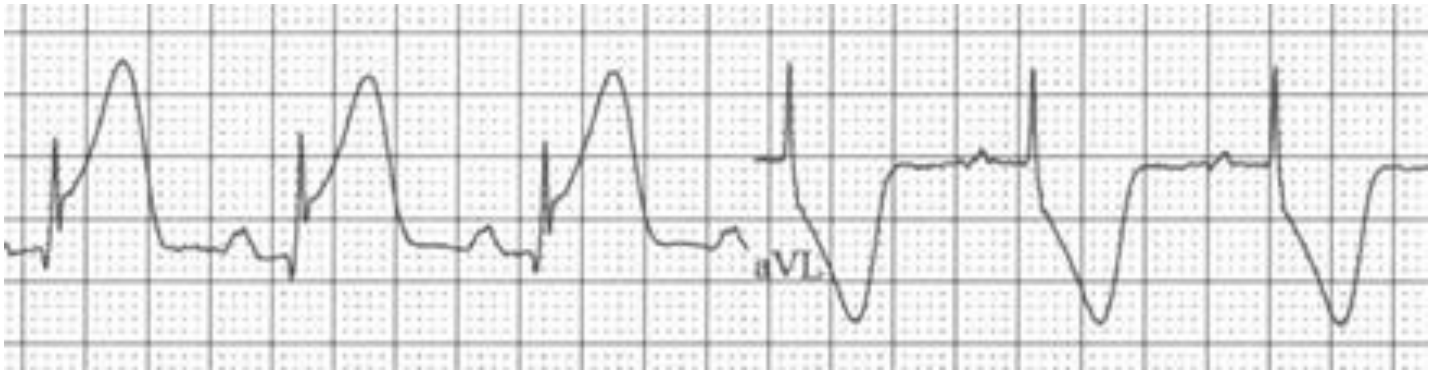
- Timing of MI
  - Based on presence of ST elevation and/or Q waves
  - Current terminology: Acute, Age indeterminate
  - Assess only ST and T-wave changes
  - Q-waves can often mislead

Location of MI

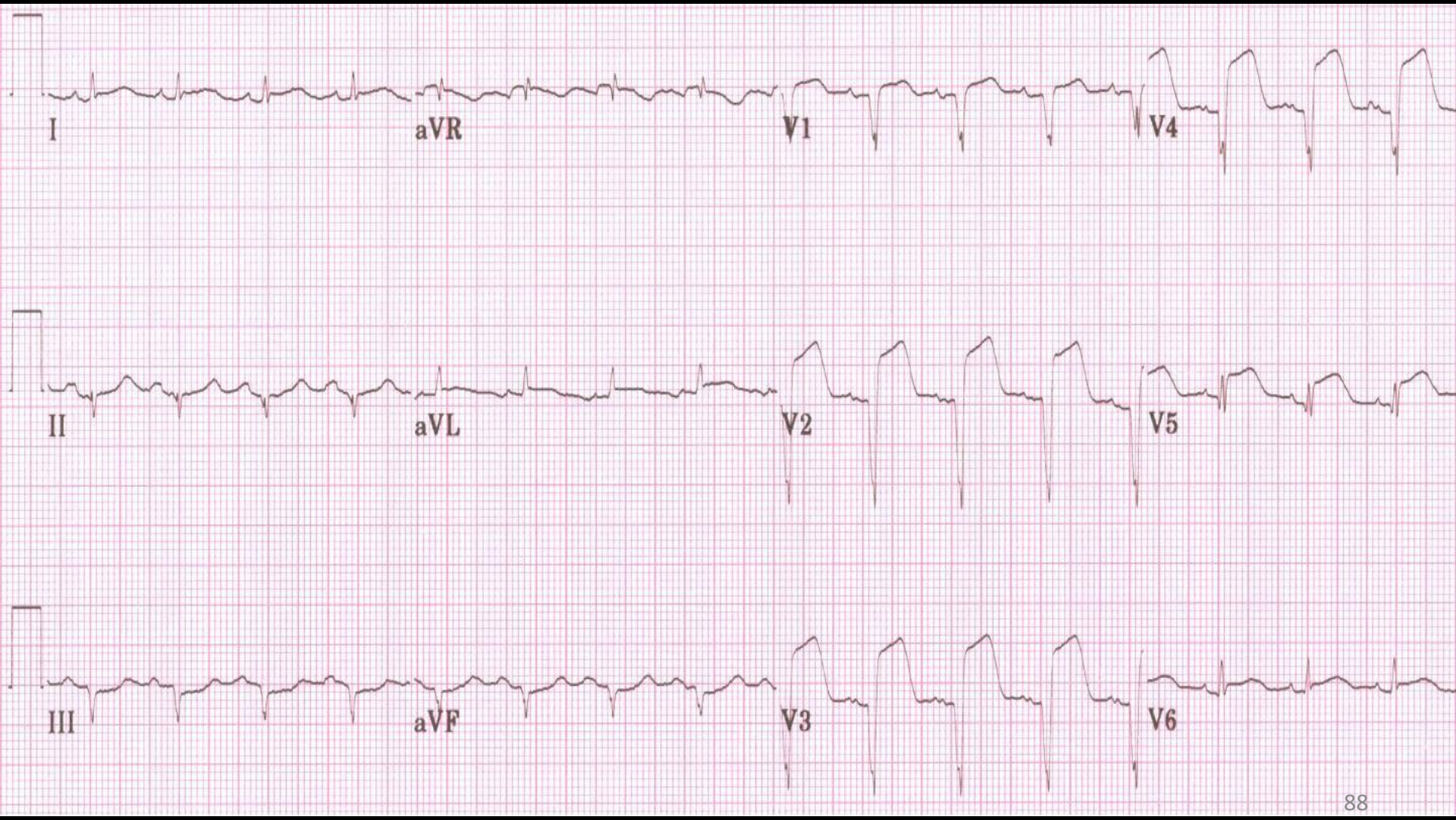
Location	Direct Changes	Reciprocal Changes	Artery Affected
High Lateral	I, aVL	II, III, aVF	Circumflex
Inferior	II, III, aVF	All other leads	RCA, Post. desc.
Anteroseptal	V_1 , V_2 , V_3	II, III, aVF	LAD
Anterolateral	V_4 , V_5 , V_6	II, III, aVF	LAD, Circumflex
Posterior	----------	V_1 - V_2	Distal Circumflex or Post. Descending

Reciprocal Changes

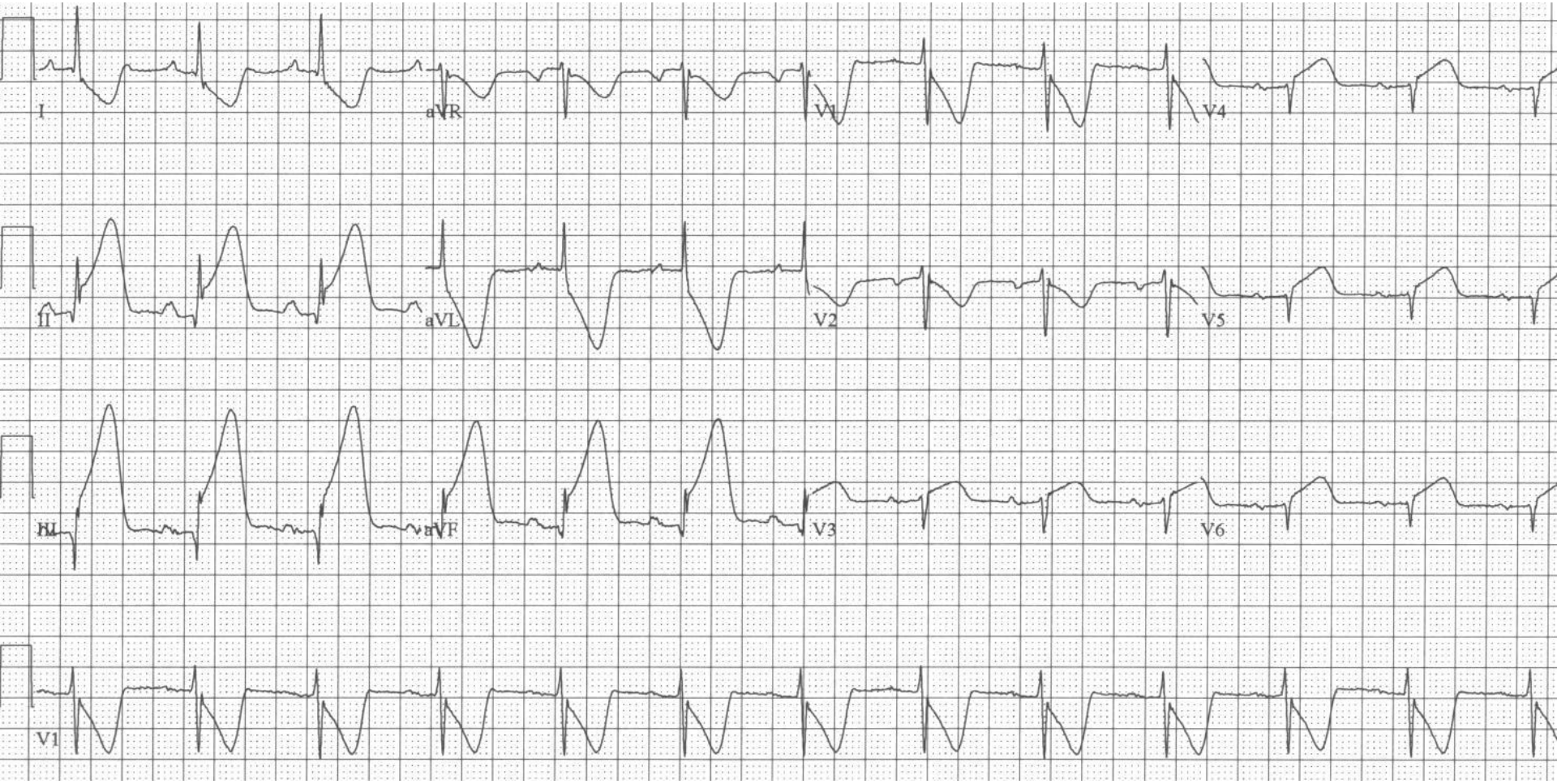
- Often associated with Acute MI, but not always
  - Usually occur very early in process
  - Do not last very long (hours)
  - Are represented by opposite ST-T changes



Myocardial Infarction



Let's Practice



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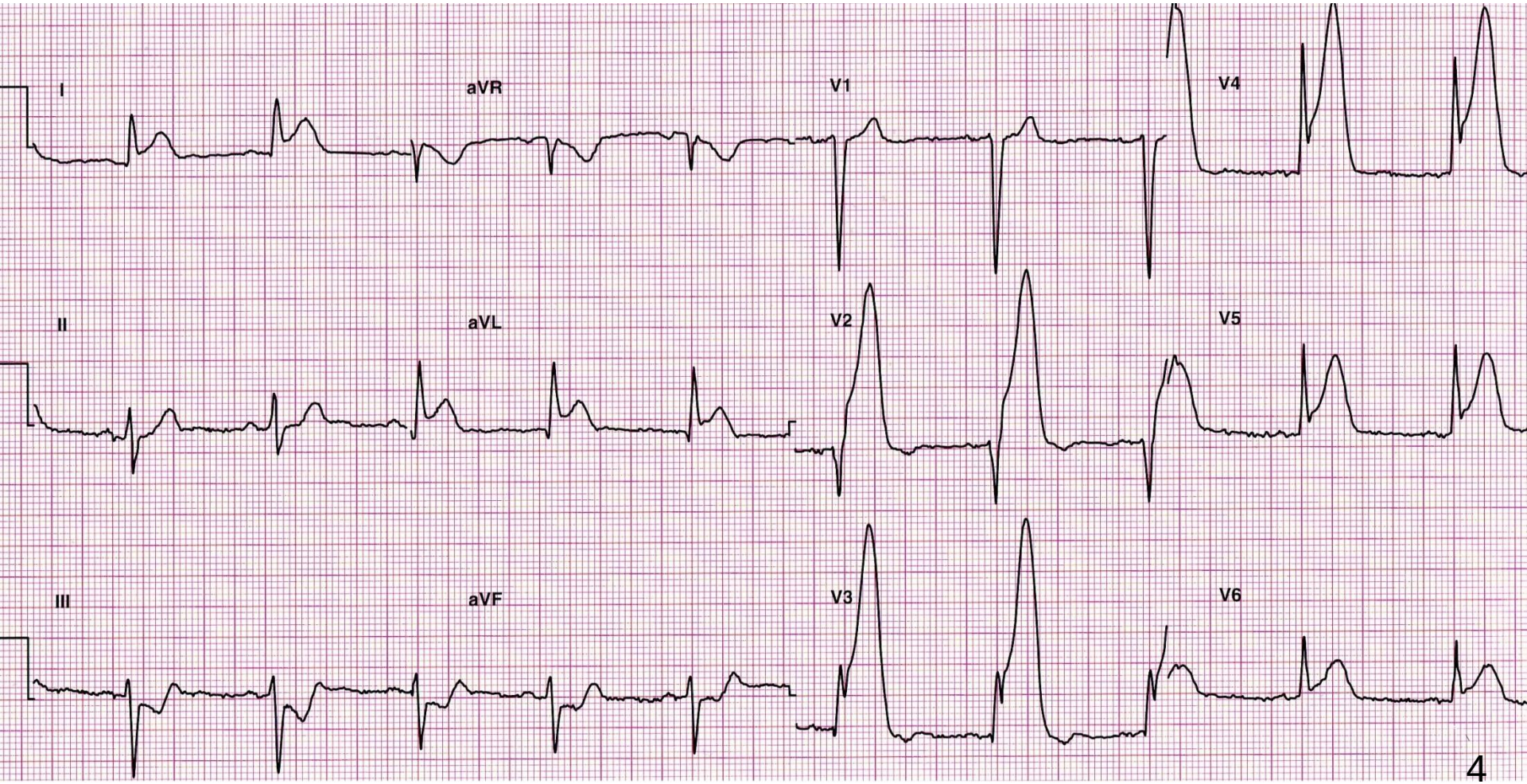
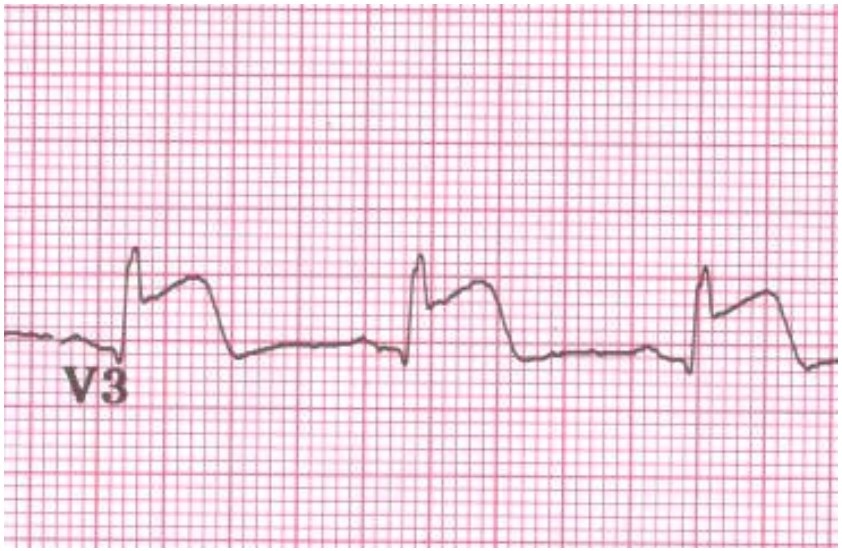

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
4

Differential Diagnosis of ST-Elevation

- Acute STEMI
- Printzmetal's Angina
- Ventricular Aneurysm
- Pericarditis
- Normal Variant
  - Early Repolarization



Causes of ST Elevation

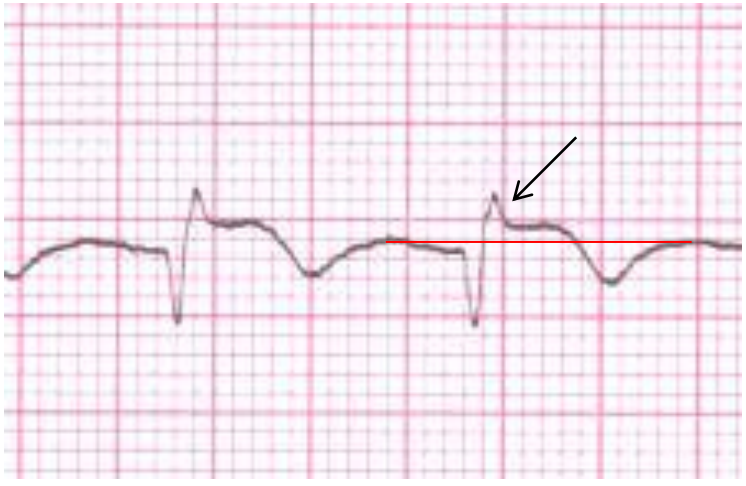
- Associated with chest pain in the ED:
  - Acute Myocardial Infarction – 15-31%
  - Left Ventricular Hypertrophy – 28-30%
  - Benign Early Repolarization – 19%
  - Myo or Pericarditis
  - Bundle Branch Blocks
  - Ventricular Aneurysm

Brady WJ, Syverud SA, Beagle C, et al. Electrocardiographic SE: the diagnosis of AMI by morphologic analysis of the ST segment. Acad Emerg Med 2001;8:961-7

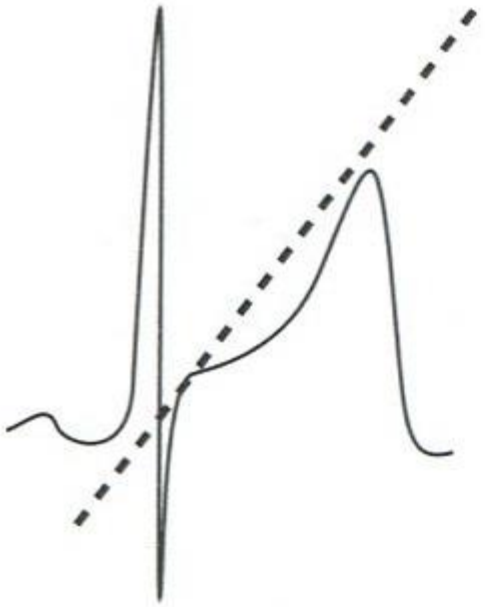
ST Elevation

- Definition
  - New ST elevation at the J point in two or more contiguous leads with the cut off points:
  - ≥ 0.2 mV (2mm) in men or ≥ 0.15mV in women in leads V2-V3
  - and/or ≥ 0.1 mV in men and women in other leads

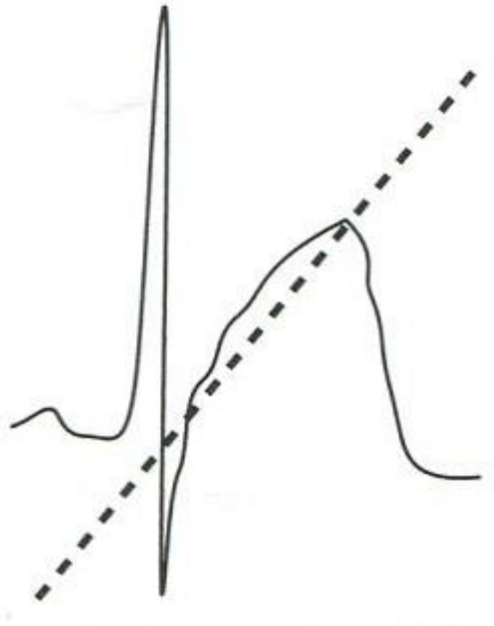
Basics of ST Segment



ST Segment Morphology



Concave
STE



Convex STE

Differential Diagnosis of ST Elevation

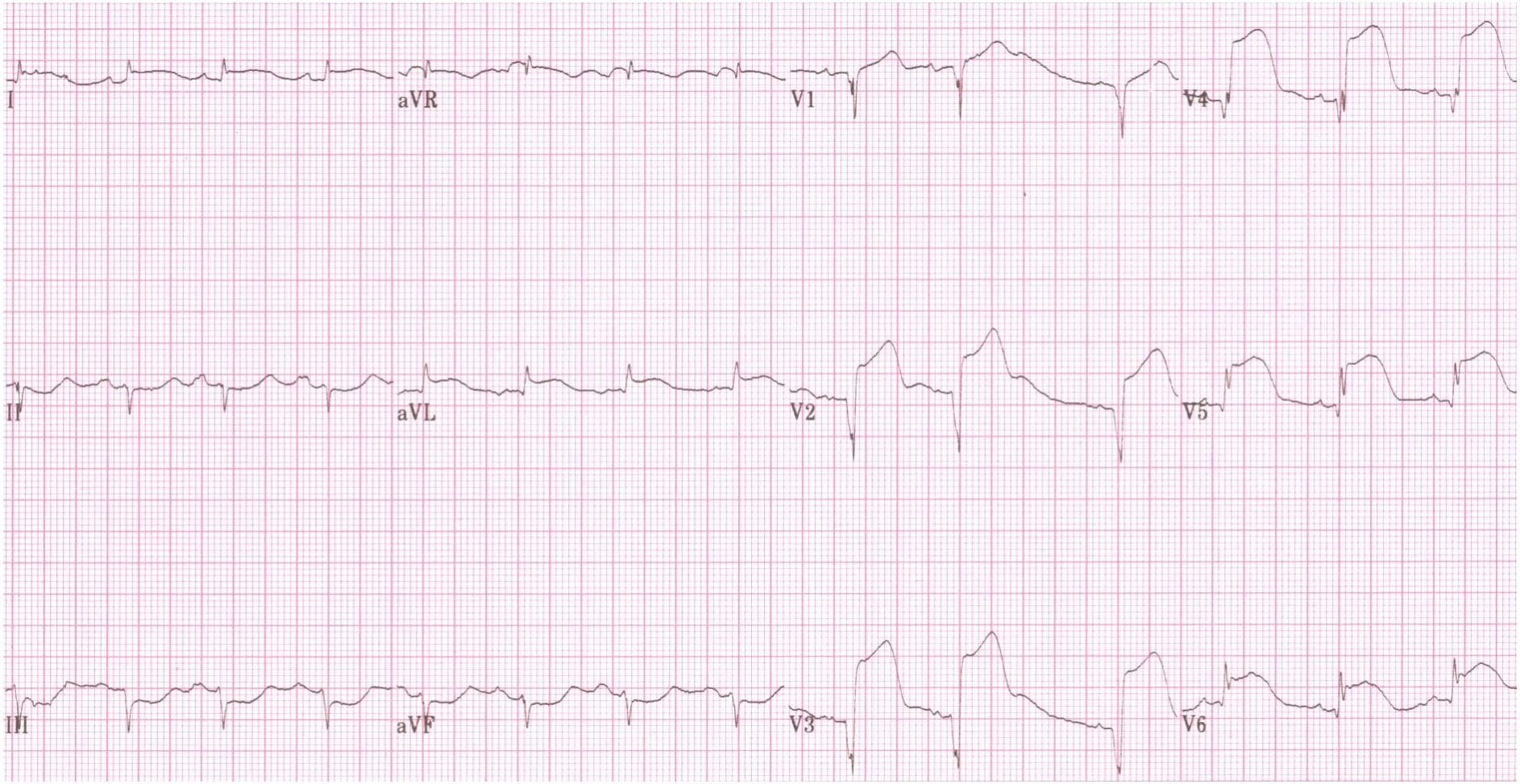
- Relatively Common
  - Acute myocardial Infarct
  - Benign early Repolarization
  - Acute pericarditis
  - Left ventricular hypertrophy
  - Bundle branch block
  - Ventricular paced rhythms
  - Hyperkalemia
  - Hypothermia
- Relatively Uncommon
  - Brugada syndrome
  - Ventricular aneurysm
  - CNS injury
  - Pulmonary embolism
  - Myocarditis
  - Cardiomyopathy
  - Post-cardioversion
  - Cardiac contusion

Summary

- Three important Take Home points!

- Develop a “system” to evaluate ECGs
- Practice does Improve Interpretative abilities
- Overread Computer ECGs
- Work with a good reference to improve skills

Unknown #1



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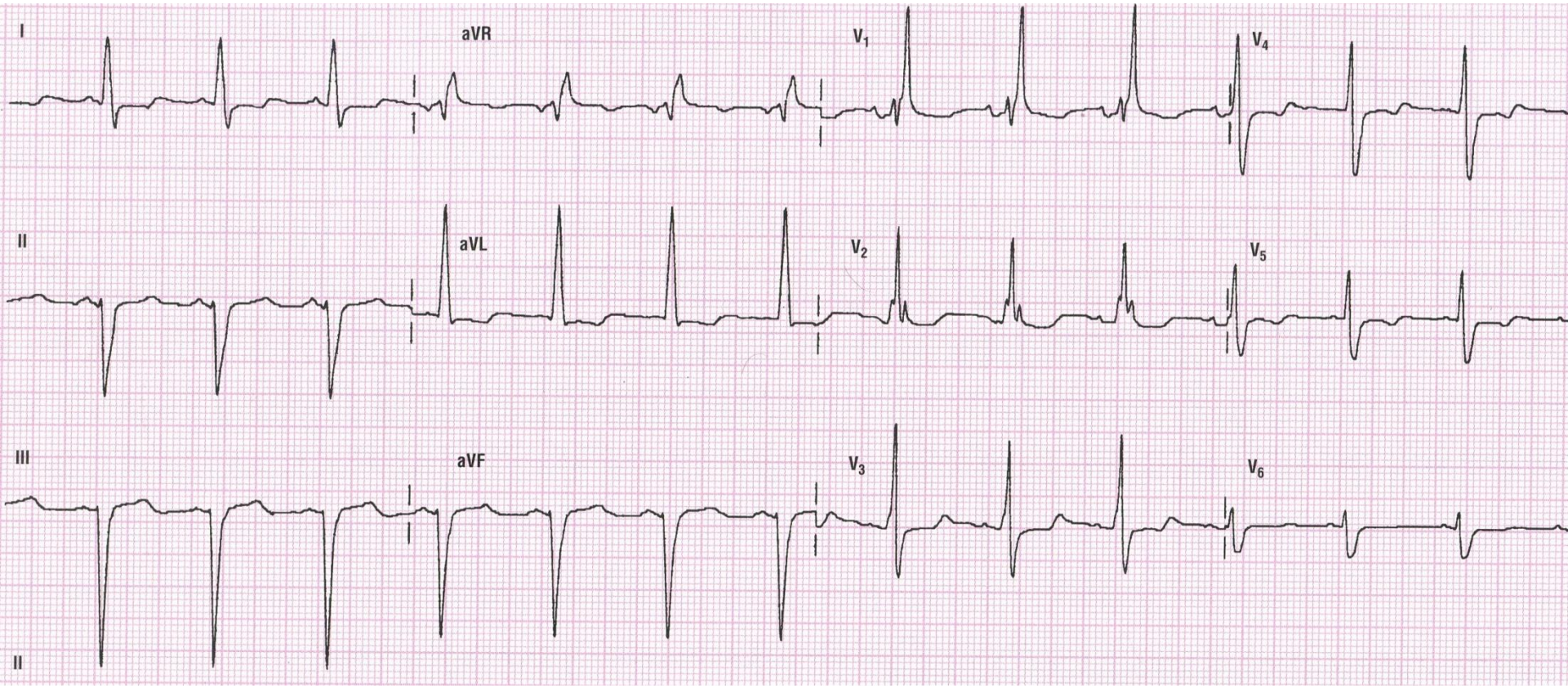

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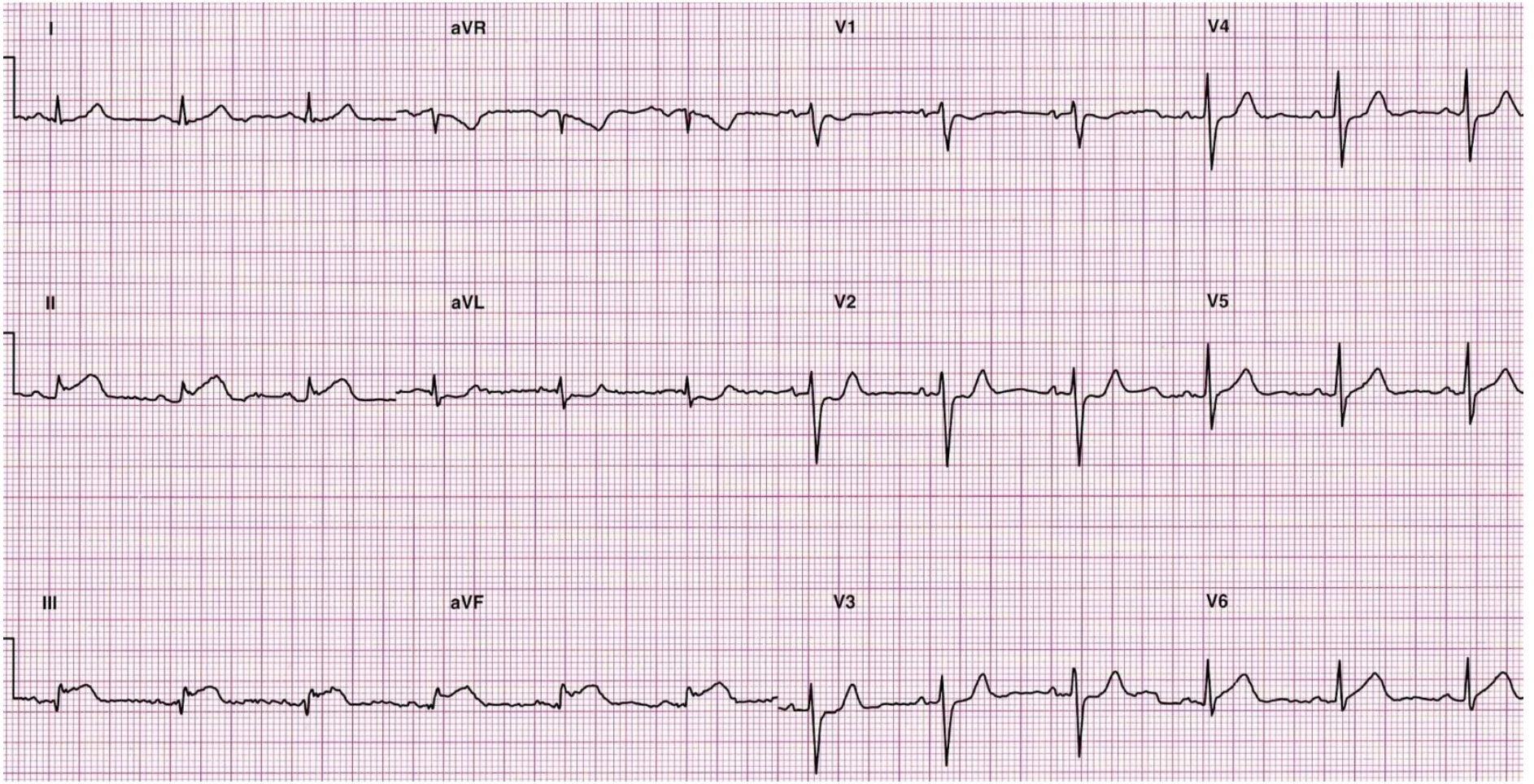

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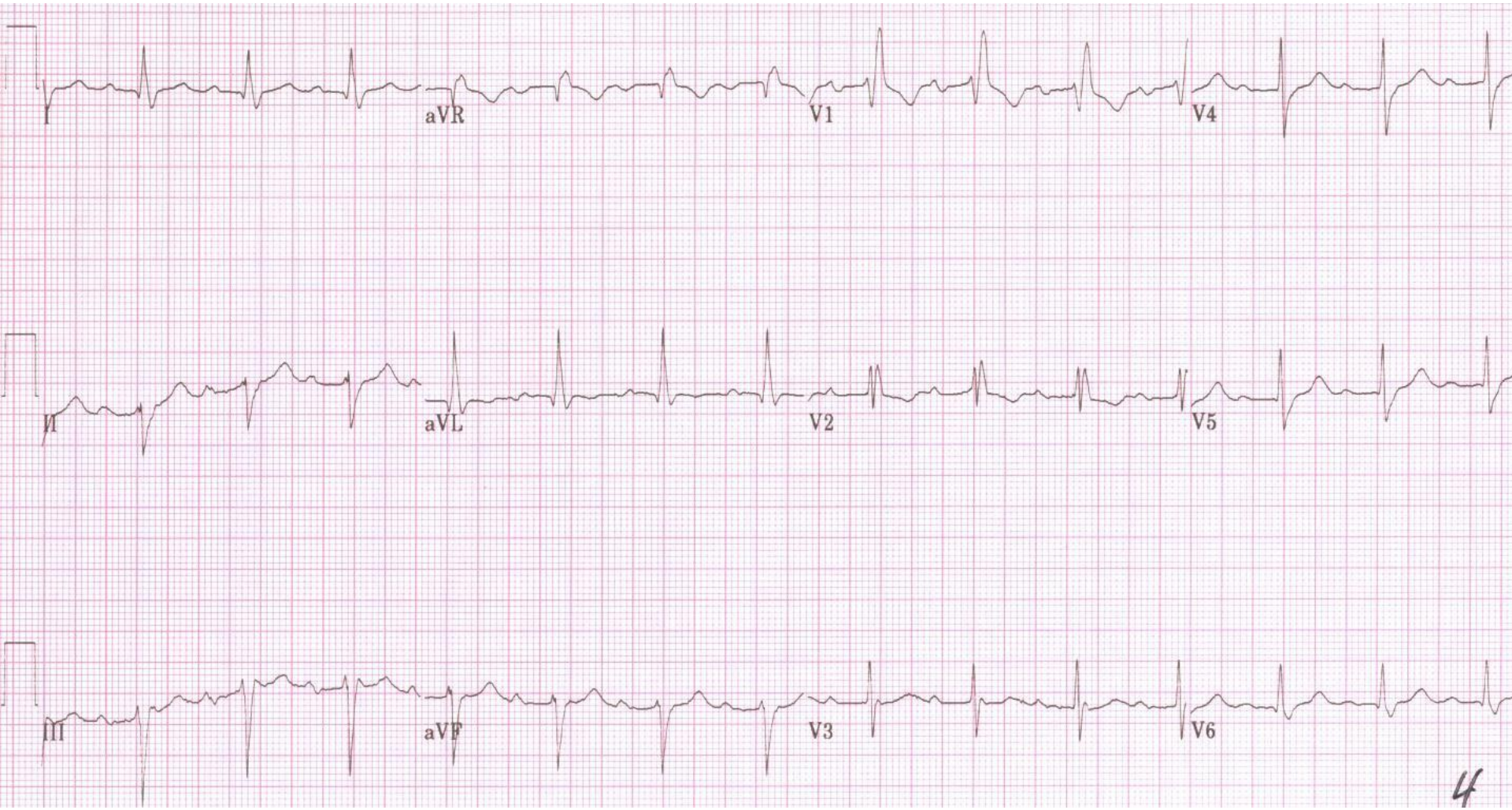

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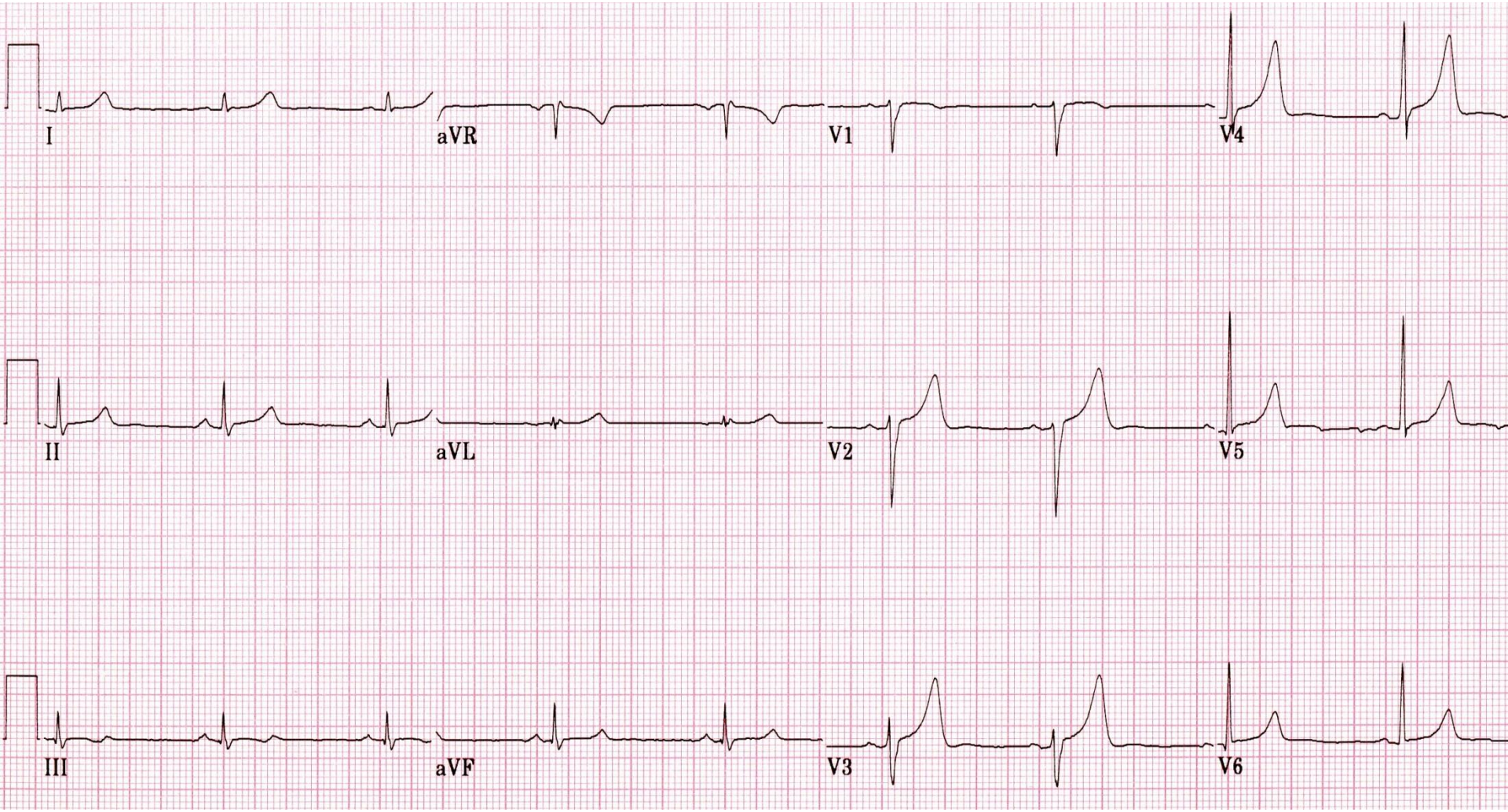

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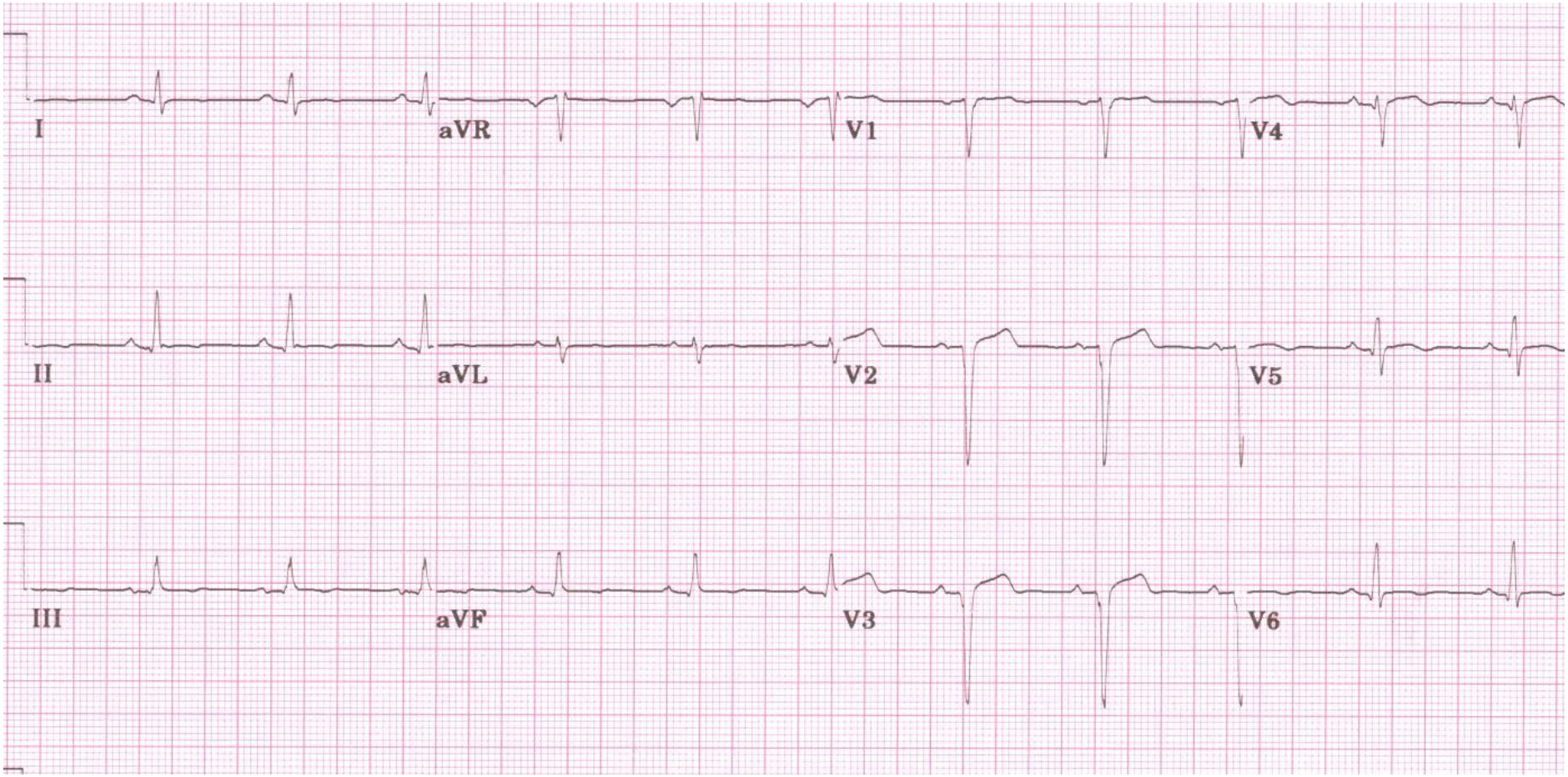

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