ECG Round Robin

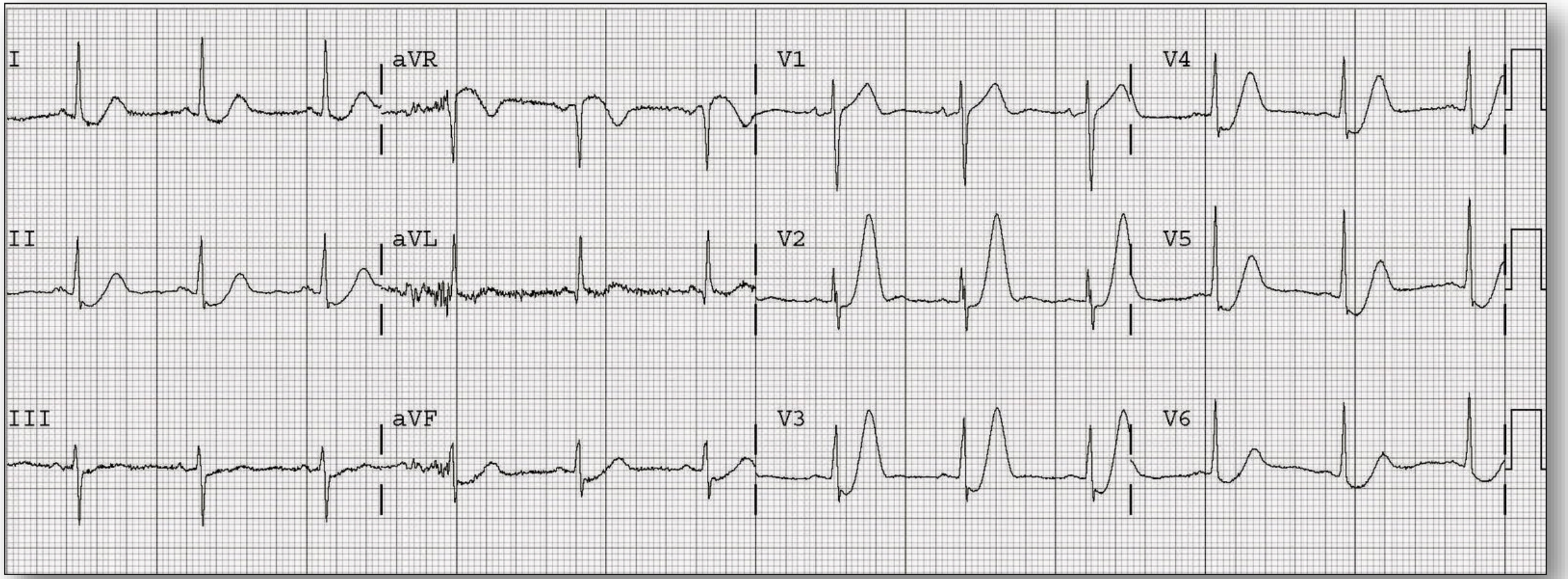
William Brady MD

University of Virginia

wb4z@uvahealth.org

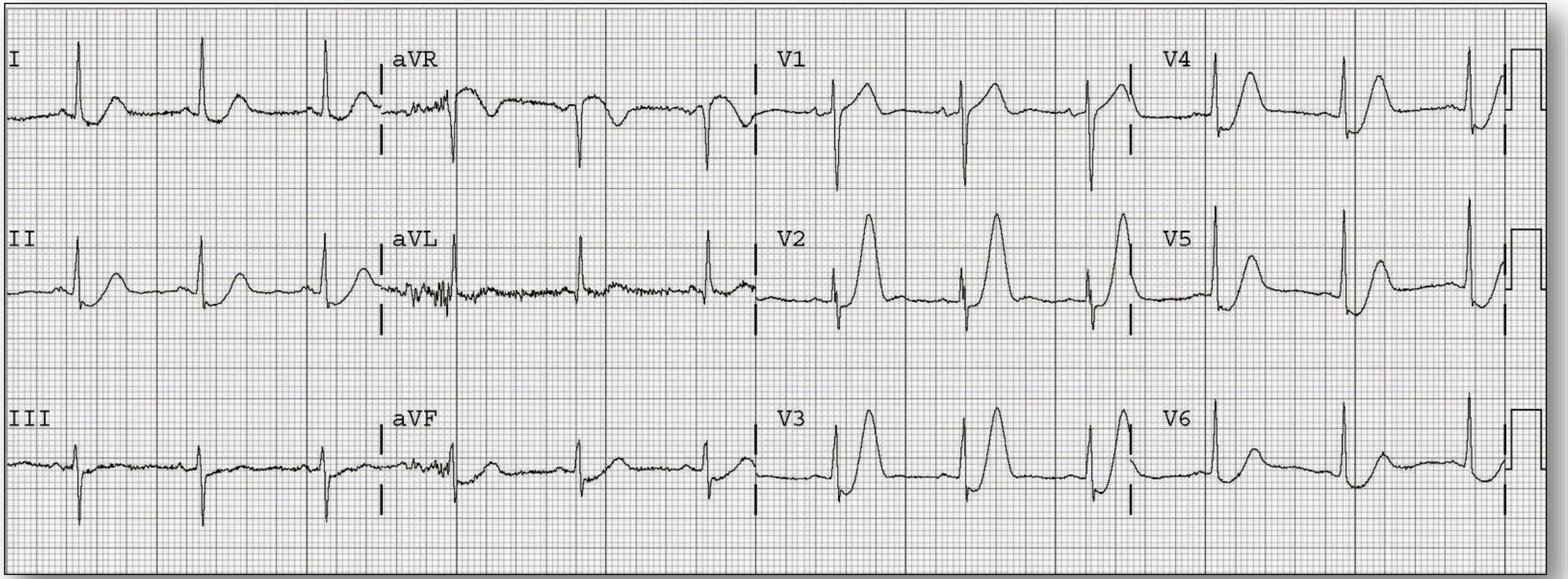
59 Male with Chest Pain

Pale, Anxious, & Diaphoretic



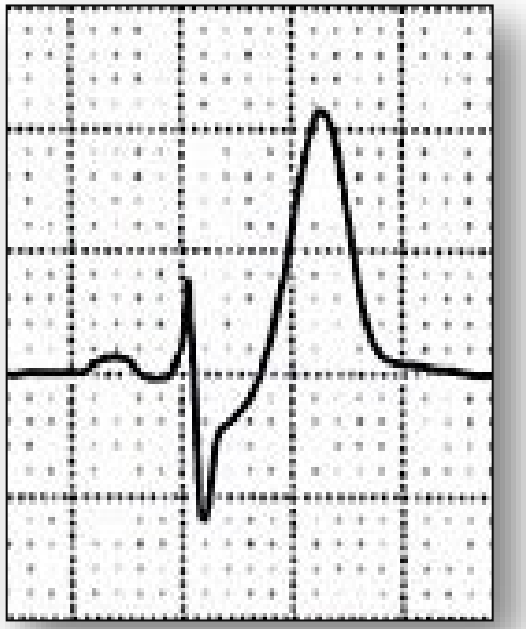
de Winter Syndrome

urgently to Cath Lab for PCI



de Winter Syndrome

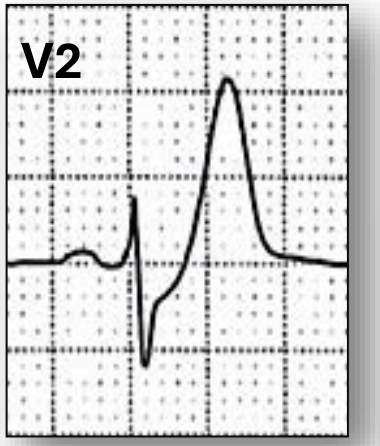
- Pattern of unique ECG findings associated with significant LAD obstruction…
- …progression to anterior wall STEMI…in minutes to hours
- Considered STEMI equivalent

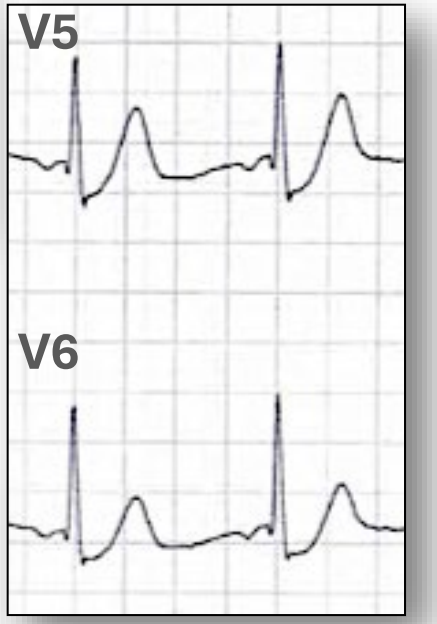


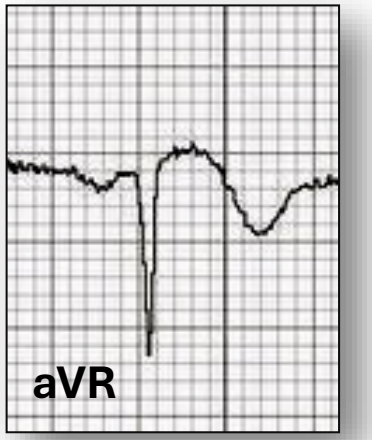
de Winter Syndrome

ECG Findings

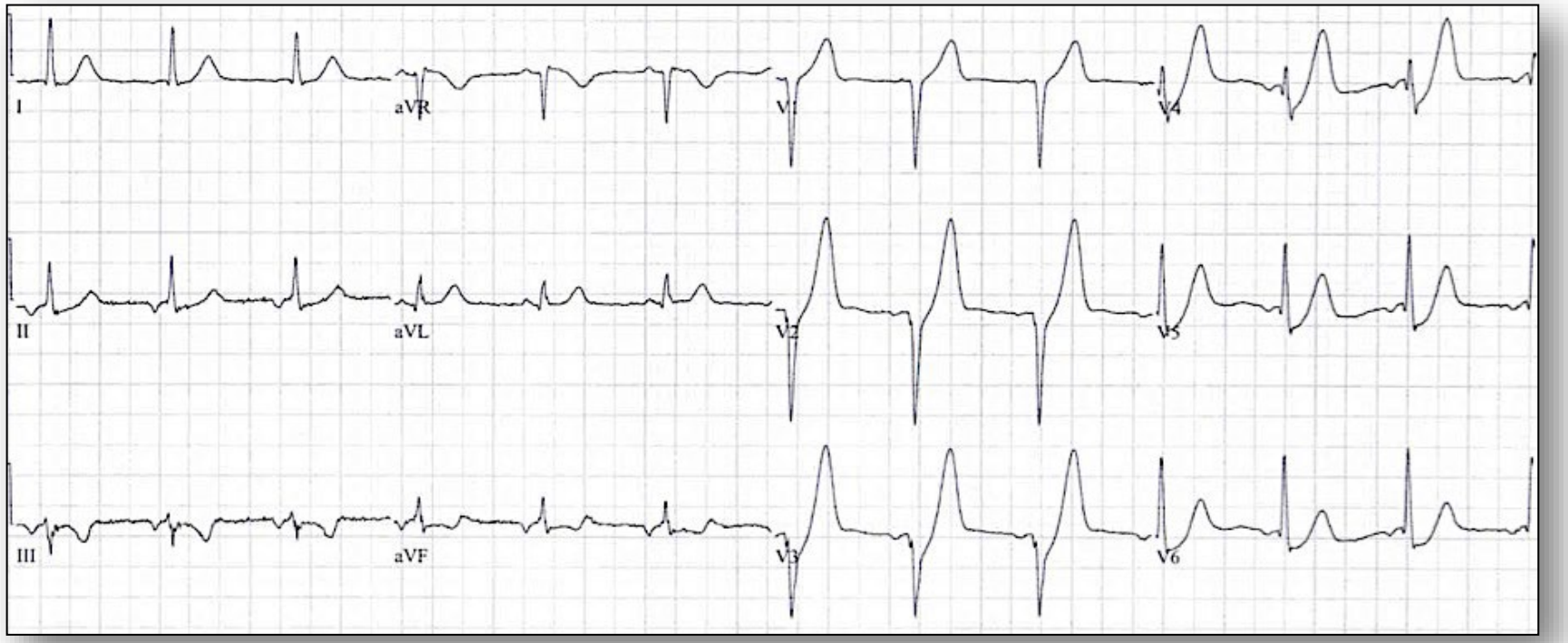
- **Prominent T wave & J point depression (leads V_1-V_3)**
- **ST segment depression in lateral leads**
- **ST segment elevation in lead aVR)**

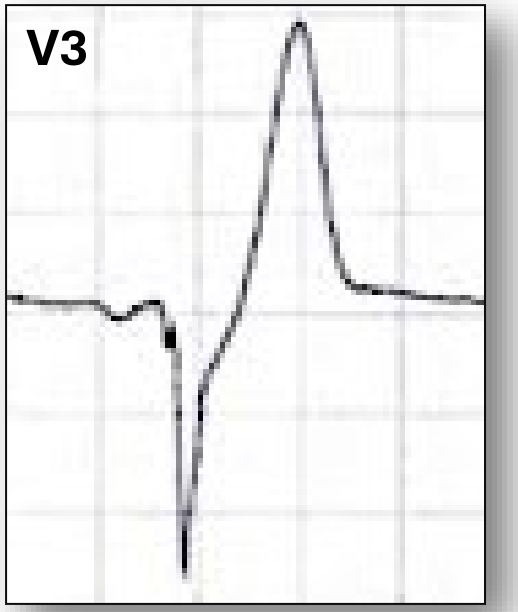






de Winter Syndrome

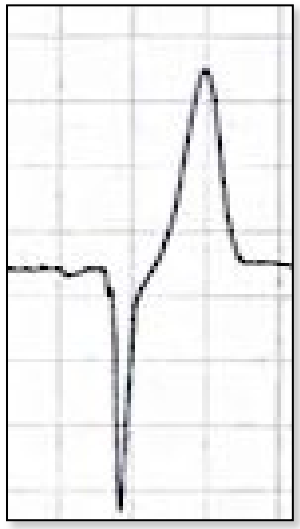


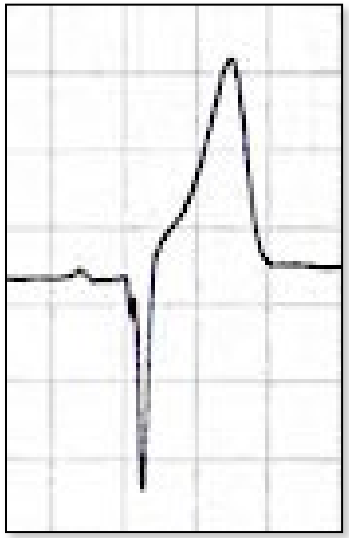


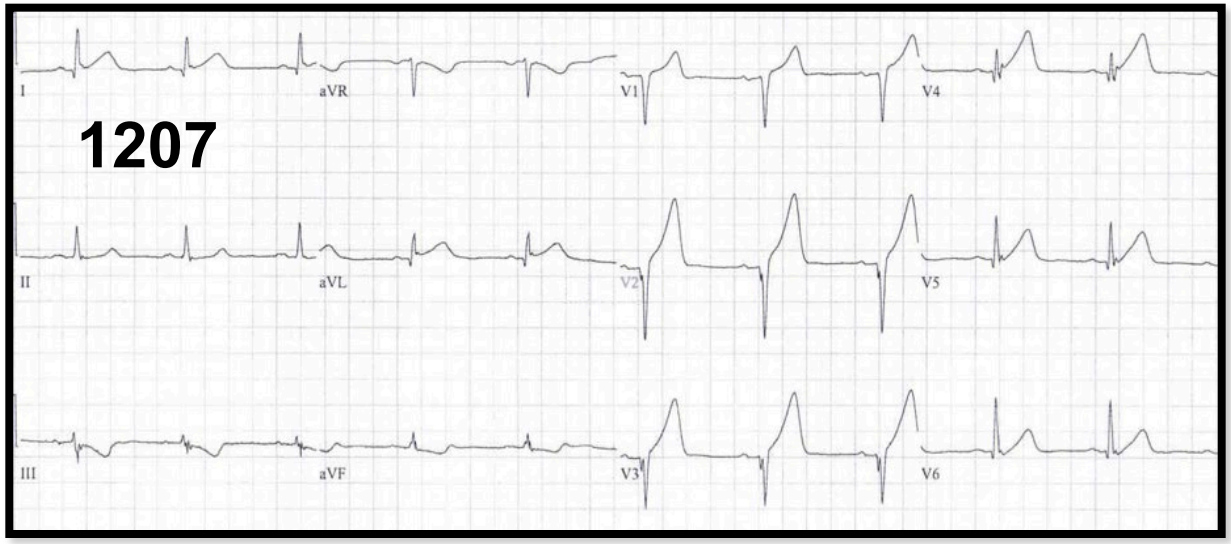
- **Precordial leads**
  - Prominent T wave & J point depression V1-V4
  - Associated lateral ST segment depression
- **ST segment elevation in lead aVr**

de Winter Syndrome

Progression to Anterior STEMI







EXPERT CONSENSUS DECISION PATHWAY

J Am Col Cardiol 2022;80:1925-60

2022 ACC Expert Consensus Decision Pathway on the Evaluation and Disposition of Acute Chest Pain in the Emergency Department

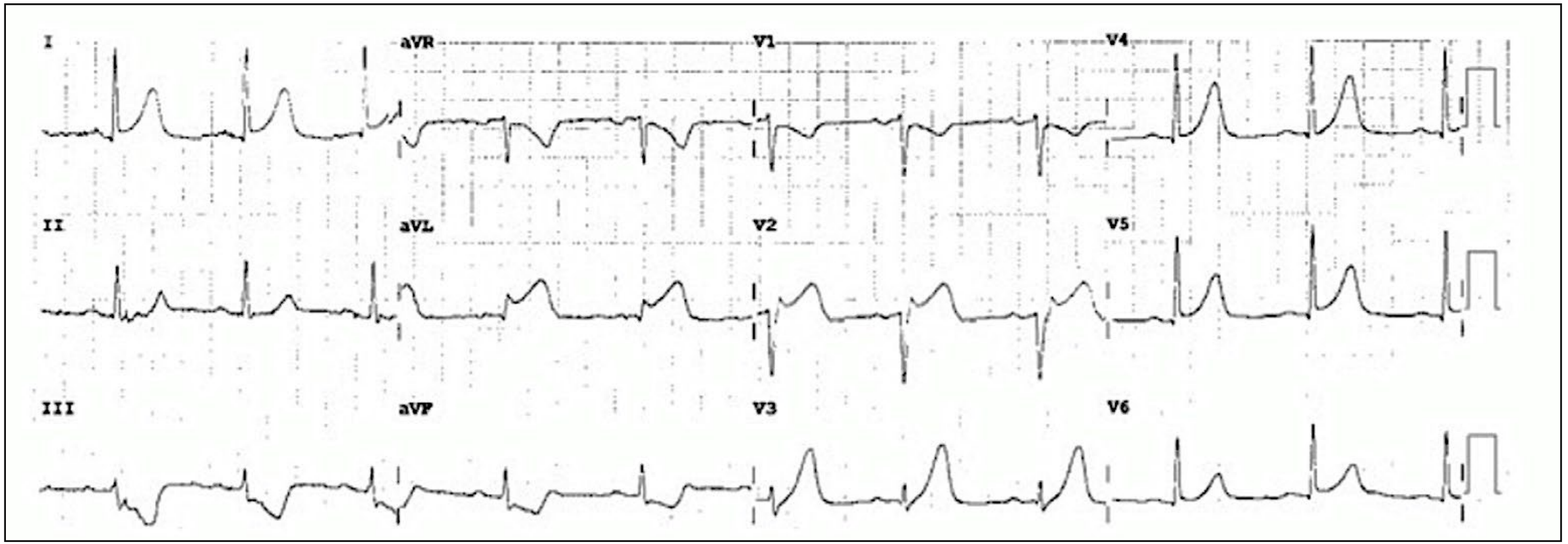
A Report of the American College of Cardiology Solution Set Oversight Committee

TABLE 1 Electrocardiogram Findings Suggestive of Ischemia

FINDING	CRITERIA
STEMI equivalents	
Posterior STEMI	**Criteria:** ■ Horizontal ST-segment depression in V_1-V_3 ■ Dominant R-wave (R/S ratio >1) in V_2 ■ Upright T waves in anterior leads ■ Prominent and broad R-wave (>30 ms) **Confirmed by:** ■ ST-segment elevation of ≥0.5 mm in at least 1 of leads V_7-V_9*
Left bundle branch block or ventricular paced rhythm with Sgarbossa Criteria	A total score ≥3 points is required: ■ Concordant ST-segment elevation ≥1 mm in leads with a positive QRS complex (5 points) ■ Concordant ST-segment depression ≥1 mm in leads V_1-V_3 (3 points) ■ Discordant ST-segment elevation ≥5 mm in leads with a negative QRS complex (2 points) If there is discordant ST-segment elevation ≥5 mm, consider ST/S ratio <−0.25
Left bundle branch block or ventricular paced rhythm with Smith-modified Sgarbossa Criteria	Positive if any of the following are present: ■ Concordant ST-segment elevation of 1 mm in leads with a positive QRS complex ■ Concordant ST-segment depression of 1 mm in V_1-V_3 ■ ST-segment elevation at the J-point, relative to the QRS onset, is at least 1 mm and has an amplitude of at least 25% of the preceding S-wave
De Winter Sign	■ Tall, prominent, symmetrical T waves arising from upsloping ST-segment depression >1 mm at the J-point in the precordial leads ■ 0.5-1 mm ST-segment elevation may be seen in lead aVR
Hyperacute T waves	Broad, asymmetric, peaked T waves may be seen early in STEMI Serial ECGs over very short intervals are useful to assess for progression to STEMI
ECG findings consistent with acute/subacute myocardial ischemia	
aVR ST-segment elevation	Most often caused by diffuse subendocardial ischemia and usually occurs in the setting of significant left main coronary artery or multivessel coronary artery disease ■ ST-segment elevation in aVR ≥1 mm ■ Multilead ST-segment depression in leads I, II, Val, and/or V_4-V_6 ■ Absence of contiguous ST-segment elevation in other leads
ST-segment depression	Horizontal or downsloping ST-segment depression ≥0.5 mm at the J-point in 2 or more contiguous leads is suggestive of myocardial ischemia
Wellen's syndrome	Clinical syndrome characterized by: ■ Biphasic or deeply inverted and symmetric T waves in leads V_2 and V_3 (may extend to V_6) ■ Recent angina ■ Absence of Q waves
Inverted T waves	May be seen in ischemia (subacute) or infarction (may be fixed and associated with Q waves) in continuous leads

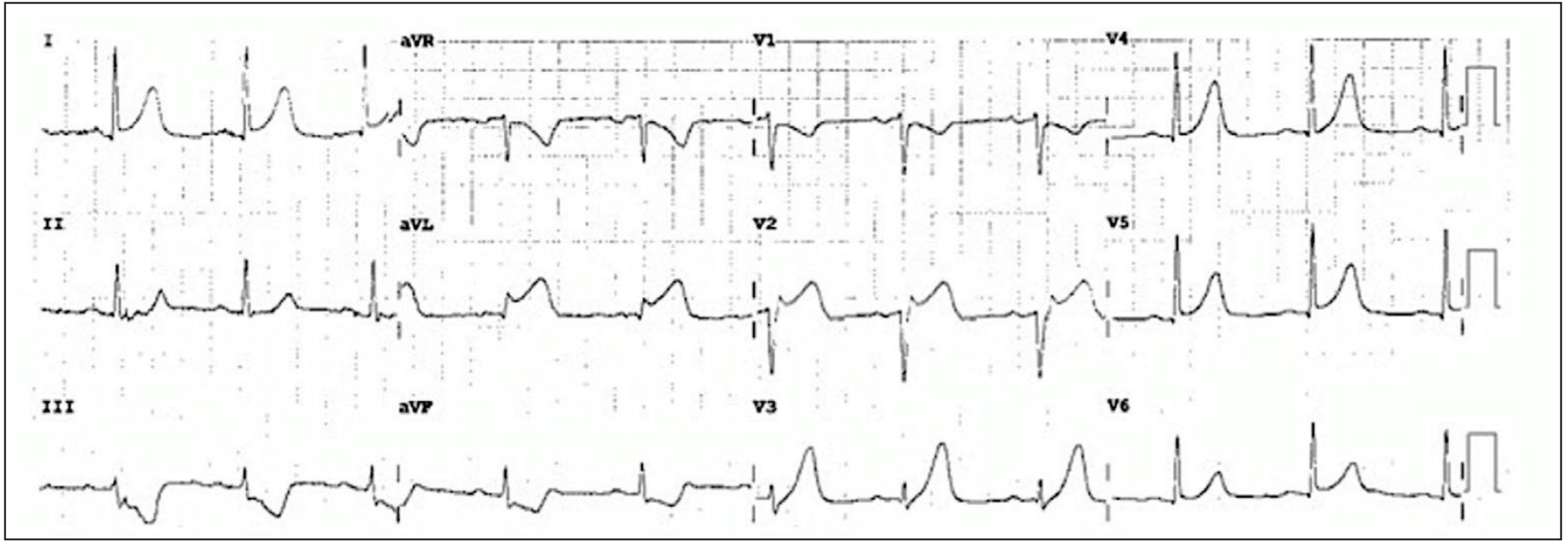
61 Female with Chest Pain, Diaphoresis, & Vomiting

Pale, Anxious, & Markedly Diaphoretic



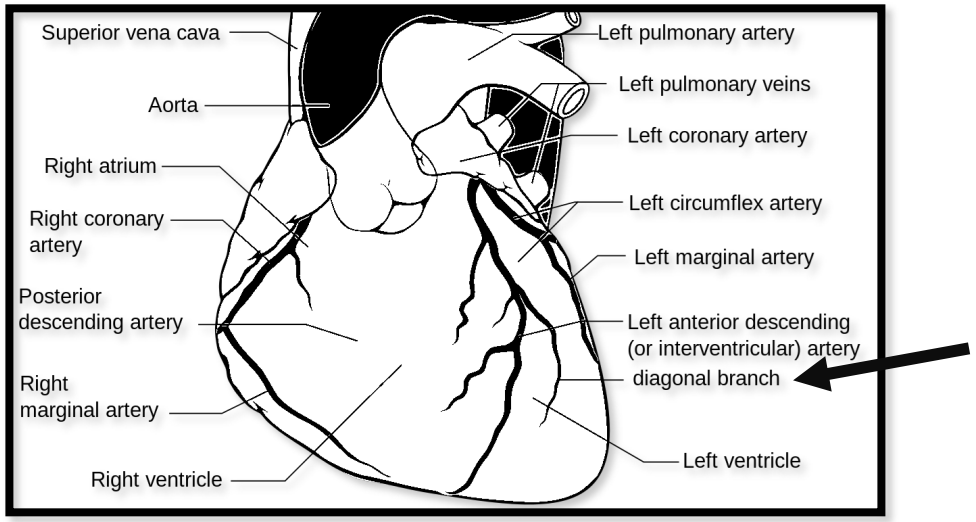
Occlusion of 1st Diagonal Branch of LAD Artery
STEMI Equivalent Pattern

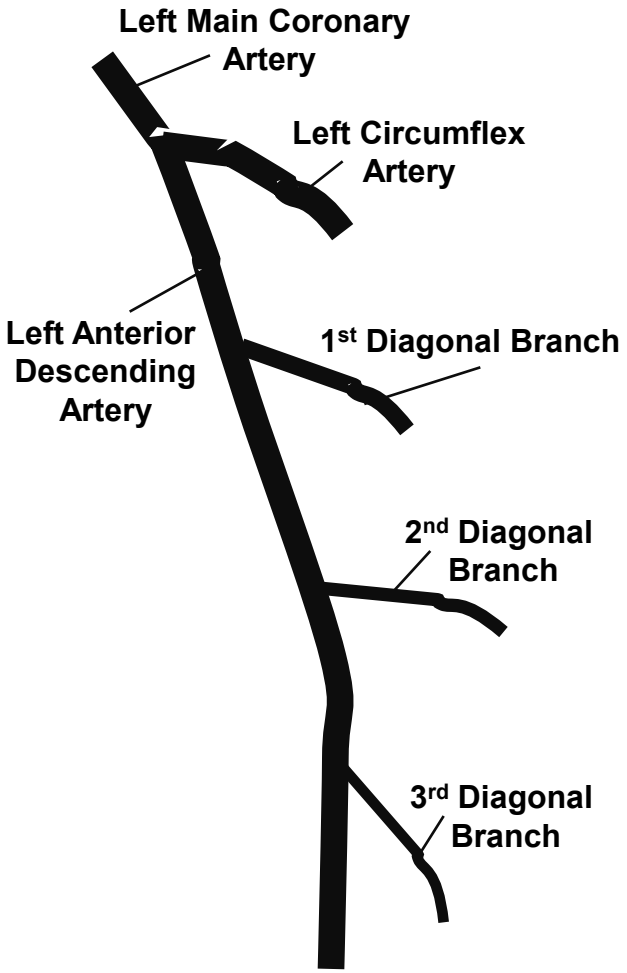
STEMI ALERT! To Cath Lab for PCI of Proximal D1 Lesion



Occlusion of 1st Diagonal Branch of LAD Artery

- Left main coronary artery bifurcates…
- Left anterior descending artery…
- Primary branches of LAD - diagonals
- First diagonal (D_1) - perfusion to large portion of LV anterior / anterolateral walls





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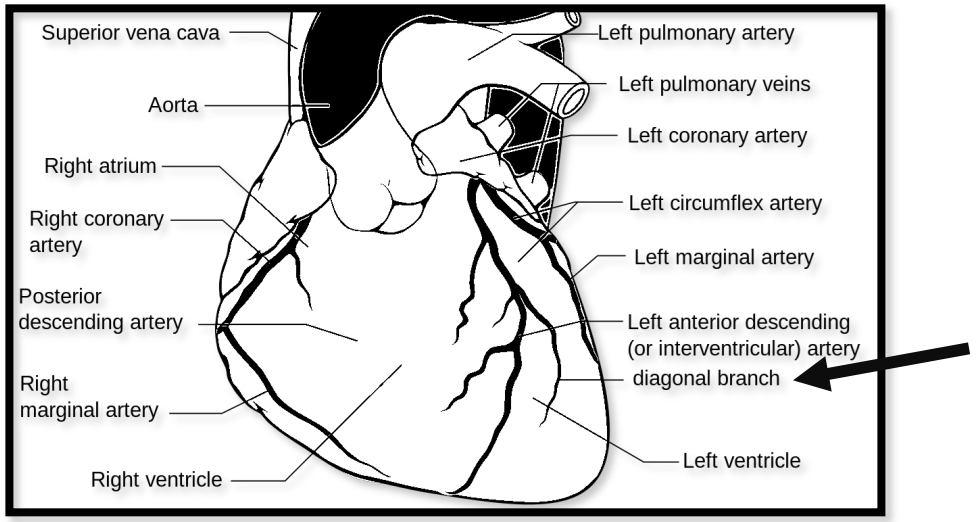
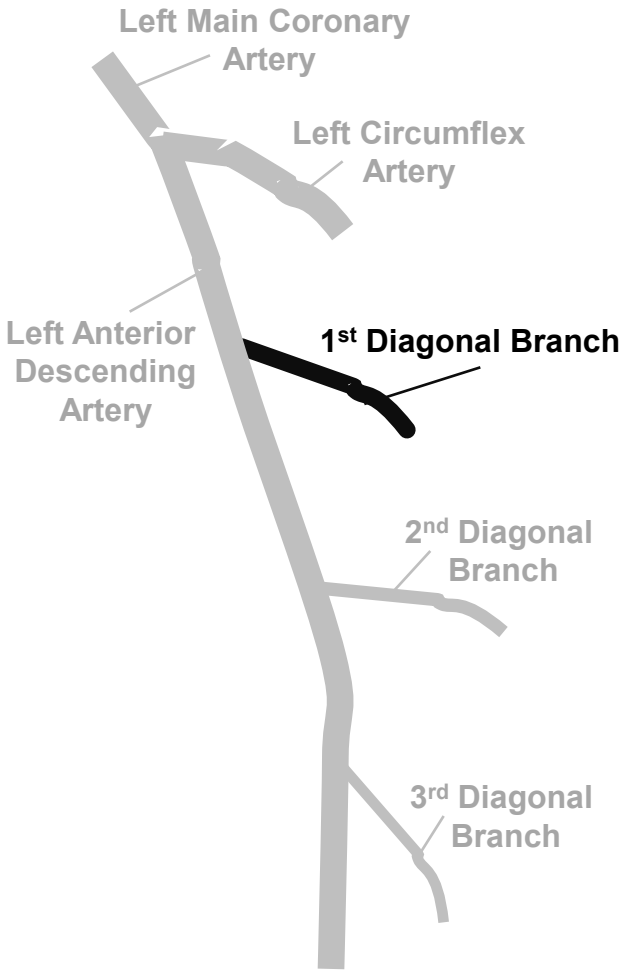




Occlusion of 1st Diagonal Branch of LAD Artery

- **ECG presentation**
  - STE in leads aVL & V_2
  - STD in leads III & aVF / variable V_4 & V_5

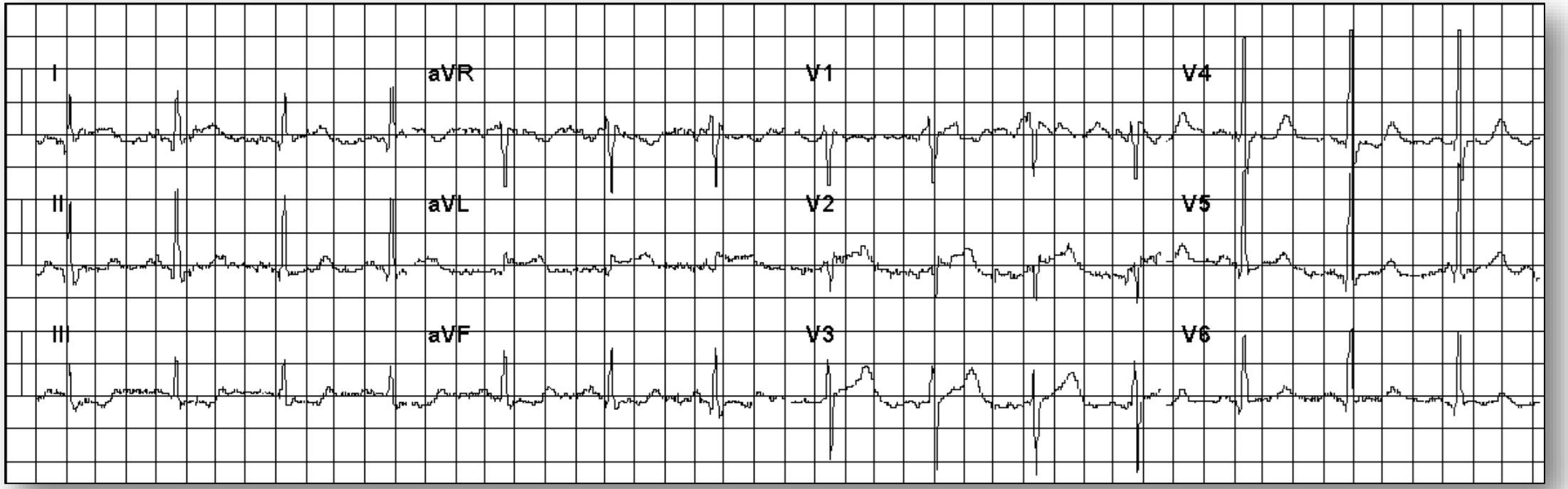
- **Does not meet traditional STEMI criteria**

- **Yet represents significant AMI**

ACC/AHA ECG Definition of STEMI

Anatomically oriented ST elevation
-- ≥ 1 mm in at least 2 limb leads
-- ≥ 2 mm in at least 2 precordial leads
-- lacking features of non-infarction syndrome

Occlusion of 1st Diagonal Branch of LAD Artery



ST Elevation aVL & V2

Courtesy Steve Smith, MD

71 Male with Weakness

Second Degree AVB with 2-1 Conduction

Well Appearing …During ED Stay, Type I Pattern Noted

Second Degree AVB with 2-1 Conduction

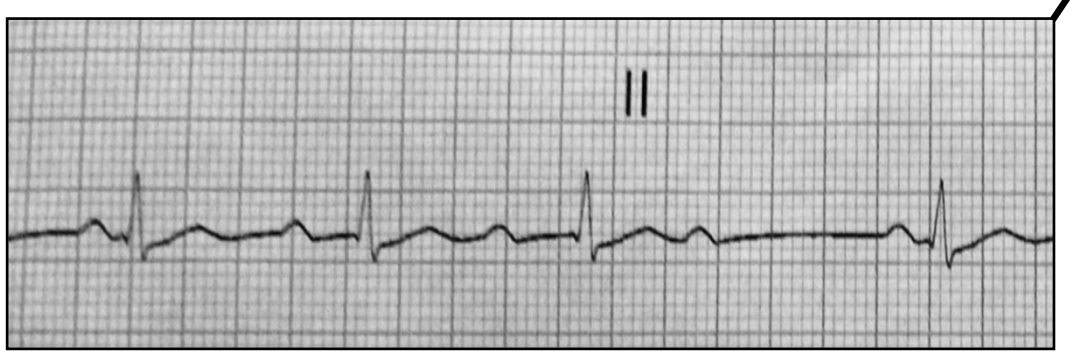
Well Appearing …During ED Stay, Type I Pattern Noted

Second Degree / Type I AVB

Second Degree AVB with 2-1 Conduction

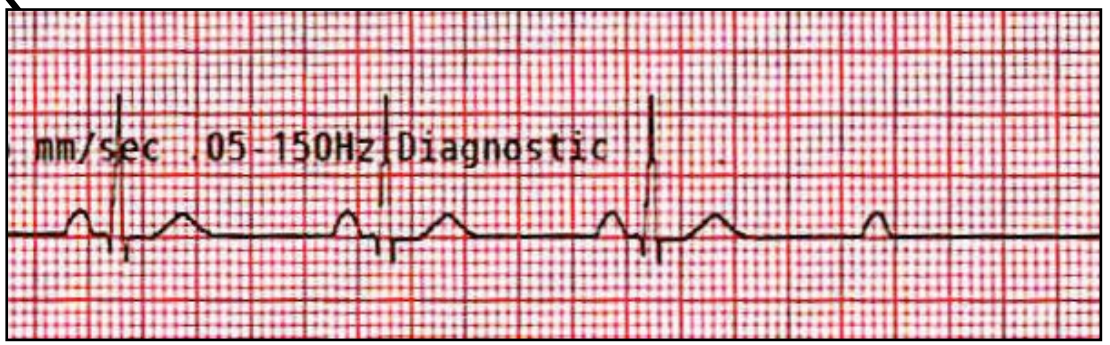
?

Second Degree Type I AVB



normal variant vs acute pathology
rarely presents with shock

Second Degree Type II AVB



always pathologic & high risk
frequently presents with shock

Second Degree AVB with 2-1 Conduction

Why make the distinction?

Significant management & prognostic differences

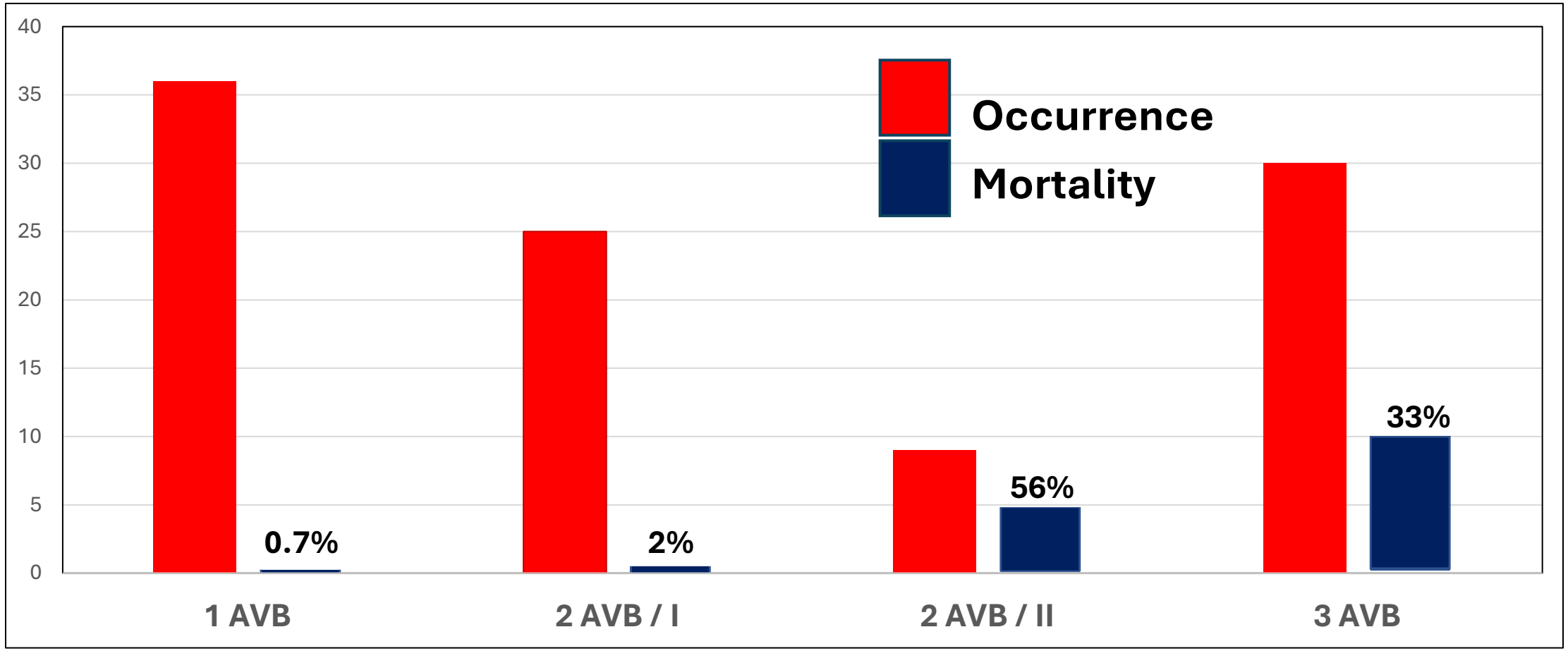
Management

AV Block

	2nd Degree / I	2nd Degree / II
Non-ACS	Observe	Standard Rx* T/C pacer while T/V pacer considered
ACS	Prophylactic placement pacing pads	Standard Rx* T/C pacer while T/V pacer placed

* limited efficacy

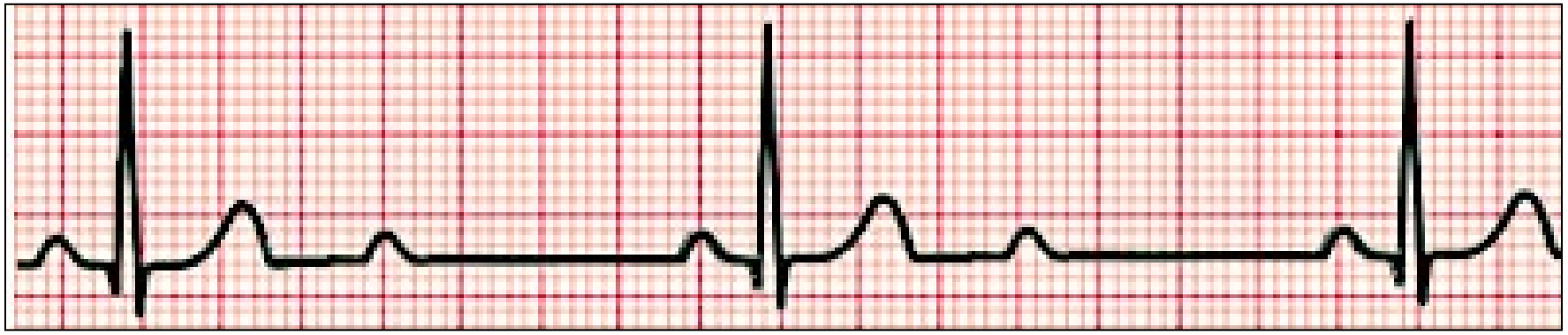
AV Block Frequency & Mortality Rates



How to Make the Distinction

Second Degree AVB with 2-1 Conduction

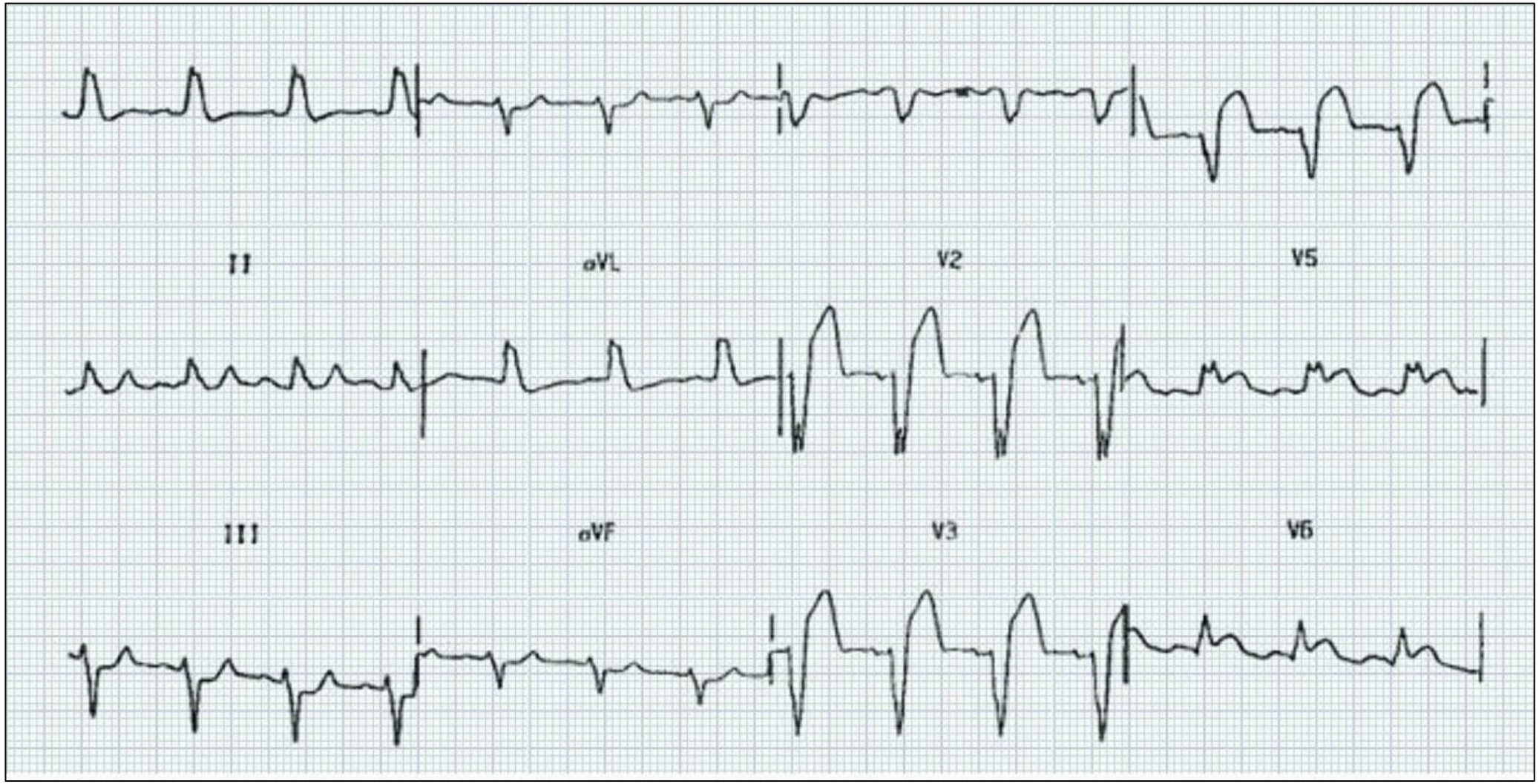
Type I vs Type II?



- **How ill is patient?** Very ill suggestive of Type II
- **Ventricular rate?** Compromising rate suggestive of Type II
- **QRS complex narrow or wide?** Wide is frequently seen with Type II
- **If in doubt, assume the worst**…Type II

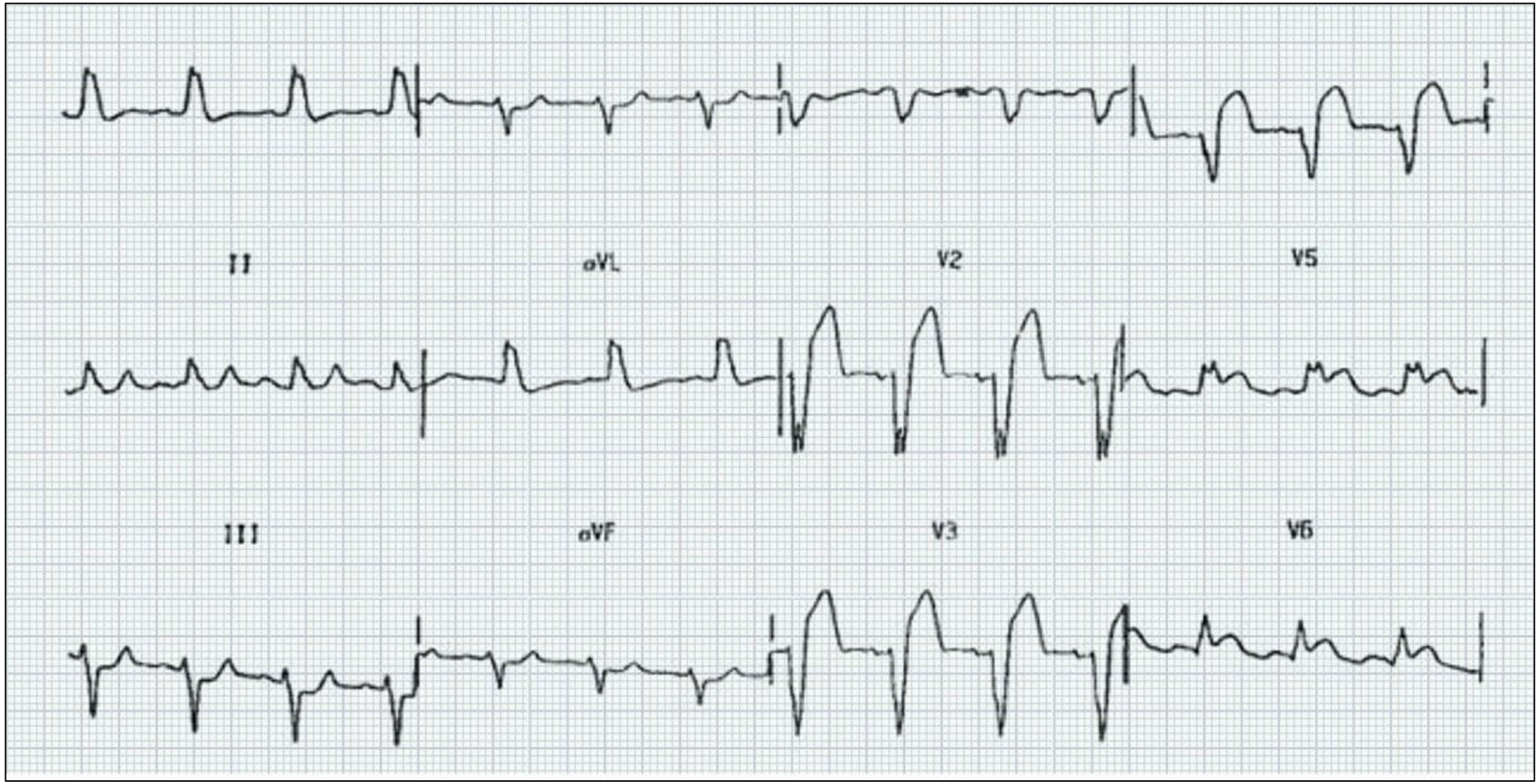
67 female with chest pain & extreme weakness

alert, pale, & sweaty - 95/75, 80, 26, Sat 90% (RA)



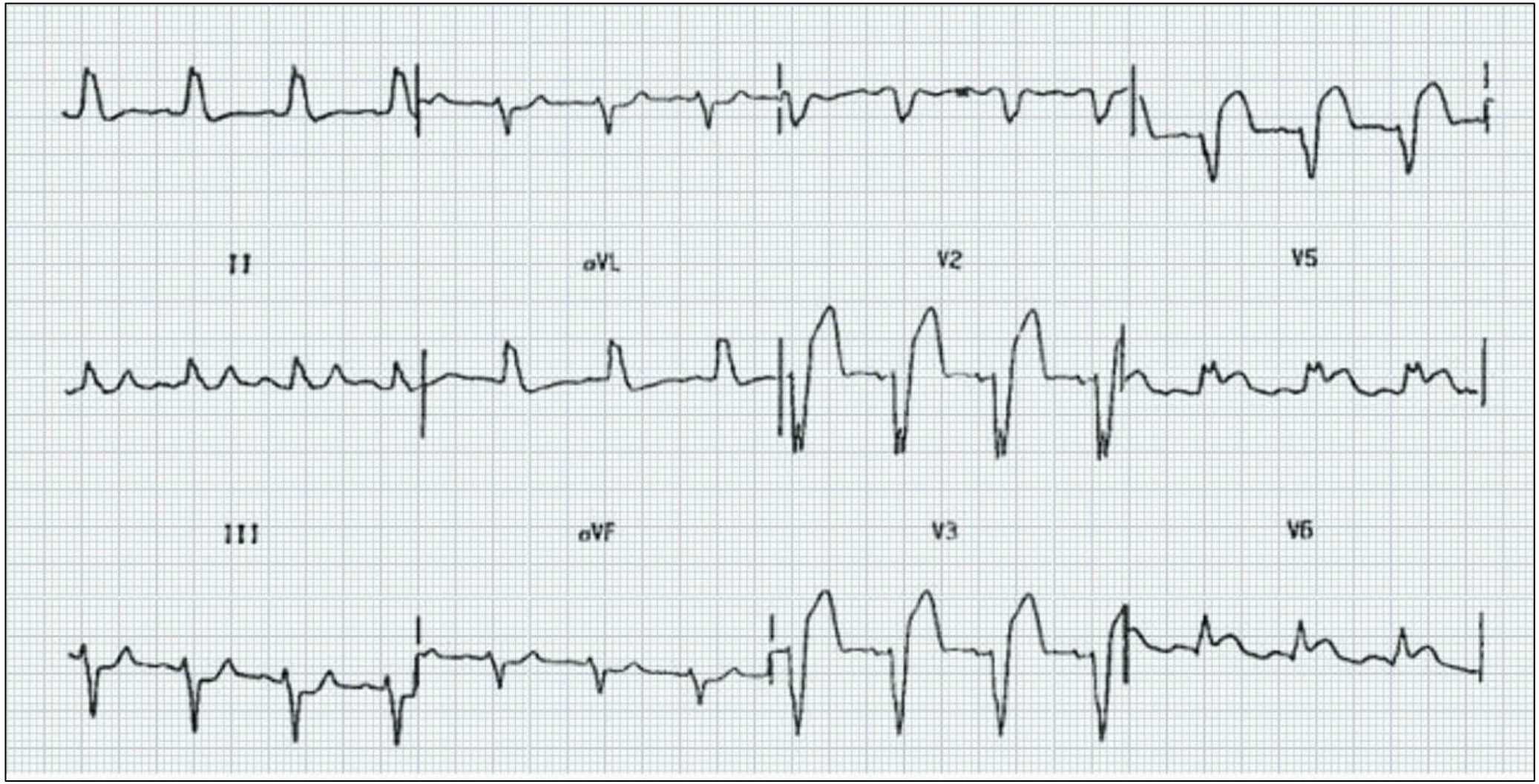
LBBB with ECG Evidence of AMI

Concordant ST Elevation V5/V6 & Excessive Discordant ST Elevation V2-V4



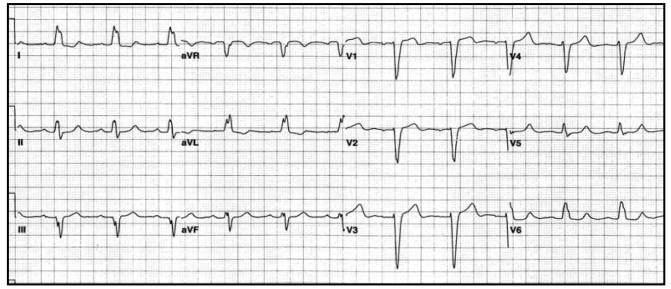
LBBB with ECG Evidence of AMI

to the cath lab for PCI



Challenge of AMI Diagnosis with LBBB

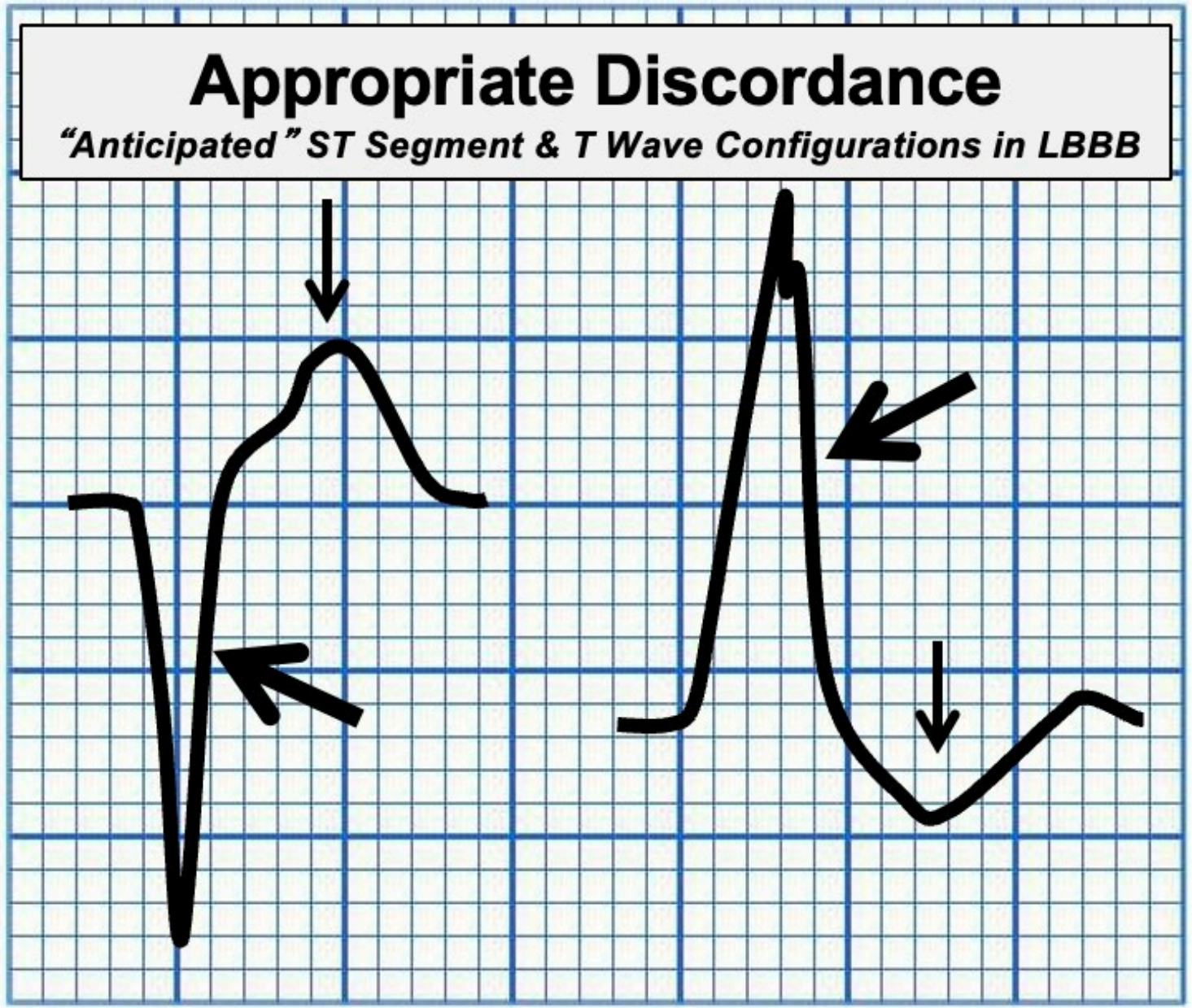
- **Confounds ECG diagnosis of AMI**
  - *Magnitude unknown*
  - *~80% of LBBB AMI "not detectable" by ECG*



- **Mimics STEMI**
  - *Most common cause of ST elevation in ACS-suspected patients*
  - *Most frequent "pseudo-infarct" pattern*
- **Associated higher CV risk**
  - *Pre-existing or new LBBB*
  - *Larger AMI with lower EF*
  - *3 AVB, VT/VF, cardiogenic shock, death more frequent*

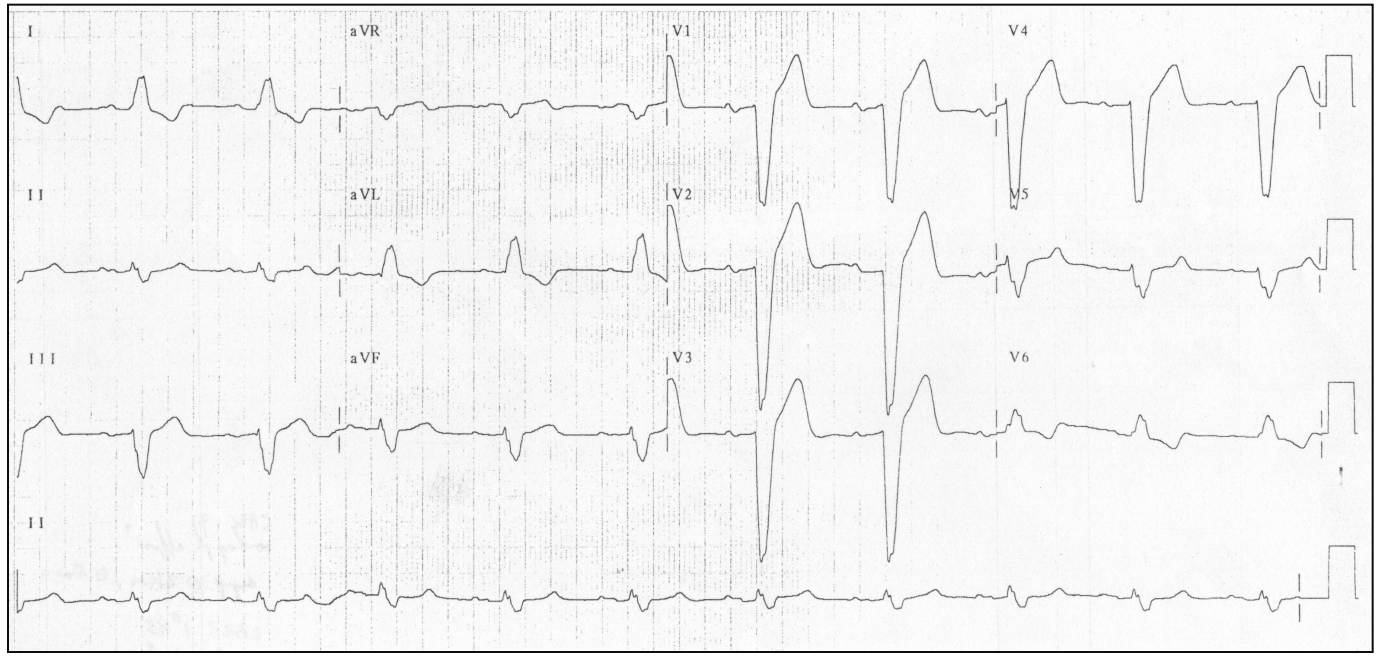
Appropriate Discordance

"Anticipated" ST Segment & T Wave Configurations in LBBB



Left Bundle Branch Block

Anticipated ST Segment & T Wave Configurations



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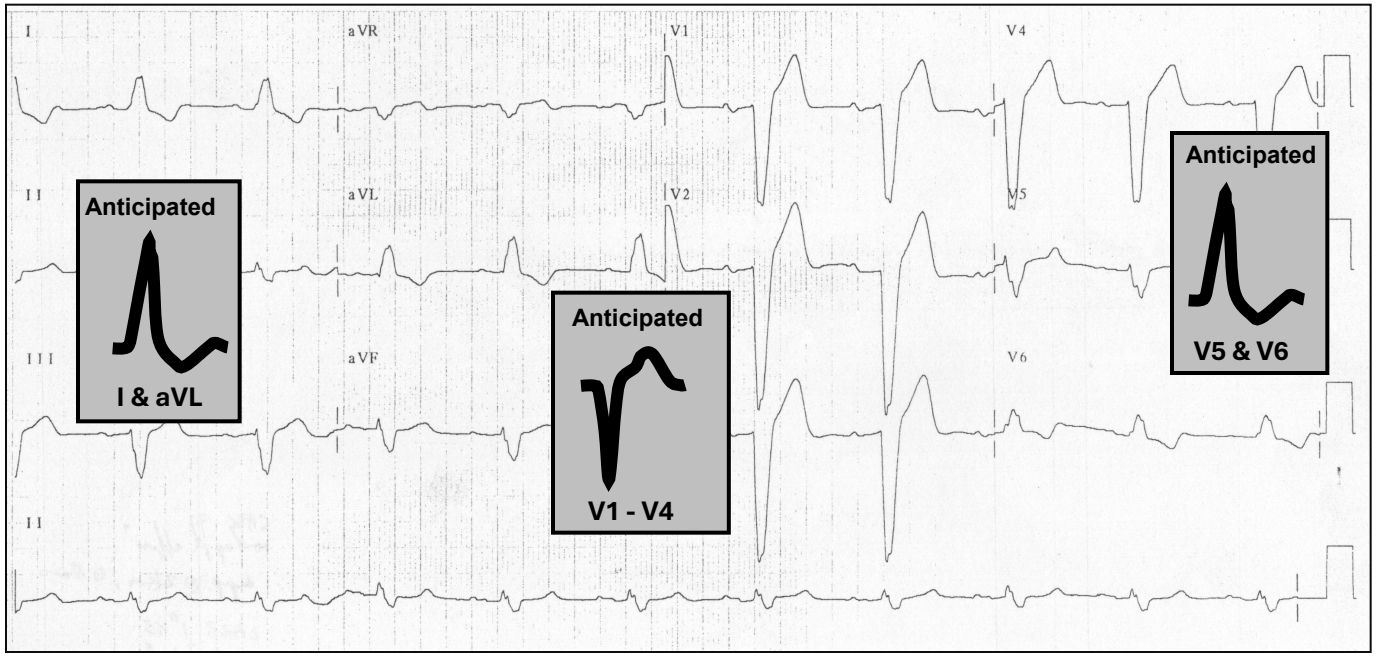


“Sgarbossa Criteria”

ST Segment Configurations Suggestive of AMI in LBBB

Original

ELECTROCARDIOGRAPHIC DIAGNOSIS OF EVOLVING ACUTE MYOCARDIAL INFARCTION IN THE PRESENCE OF LEFT BUNDLE-BRANCH BLOCK

ELENA B. SGARBOSSA, M.D., SERGIO L. PINSKI, M.D., ALEJANDRO BARBAGELATA, M.D., DONALD A. UNDERWOOD, M.D., KATHY B. GATES, ERIC J. TOPOL, M.D., ROBERT M. CALIFF, M.D., AND GALEN S. WAGNER, M.D., FOR THE GUSTO-1 (GLOBAL UTILIZATION OF STREPTOKINASE AND TISSUE PLASMINOGEN ACTIVATOR FOR OCCLUDED CORONARY ARTERIES) INVESTIGATORS

NEJM 1996;334:481

Modified

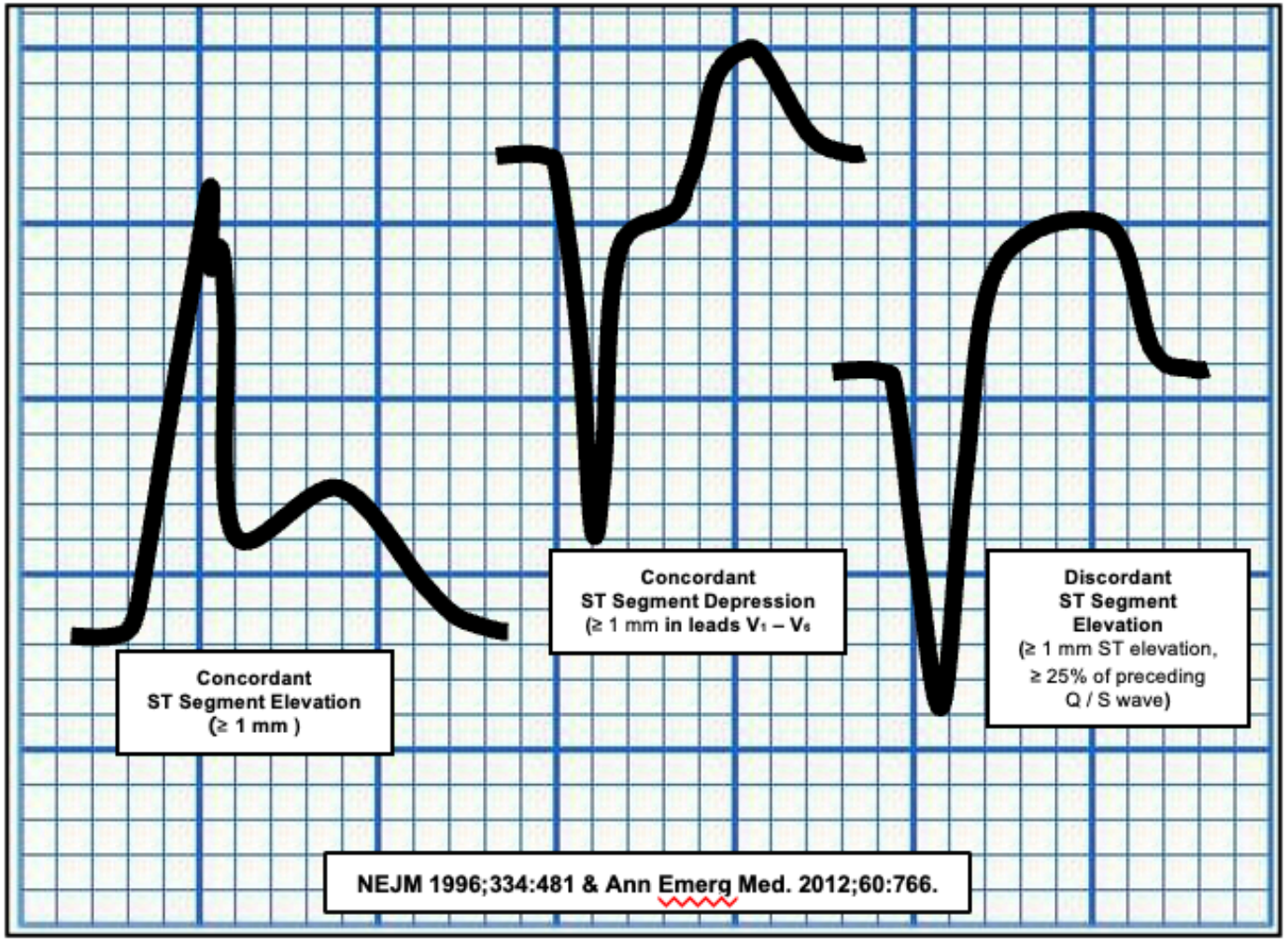
Diagnosis of ST-Elevation Myocardial Infarction in the Presence of Left Bundle Branch Block With the ST-Elevation to S-Wave Ratio in a Modified Sgarbossa Rule

Stephen W. Smith, MD, Kenneth W. Dodd, MD, Timothy D. Henry, MD, David M. Dvorak, MD, Lesly A. Pearce, MS

Ann Emerg Med 2012;60:766

Modified Sgarbossa Criteria

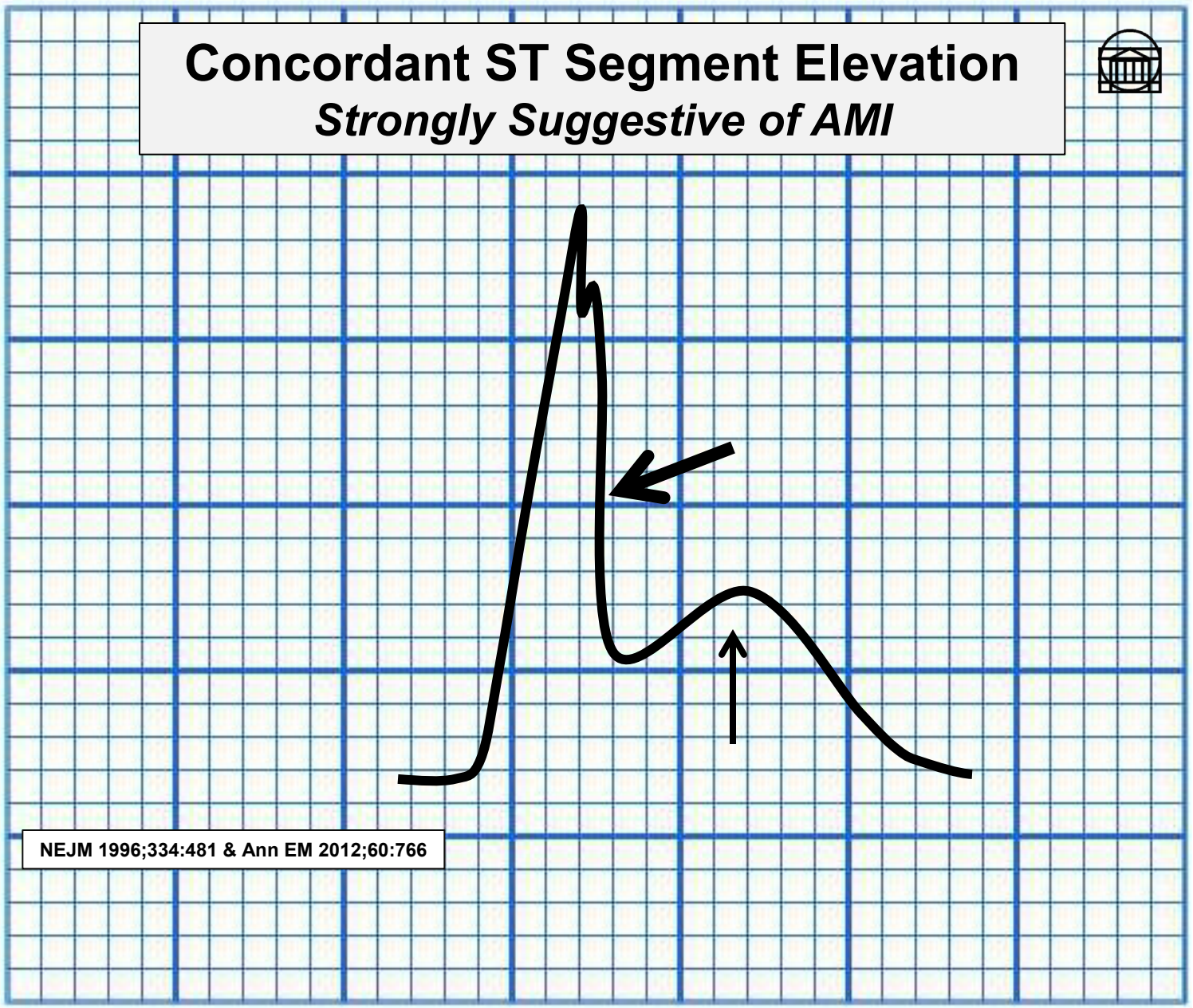
ST Segment Configurations Suggestive of AMI in LBBB



Required in only 1 lead

Concordant ST Segment Elevation

Strongly Suggestive of AMI



NEJM 1996;334:481 & Ann EM 2012;60:766

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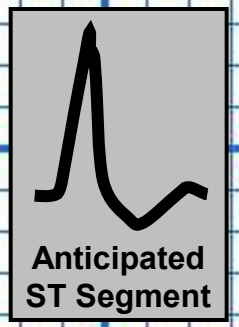
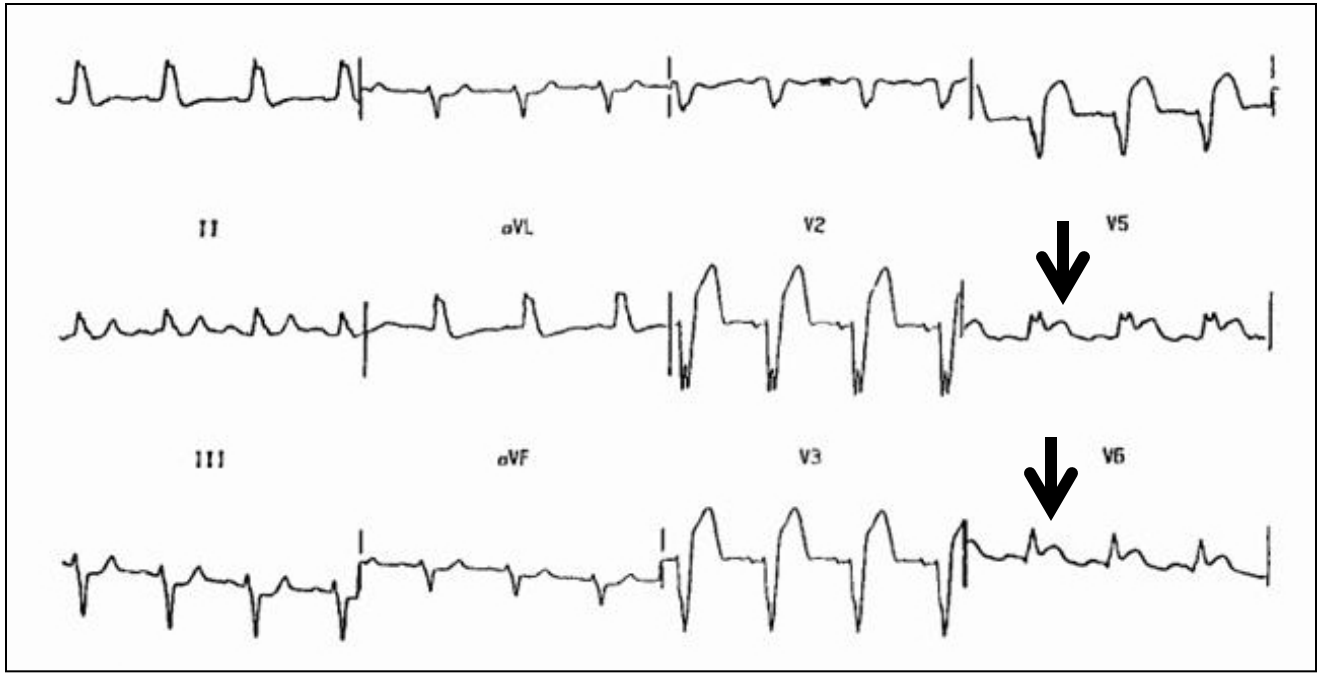


NEJM 1996;334:481 & Ann EM 2012;60:766

LBBB with AMI

Concordant ST Segment Elevation



LBBB with AMI

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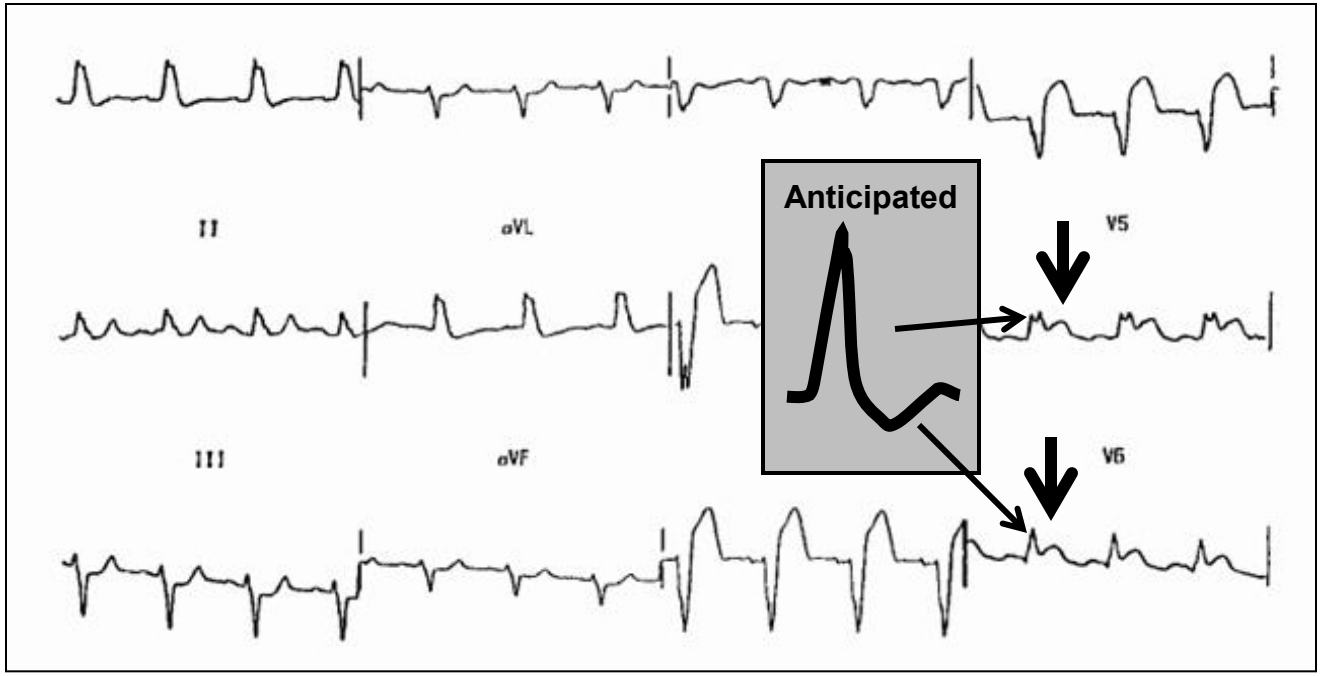
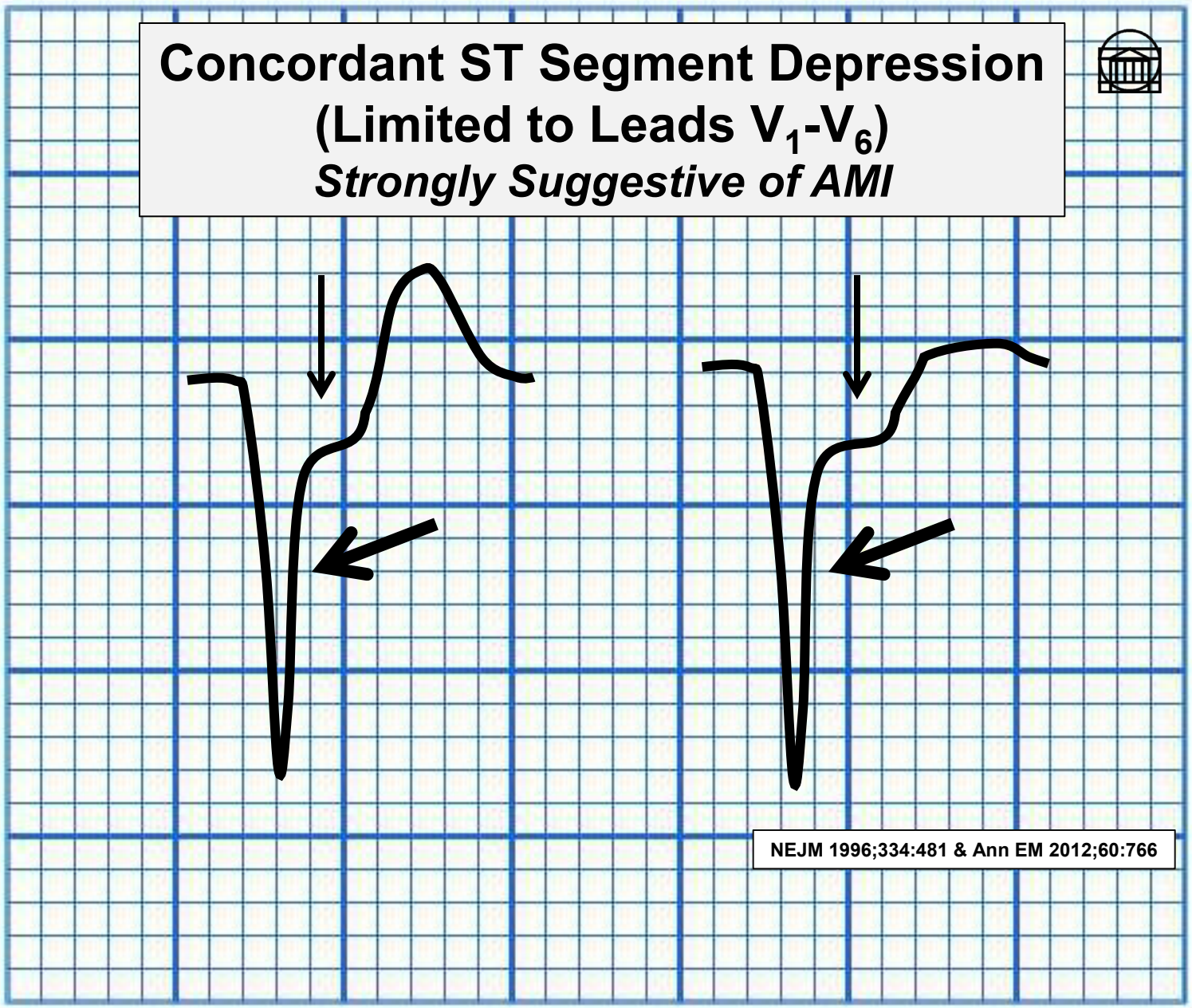


Concordant ST Segment Depression (Limited to Leads V_1-V_6)

Strongly Suggestive of AMI



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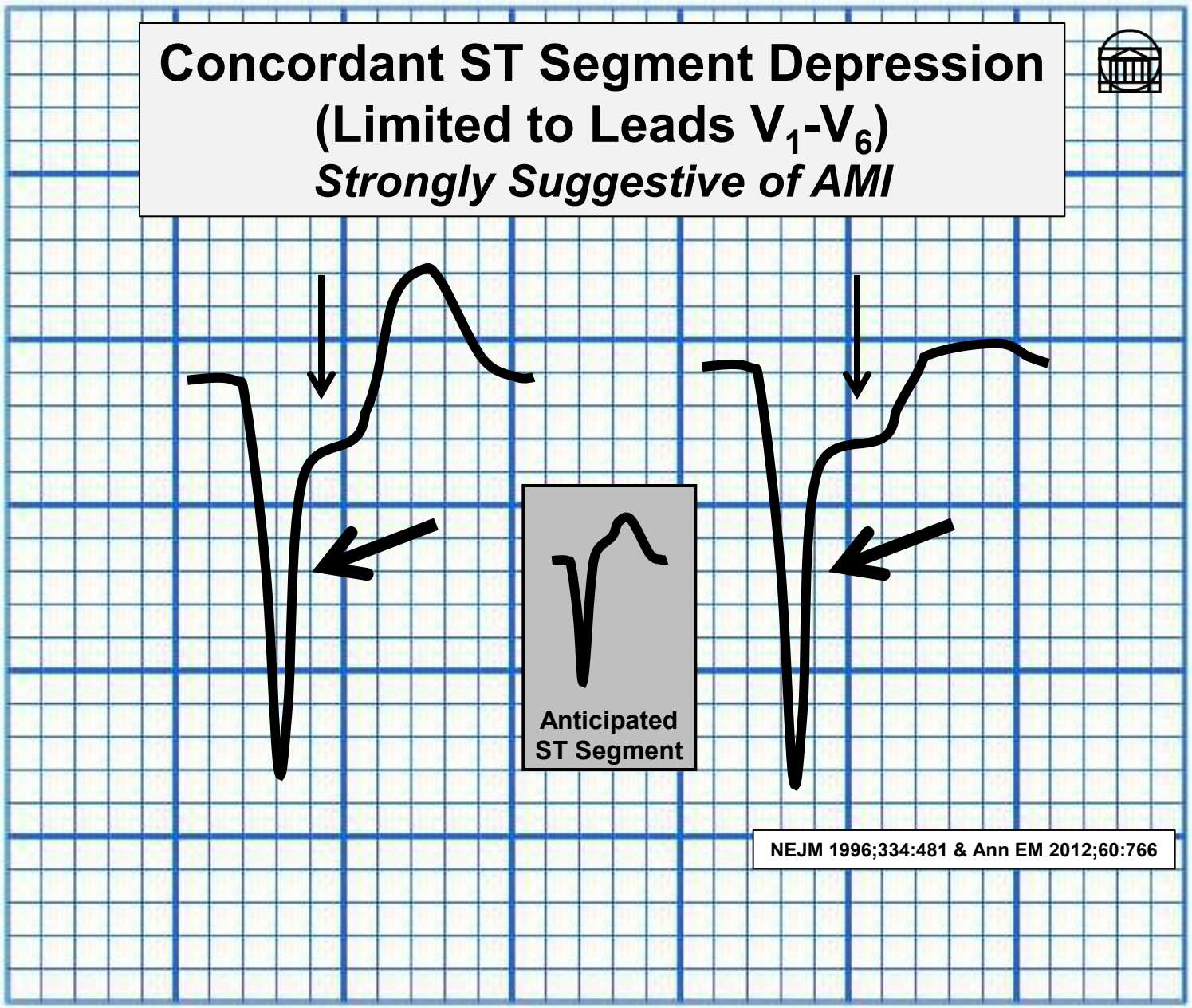

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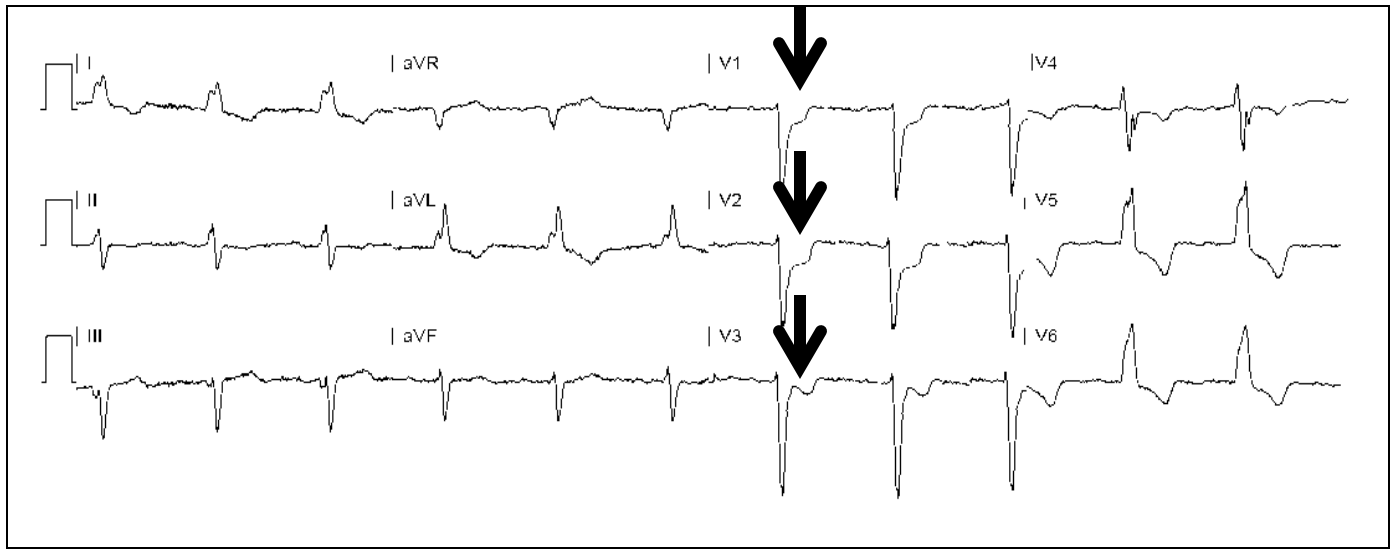
LBBB with AMI

Concordant ST Segment Depression



LBBB with AMI

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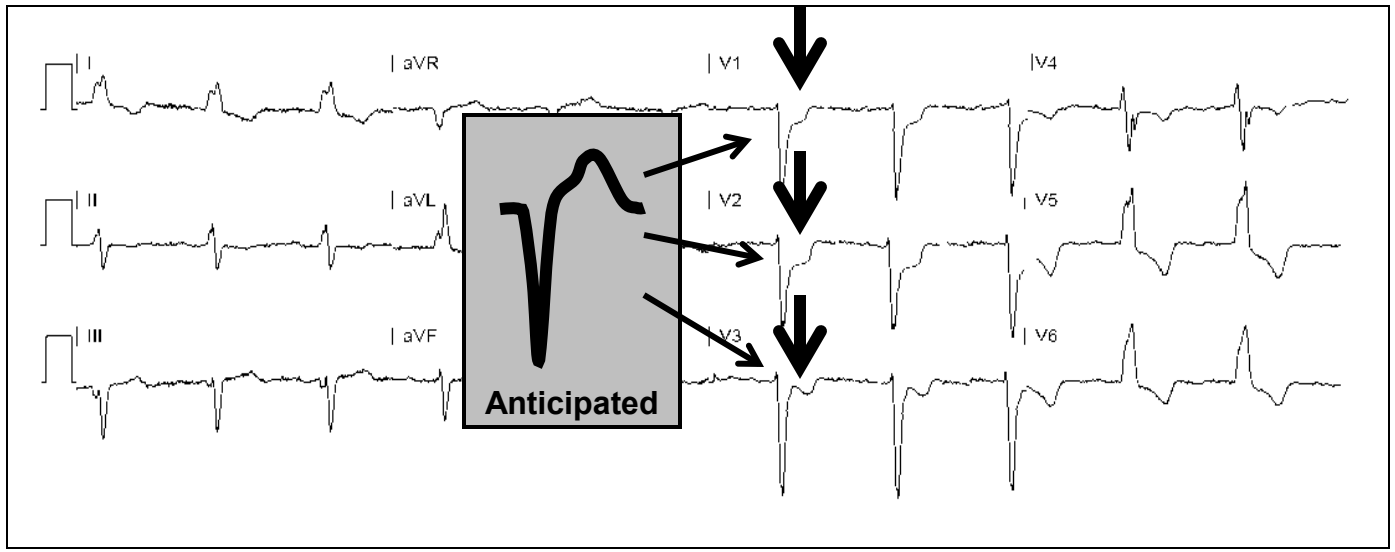
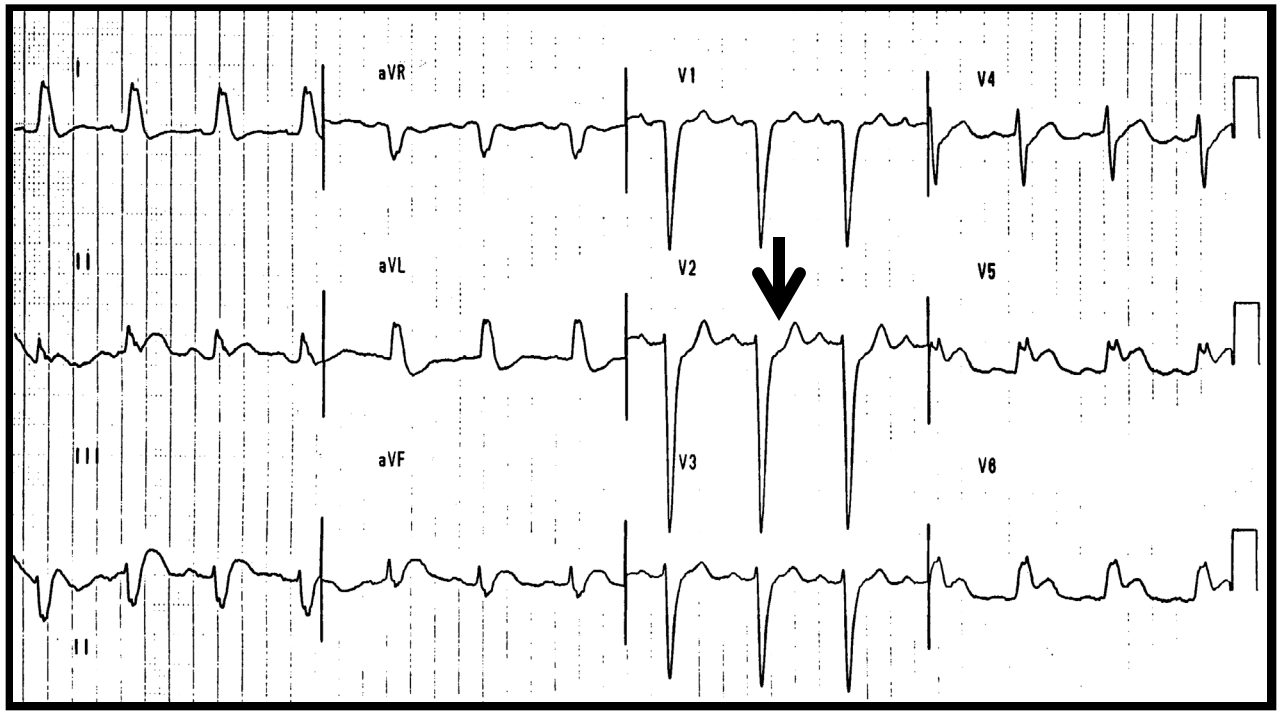


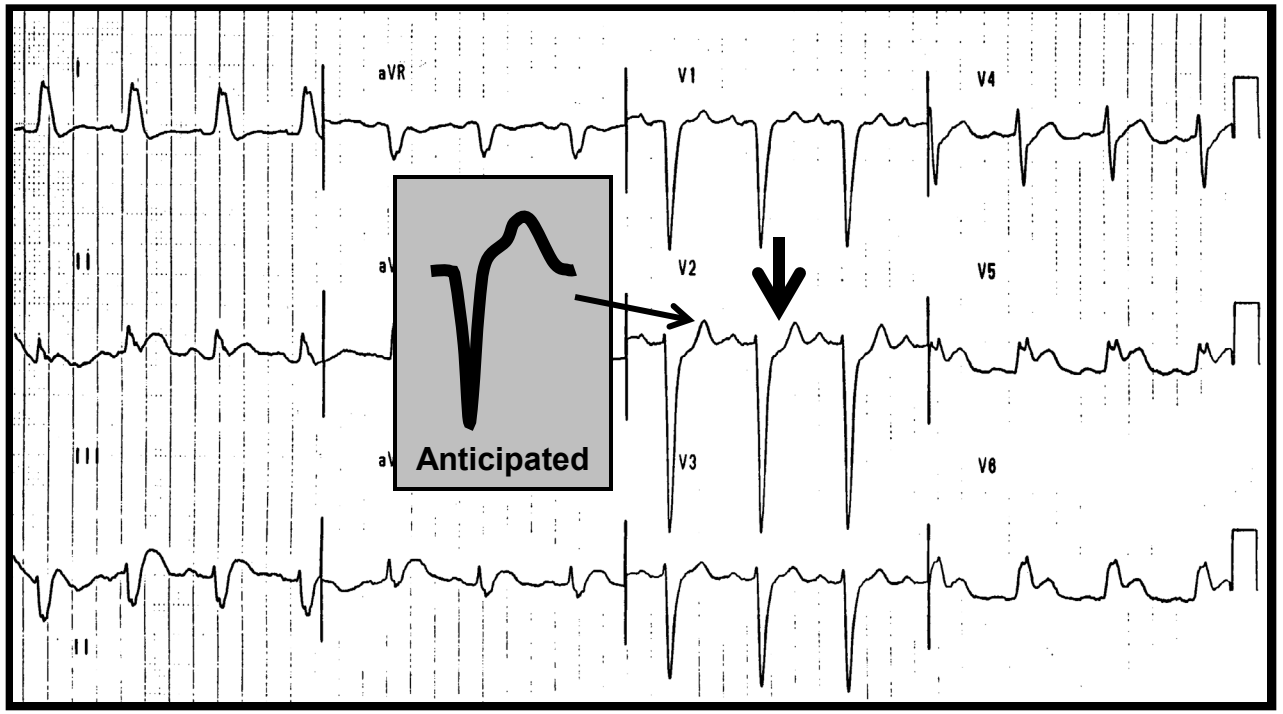
LBBB with AMI

Concordant ST Segment Depression



LBBB with AMI

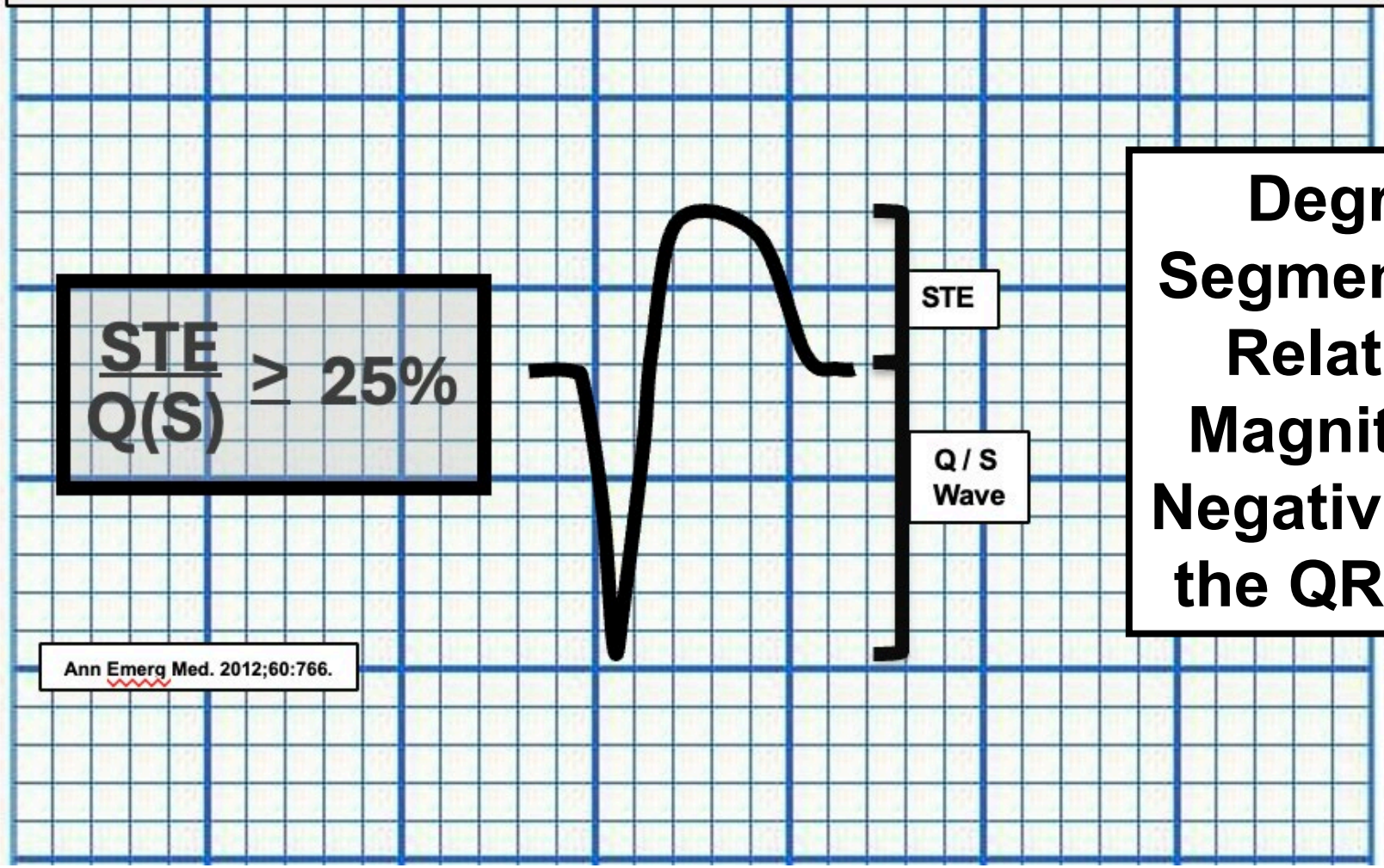
Concordant ST Segment Depression



Discordant ST Segment Elevation

≥ 1 mm ST elevation, ≥ 25% of preceding Q / S wave

Strongly Suggestive of AMI

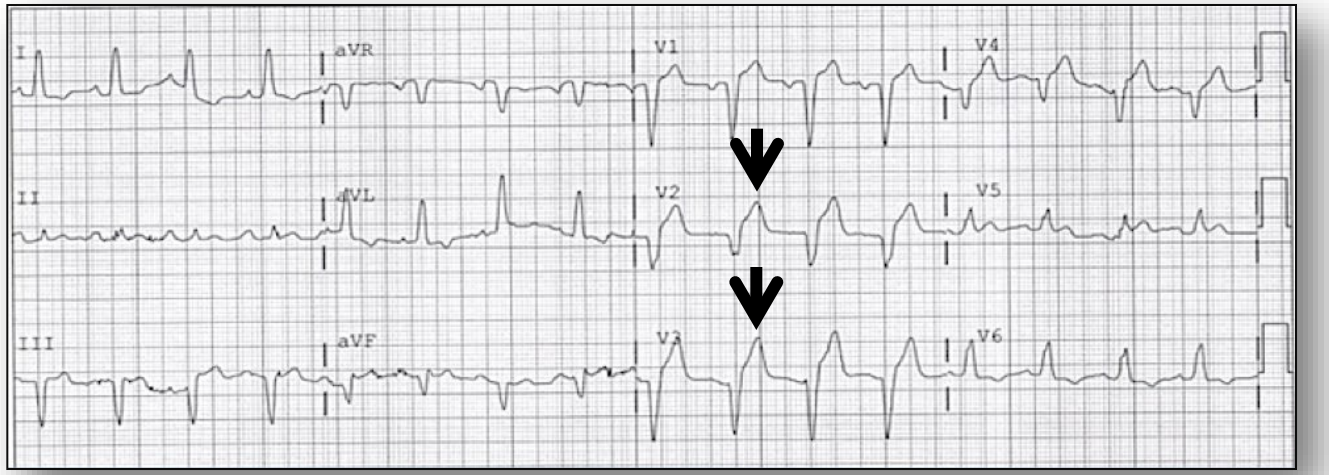


Degree of ST Segment Elevation Relative to the Magnitude of the Negative Portion of the QRS Complex

LBBB with AMI

Discordant ST Segment

Elevation ≥ 25% Q/S Wave

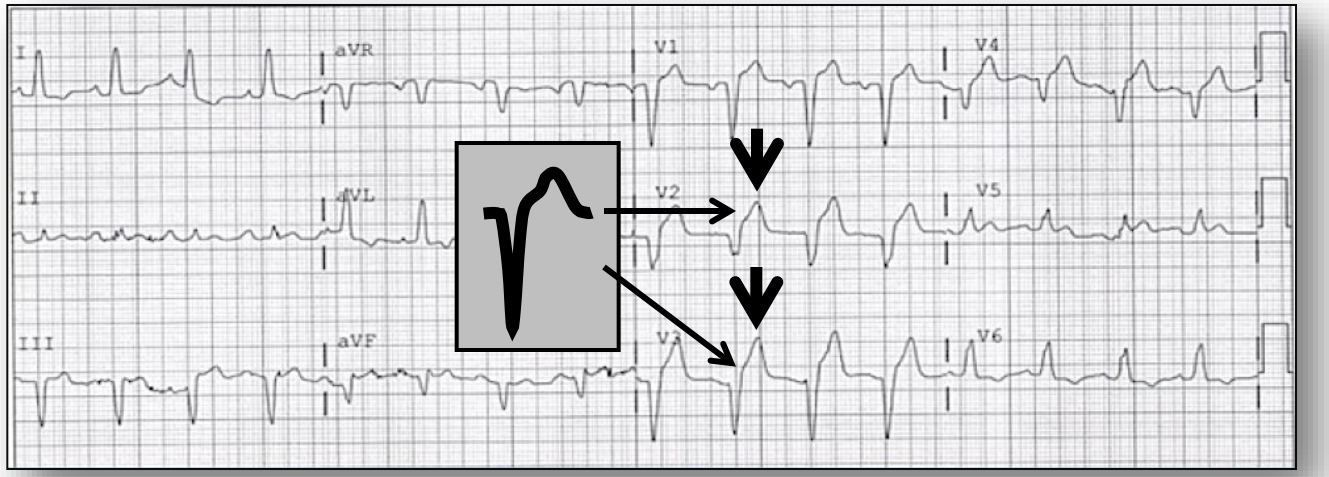


Courtesy of Steve Smith, MD - lifeinthefastlane.com/ecg-library/basics/sgarbossa

LBBB with AMI

Discordant ST Segment

Elevation ≥ 25% Q/S Wave



Courtesy of Steve Smith, MD - lifeinthefastlane.com/ecg-library/basics/sgarbossa

LBBB with AMI

Discordant ST Segment

Elevation ≥ 25% Q/S Wave

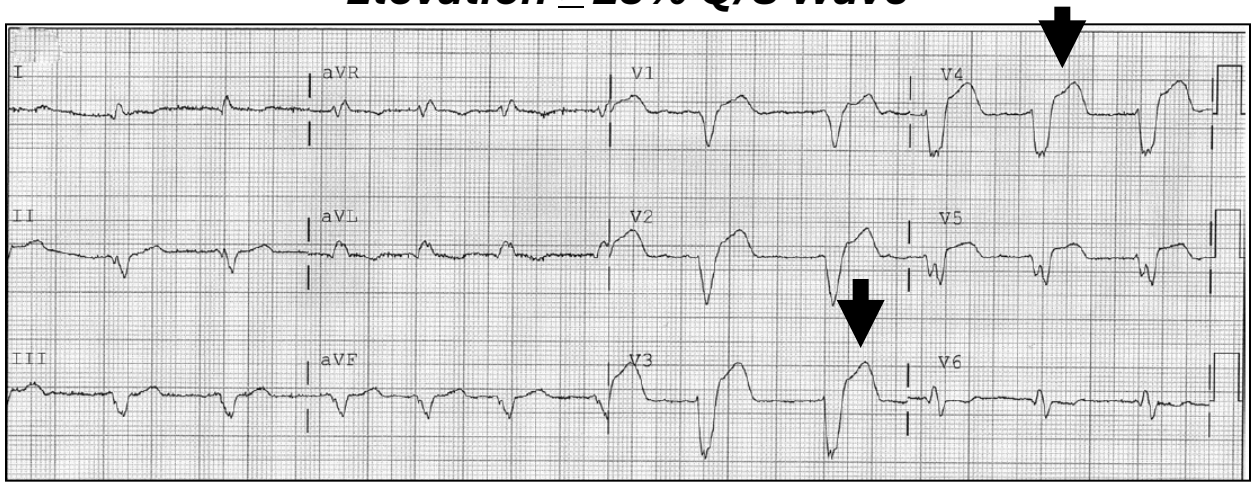
“Negative” for AMI by Original Sgarbossa Criteria

Courtesy of Steve Smith, MD - lifeinthefastlane.com/ecg-library/basics/sgarbossa

LBBB with AMI

Discordant ST Segment

Elevation ≥ 25% Q/S Wave

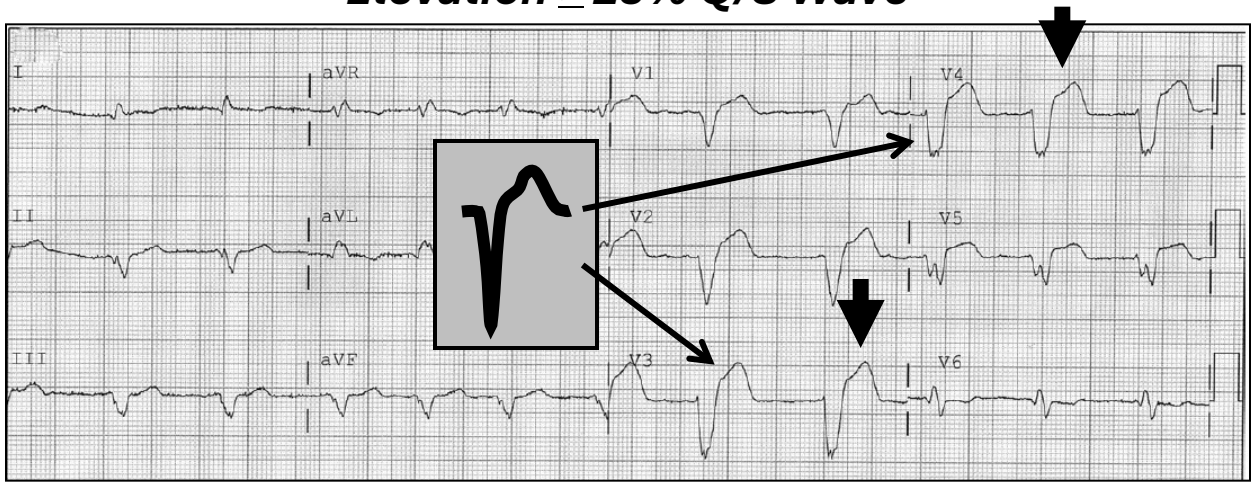


Smith S et al: Ann Emerg Med 2012

LBBB with AMI

Discordant ST Segment

Elevation ≥ 25% Q/S Wave

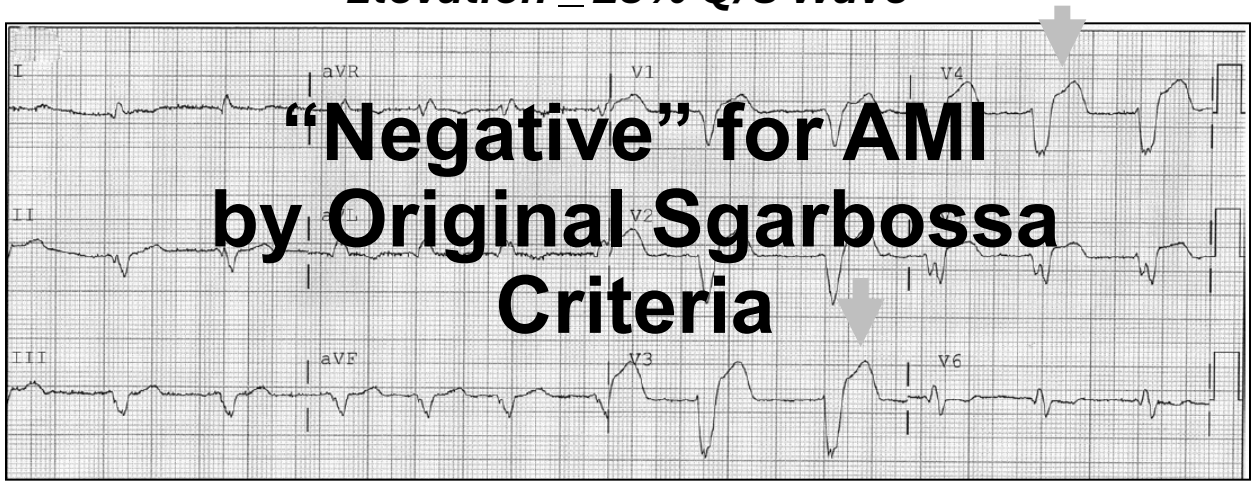


Smith S et al: Ann Emerg Med 2012

LBBB with AMI

Discordant ST Segment

Elevation ≥ 25% Q/S Wave

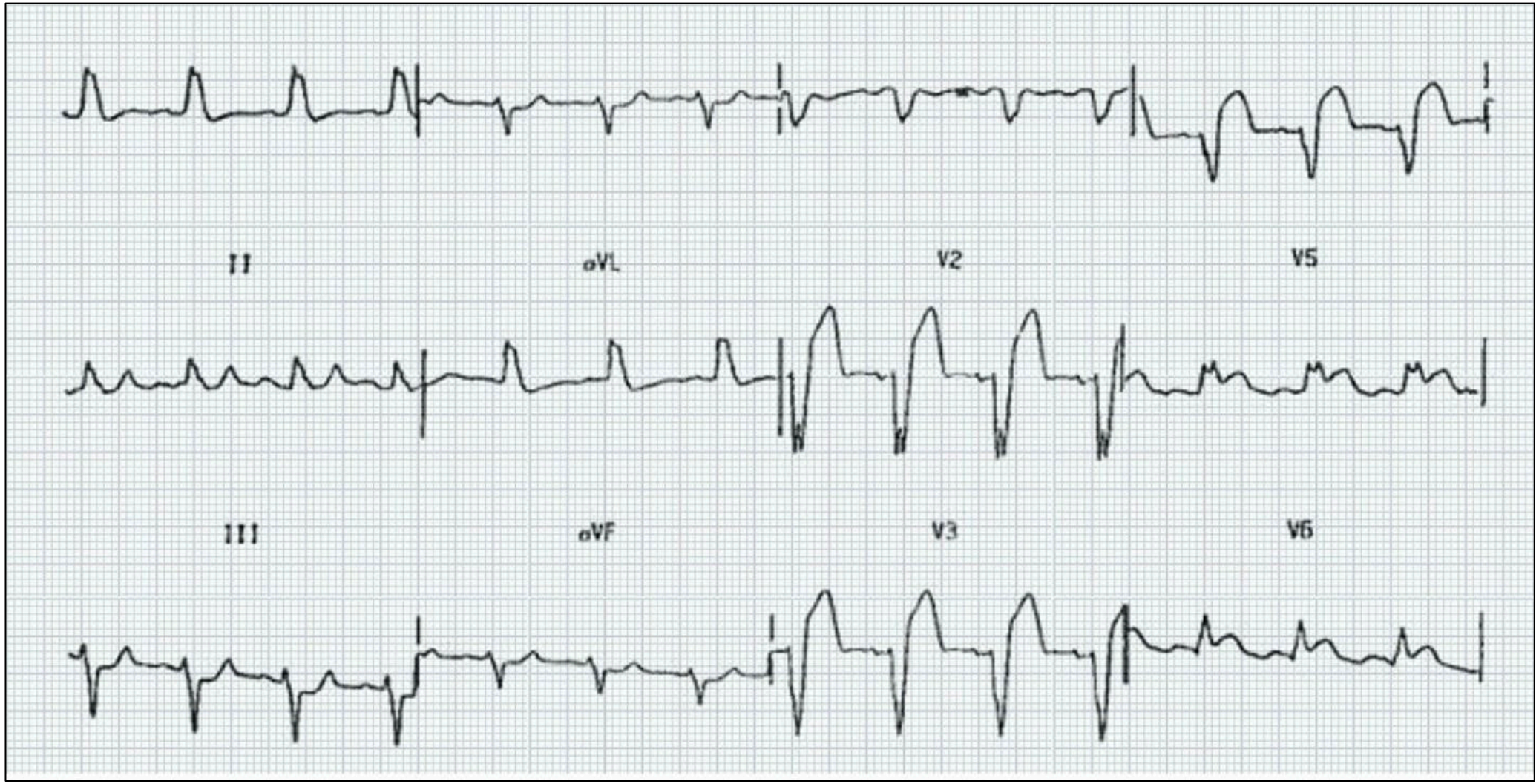


“Negative” for AMI by Original Sgarbossa Criteria

Smith S et al: Ann Emerg Med 2012

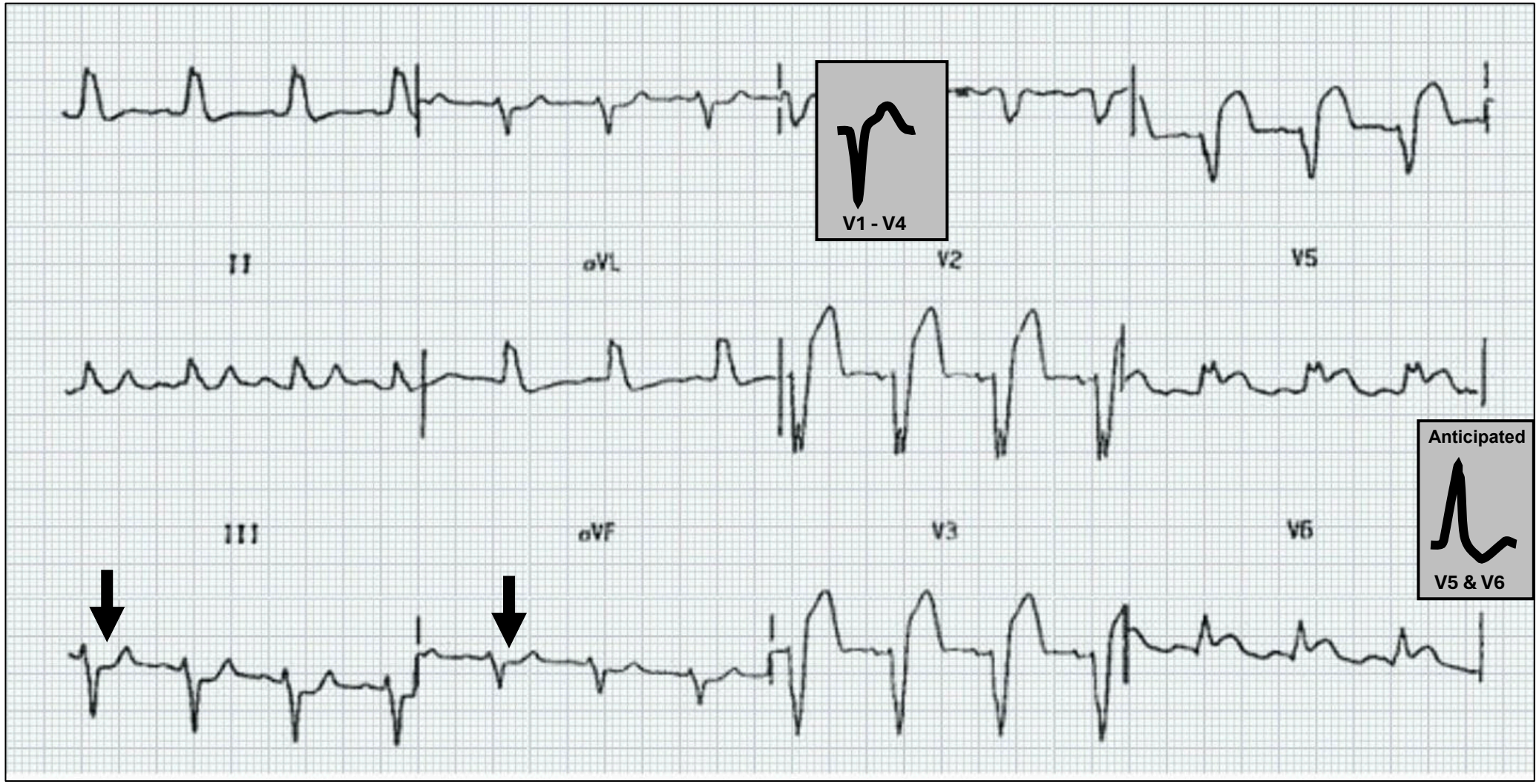
67 female with chest pain & extreme weakness

alert, pale, & sweaty - 95/75, 80, 26, Sat 90% (RA)

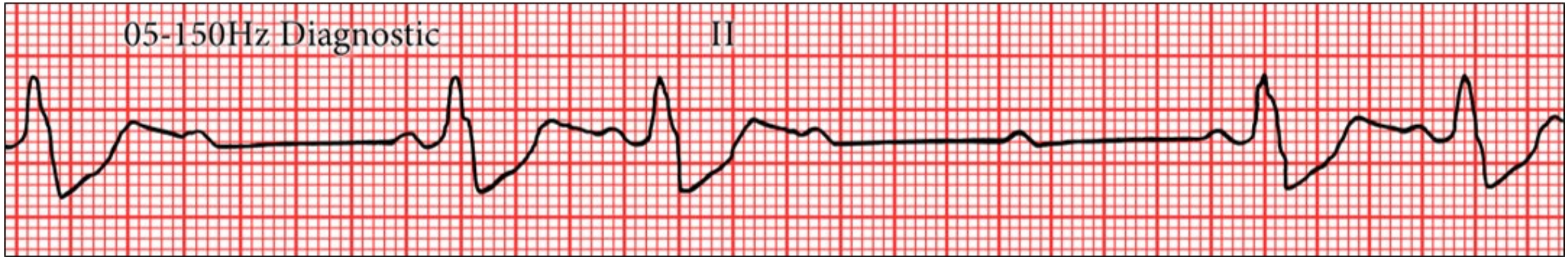


LBBB with ECG Evidence of AMI

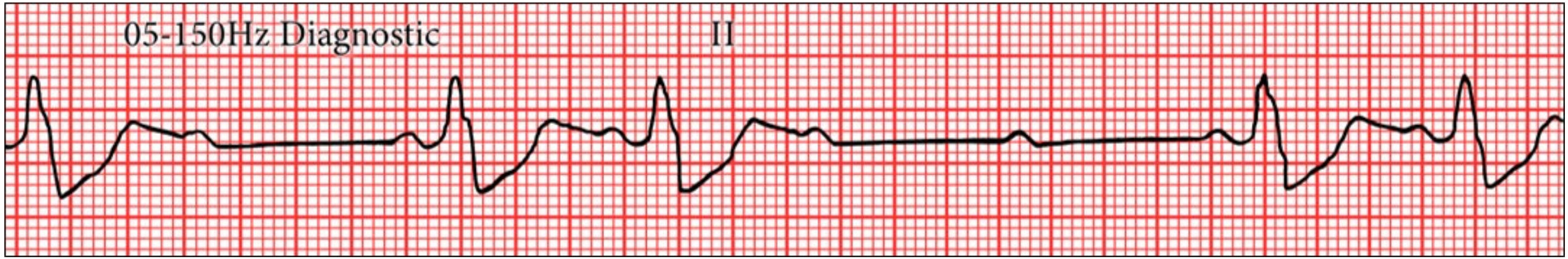
Concordant ST Elevation V5/V6 & Excessive Discordant ST Elevation V2-V4



64 Female with Chest Pain, Dyspnea, & Syncope...
Patient is ill-appearing



2 AV Block / II with High Grade Block



2 AV Block / II with High Grade Block

2nd / Type II AVB

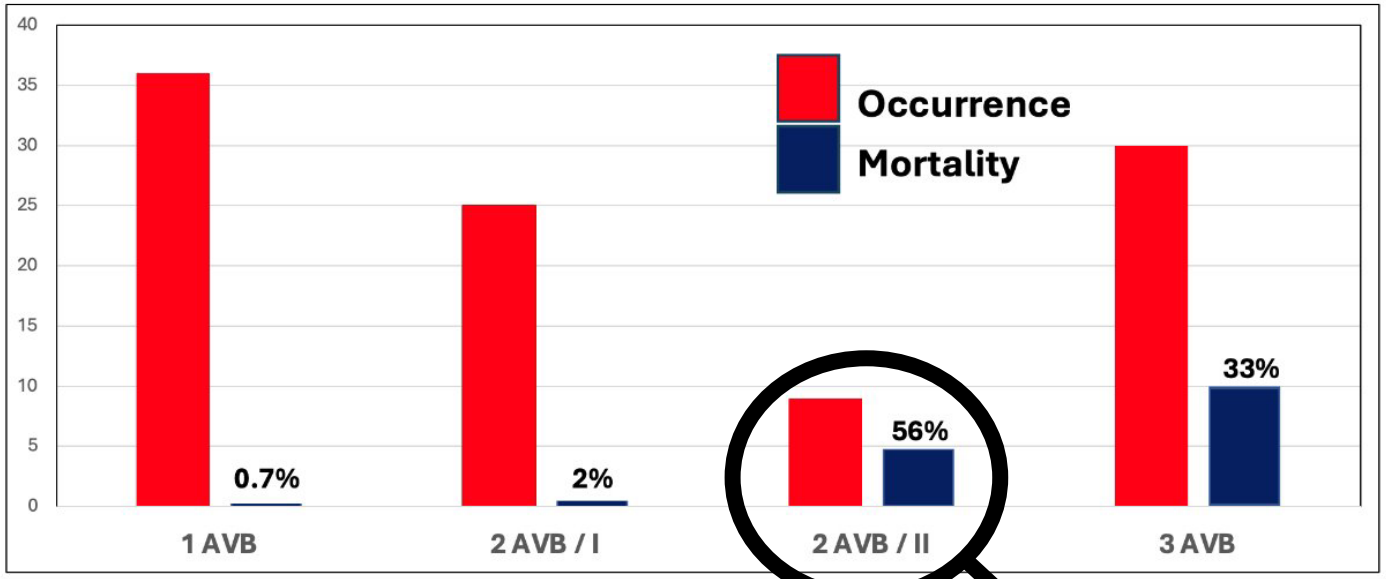
- Fixed PR interval with sudden non-conducted beat
- QRS complex, usually widened / less commonly narrow

- …with High Grade Block

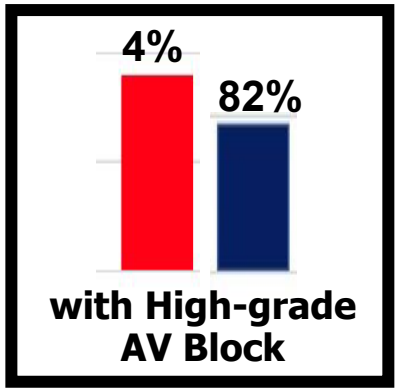
  - >1 consecutive non-conducted P wave
  - Usually with extensive anterior STEMI
  - Extremely high risk

2nd / Type II AVB

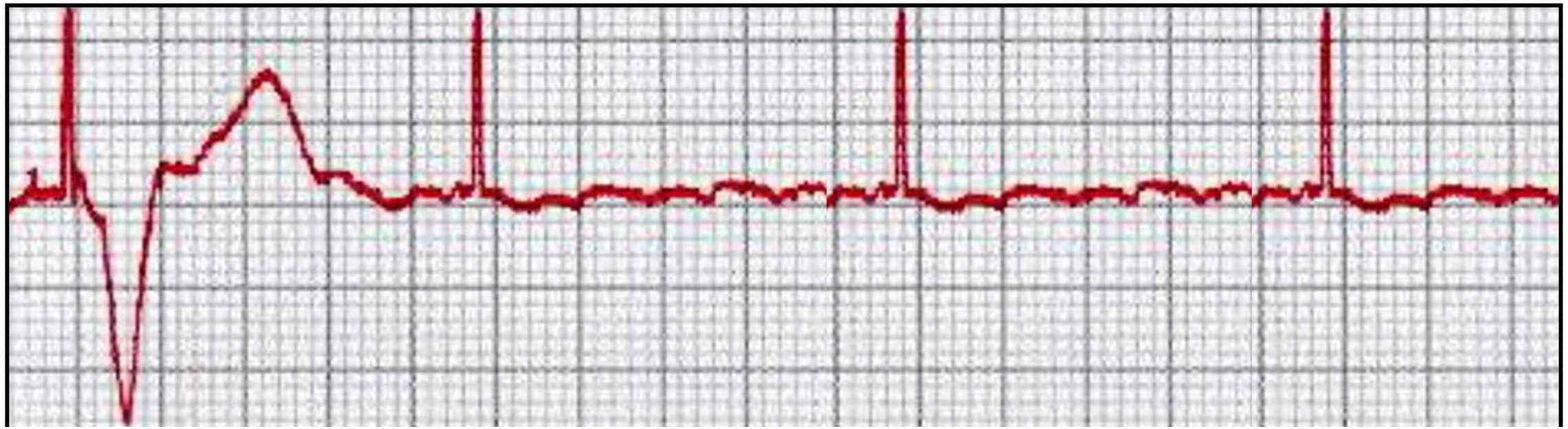
AV Block Frequency & Mortality Rates



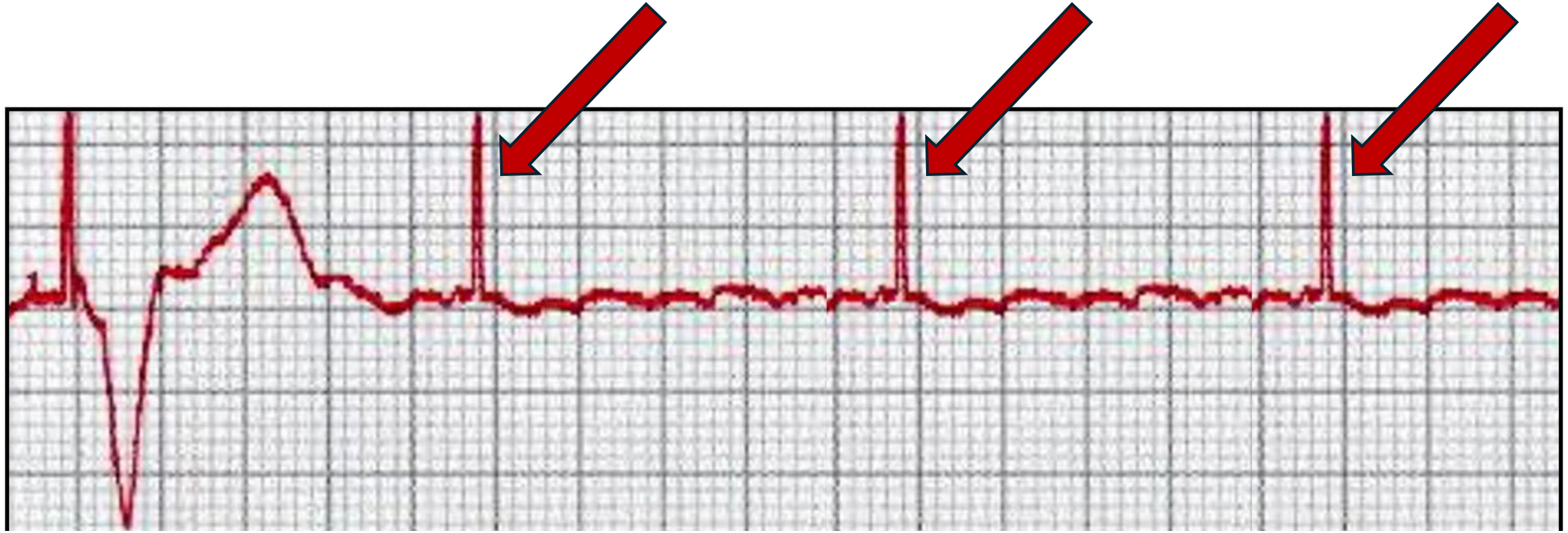
- Least common
- Highest risk



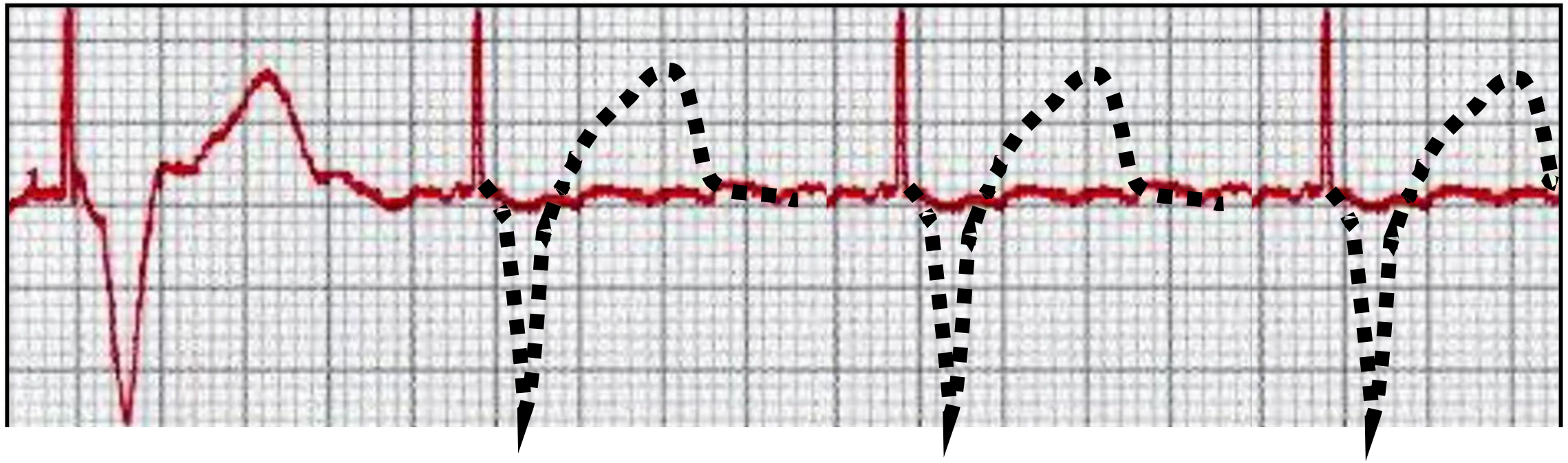
83 Female with Recent Pacemaker Placement
“*she dun fell out!*”



Failure to Capture

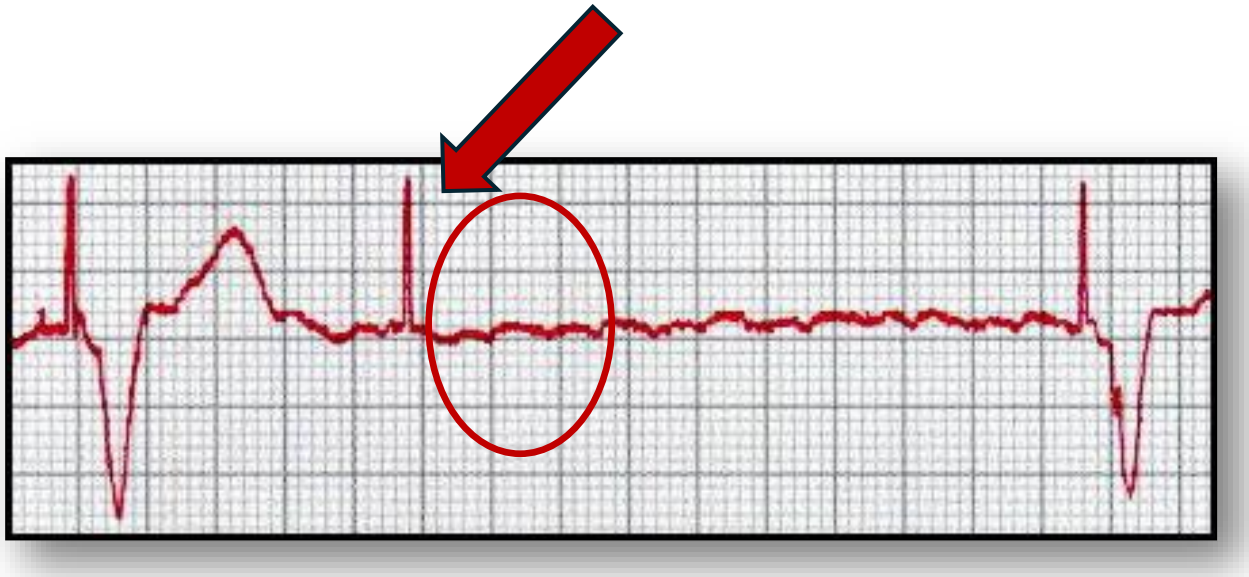


Failure to Capture



...if appropriate capture occurred

Failure to Capture



Pacer spike is seen without accompanying QRS complex

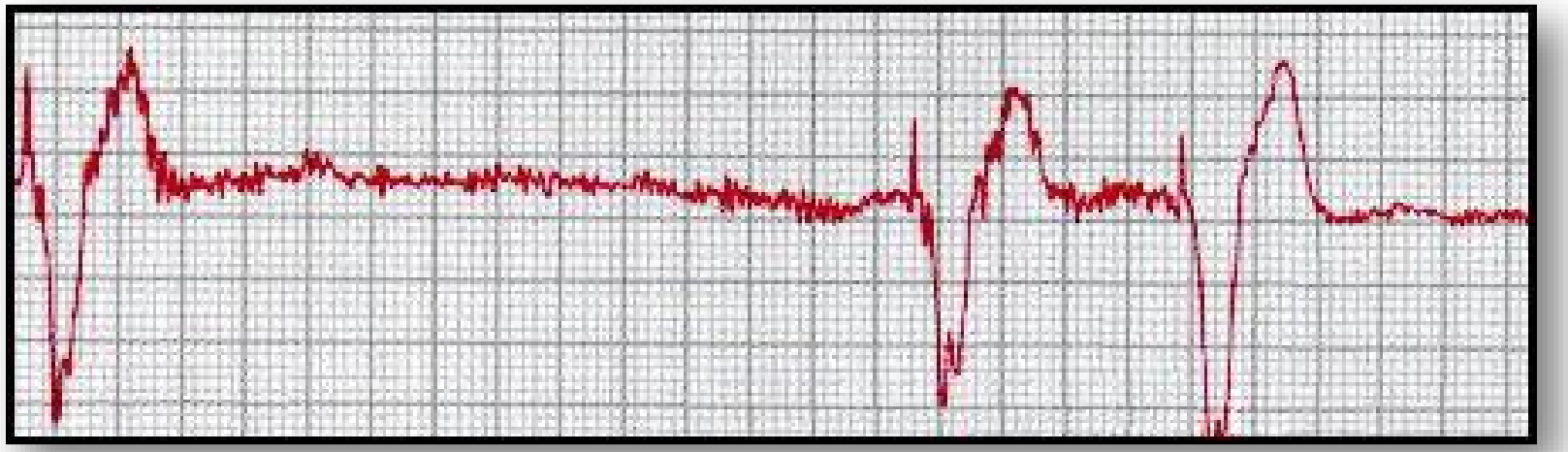
Potential Causes

- **battery depletion**
- **circuit failure**
- **lead dislodgement or scarring**
- **elevated capture thresholds**
  - progressive cardiac disease
  - metabolic abnormalities
  - medications

Other Common Forms of Pacemaker Malfunction

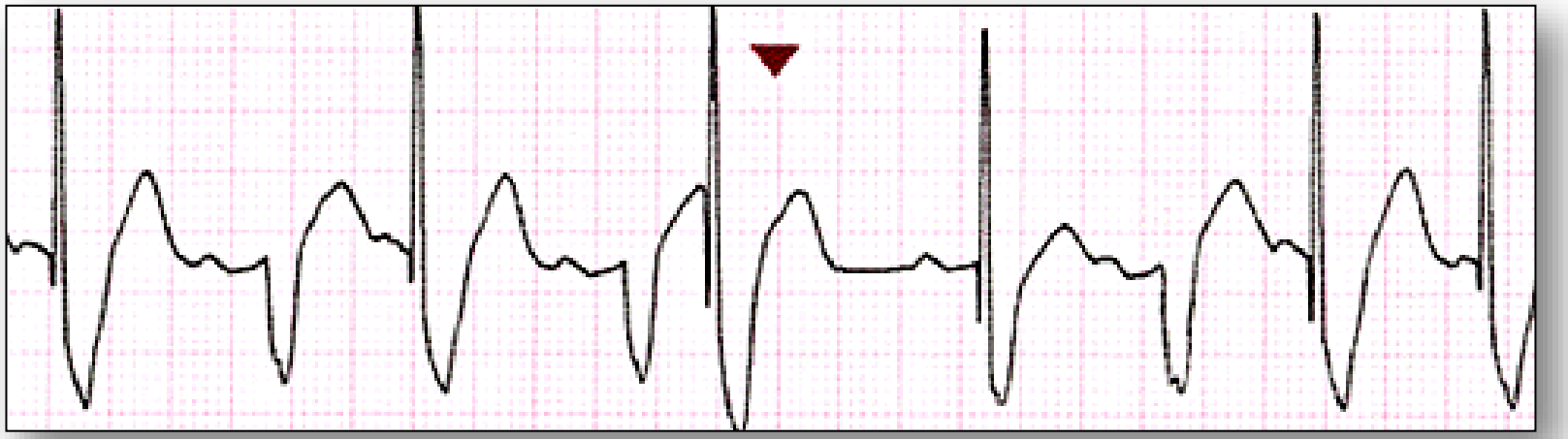
- **Failure to Pace**

  No pacer spike

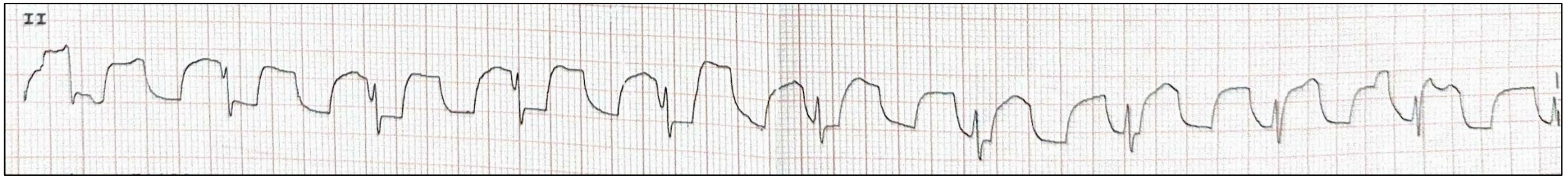


- **Failure to Sense**

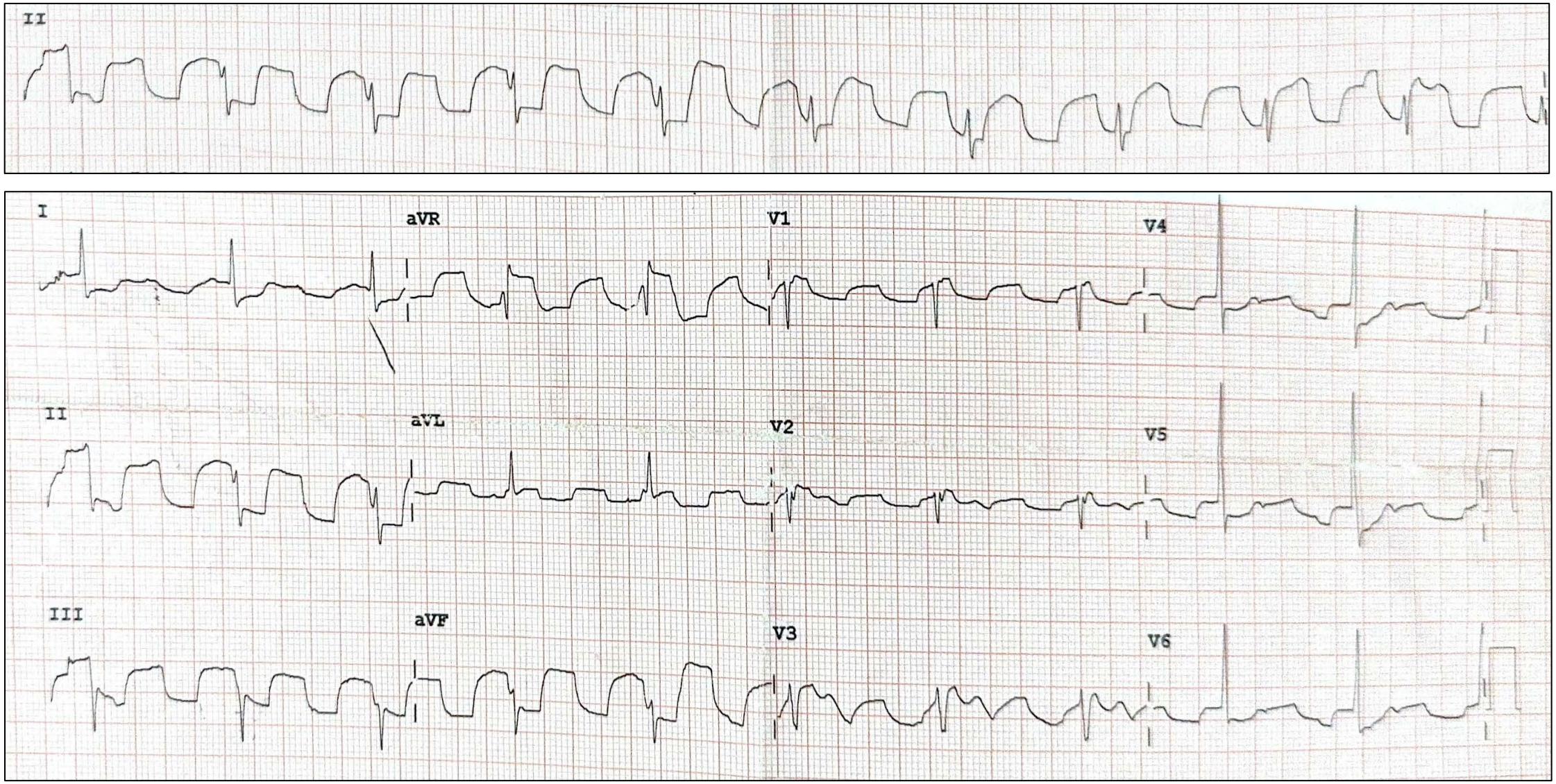
  Pacer spike occurring without association to QRS complex



39 Male with N/V/D & Fever
Patient is well-appearing

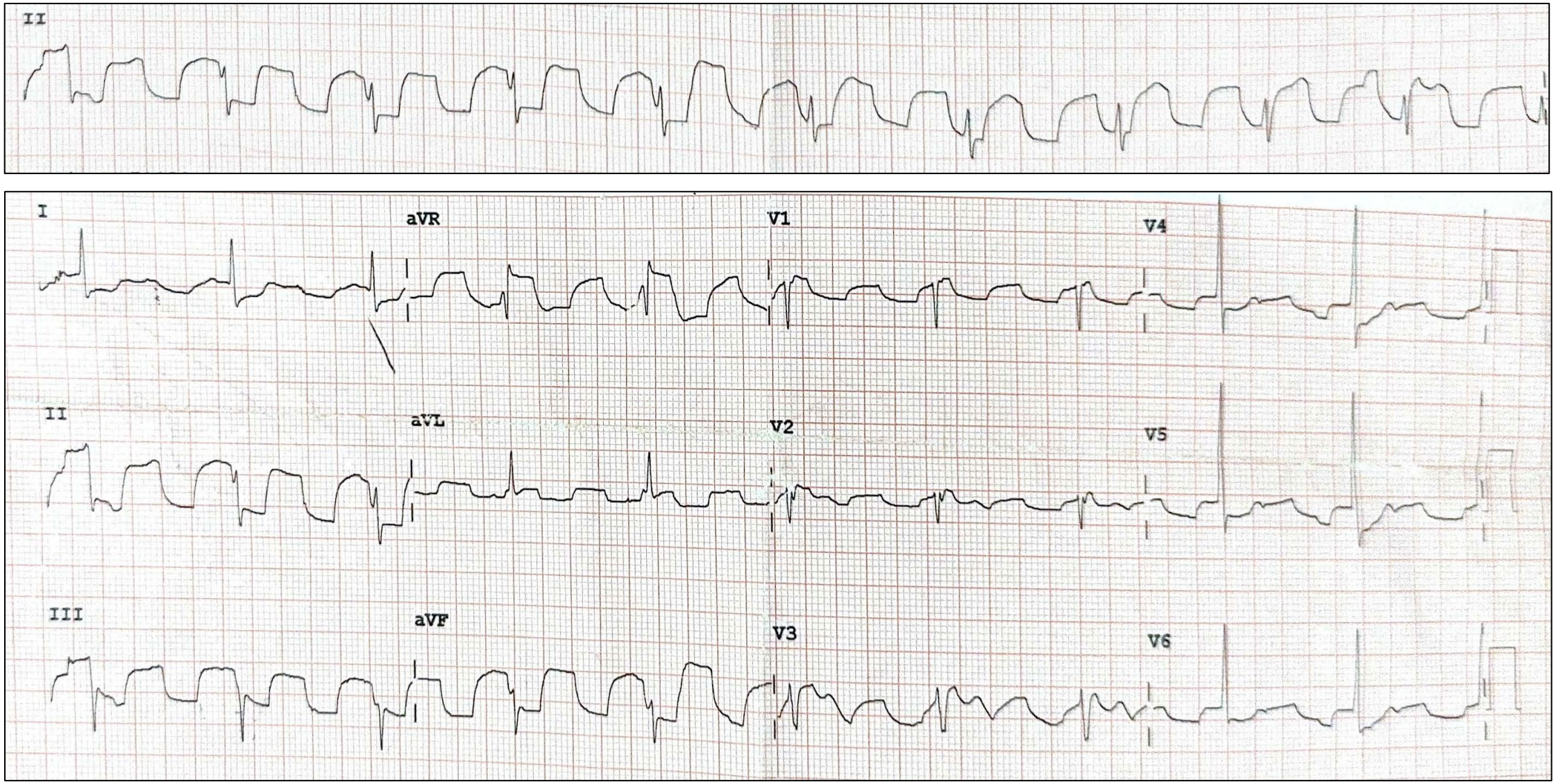


39 Male with N/V/D & Fever
Patient is well-appearing



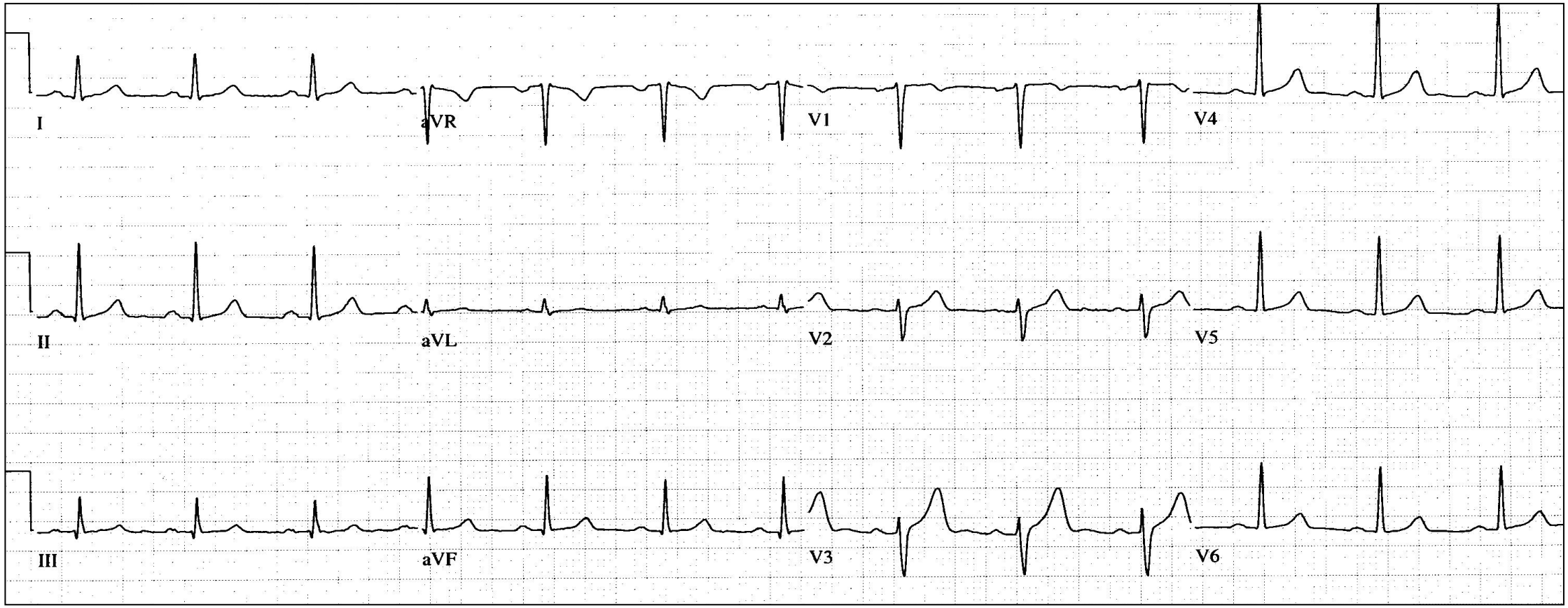
Pulse Tapping – Mechanical Artifact

reposition leads & repeat ECG



Normal ECG

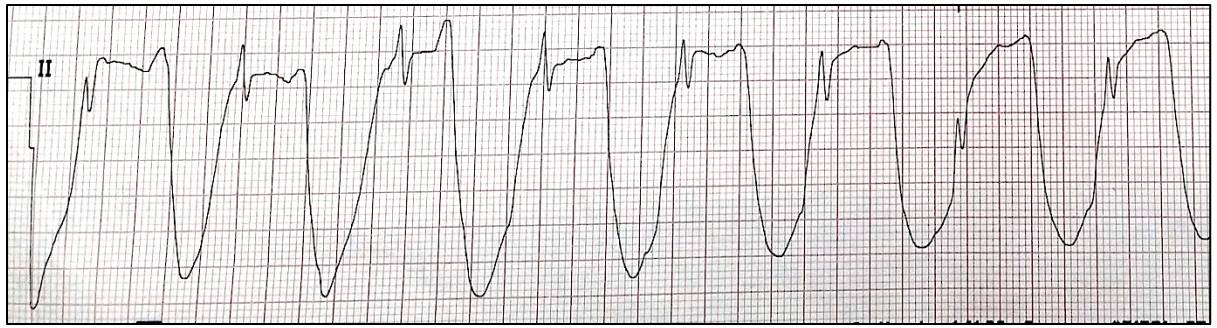
repositioned leads & ECG repeated



ECG Pulse Tapping

- Electrocardiographic artifact caused by cardiac or arterial vascular pulsations

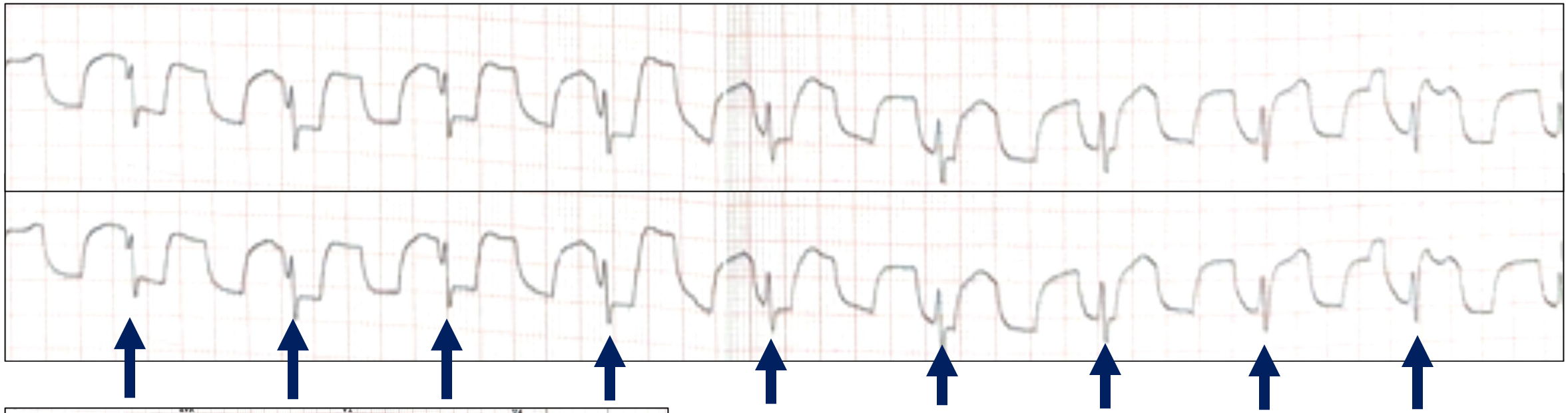
- ECG lead is placed adjacent to heart or vascular tissue …mechanical artifact produced by pulsations

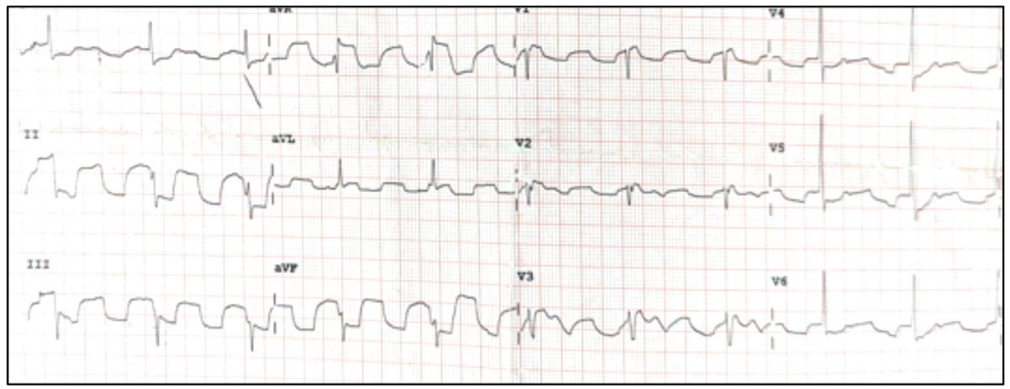


- Also known as an electromechanical association artifact or Aslanger's sign

ECG Pulse Tapping

39 Male with N/V/D & Fever - Patient is well-appearing



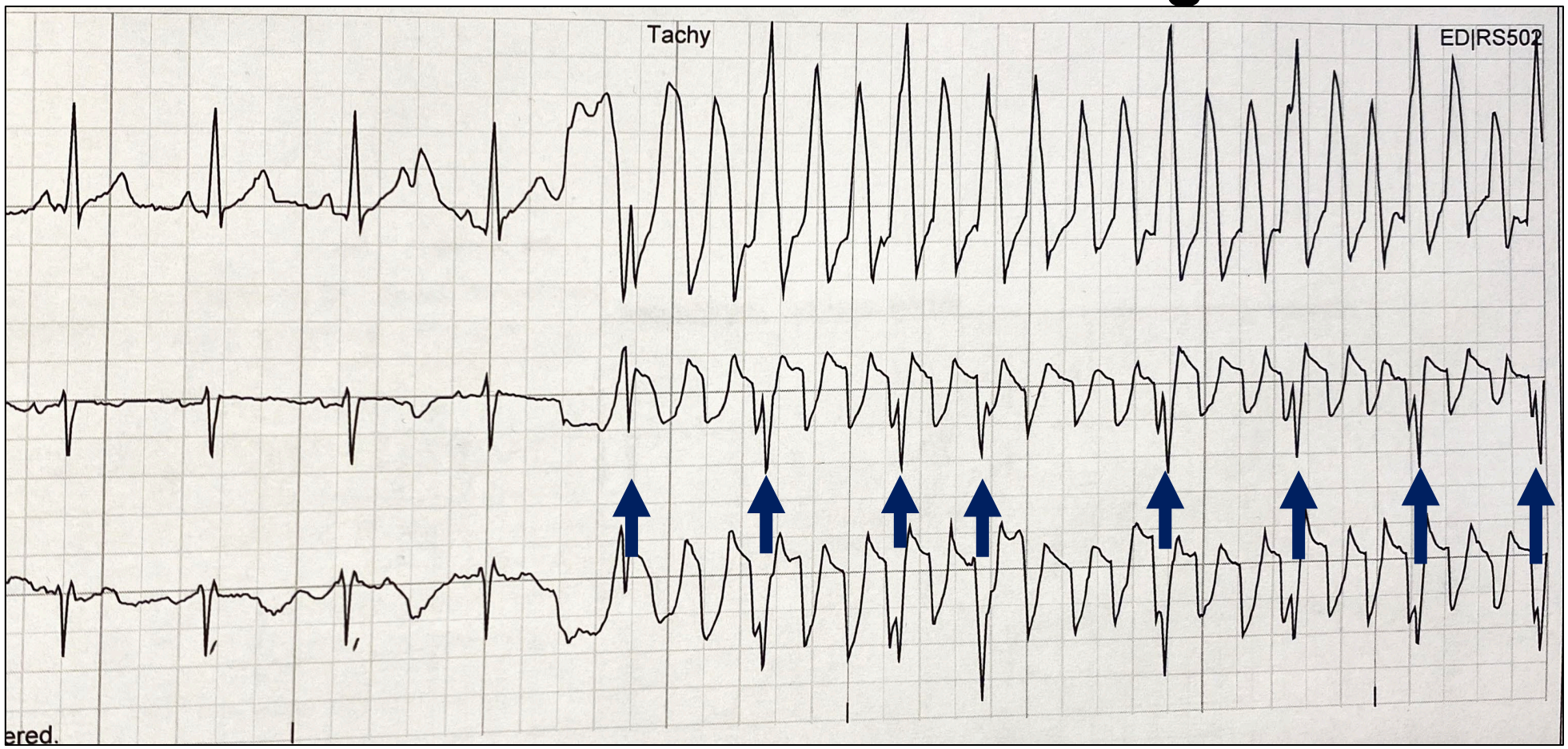


160/105, 65, 32, 36.5, 89% RA

Alert & oriented

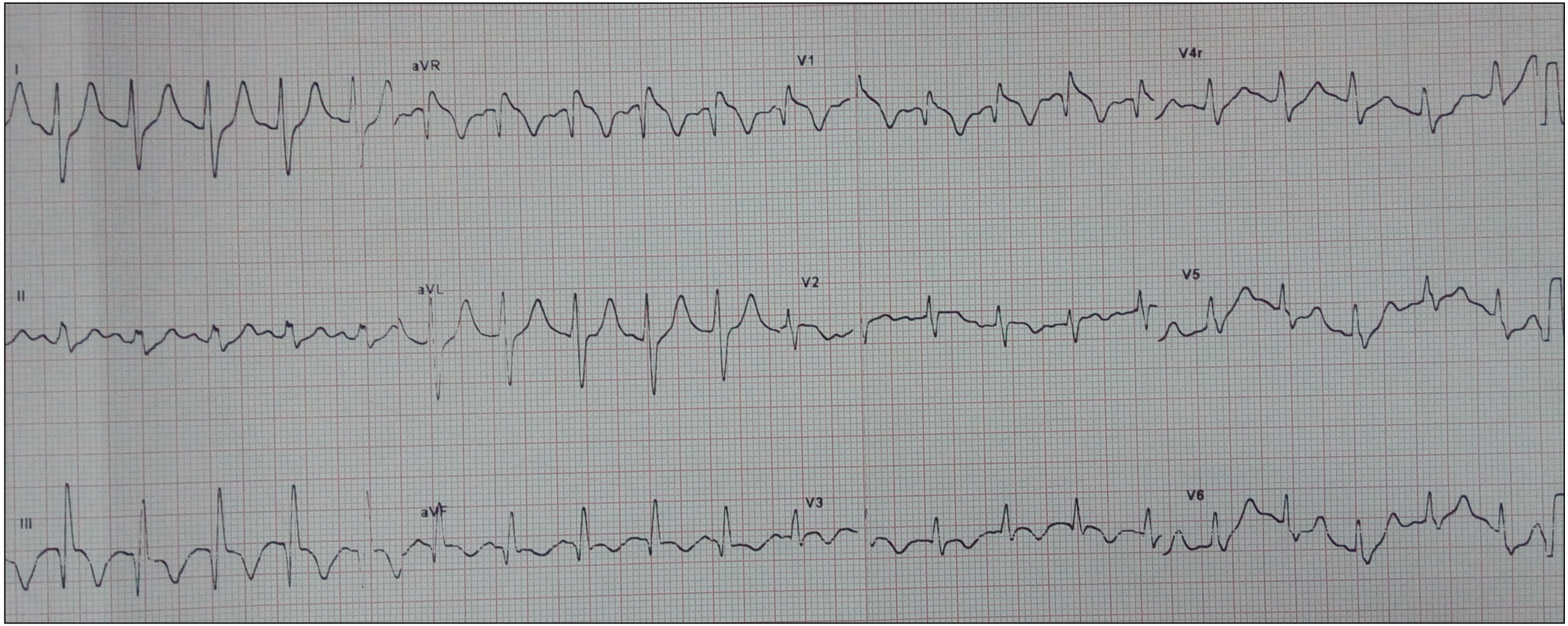
Moderate respiratory distress

Motion Artifact
43 male with Pneumonia - Rigors

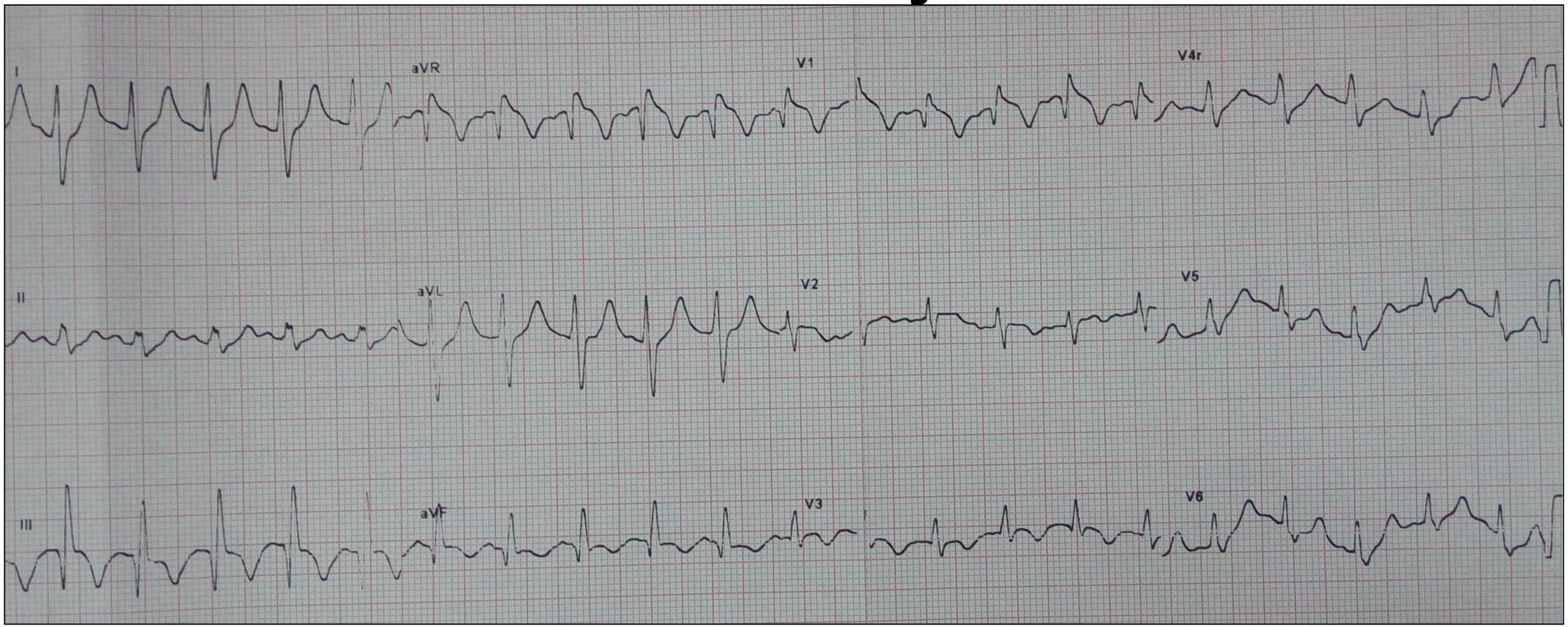


Clinical correlation? **“Causes” of artifact?** **Portions of “normal” QRS complexes march through?**

45 Female with SOB & Chest Pain



Massive Pulmonary Embolus



PE Alert…

Pathophysiology of ECG Abnormalities

- dilation of right heart …subsequent heart rotation
- RV strain/ischemia
- sympathetic stimulation due to hypoperfusion, hypoxia, pain, & anxiety

20% of Patients with PE have **NORMAL** ECGs

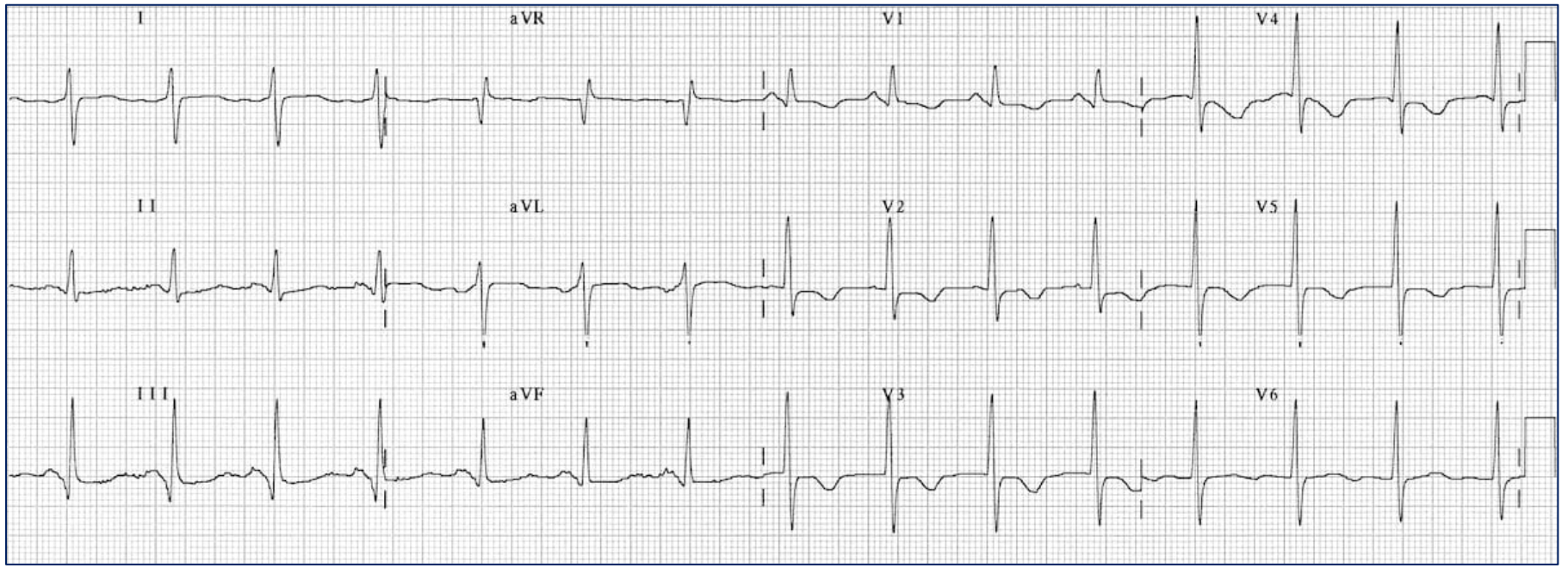
increasing PE size

increasing cardiorespiratory impact
&
increasingly abnormal ECG

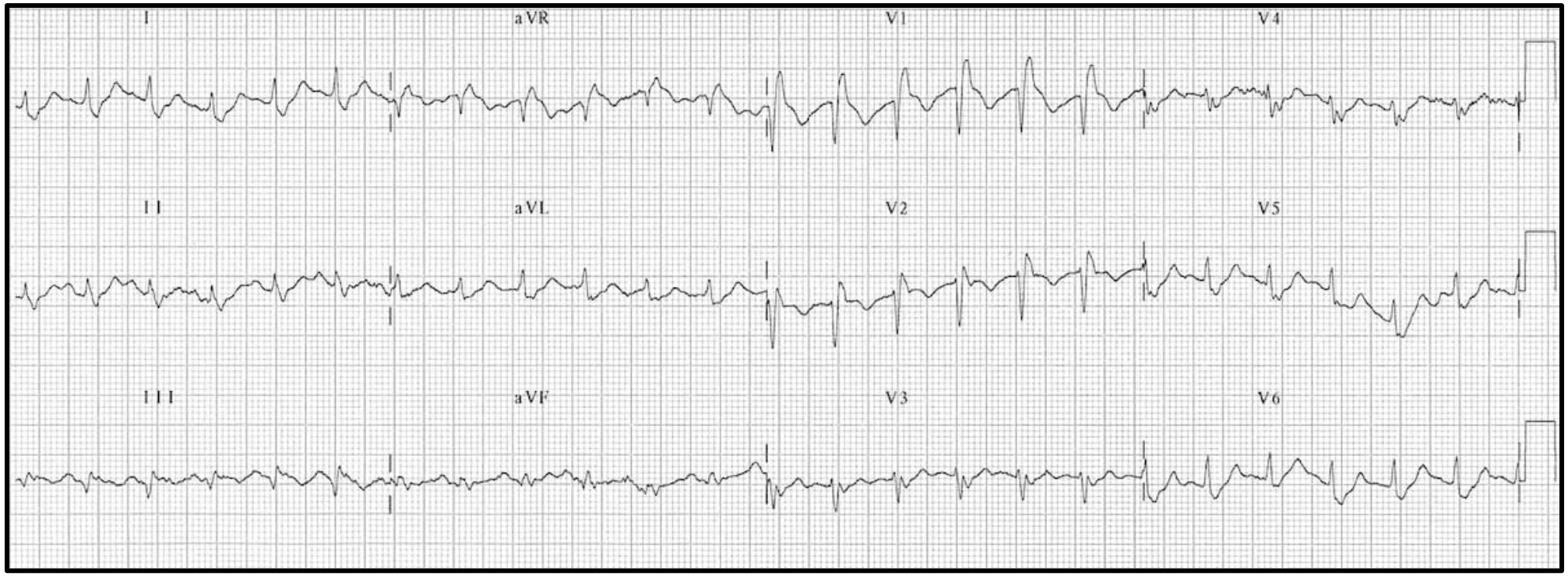
ECG Abnormalities

- sinus tachycardia .....**50% – *Sympathetic Stimulation***
- non-specific changes - ST & T .....**50% - *Multifactorial***
- T wave inversion V1-V4 +/- II, III, & aVF .....**33% - *RV Strain***
- ST segment elevation V1, V2, +/- aVR ..... **25% – *RV Strain***
- RBBB .....**20% – *RV Dilation***
- Right axis deviation **40%**, extreme .....**20% – *RV Dilation with Rotation***
- large R wave in V1 +/- V2 .....**20% - *RV Dilation***
- persistent large S wave V5 & V6 .....**20% – *RV Rotation***
- atrial arrhythmias .....**10% - *Multifactorial***
- S1Q3T3 .....**10% - *RV Strain***
- none (normal) **20%**

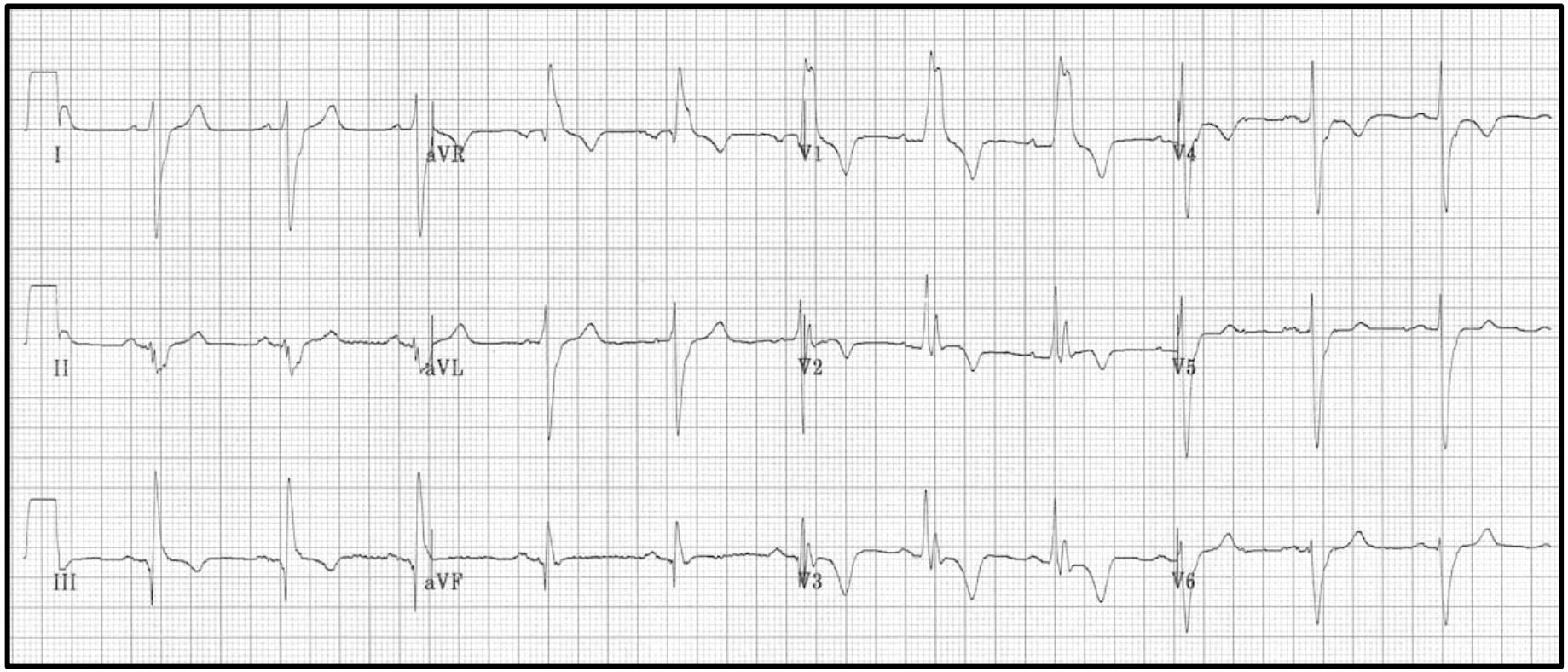
- Right axis deviation
- T wave inversions V1-V5
- Large R waves V1 & V2
- Deep S waves V5 & V6



- Sinus tachycardia
- RBBB
- ST elevation aVR, V1, & V2
- T wave inversion V1-V3

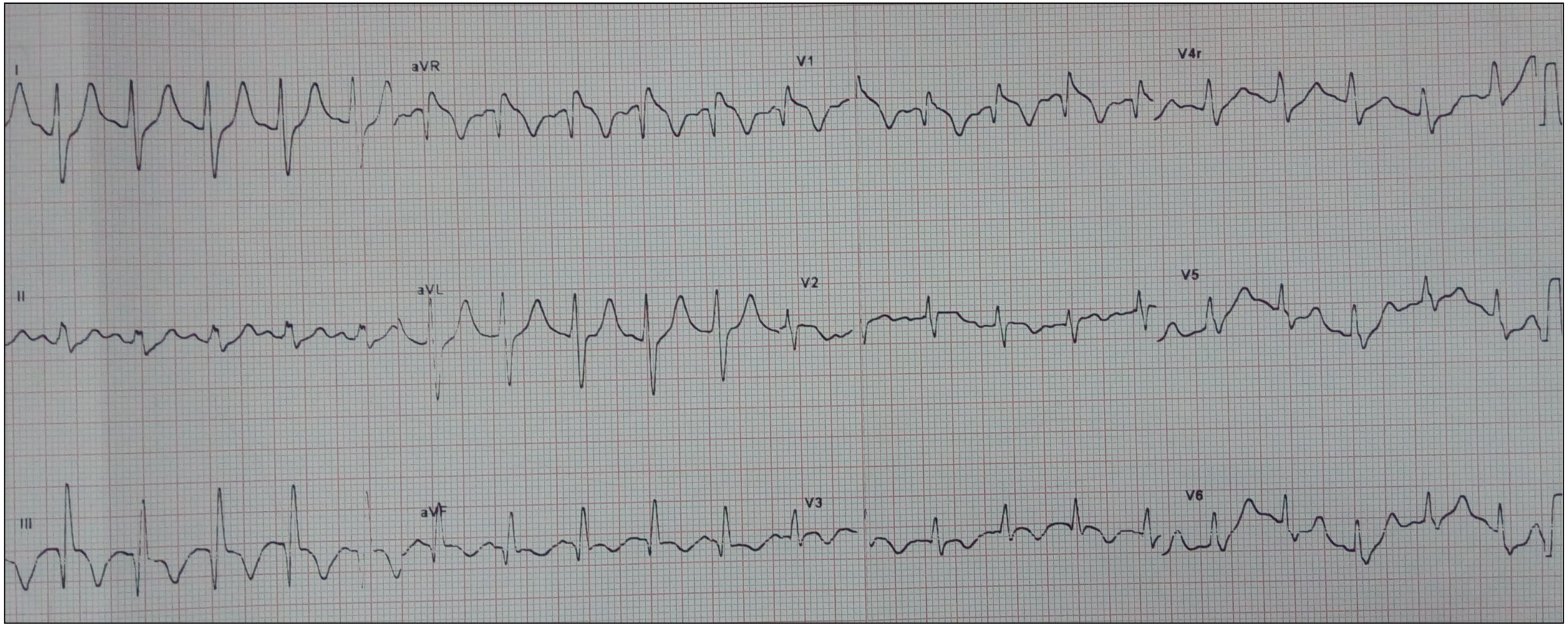


- **Right axis deviation (extreme)**
- **RBBB**
- **T wave inversion V1-V4**
- **S1Q3T3**

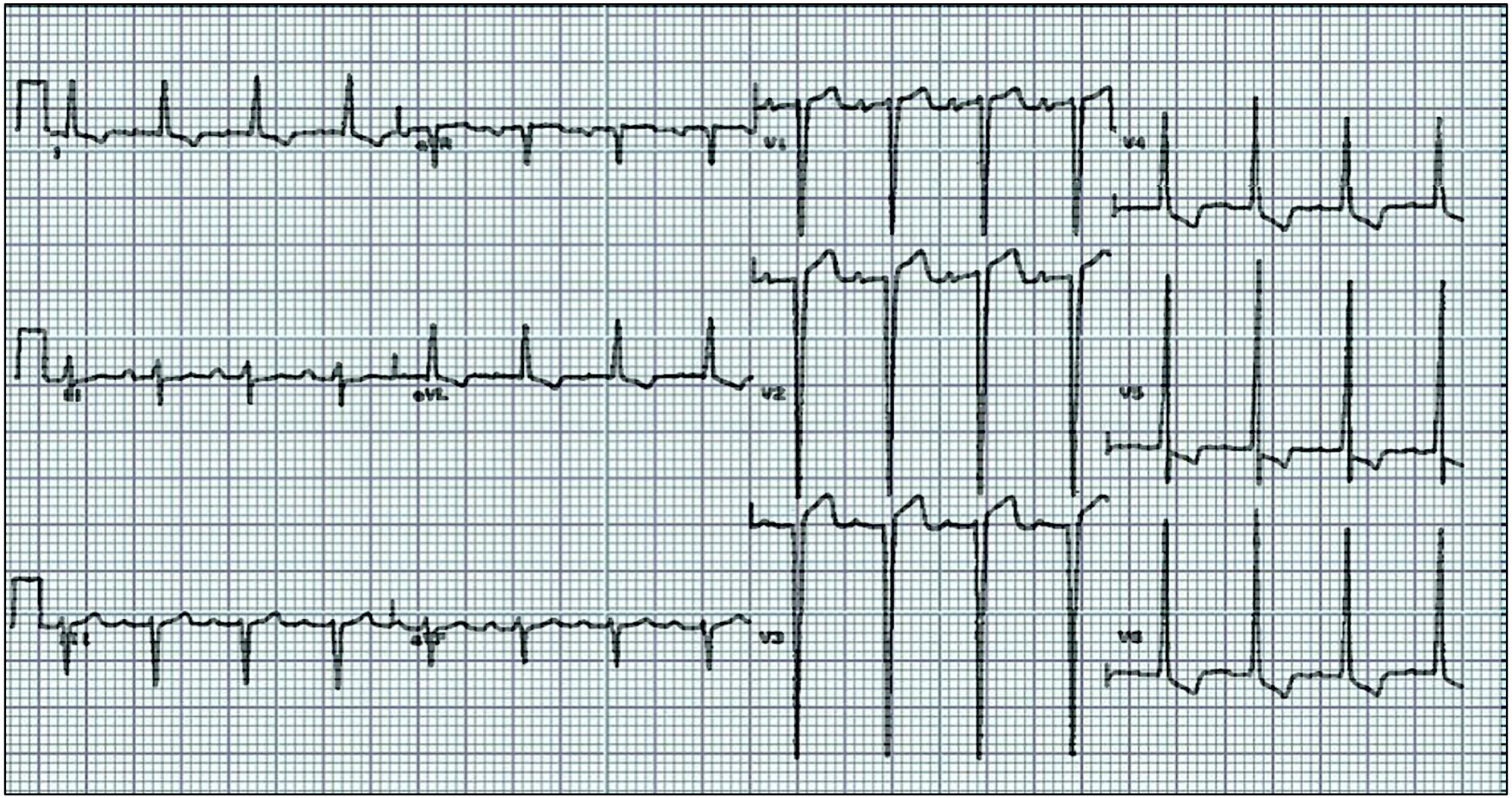


...back to our patient

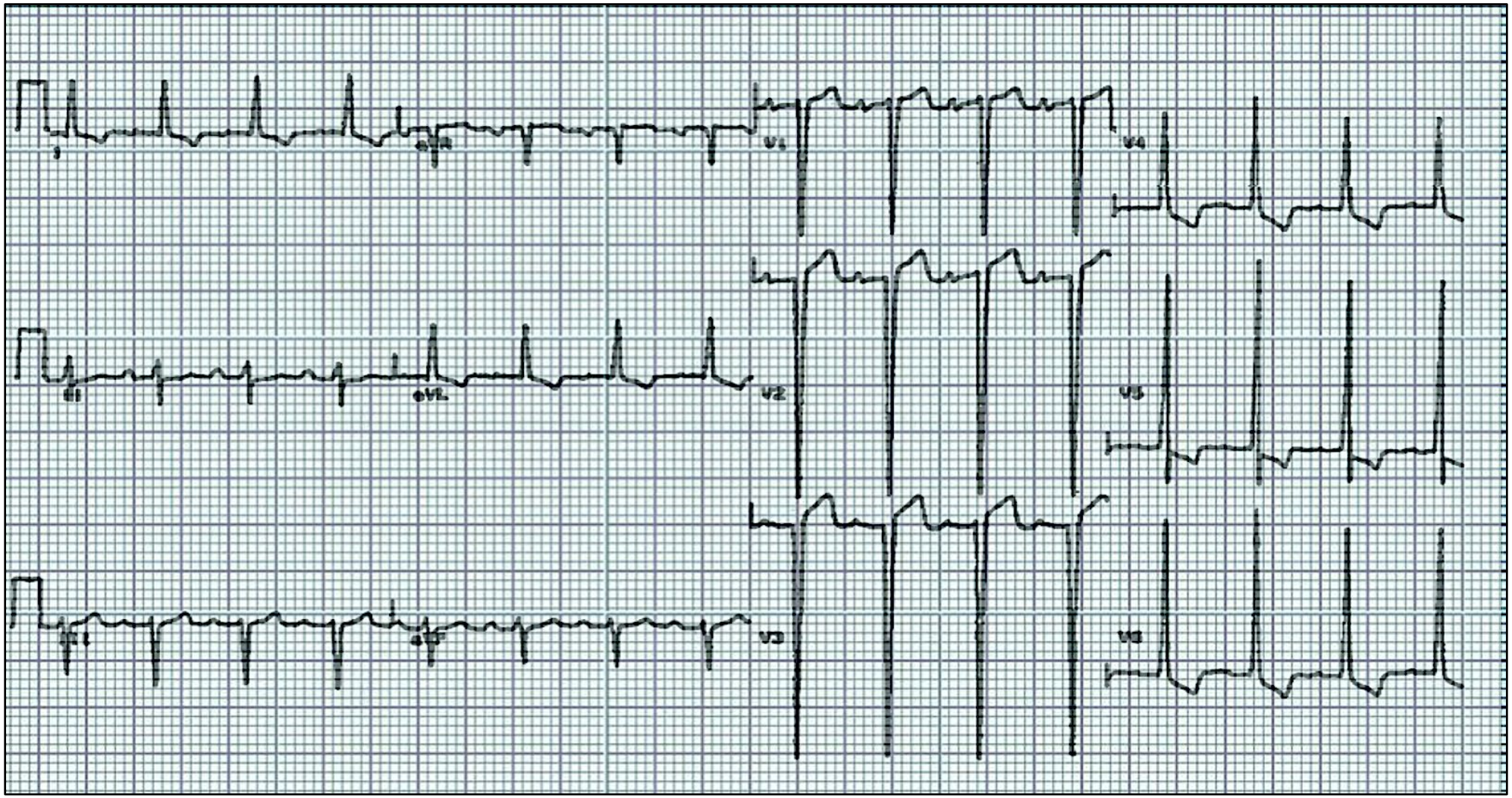
- **Sinus tachycardia**
- **Incomplete RBBB**
- **ST elevation aVR, V1, & V2**
- **T wave inversion V1-V3 & III, aVF**



55 Male with Substernal Chest Pain



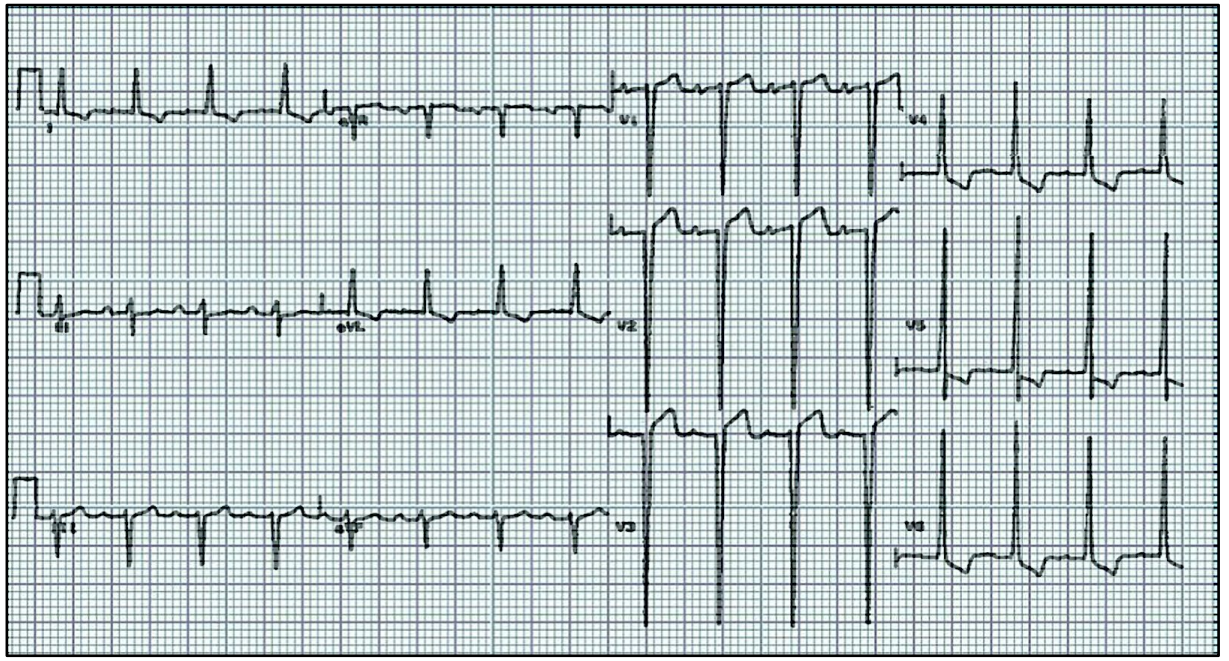
Left Ventricular Hypertrophy by Voltage with Strain Pattern



serial ECGs with Troponin …continued ED monitoring

Left Ventricular Hypertrophy with Strain Pattern

- Confounds AMI Dx
- Mimics ACS…STEMI
- Associated CV risk



So, what is…

1. Left Ventricular Hypertrophy
2. …by Voltage Criteria
3. …with Strain

Step #1 of 3
Left Ventricular Hypertrophy

- "…*enlargement and thickening of the walls of the left ventricle*"

--The Mayo Clinic Medical Dictionary

- Focuses on **anatomic** LVH

- Yet we are interested in **electrocardiographic** LVH pattern

…which is noted via voltage

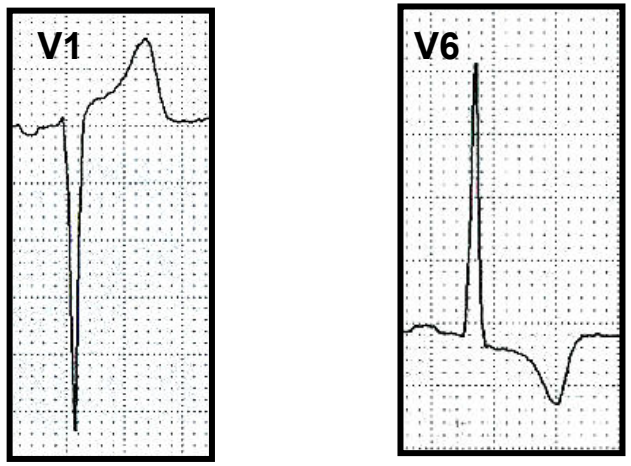
Step #2 of 3
by Voltage

- Increased QRS complex **<u>voltage</u>**

Multiple criteria

- Sokolow-Lyon Criteria useful & easy

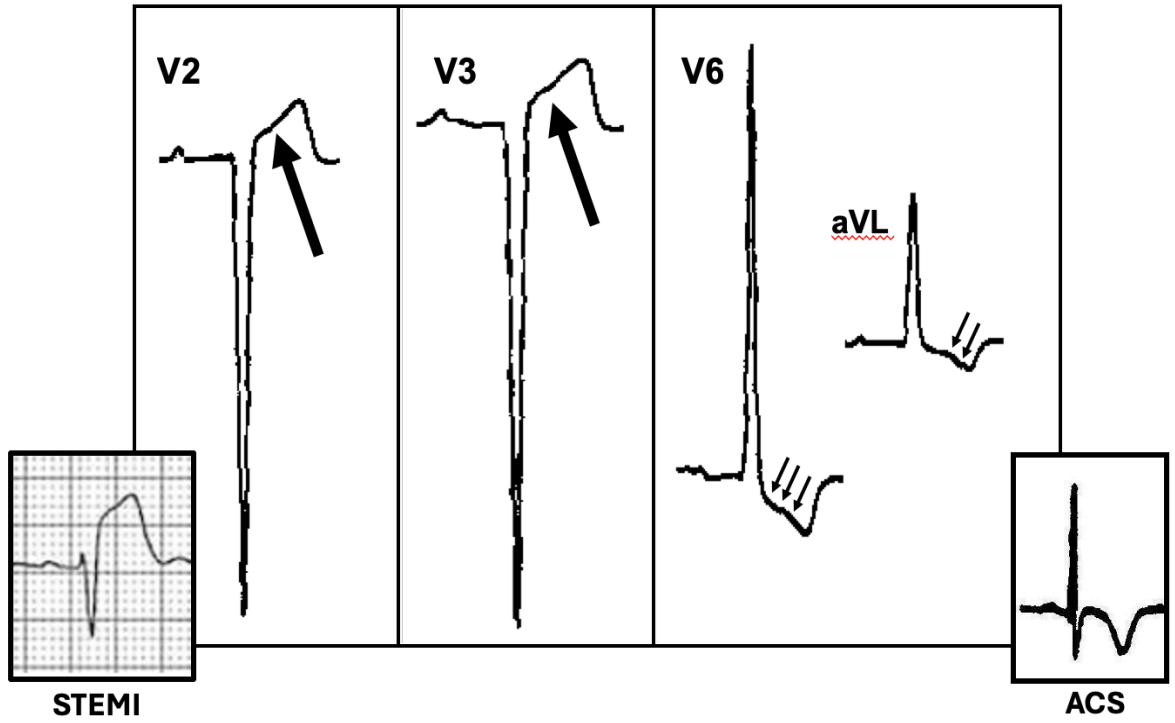
S (Q) wave V1 + R wave V5 or V6 > 35 mm



……Sokolow & Lyon, *Am Heart J* 1949

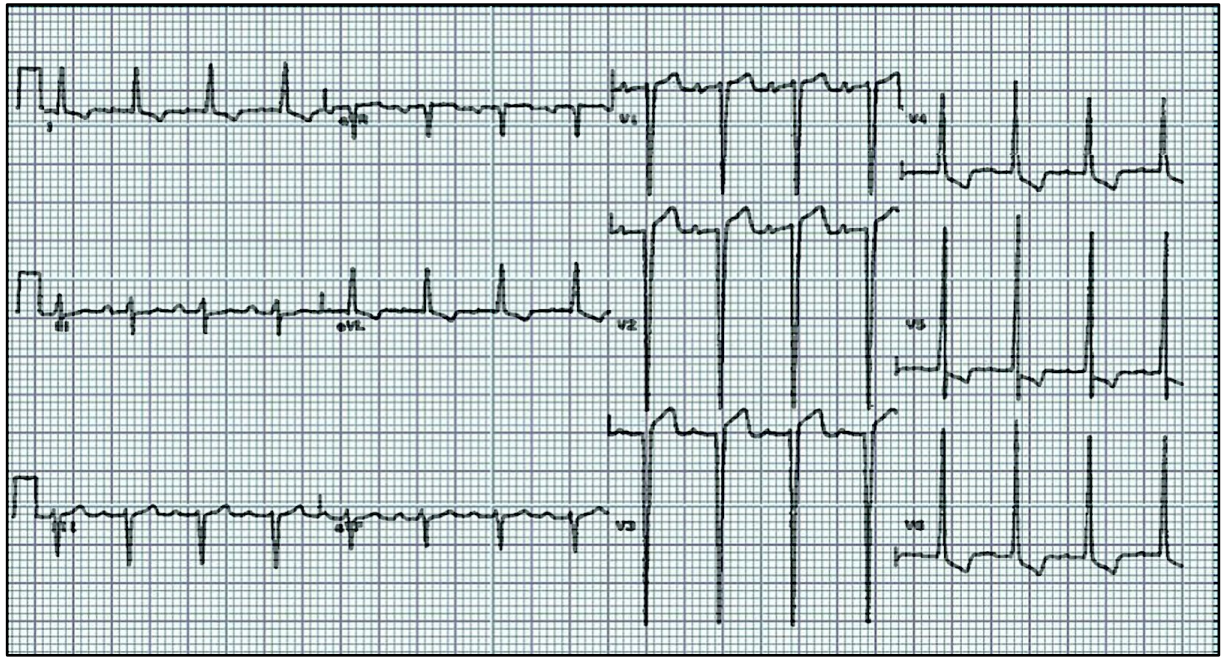
Step #3 of 3
…with Strain Pattern

- Strain = ST segment +/- T wave changes



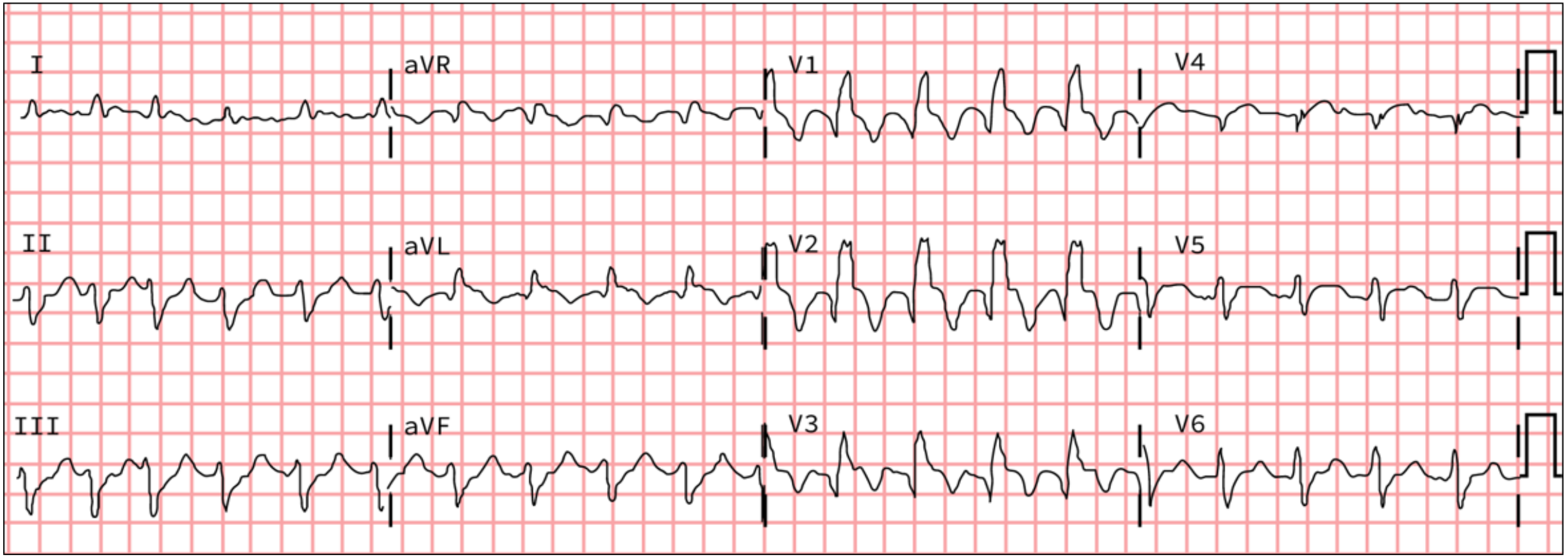
- ~80% of LVH by voltage ECGs

Left Ventricular Hypertrophy with Strain Pattern



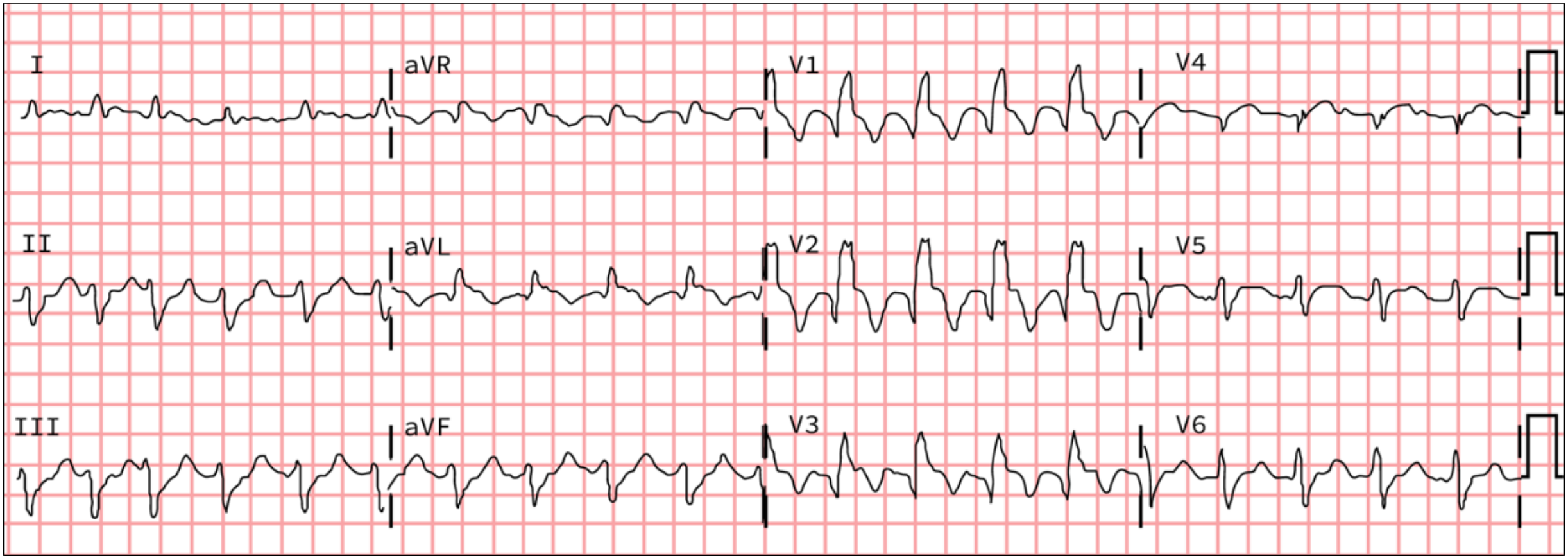
- Confounds AMI Dx
- Mimics ACS…STEMI
- Associated CV risk

58 Male with Severe Aching Mid-sternal Chest Pain
Patient is diaphoretic & ill-appearing



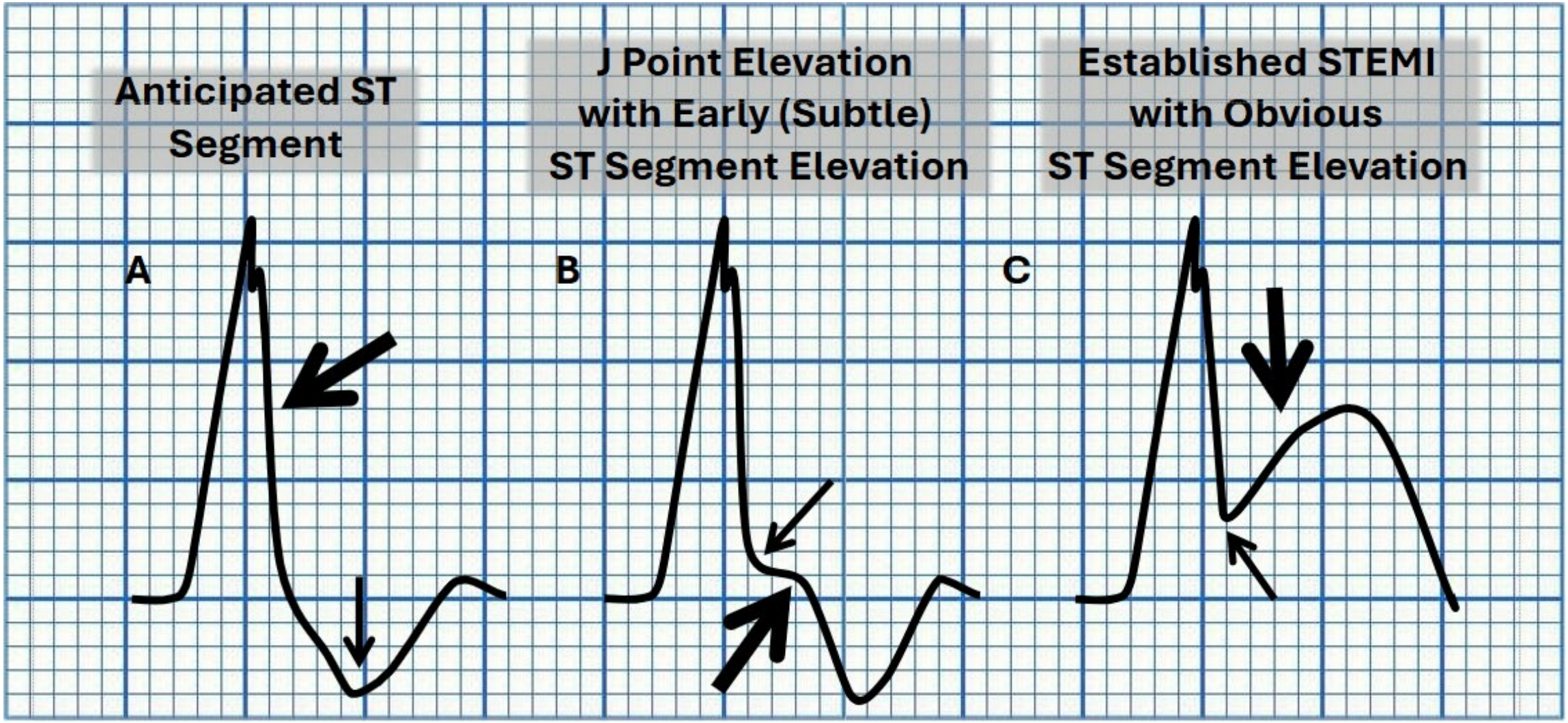
RBBB with STEMI

patient experienced VF arrest …ROSC to Cath Lab for PCI



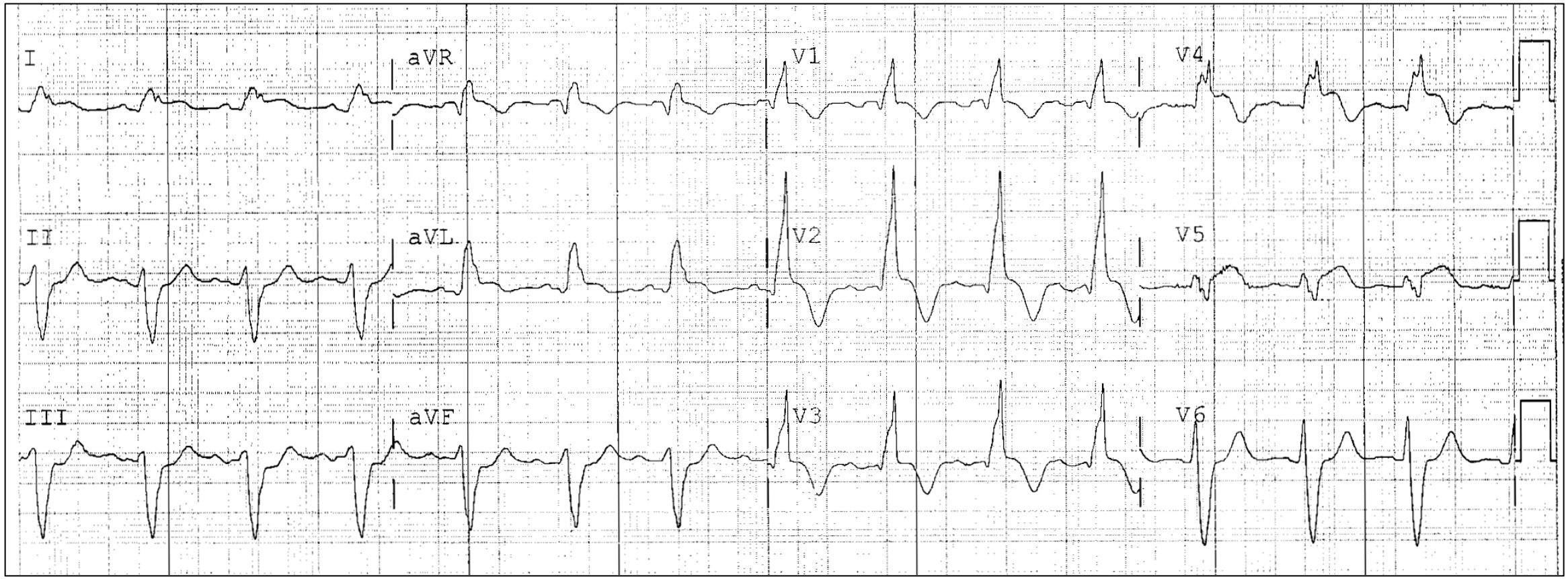
- **RBBB impact on ECG DX STEMI**
  - Does not confound AMI diagnosis
  - Does complicate interpretation
- **CV risk ranges from very low to extremely high**
  - RBBB without STEMI – minimal risk
  - Pre-existing RBBB with STEMI – moderate risk
  - New RBBB with STEMI – extremely high risk

Right Bundle Branch Block – ST Segment in Lead V_1

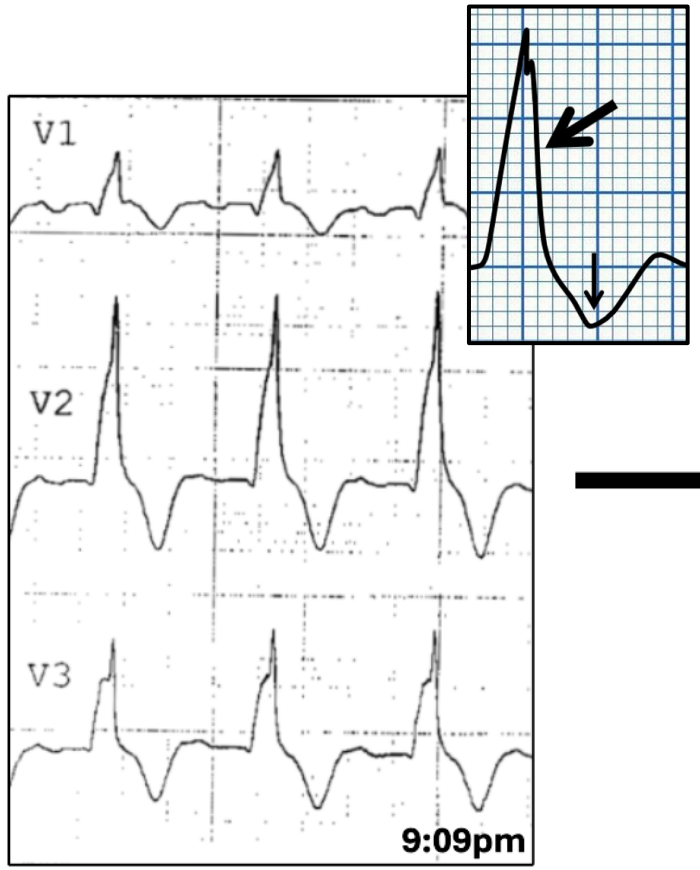


61 female with past MI & CAD c/o substernal chest pain

Pale, anxious, & diaphoretic
90/70, 70, 28, Sat 95% (RA)

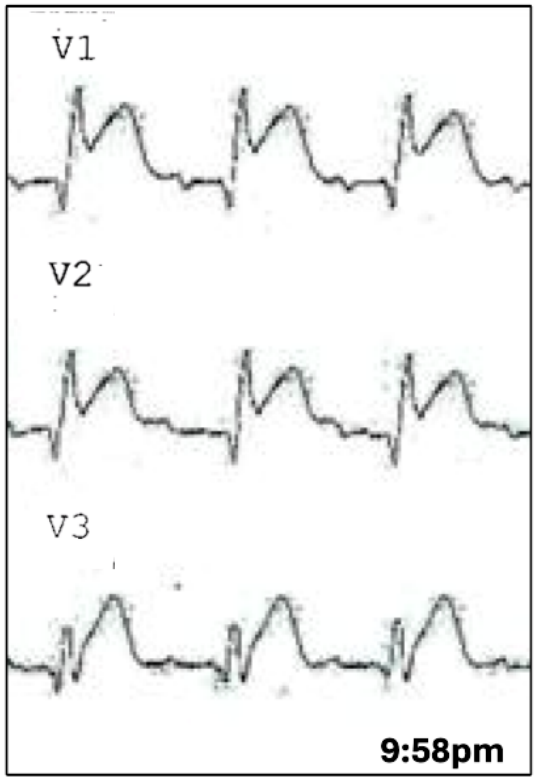


Right Bundle Branch Block – Anterior STEMI Progression (leads V_1-V_3)



Minimal J Point Elevation

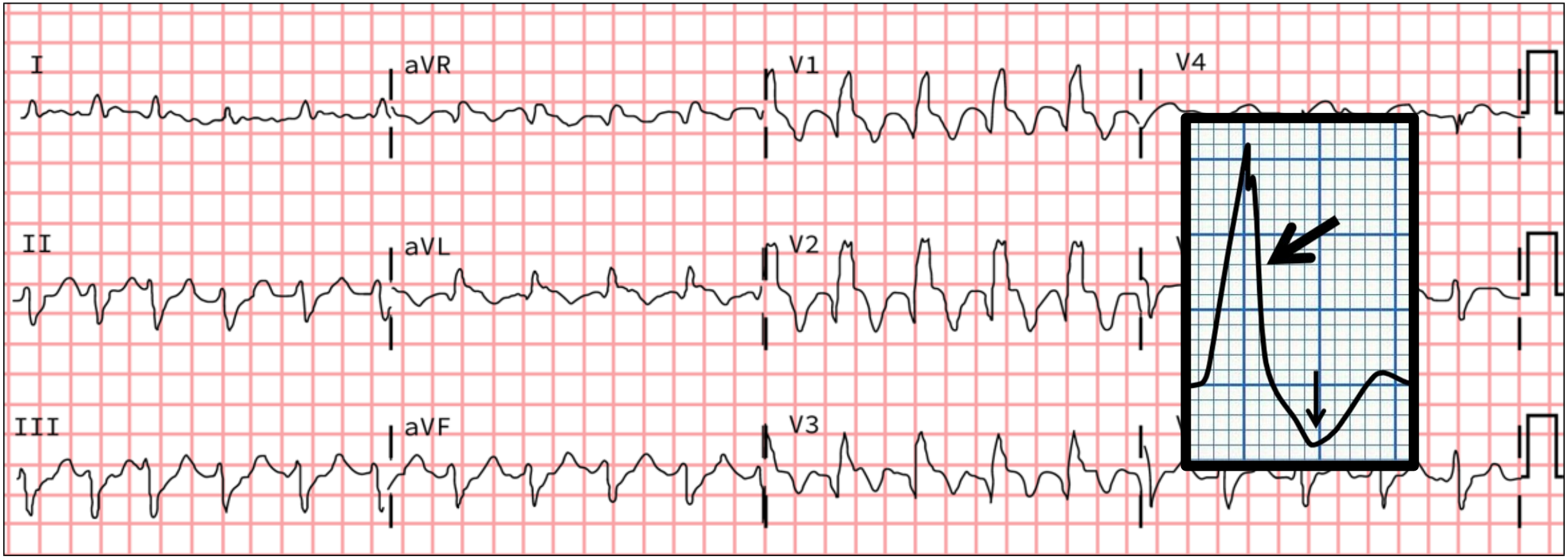
Interval increase in J point elevation with increased ST segment elevation



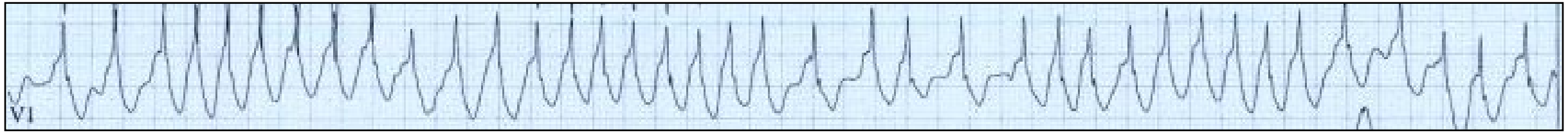
Anterior STEMI

…back to our patient

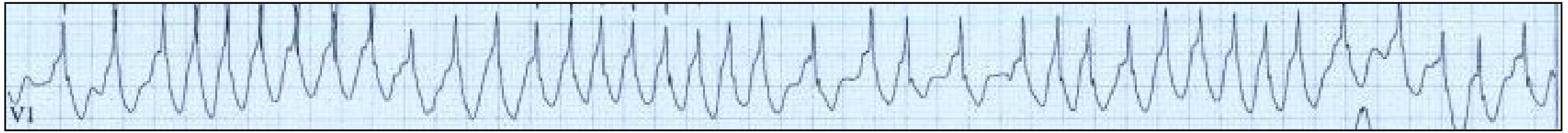
RBBB with STEMI
ST Elevation V1 – V3



19 Male who notes that my heart is beating really &@$#%*+ fast!
…Patient is Alert with BP 105/P

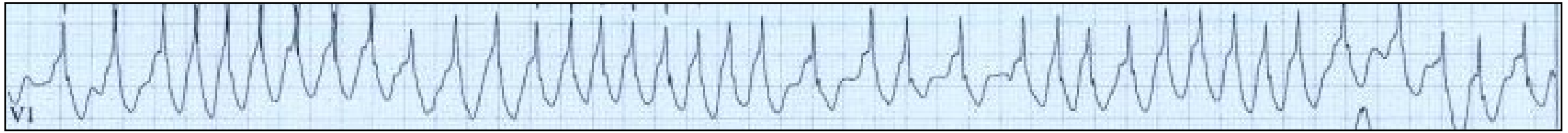


19 Male who notes that my heart is beating really &@$#%*+ fast!
…Patient is Alert with BP 105/P



WPW-related Atrial Fibrillation

synchronized electrical cardioversion with sedation

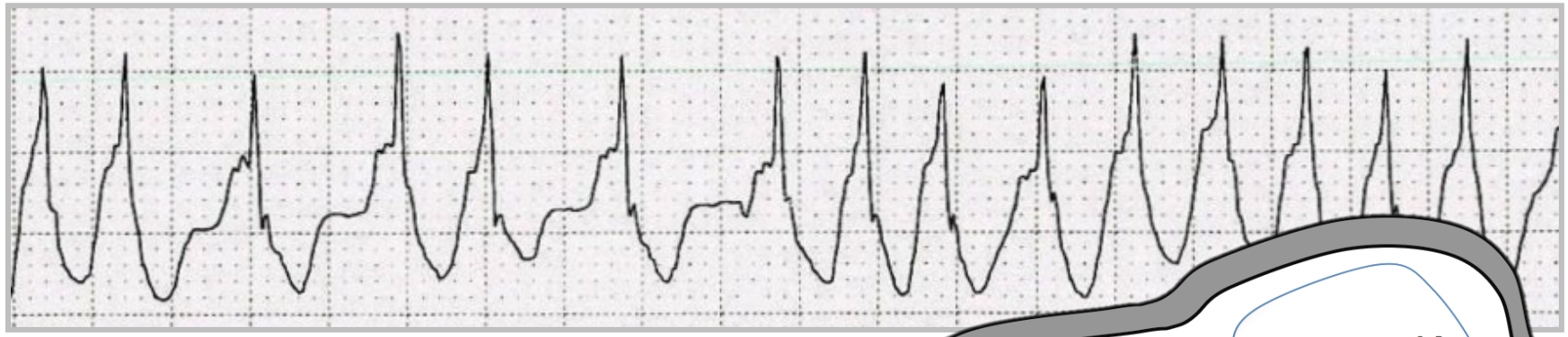


WPW-related Atrial Fibrillation

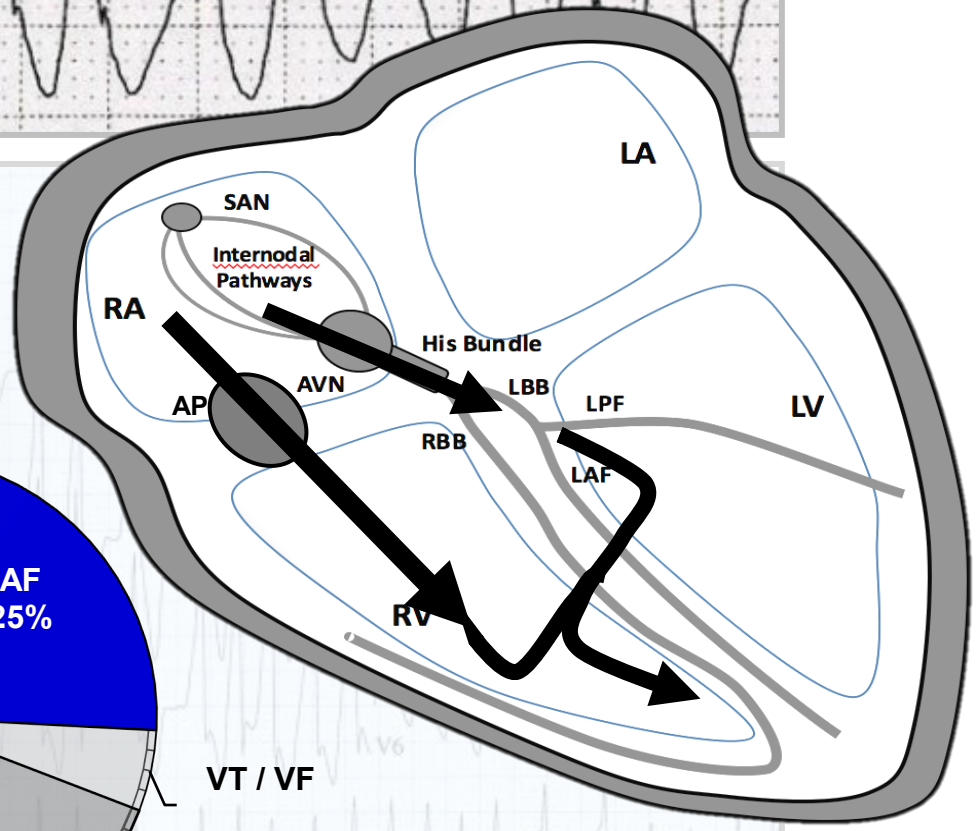
- Irregularly irregular
- Very rapid rates

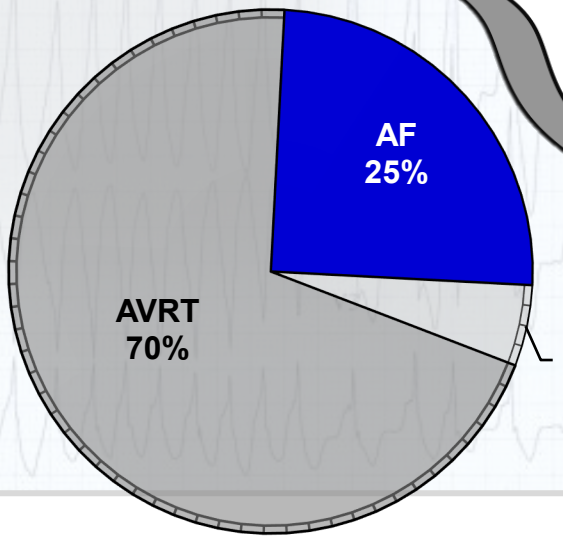
- Wide QRS
- Beat-to-beat QRS variation
- Occasional narrow QRS

WPW-related Atrial Fibrillation

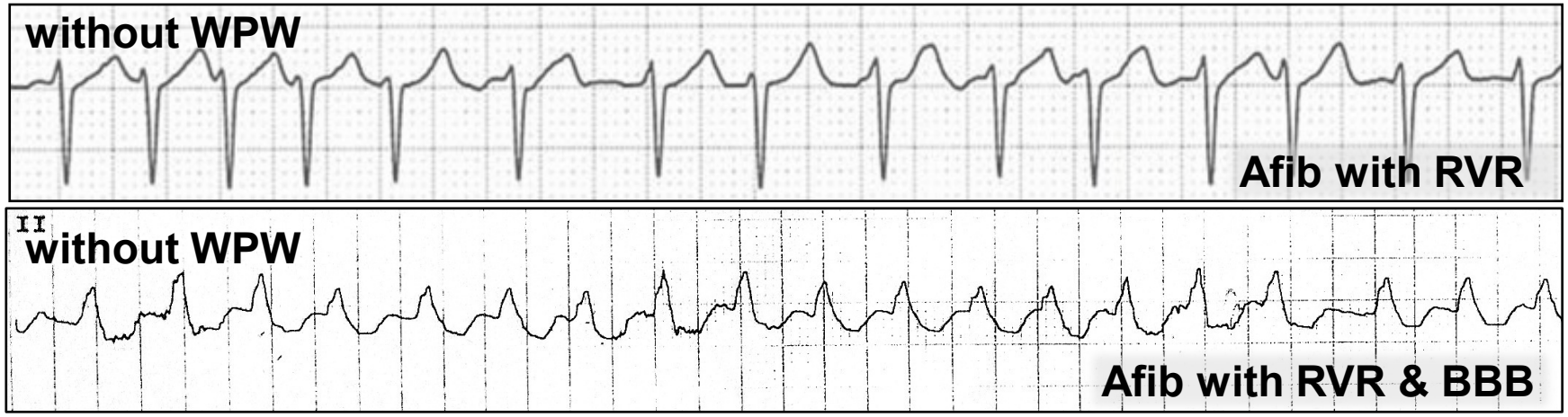


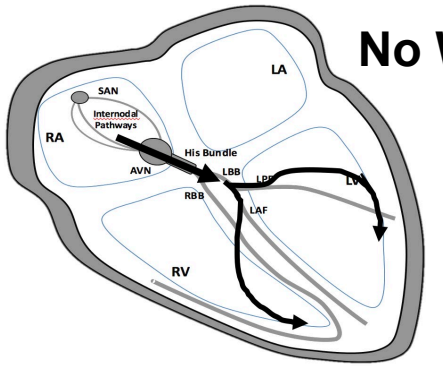
- With WPW…loss of AV node “rate control” protection
- Potentially malignant
- 25% WPW arrhythmias



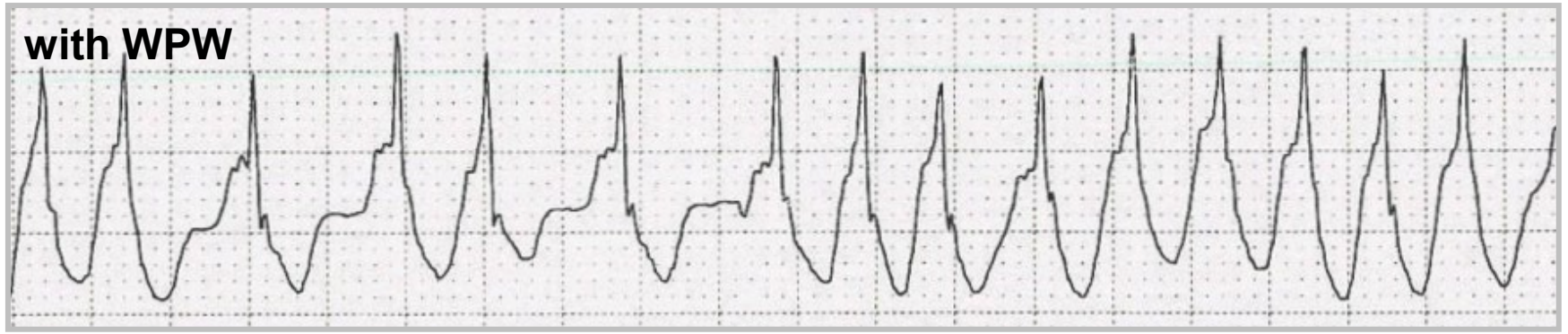


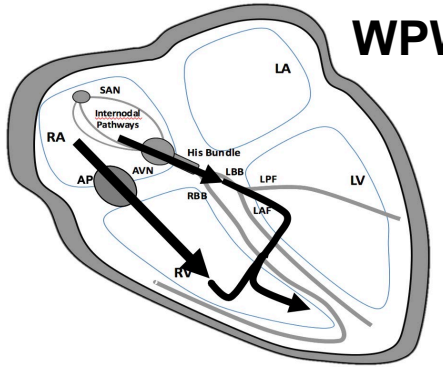
Atrial Fibrillation with RVR…*without & with WPW*





- Rapid…up to 190s
- AVN protects from <u>sustained</u> <u>excessively</u> rapid rates

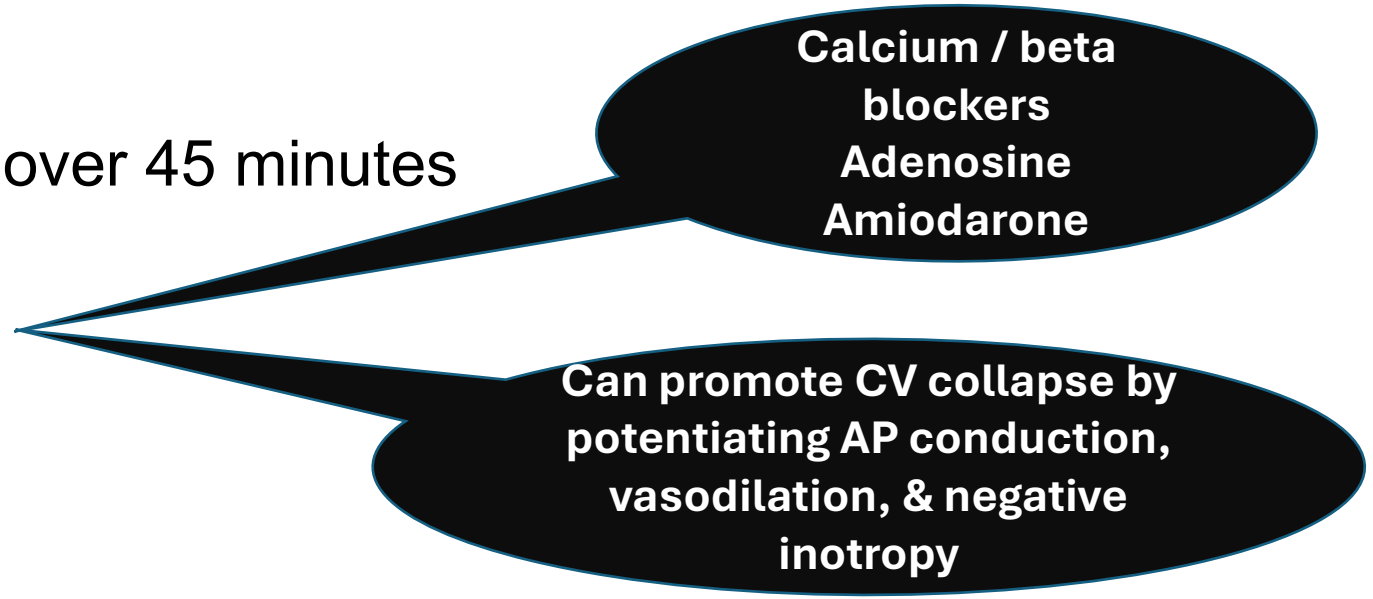




- Very rapid…over 200…beat-to-beat variation in QRS width & shape
- Loss of AVN protection`

Significance

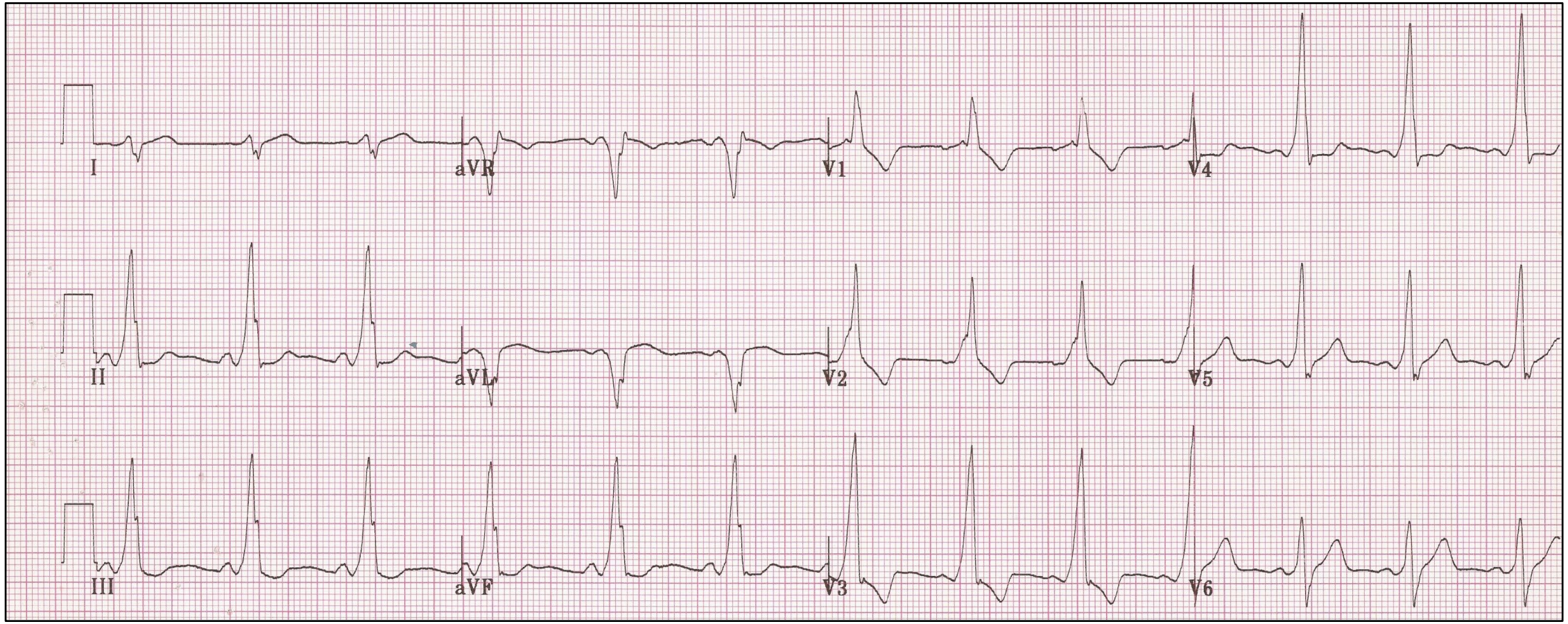
- **Recognition…unusual appearing dysrhythmia**
  - Rapid, irregular, wide QRS rhythm with beat-to-beat QRS variation
- **Required alterations in treatment**
- **Unstable – sedated synchronized electrical cardioversion**
- **Stable**
  - Procainamide 17 mg/kg IV over 45 minutes
  - Electrical conversion
  - Avoid AVN blocking agents



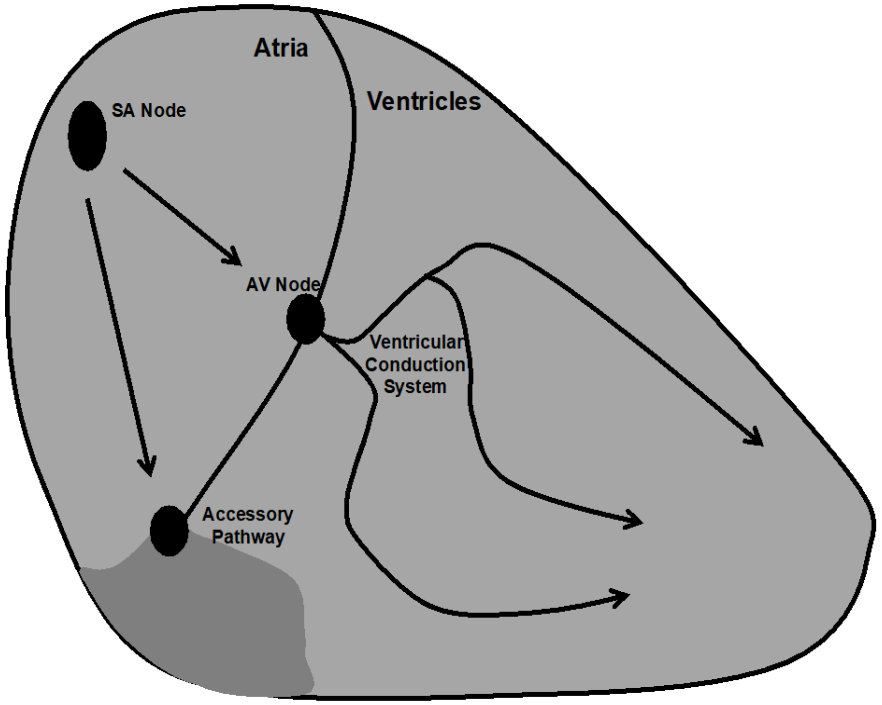
…back to our patient

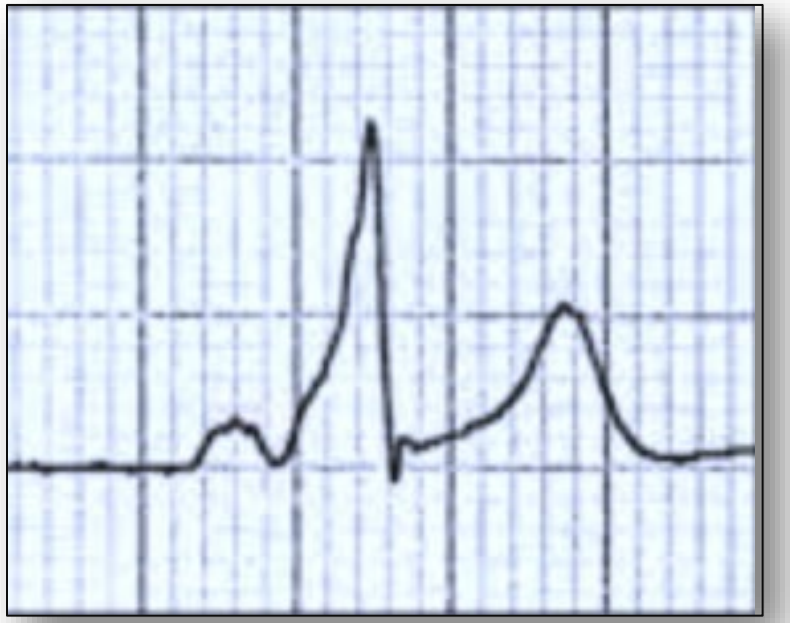
Post-conversion ECG

WPW ECG triad



CLASSIC ECG TRIAD - WPW



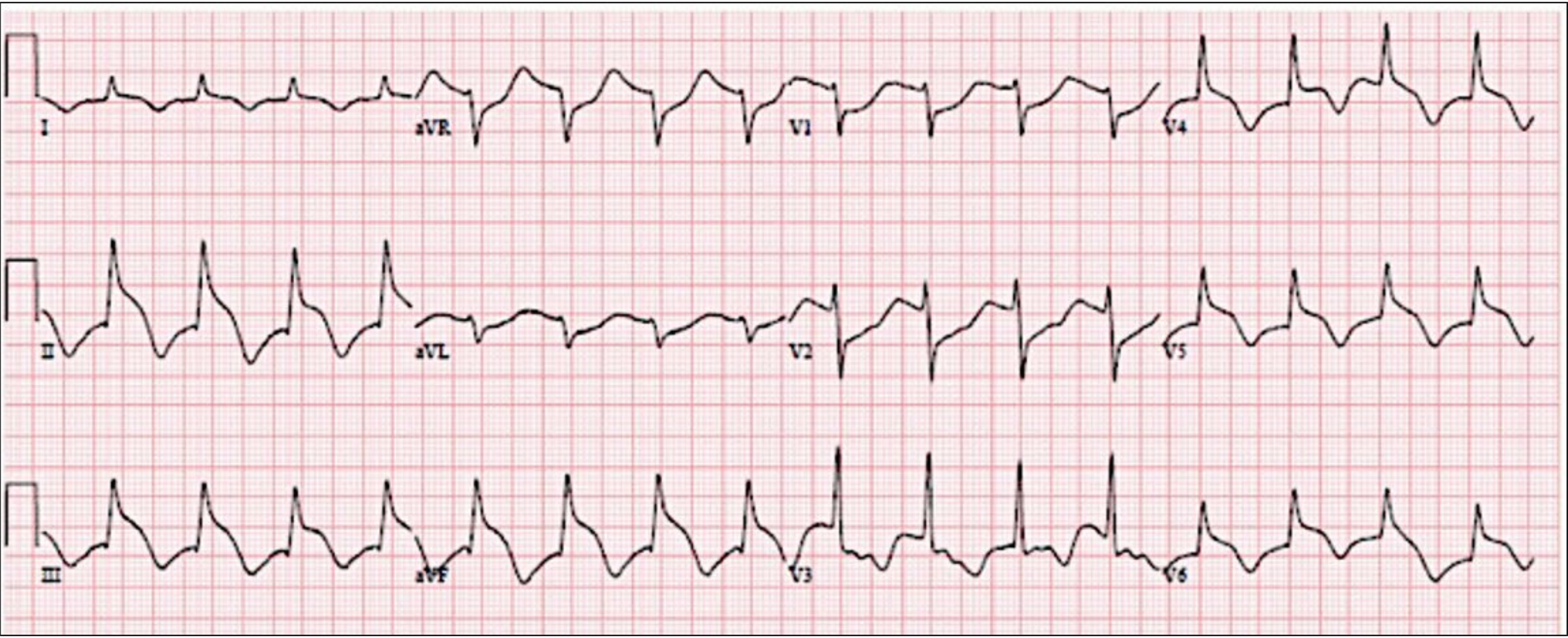


Shortened PR interval – impulse bypasses AV node

Delta wave – early activation of ventricular myocardium

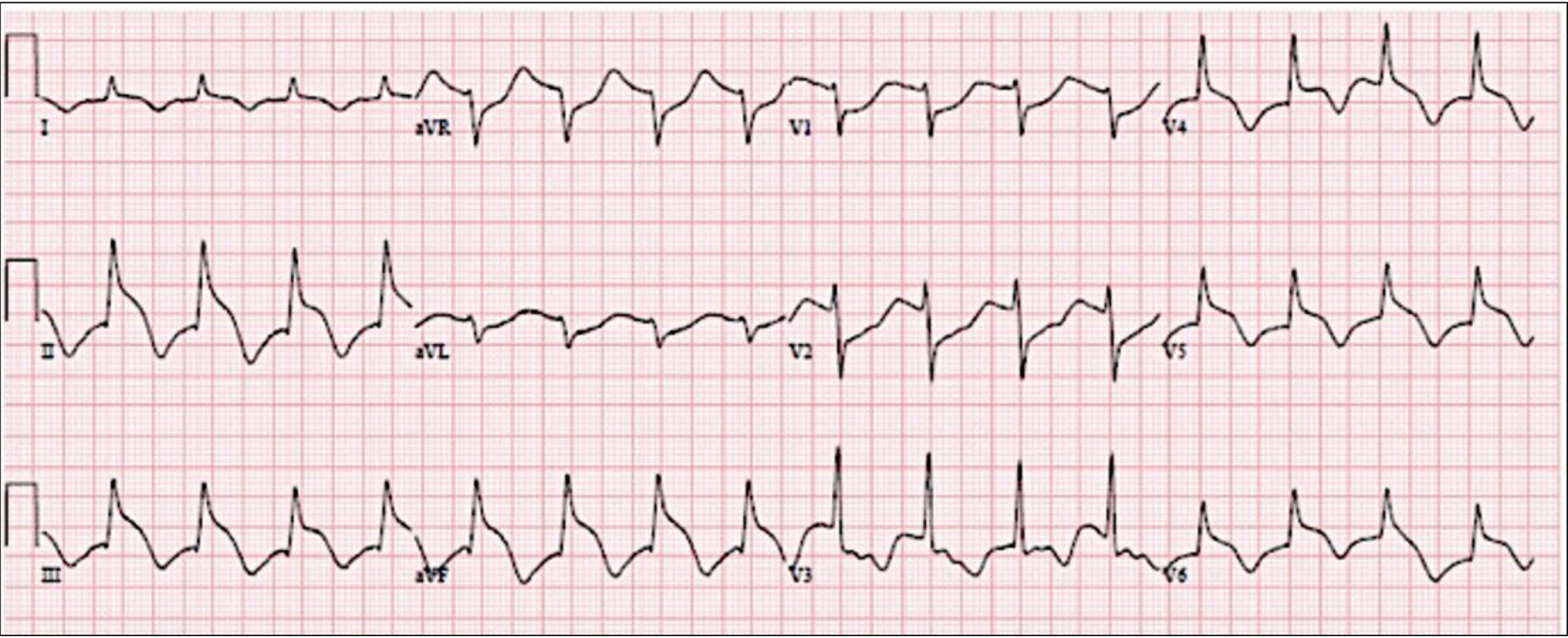
Widened QRS complex – inefficient conduction within ventricle

68 Female with Diffuse Abdominal Pain with Emesis
Mid-epigastric Extreme Tenderness



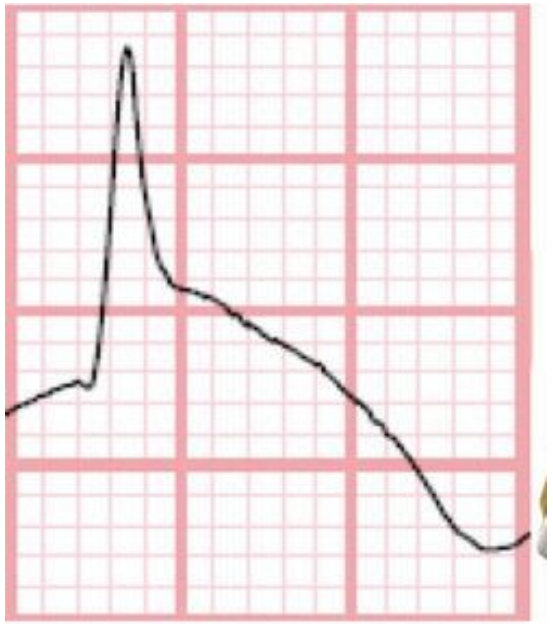
Spiked Helmet Sign

hemorrhagic pancreatitis noted on abdominal CT



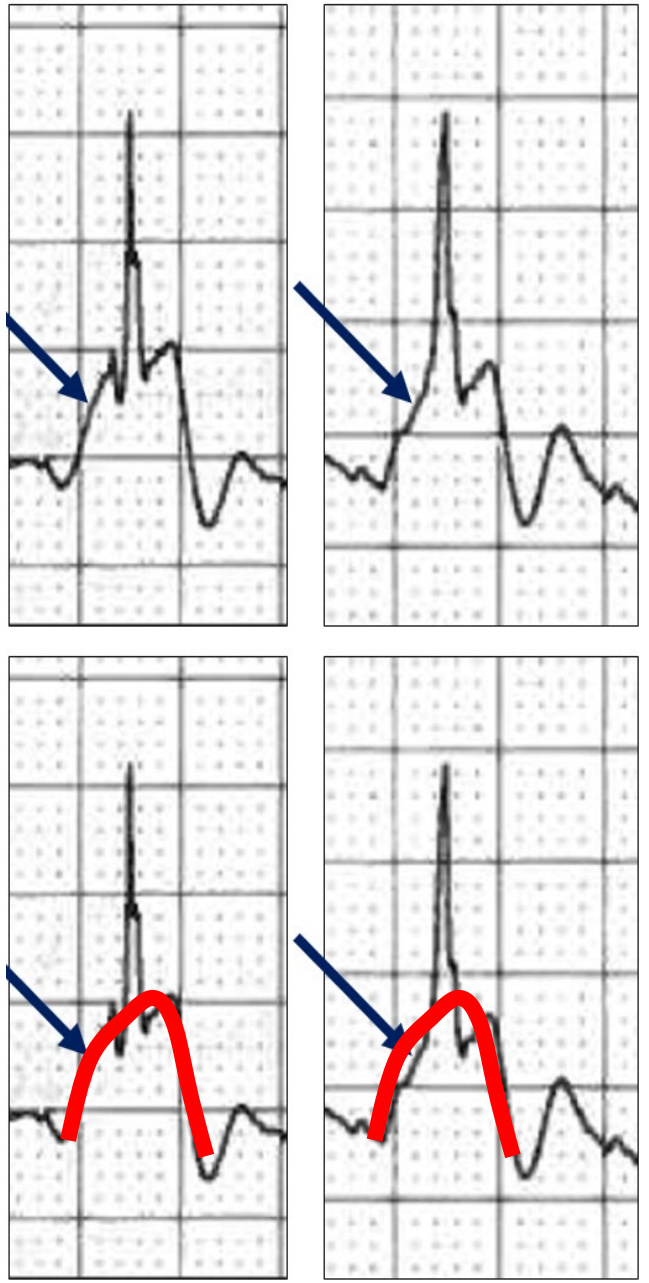
Spiked Helmet Sign

- Unusual ECG finding
- Associated high mortality rate
- Usually non-cardiac origin
- The pickelhaube, Prussian spiked helmet late 19th century



Spiked Helmet Sign

- **Appears as if QRS complex superimposed on wide-based upward convex slope shape**
- **“Dome & spike appearance”**
- **Elevation is frequently apparent before start of QRS complex**
  - Important differentiation from STEMI



Spiked Helmet Sign

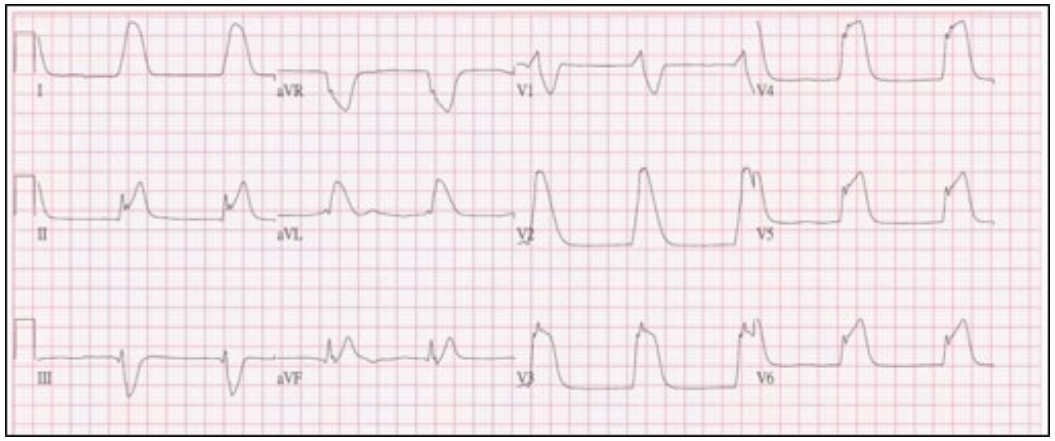
- **Inferior / inferolateral leads**

  abdominal event
  - bowel perforation
  - peritonitis
- **Anterior leads**

  intrathoracic event
  - pneumothorax
  - aortic dissection
  - esophageal perforation
- **Also seen in CNS hemorrhage**

Small Bowel Perforation - Inferolateral Leads

Esophageal Rupture - Anterolateral Leads



40 Male with Palpitations

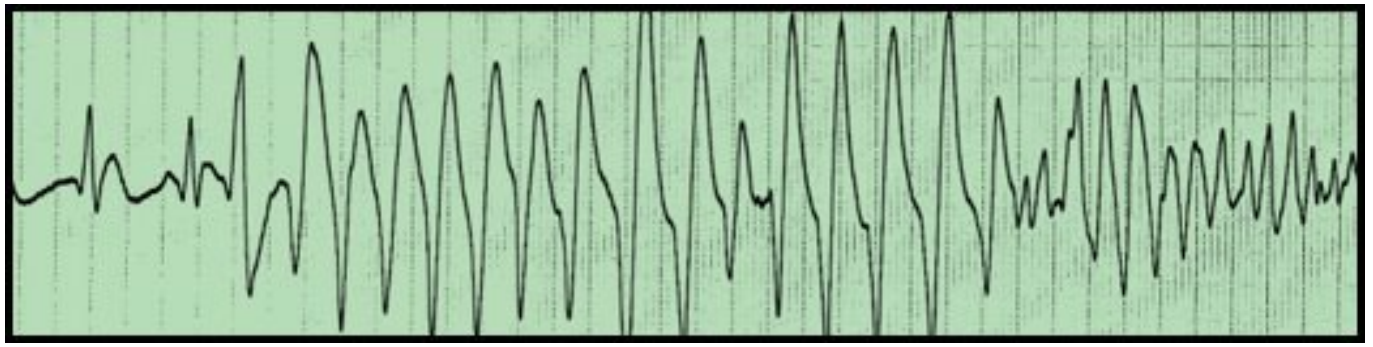
…as You Enter the Room, He Becomes Unresponsive without a Pulse

R-on-T PVC leading to VF Arrest

compressions & defibrillation …ROSC …attention to PVC burden

R-on-T PVC

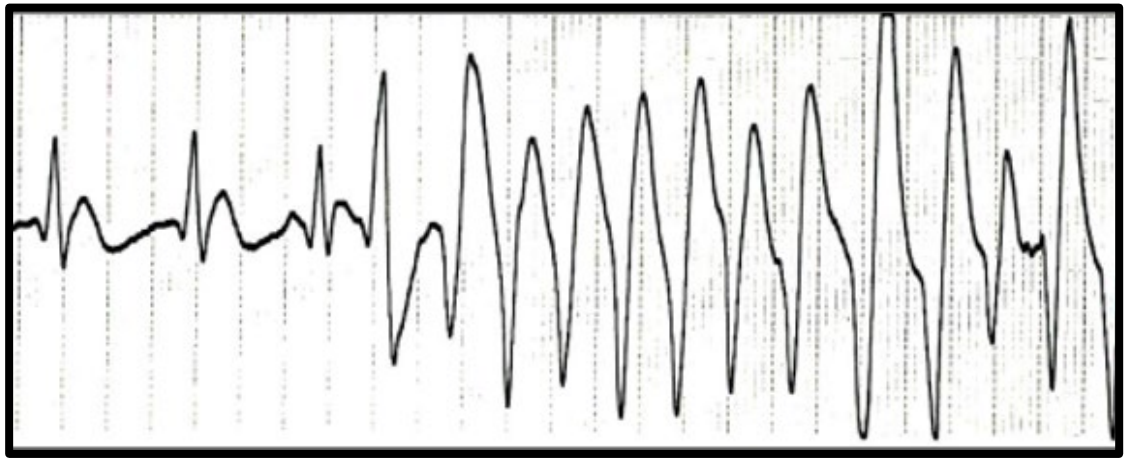
PVC (R wave) falls on T wave of previous supraventricular beat

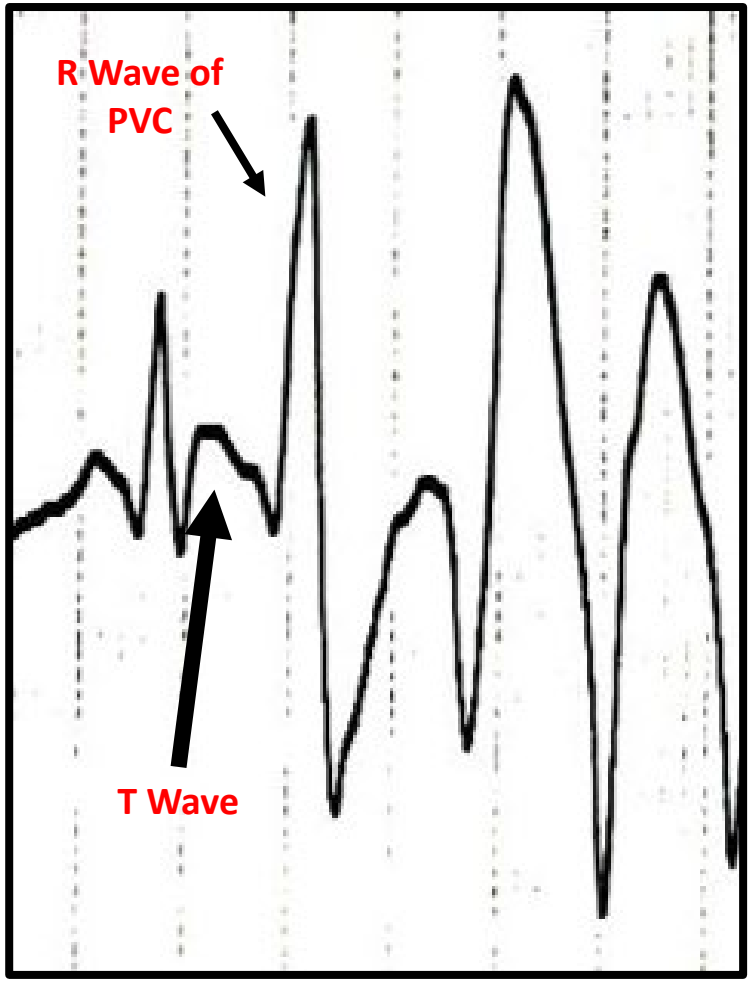


- **PVC falls on repolarizing myocardium** (T wave)
- **Electrically irritable period**
- **Potentially malignant**…can result in VT or VF

R-on-T PVC

…leading to malignant ventricular dysrhythmia





PVCs – Frequency, Patterns, & Risk

Lown Grading Classification of PVC Occurrence

- **Grade 0:** none
- **Grade 1:** occasional (< 30/hr)
- **Grade 2:** frequent (> 30/hr)
- **Grade 3:** multifocal
- **Grade 4:** repetitive
  - **Grade 4A:** couplets
  - **Grade 4B:** triplets
- **Grade 5:** R-on-T PVCs

Consider "More Aggressive" Treatment with Increasingly Higher Grade Classifications,* Particularly with Objective Evidence of ACS

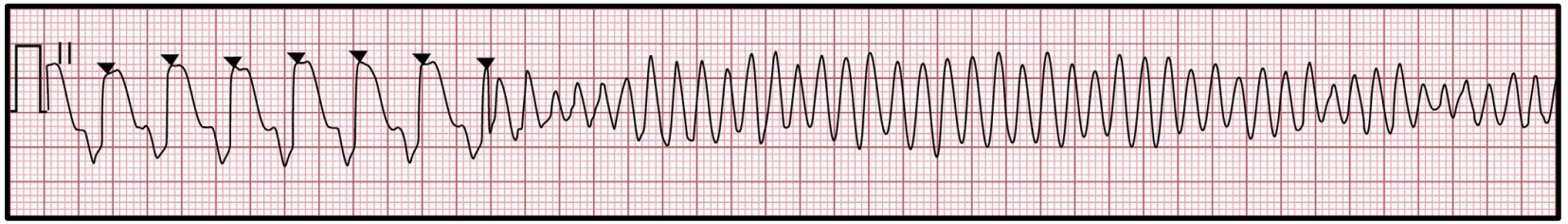
5 & 4 > 3

* ***No benefit has been established RE reduced progression to VT/VF or mortality***

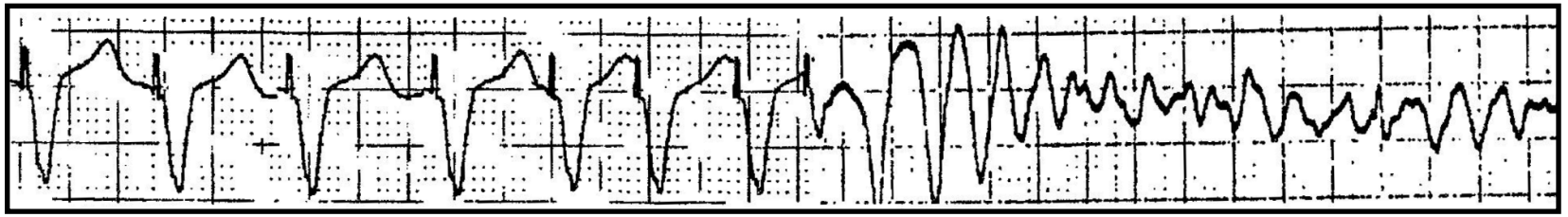
Avoid the T Wave!

- **Ron-T PVC**
  - PVC falls on T wave

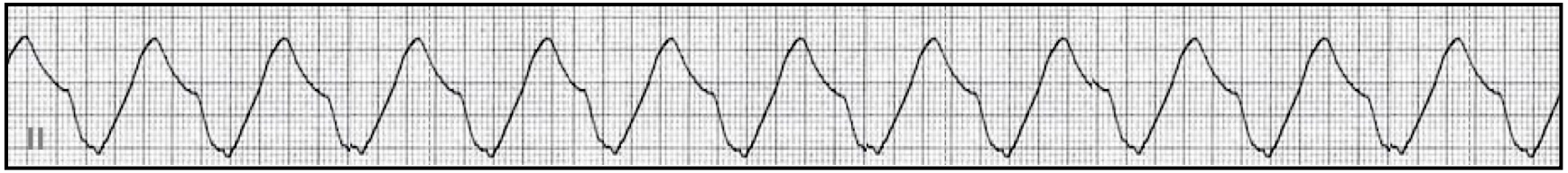
- **Synchronized Shock on T Wave**
  - DC shock on T wave



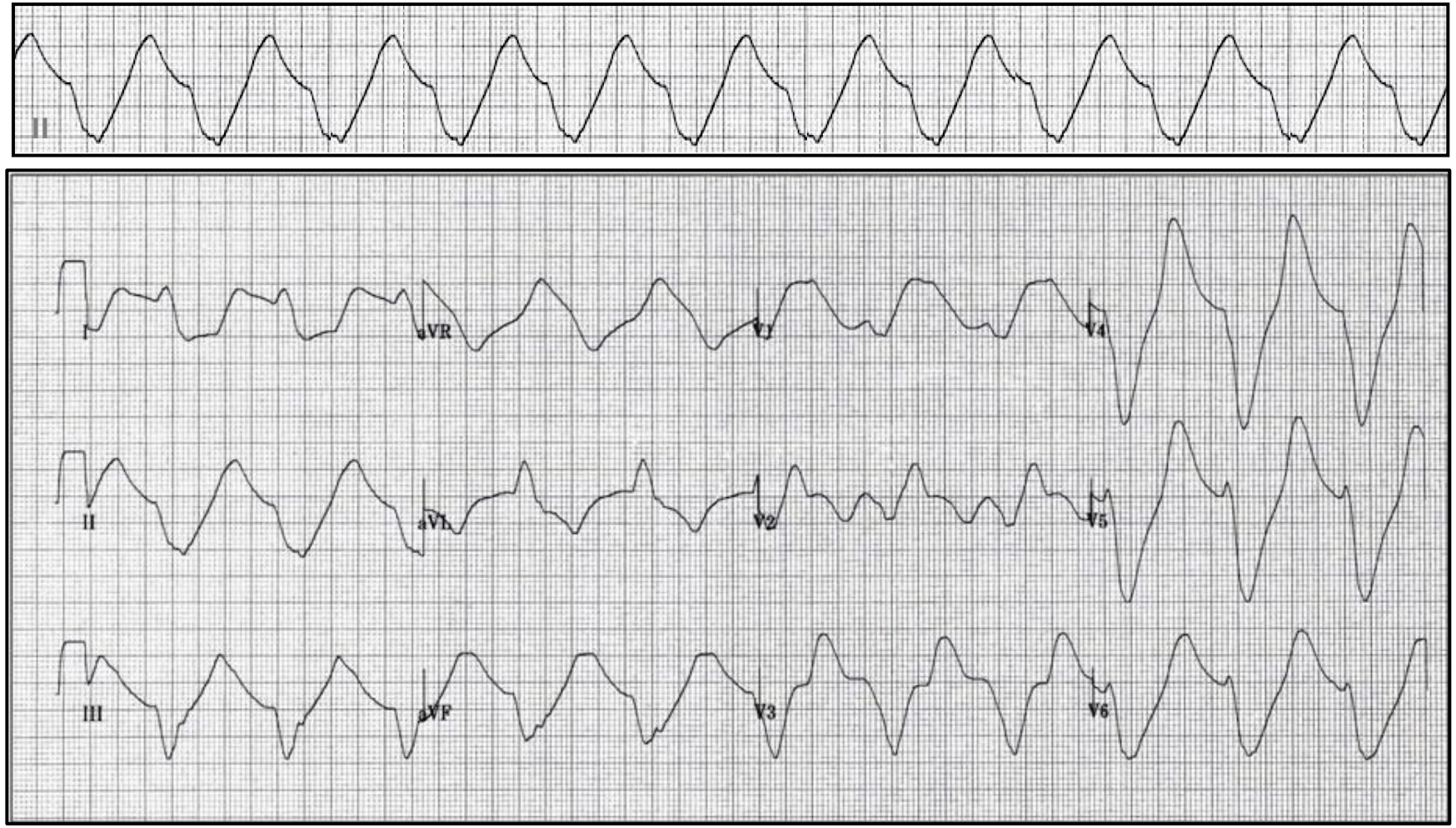
- **Failure to Sense with Pacemaker**
  - Pacer spike falls on T wave



33 Male with N/V & Lethargy
unknown medical history

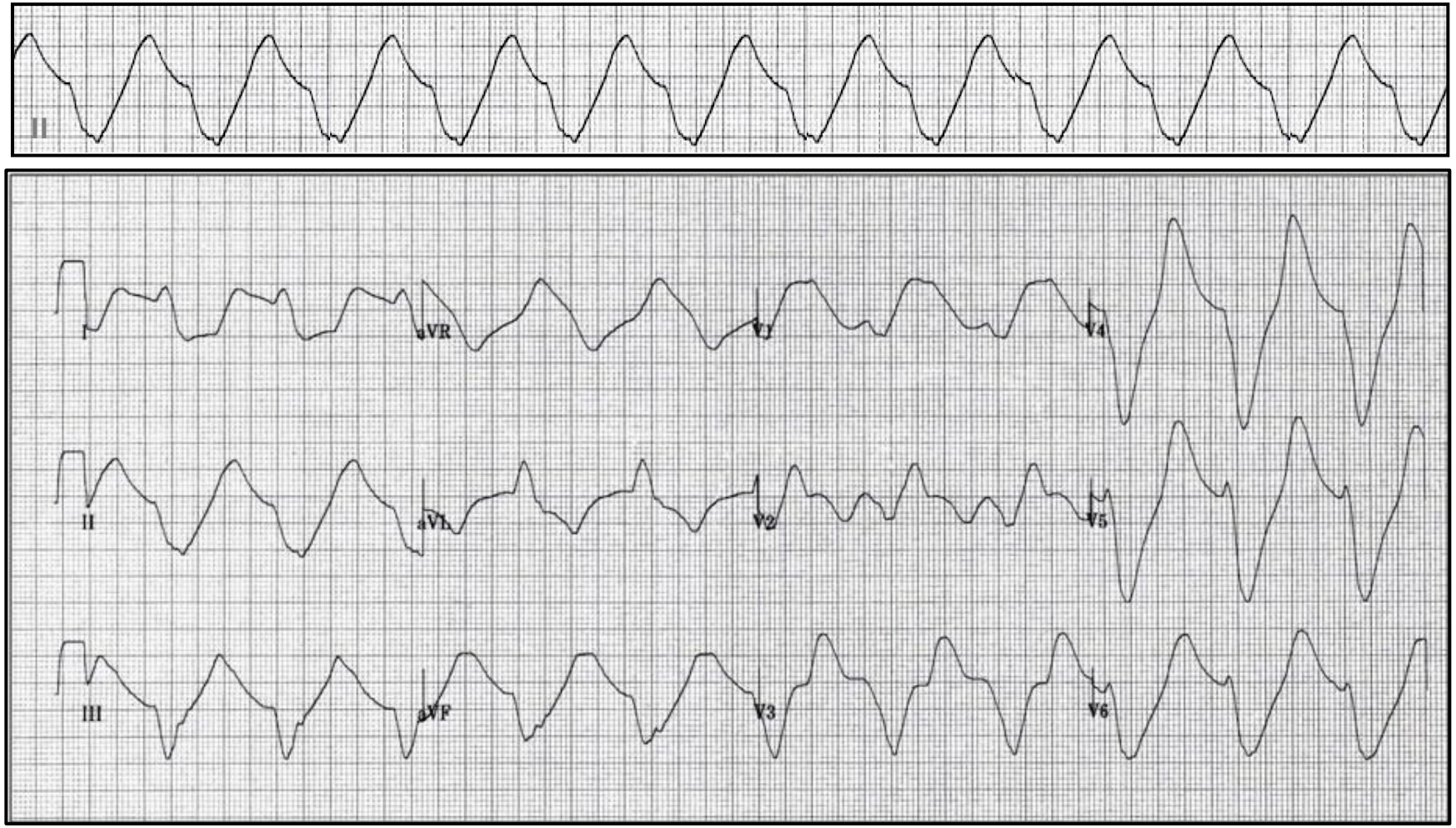


33 Male with N/V & Lethargy
unknown medical history

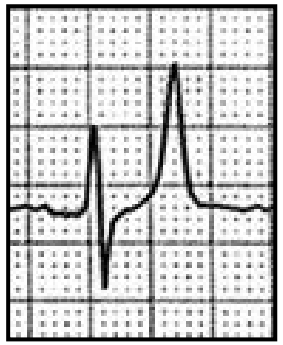


Sinoventricular Rhythm due to Hyperkalemia

treatment aimed at lowering the K!

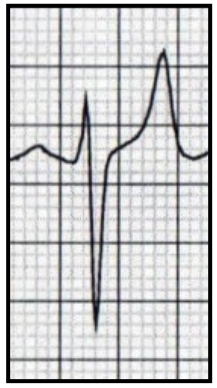


ECG Findings of Hyperkalemia

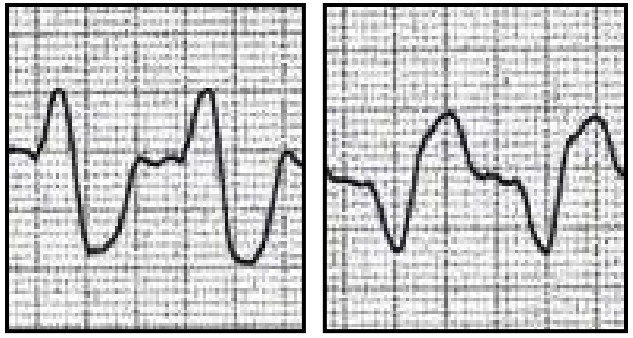


Prominent T wave

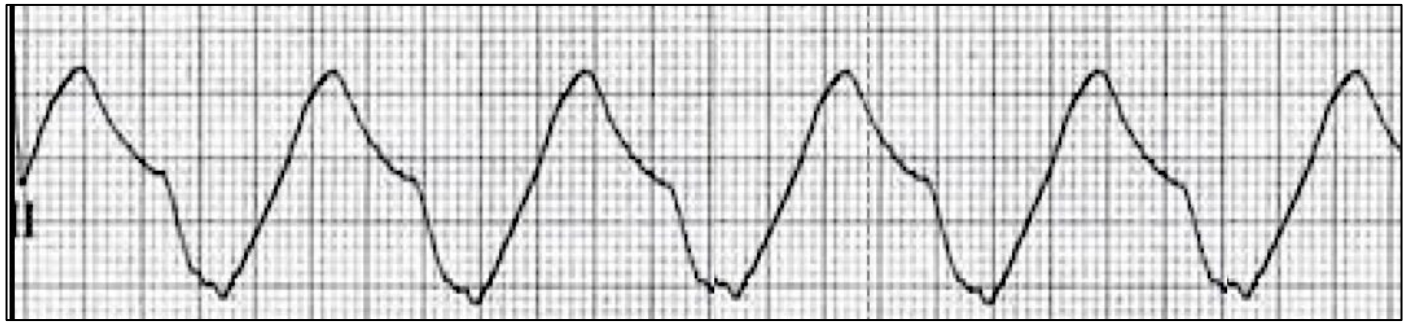
More pronounced QRS complex widening



Prominent T wave & minimal QRS complex widening

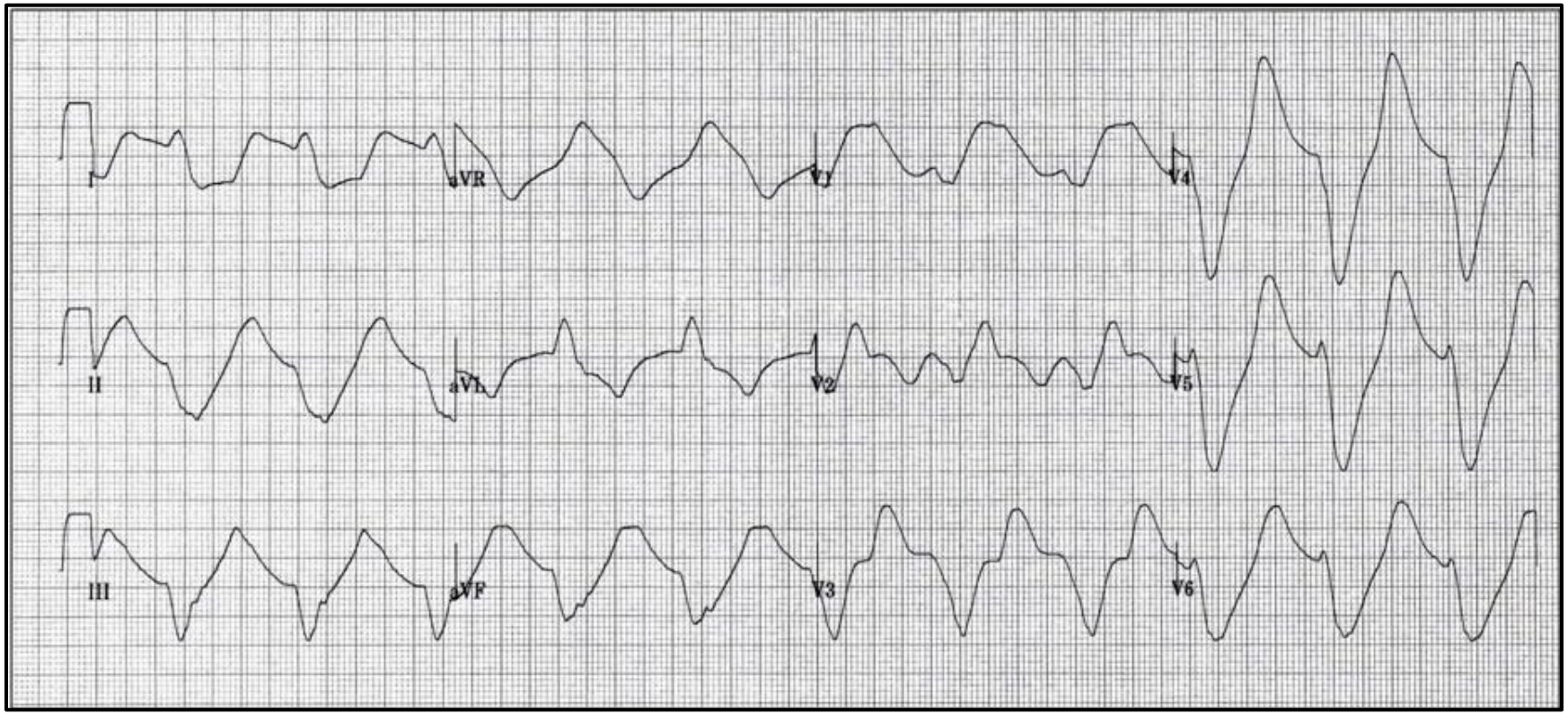


Pronounced QRS complex widening



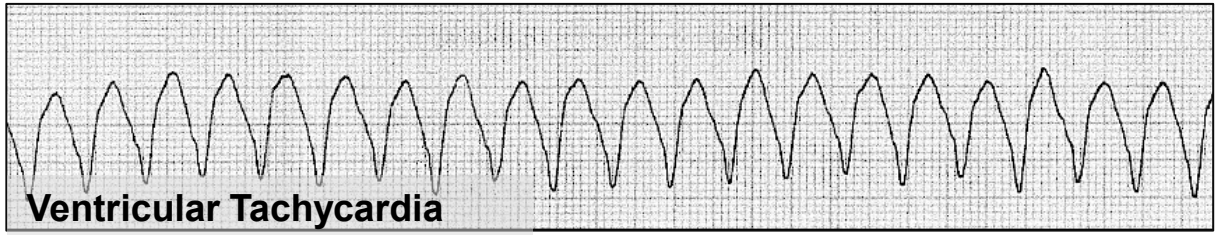
Sinoventricular rhythm… slow, regular, & very wide QRS complex

Sinoventricular Rhythm
Severe Hyperkalemia



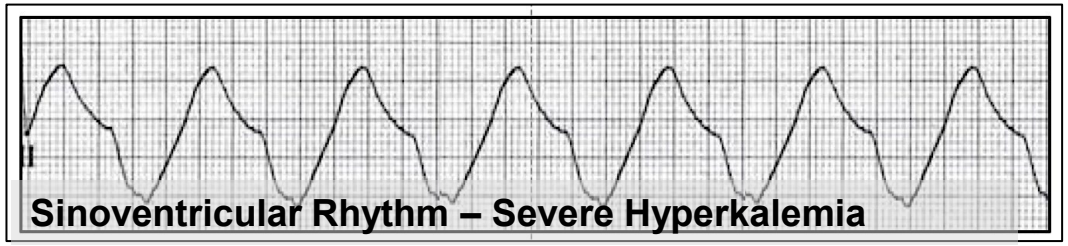
Regular, Slow to Slow-normal Rate with <u>Extremely</u>
Widened QRS Complex…& no P Waves

Comparison of Rhythms

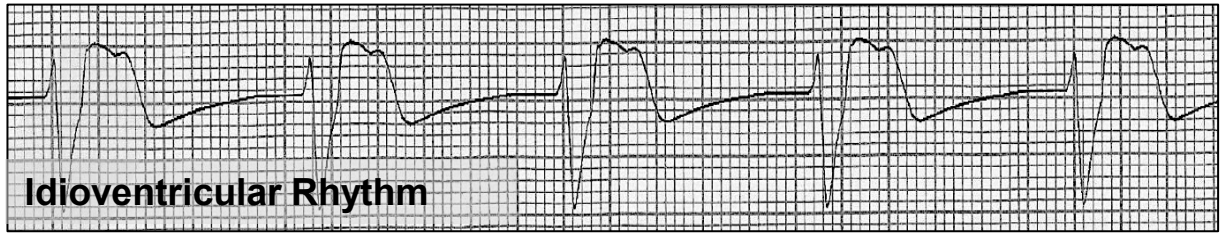


- Tachycardia ~ 170 - 190 bpm
- QRS width ~ 0.12 – 0.16 sec

- Normal rare ~ 100 bpm
- QRS very width ~ 20 sec

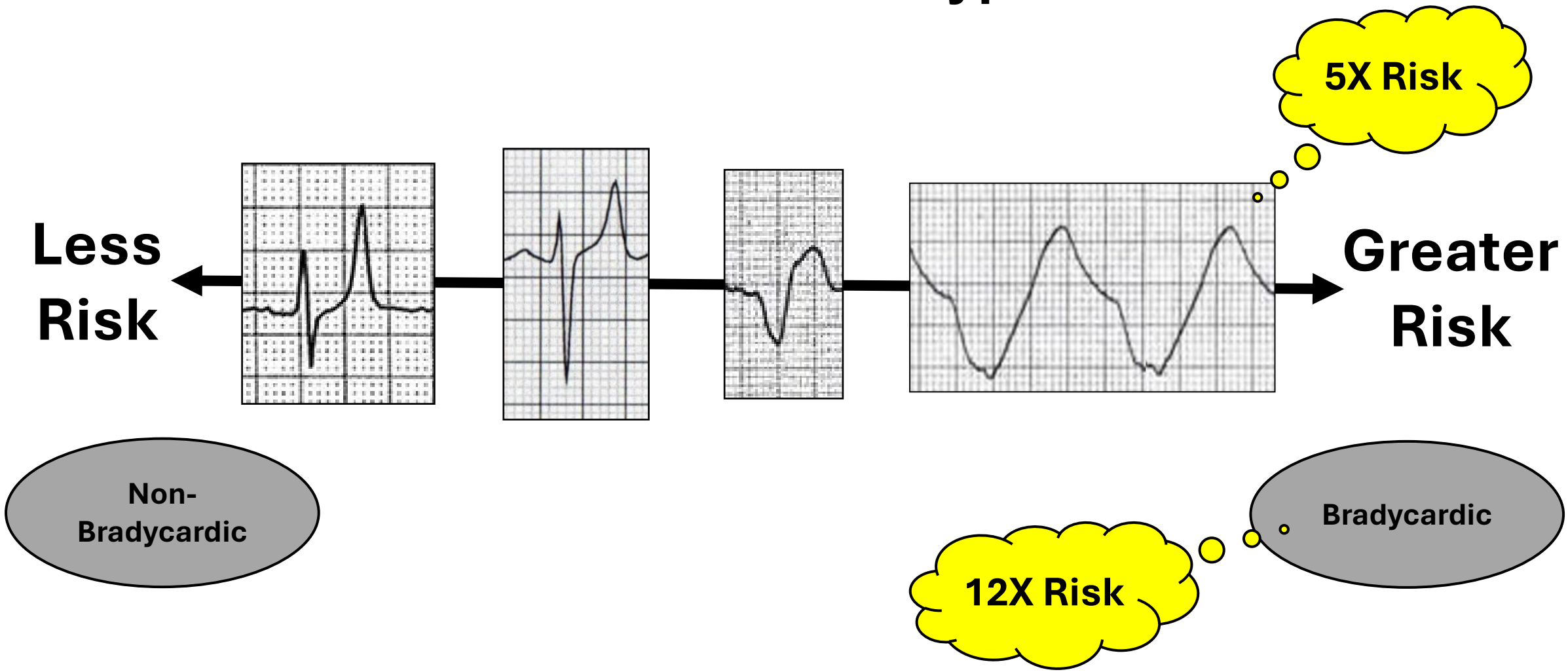


- Slow to slow-normal rate
- QRS extremely wide ~ 0.20 – 0.40 sec



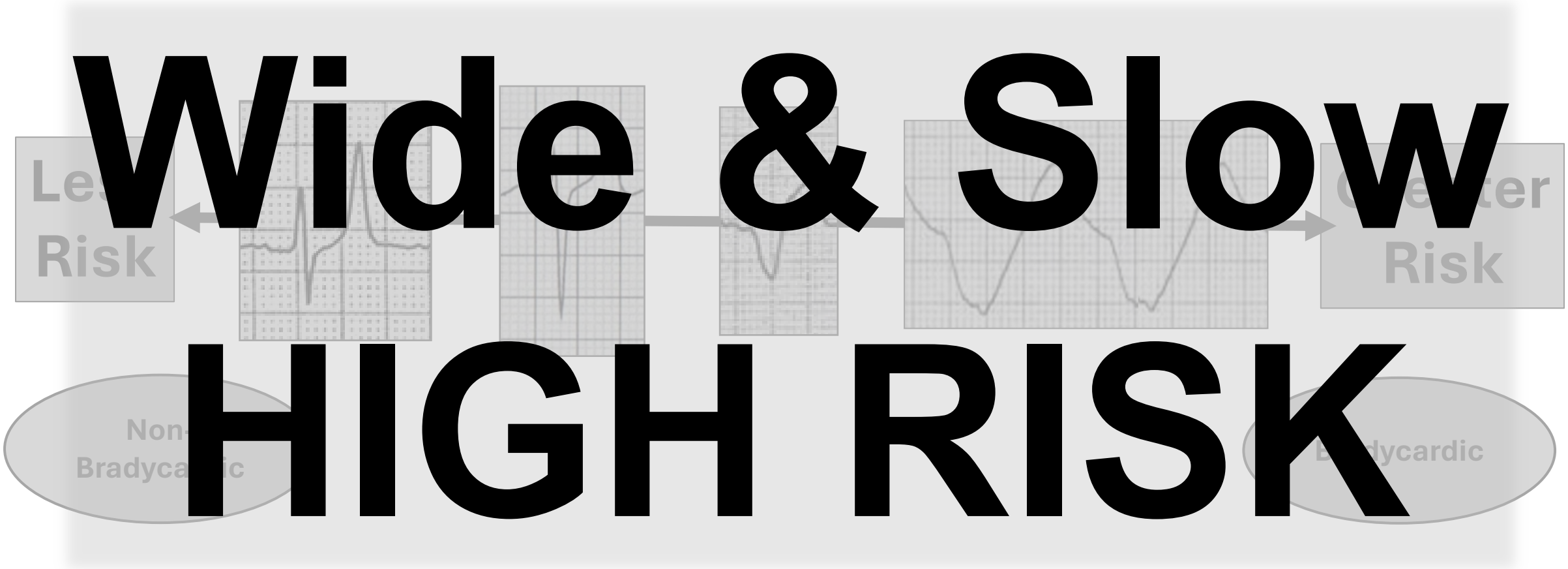
- Bradycardia ~ 30 – 45 bpm
- QRS width ~ 0.12 – 0.16 sec

ECG Prediction of Short-term Adverse Outcome with Hyperkalemia



Durfey et al, West J Emerg Med 2017

ECG Prediction of Short-term Adverse Outcome with Hyperkalemia



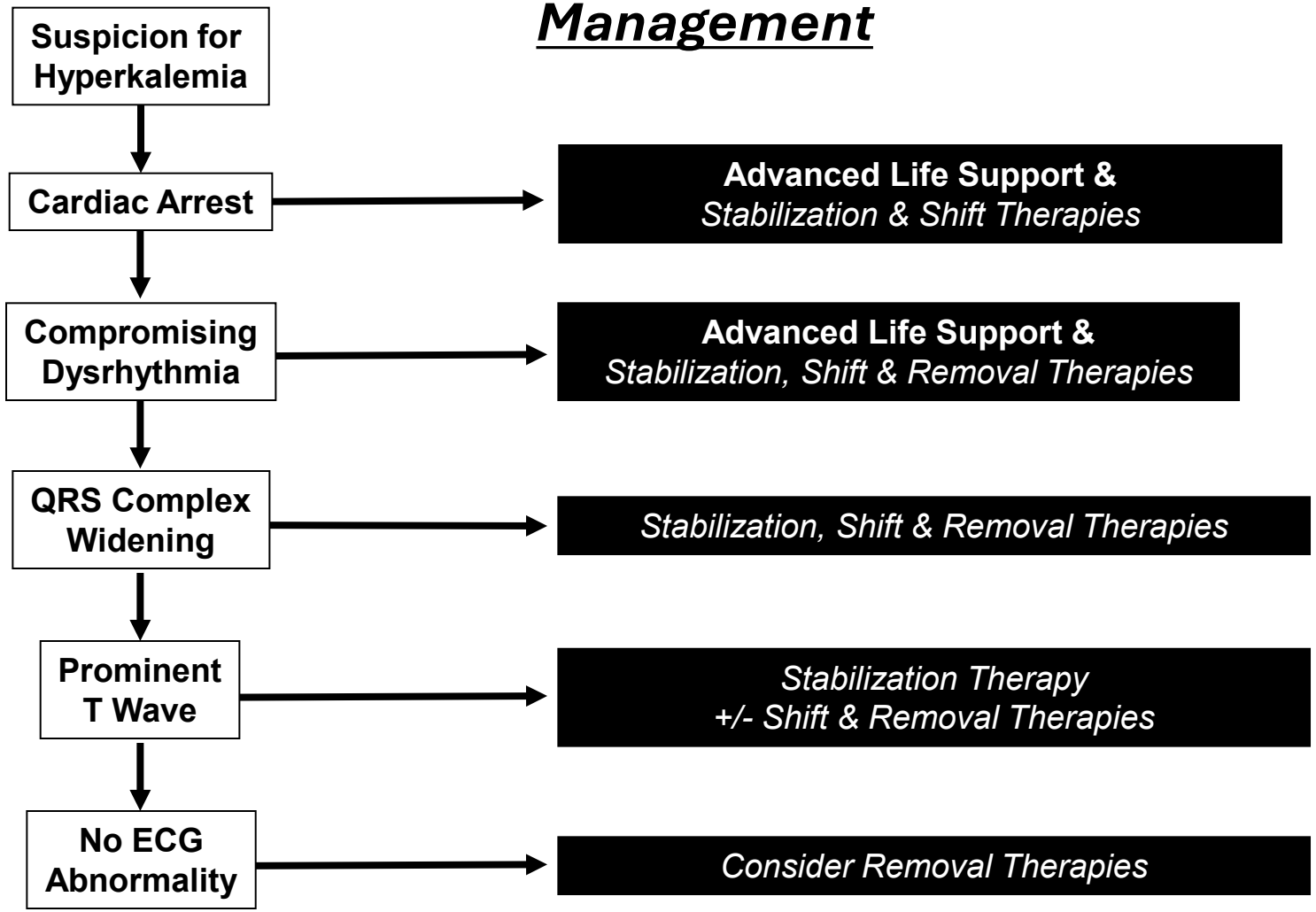
Wide & Slow
HIGH RISK

Hyperkalemia Treatment

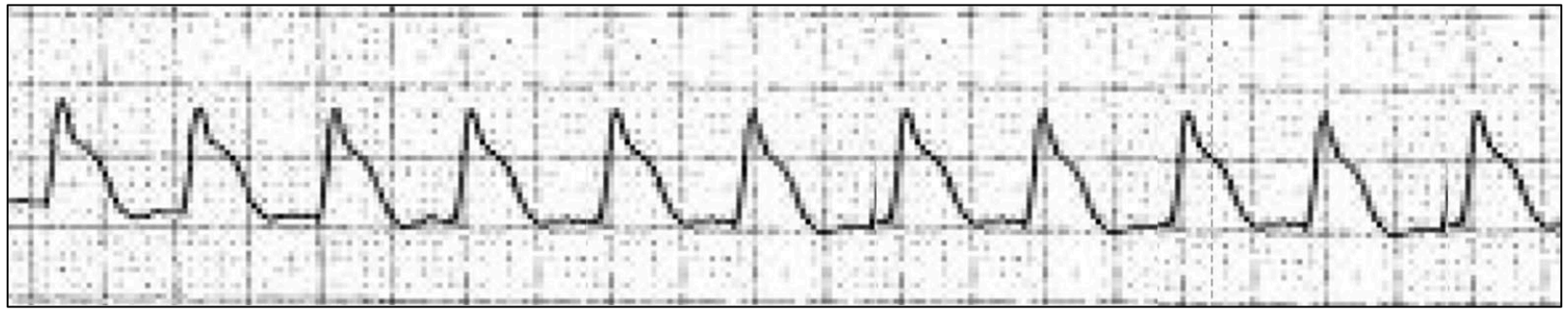
Goals of Therapy

1. **Membrane Stabilization**
   - Calcium
2. **Intracellular Potassium Shift**
   - Bicarbonate
   - Glucose / insulin
   - Adrenergic agonists
3. **Permanent Potassium Removal**
   - GI binding resin
   - Loop diuretics / IVF
   - Hemodialysis

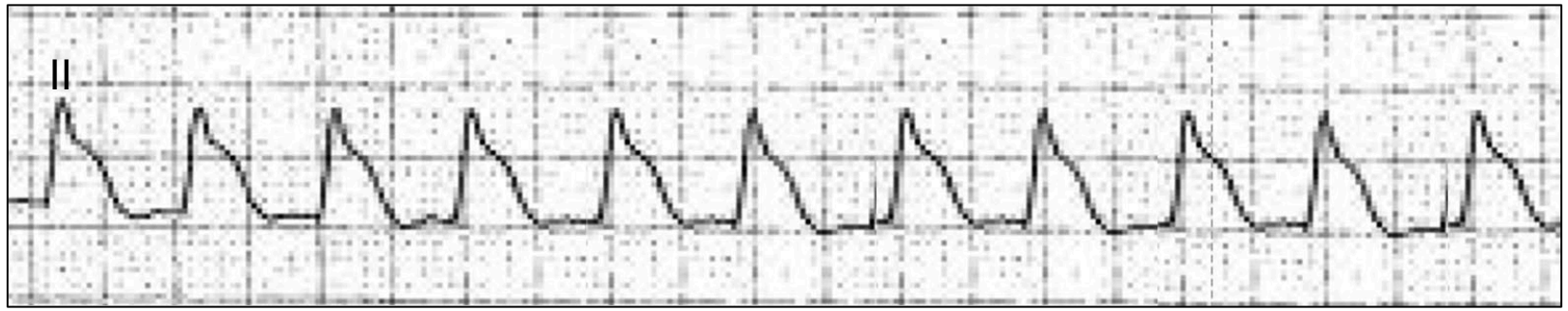
ECG-Guided Management

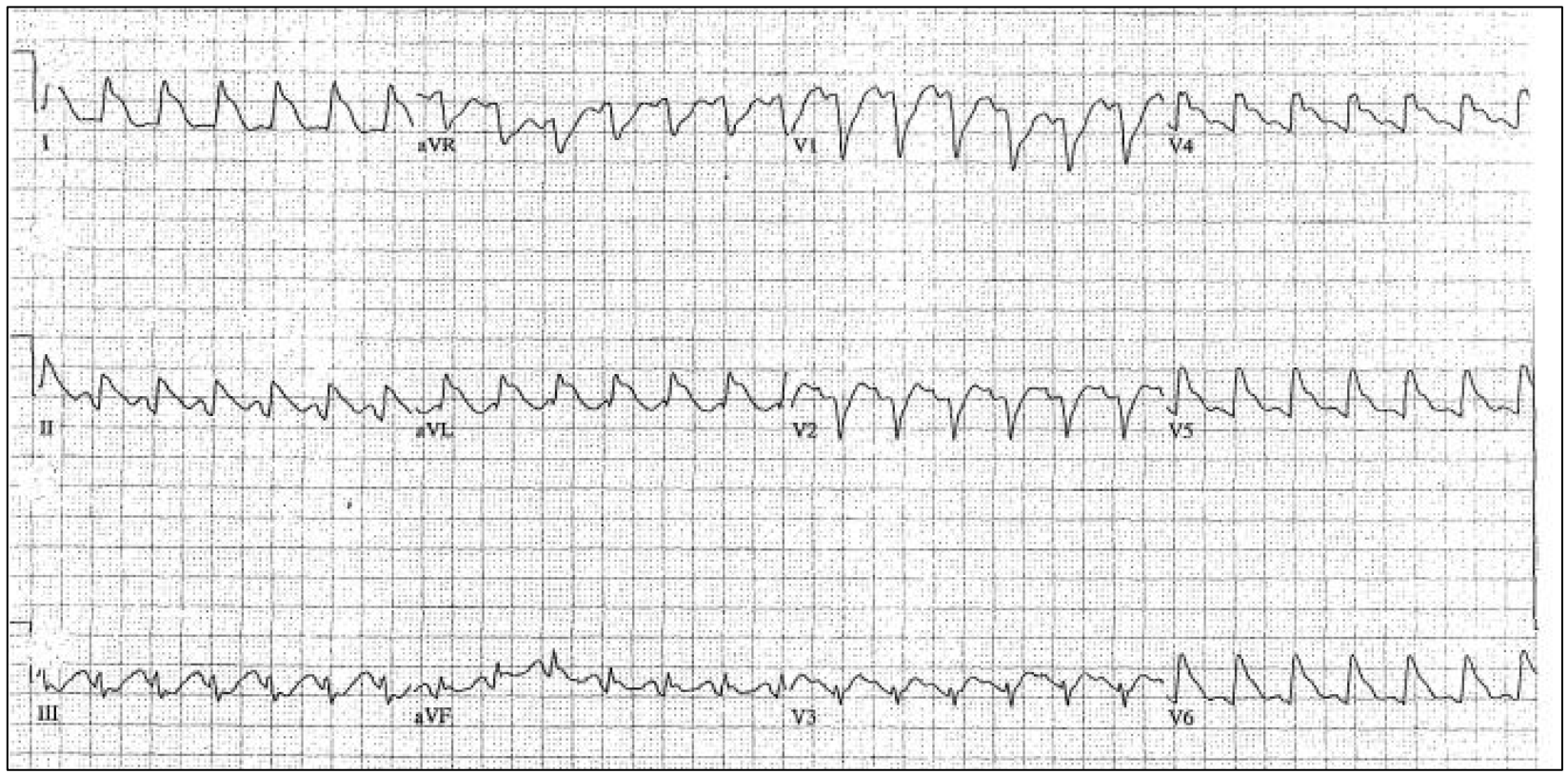


45 Male with Chest Pain & Dyspnea



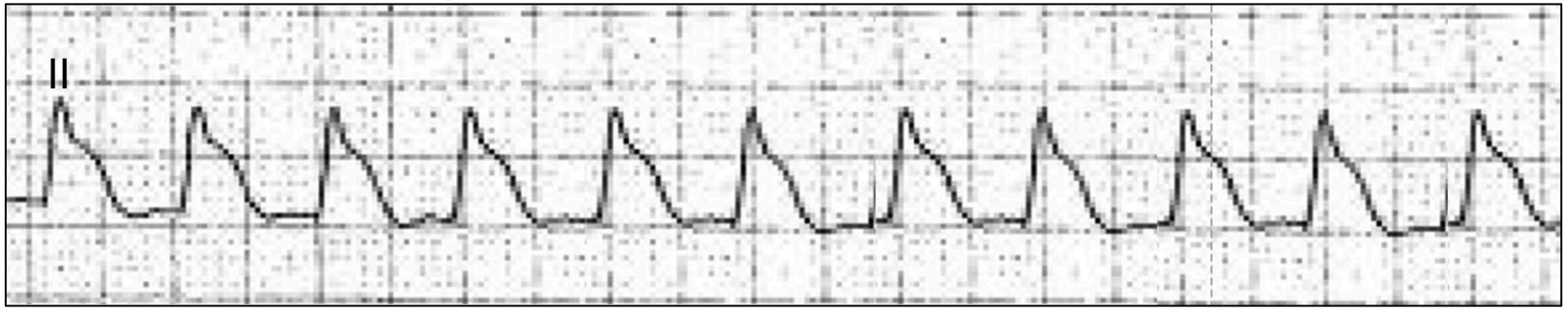
45 Male with Chest Pain & Dyspnea

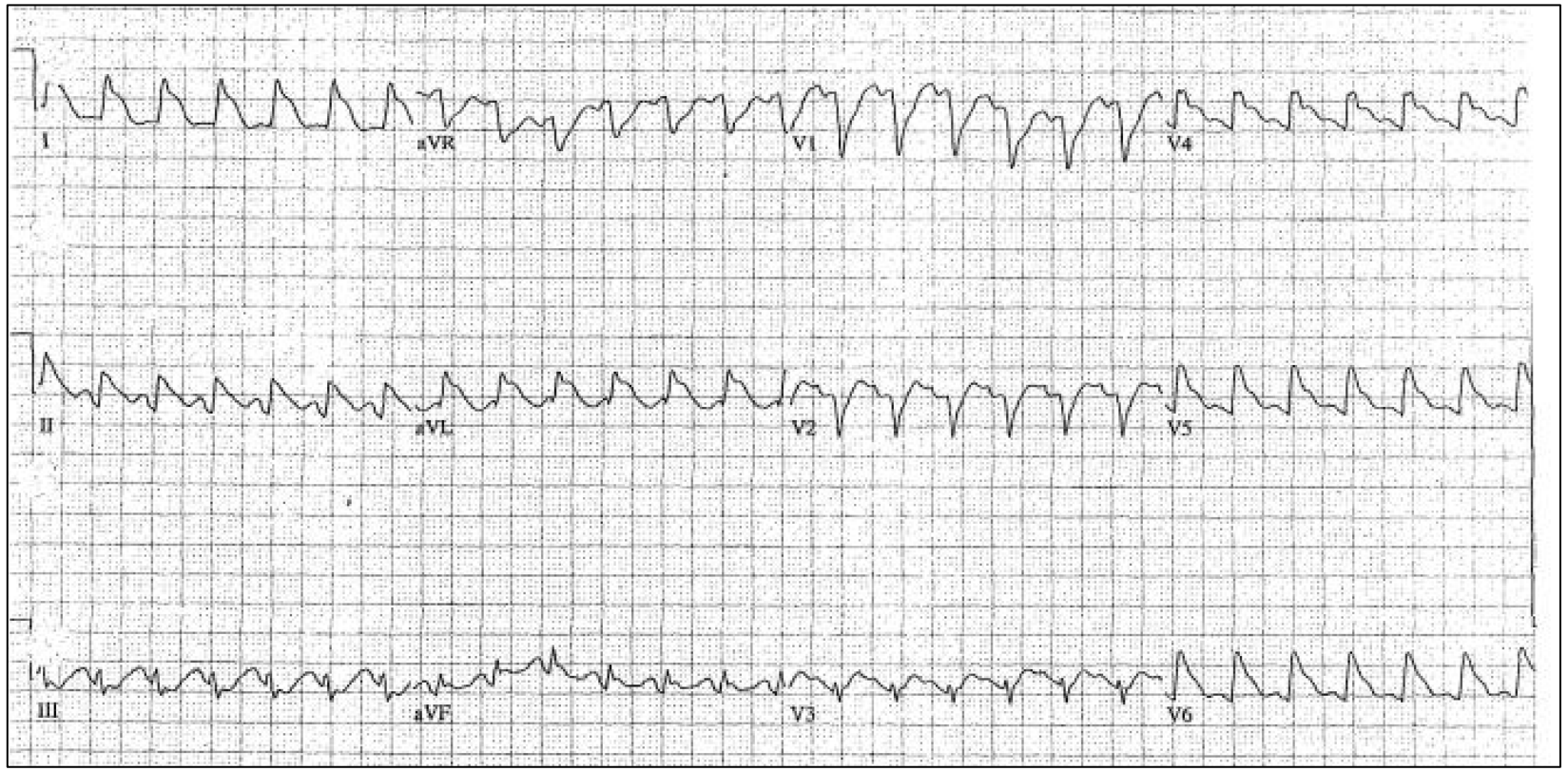




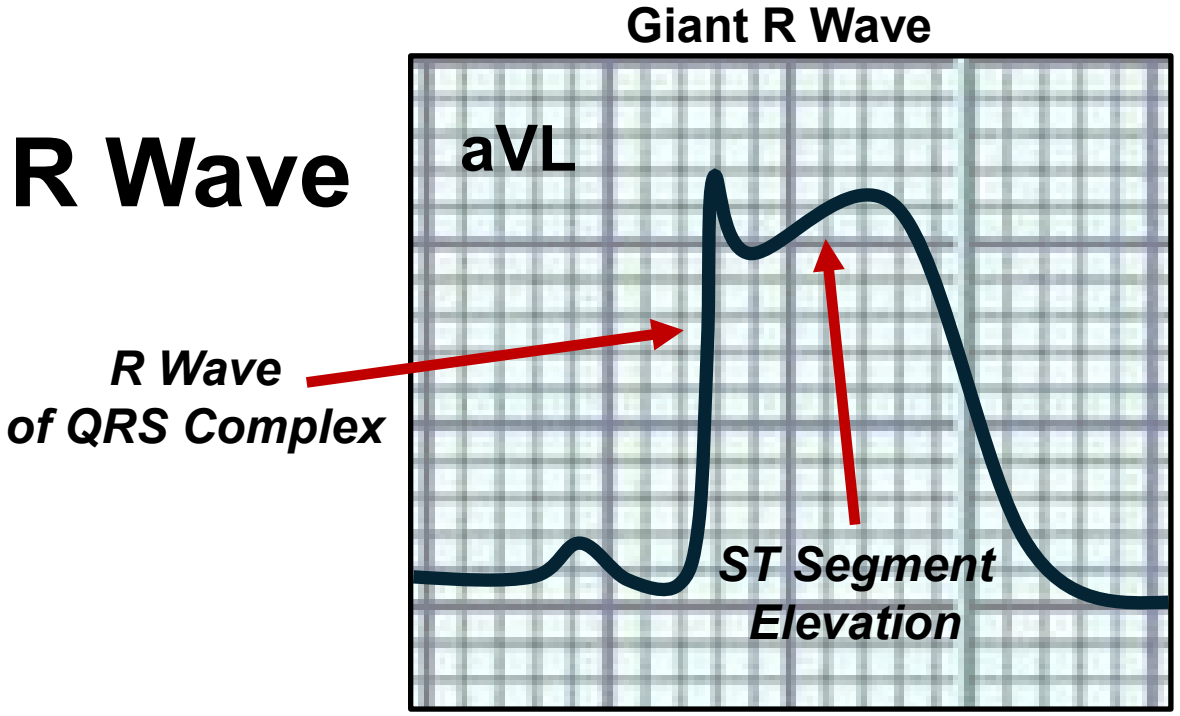
Sinus Tachycardia with Giant R Wave

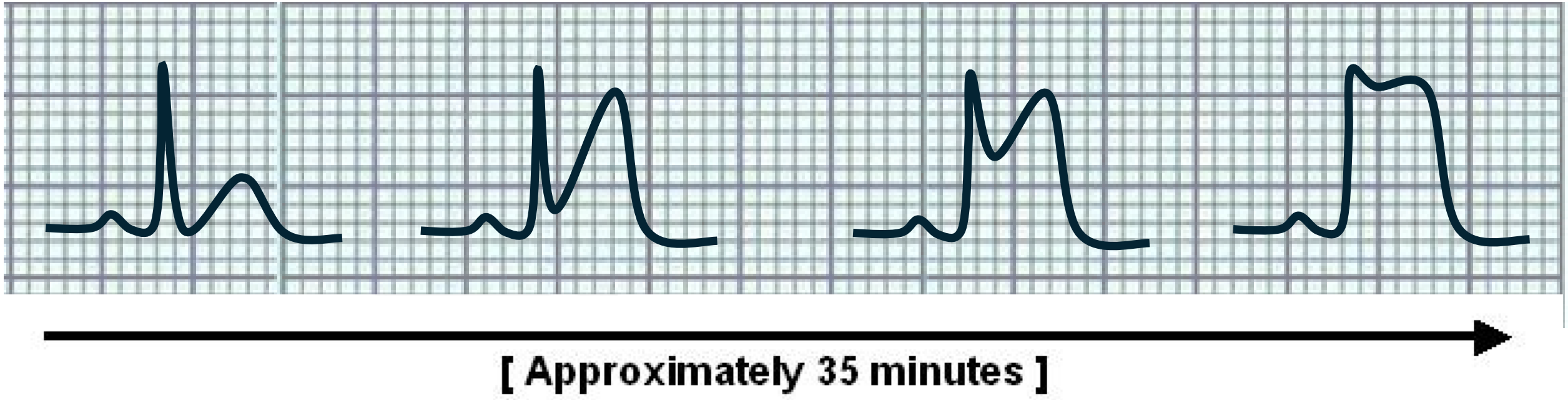
early anterolateral STEMI



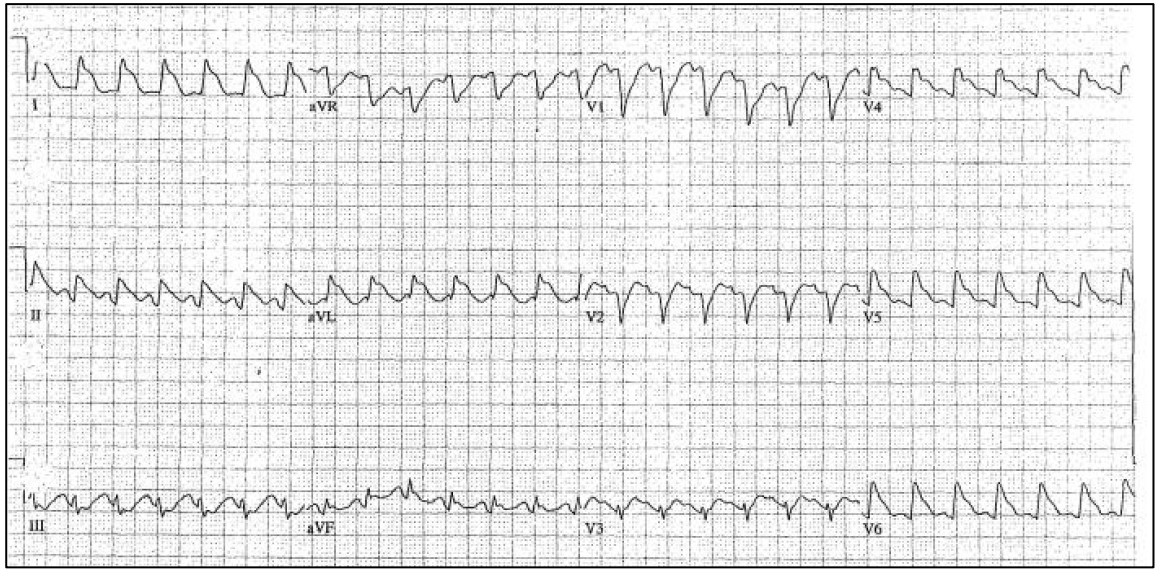


What is the Giant R Wave in Early STEMI?



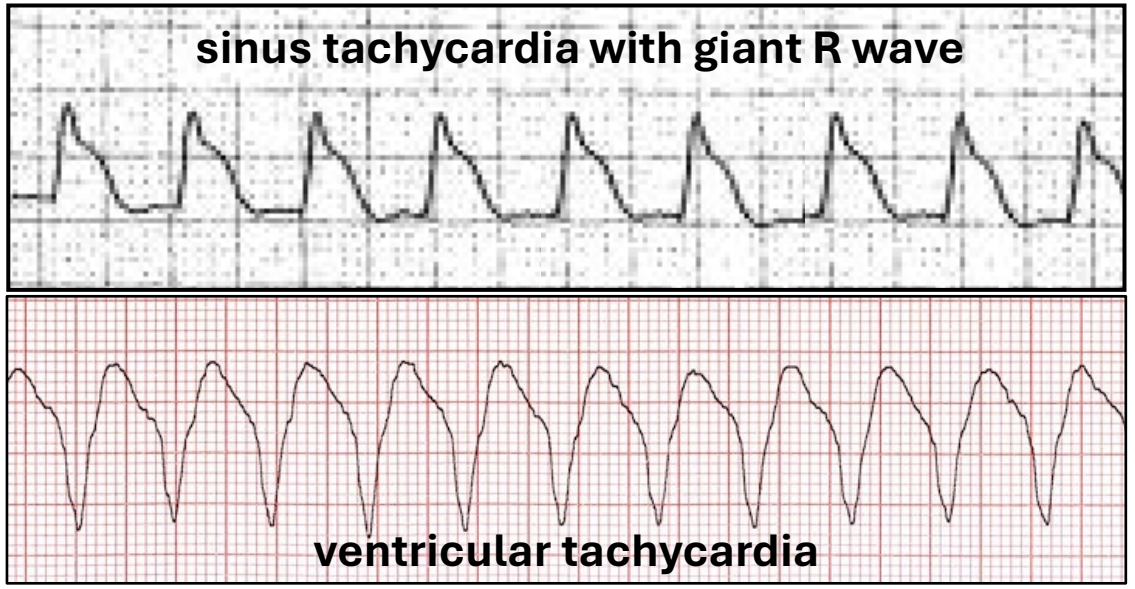


Do Not Confuse with Ventricular Tachycardia!

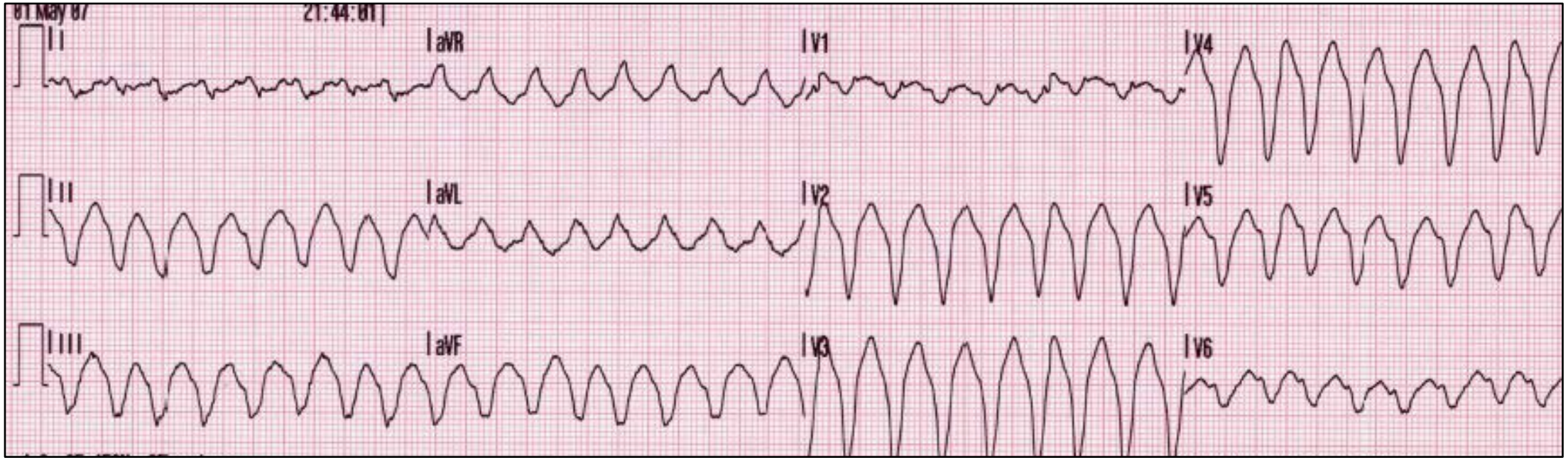


Sinus Tachycardia
STEMI with Giant R Wave

Do not confuse with VT

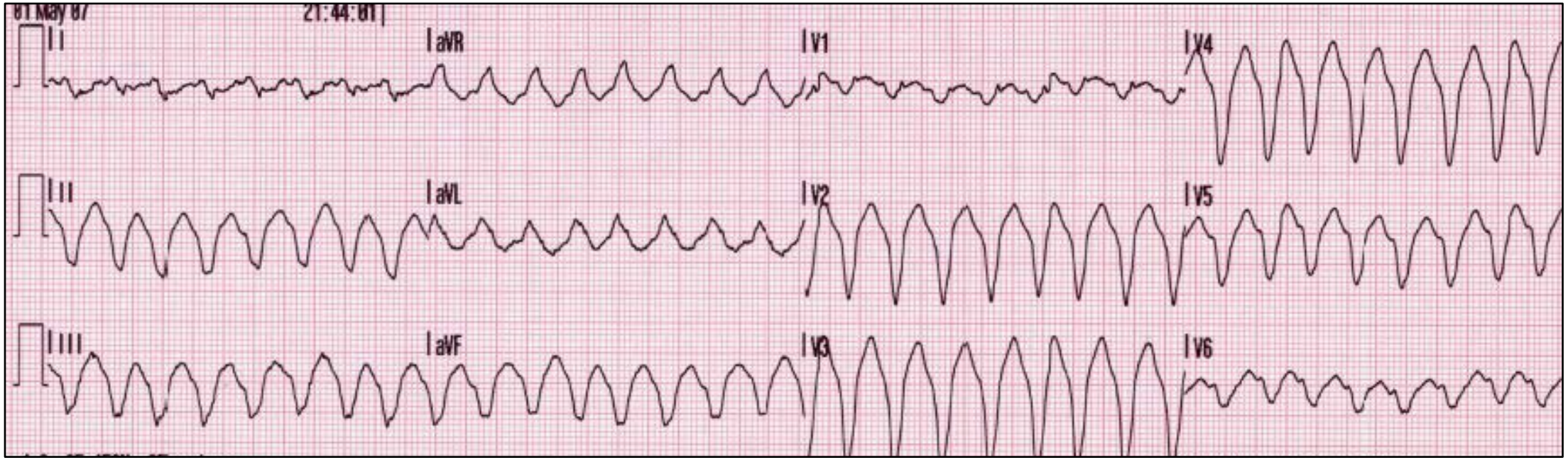


66 Female with with Palpitations, Weakness, & Syncope
PMH MI & CHF
Alert & Oriented with BP 70/60

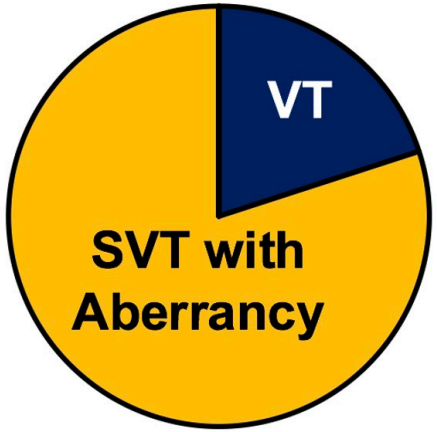


Ventricular Tachycardia

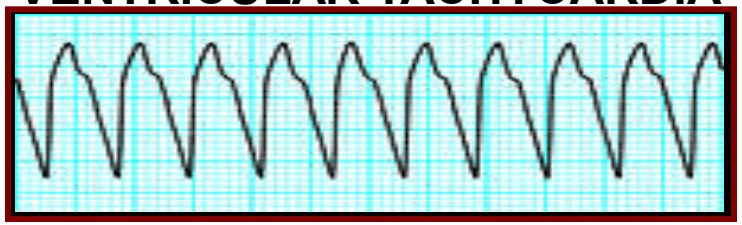
urgent synchronized cardioversion with sedation



Wide Complex Tachycardia

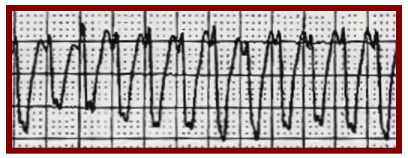


VENTRICULAR TACHYCARDIA

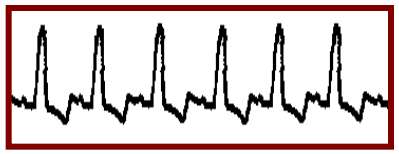


ABERRANT SVT

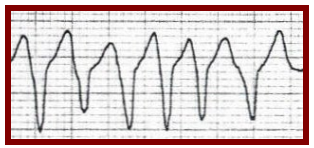
AVNRT w/ BBB



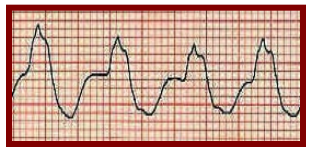
ST w/ BBB



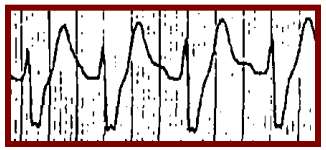
WPW AFIB



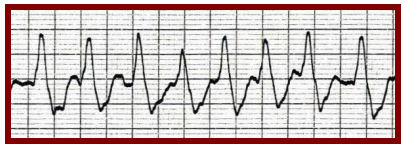
METABOLIC



TOXIC



AFIB w/ BBB



WPW AVRT

Factors Suggesting Ventricular Tachycardia

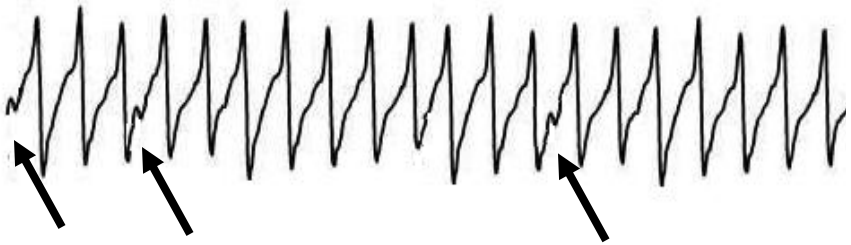
- **Increasing Patient Age & CAD/MI/CHF suggests VT**

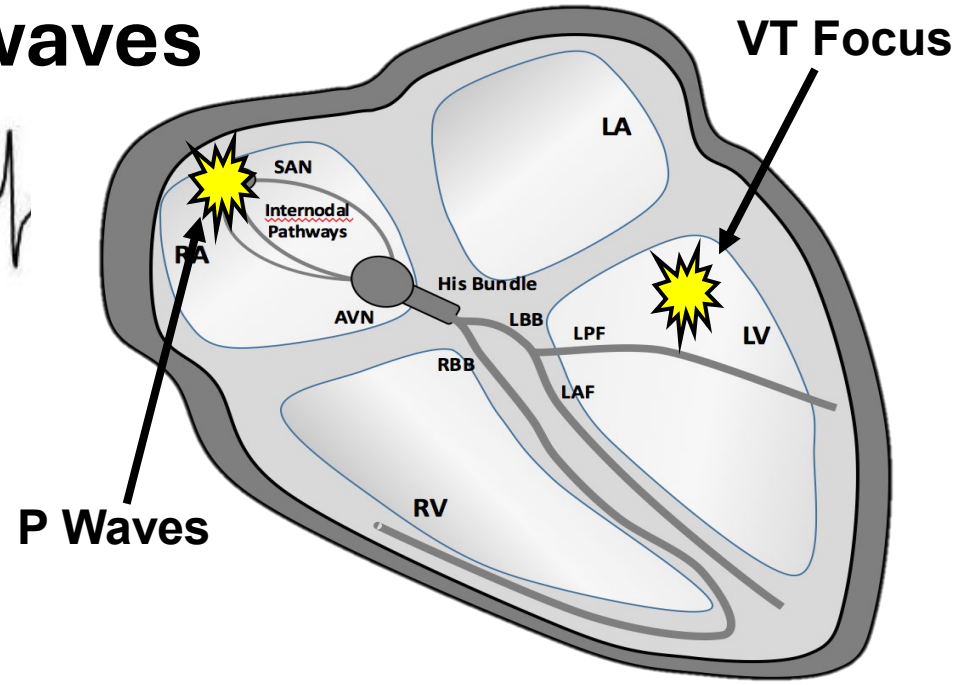
- **ECG – suggestive of VT**
  - Rapid, regular, wide QRS rhythm
  - AV dissociation
  - Precordial concordance (negative > positive)

- **<u>NOT</u> useful in distinction of VT from SVT with aberrancy**
  - Symptoms
  - Stability / instability

AV Dissociation

- Ventricular focus produces WCT
- Continued SAN activity…atrial depolarization…P waves



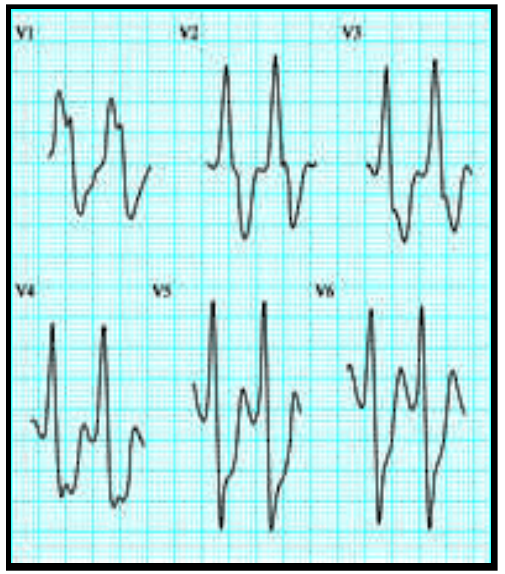


- +/- common
- Strongly favors VT

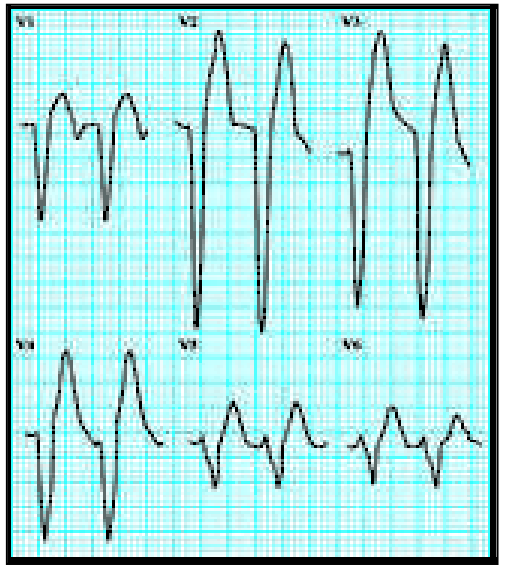
Precordial Concordance

- **QRS complexes V1-V6 with same polarity** …positive or negative

- **Suggestive of VT**
  - Positive “frequently VT”
  - Negative “always VT”



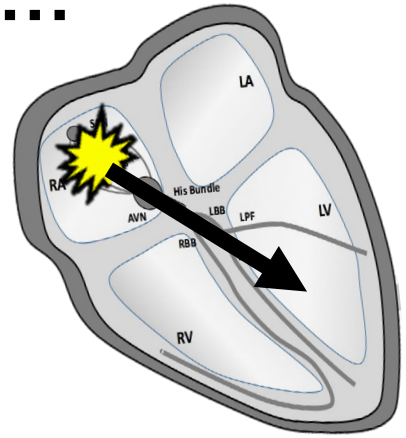
Positive Concordance



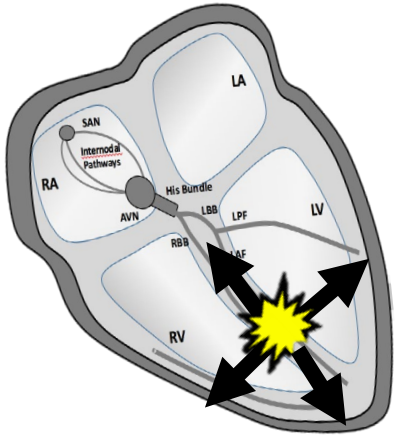
Negative Concordance

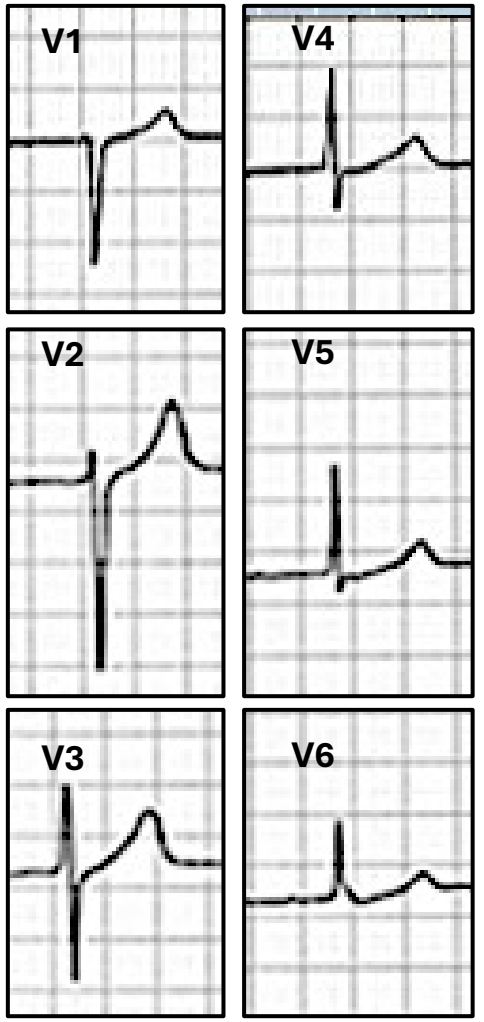
Precordial Concordance

- **If supraventricular source of rhythm…**
  - Negative QRS in lead V1
  - Transitions from NEGATIVE to POSITIVE
  - Positive QRS in lead V6
  - R wave progression



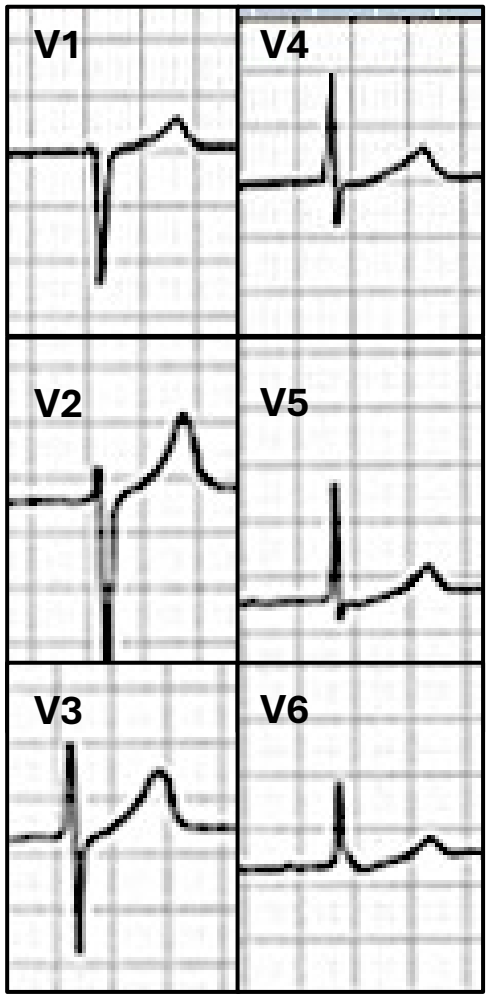
- **If ventricular source of rhythm…**
  - R wave progression can be lost
  - QRS's either all negative or positive



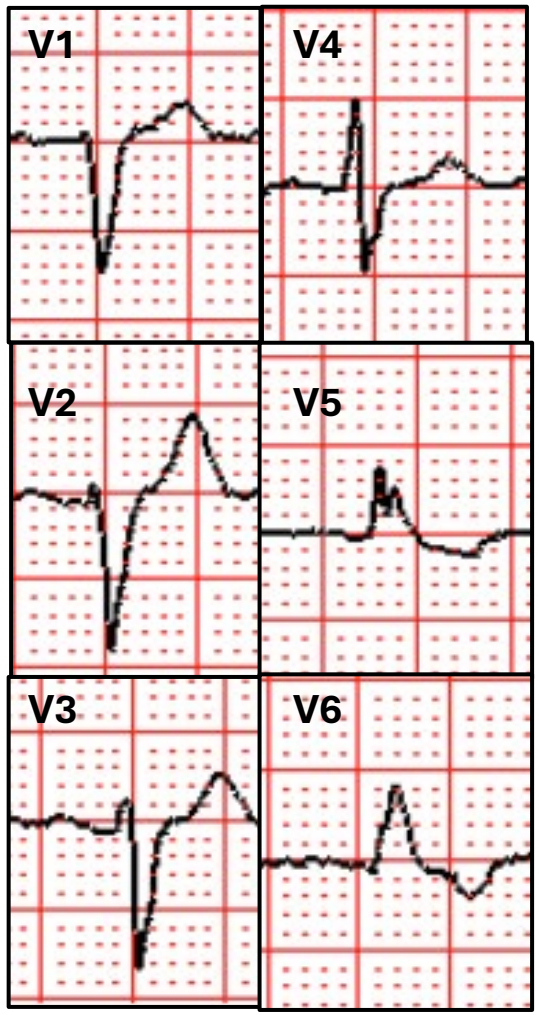


Normal R Wave Progression (V1-V6)
negative to positive
NO CONCORDANCE

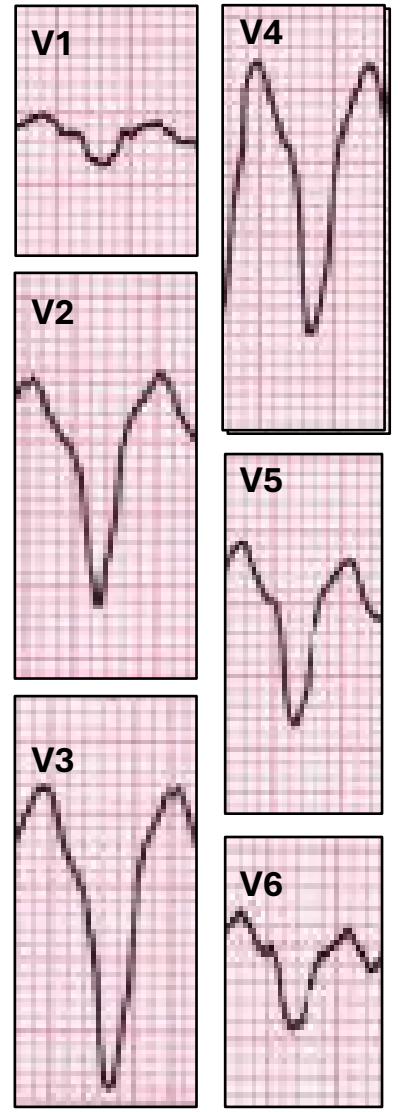
Precordial Concordance in Ventricular Tachycardia



Sinus Rhythm without Precordial Concordance

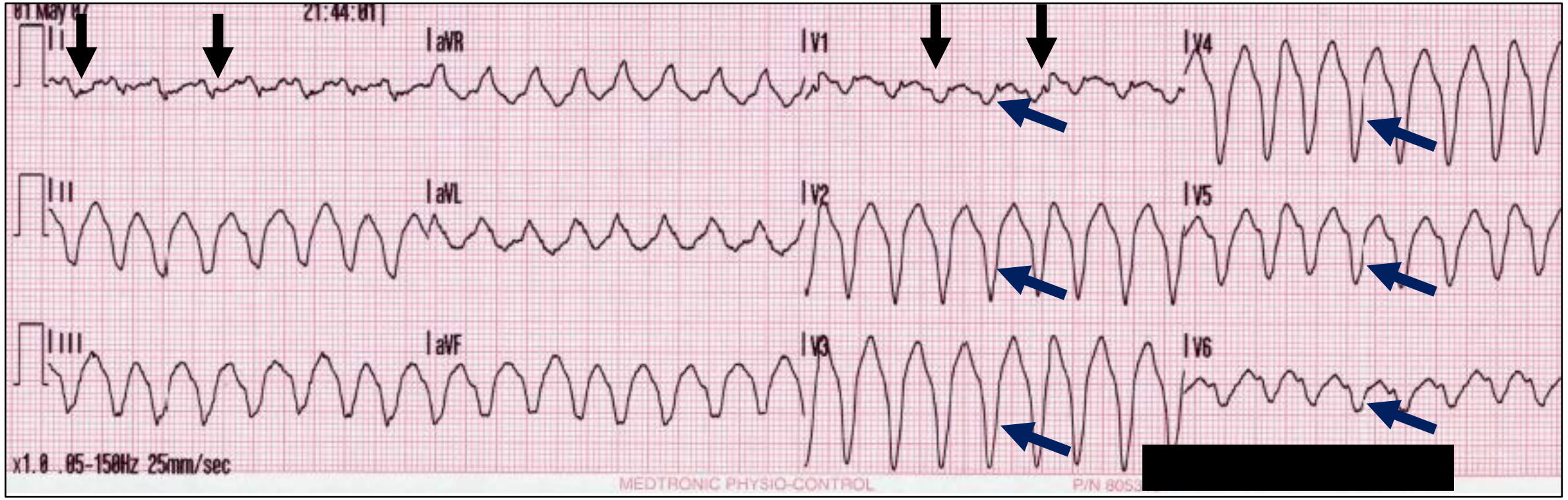


Sinus Rhythm with LBBB & Without Precordial Concordance



Ventricular Tachycardia with Precordial Concordance

AV Dissociation & Precordial Concordance

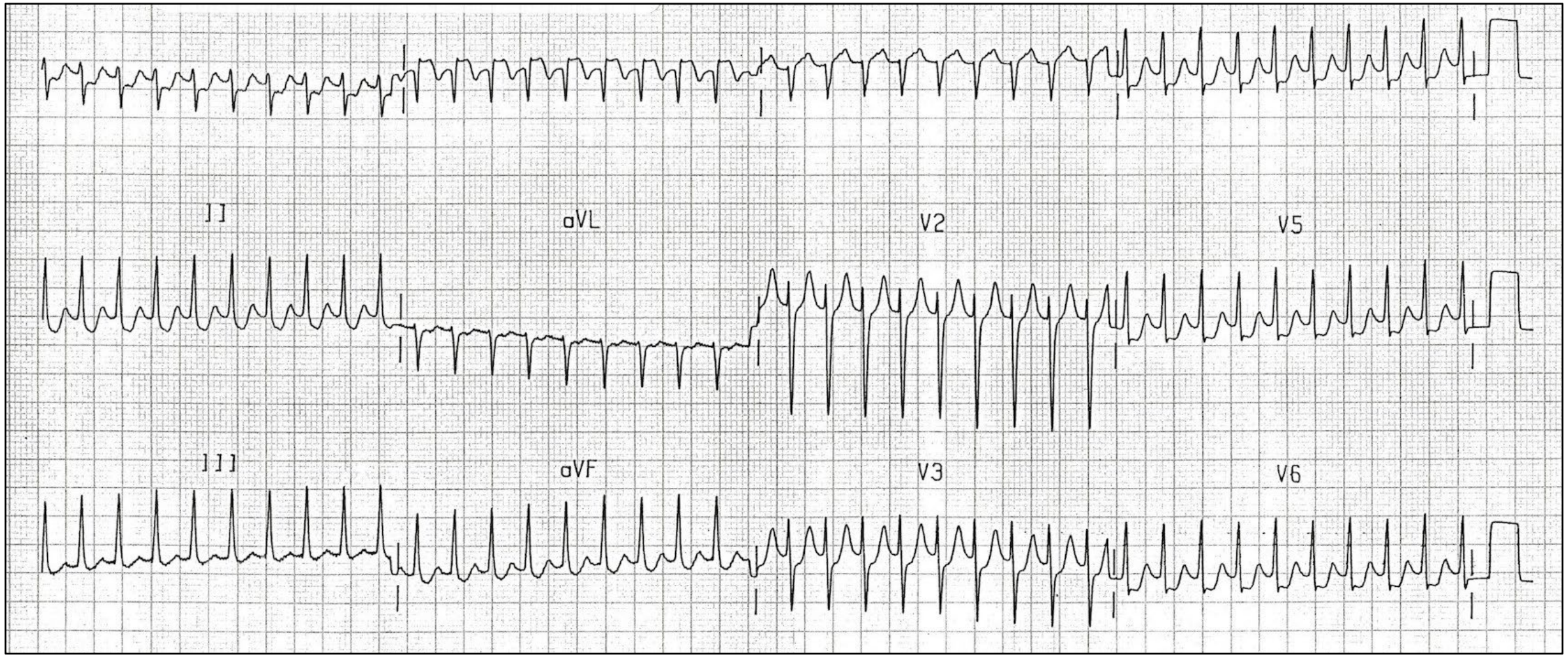


Wide Complex Tachycardia

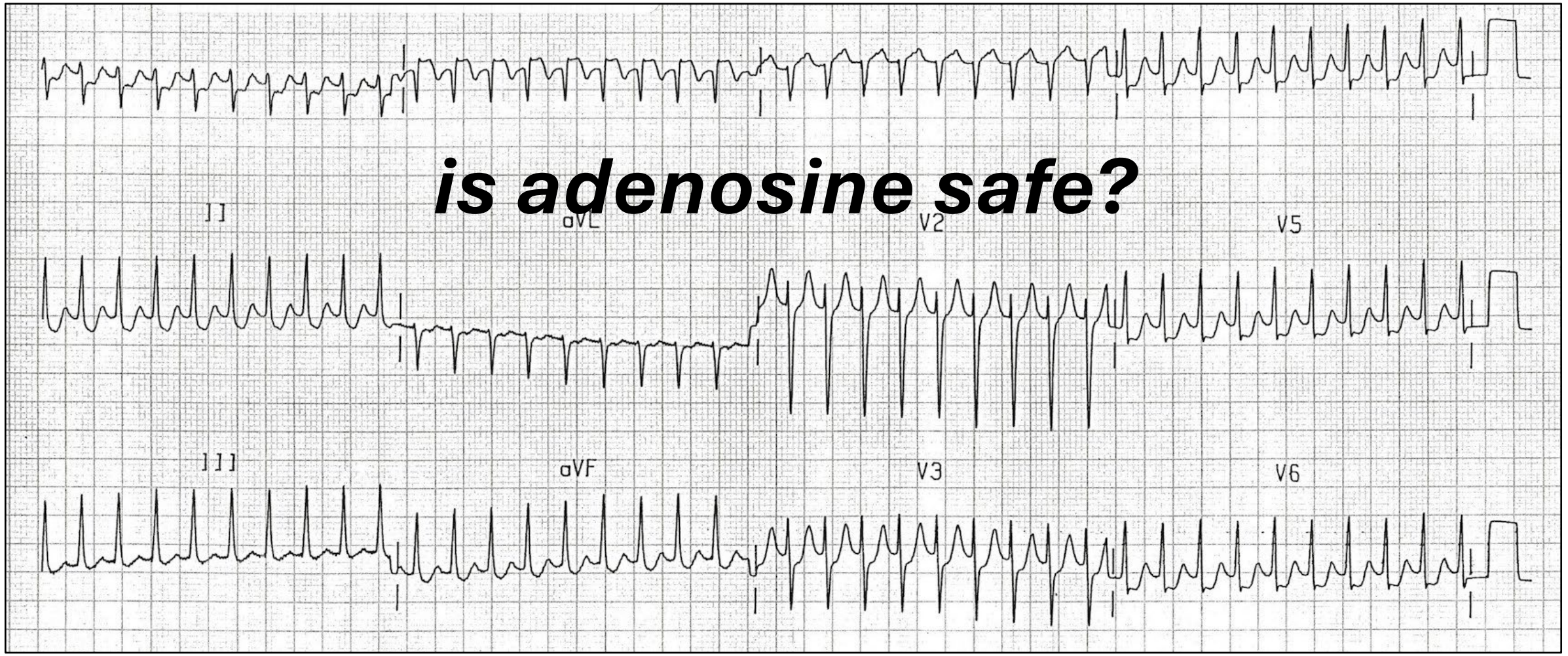
When in Doubt...

treat as Ventricular Tachycardia

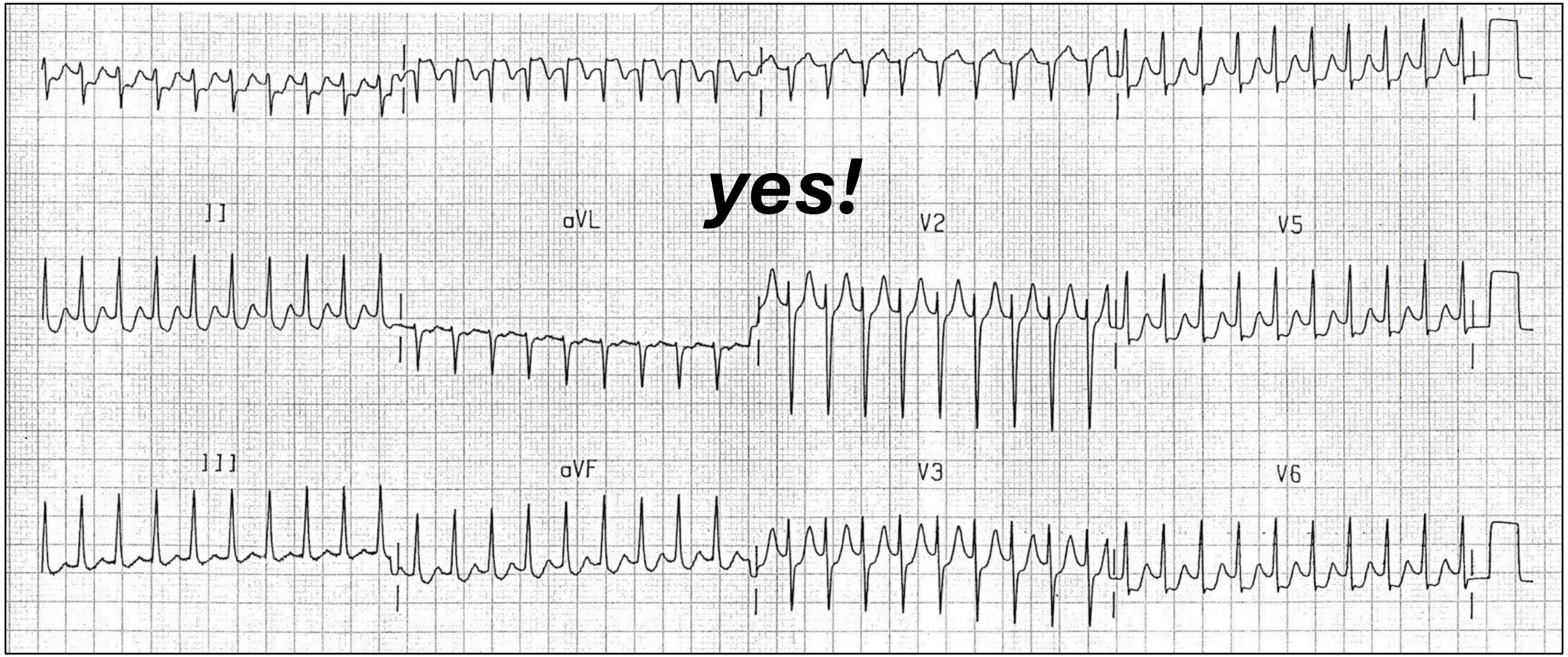
6 Female…"*My Tummy Hurts Bad*"
Perfusion is normal



Narrow Complex Tachycardia
AV Nodal Re-entrant Tachycardia vs AV Re-entrant Tachycardia

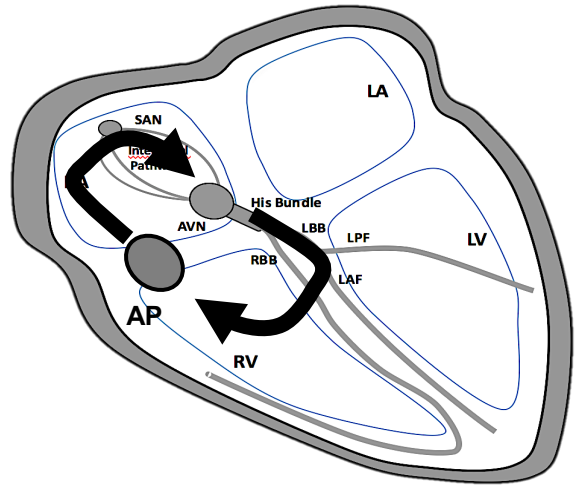


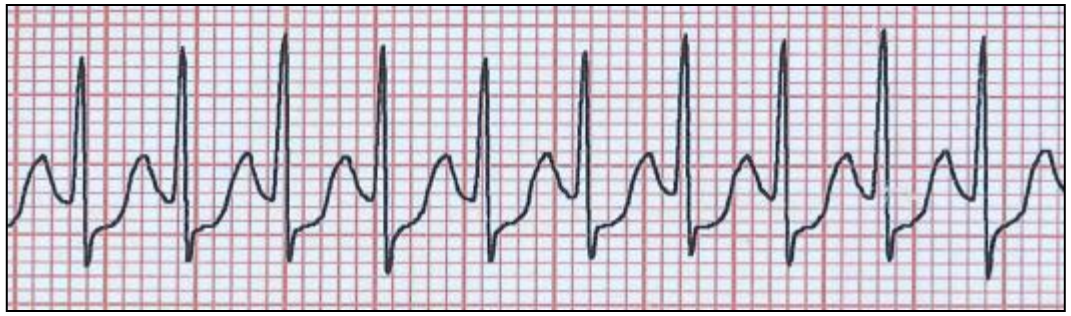
Narrow Complex Tachycardia
WPW-related AV Re-entrant Tachycardia



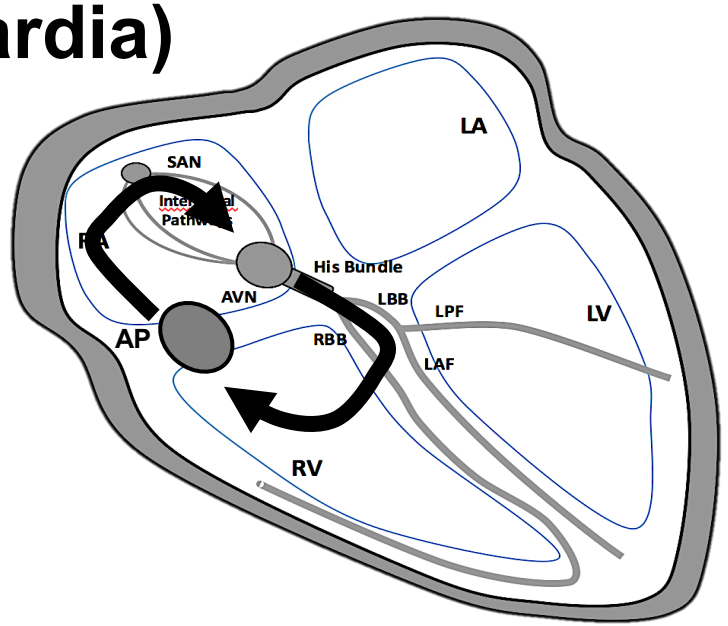
AV Re-entrant Tachycardia

- AVRT - Orthodromic
- Most common – 65%
- AV conduction is antegrade
- Rapid & regular
- Narrow QRS complex
- Nearly indistinguishable from “typical” PSVT (AVNRT)

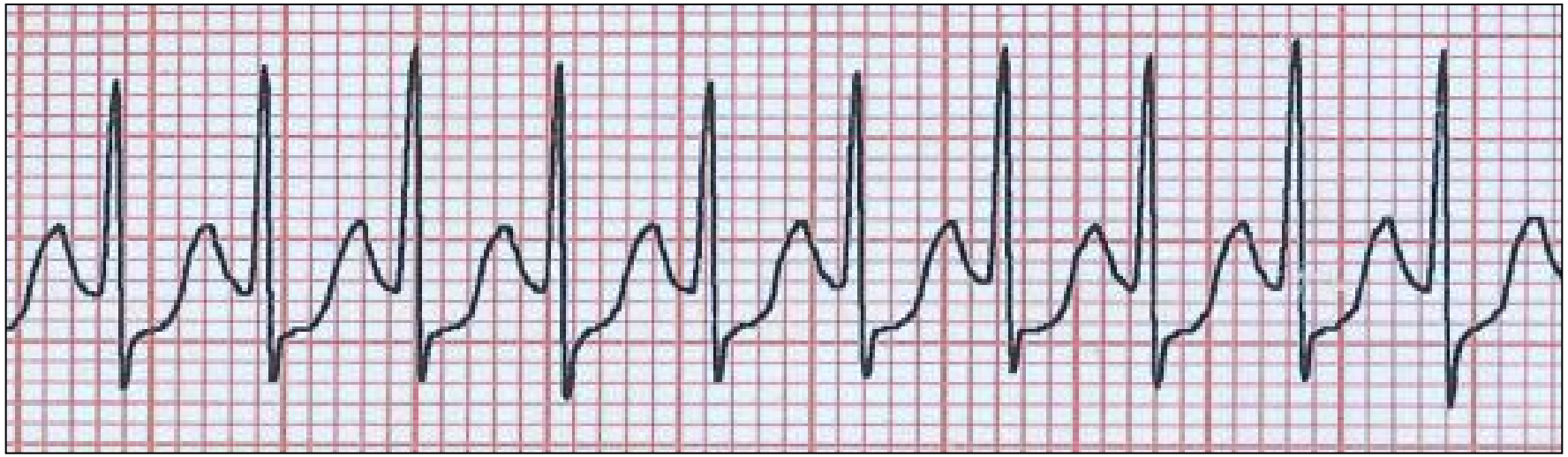




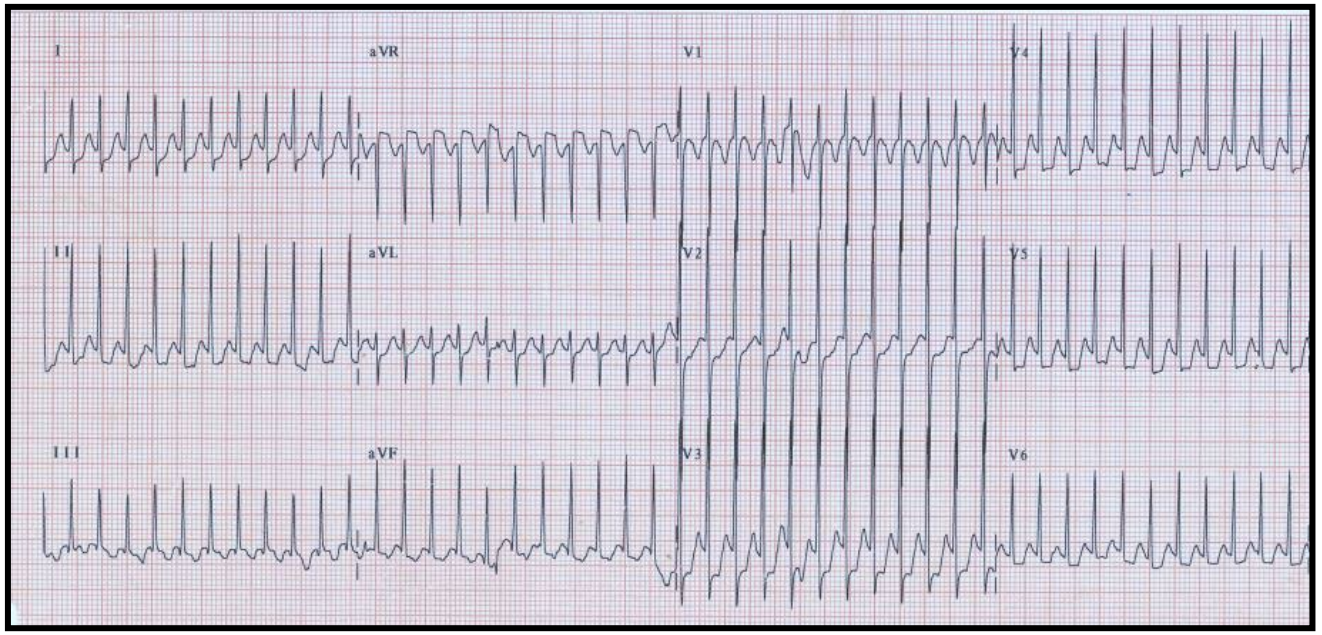
AVRT (AV Re-entrant Tachycardia) Orthodromic

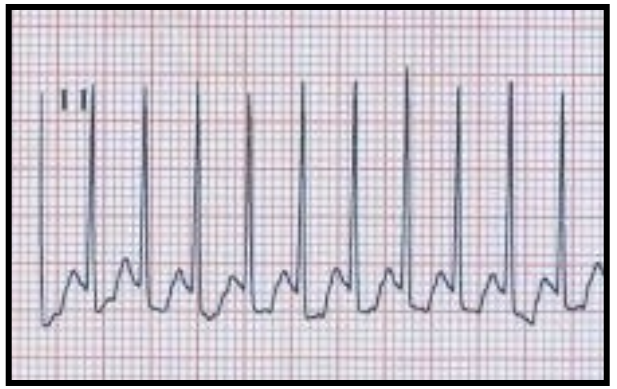


- **Conduction**
  - Antegrade at AVN
  - Retrograde at AP
- **QRS complex is narrow**

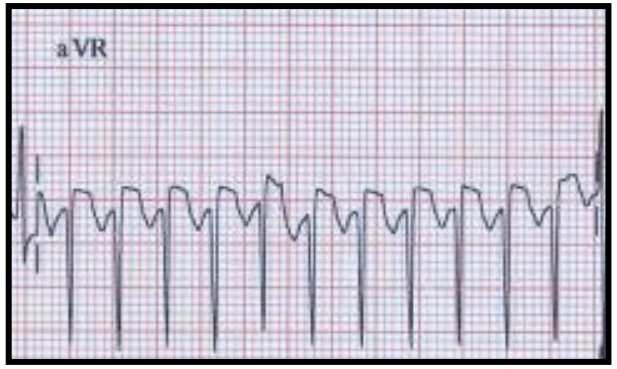


Orthodromic AV Re-entrant Tachycardia





- Narrow QRS complex
- Very rapid & regular



- ST segment elevation in lead aVR

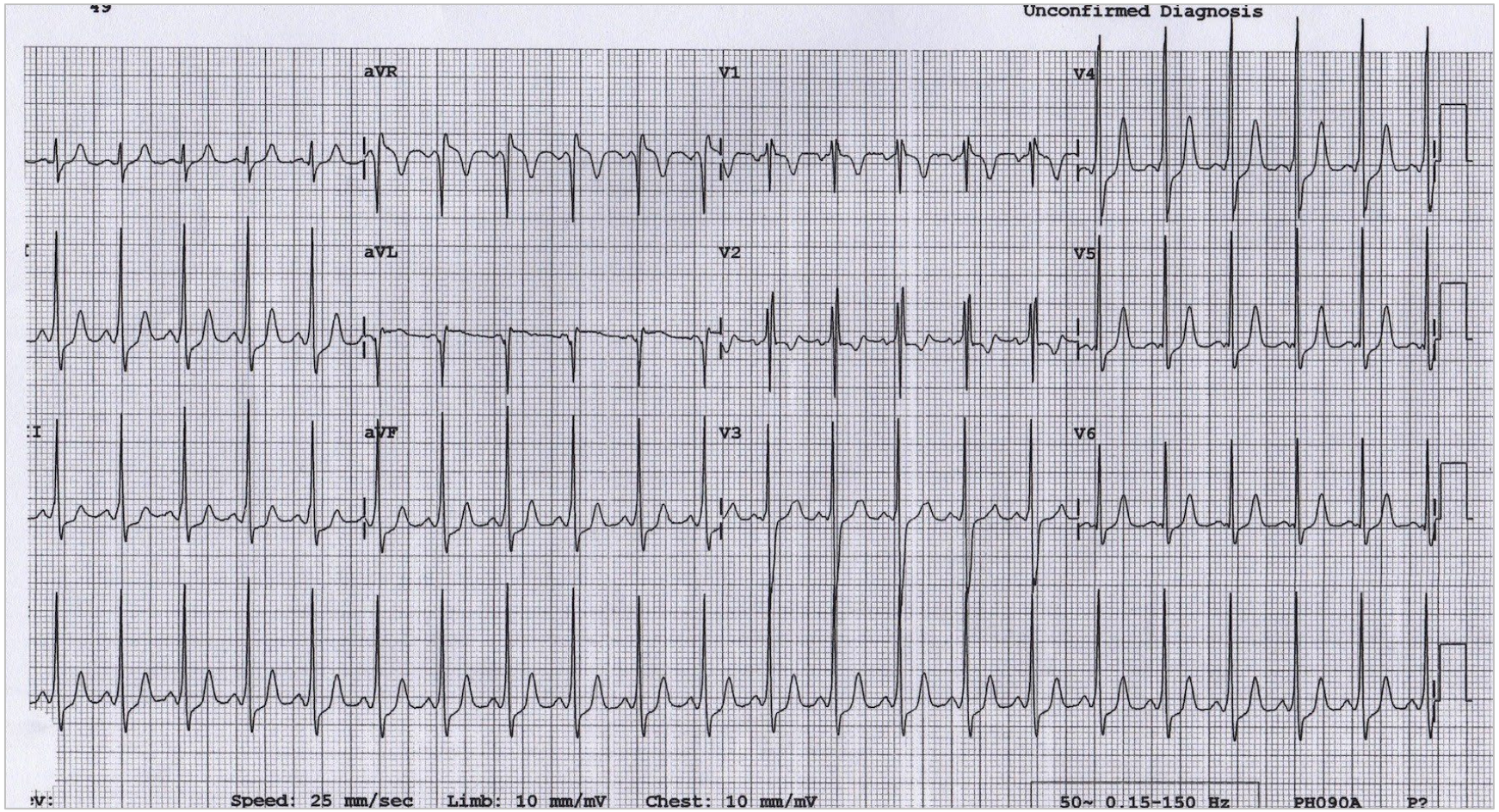
Comparison
WPW-related Orthodromic AVRT versus AVNRT

Orthodromic AVRT (WPW)

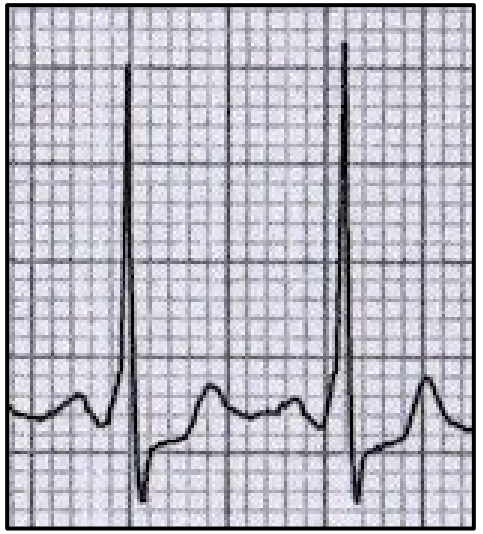
AVNRT

6 Female – “my tummy feels better”

AV Re-entrant Tachycardia



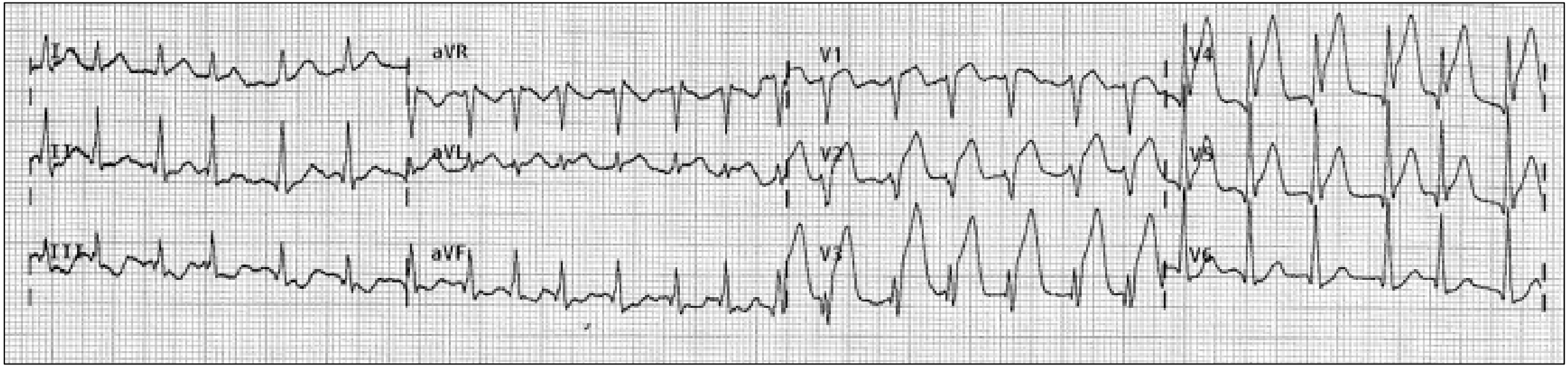
ECG Triad



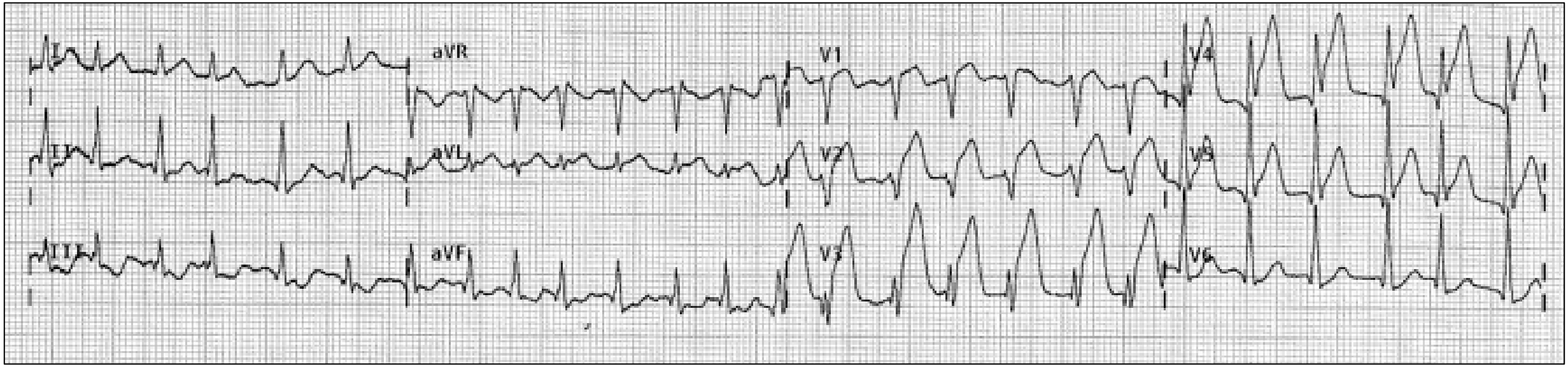
- **Shortened PR interval**
- **Delta wave**
- **Widened QRS complex**

41 male with sub-sternal chest pain & diaphoresis

A/O but ill-appearing
154/78, 133, 24, Sat 95% (RA)



Early Anterolateral STEMI
Hyperacute T Waves



Hyperacute T Wave

- Very early indicator of STEMI
- Appears 5 - 30 min after coronary occlusion
- Transient feature…often not seen
- ECG indication for urgent reperfusion…with appropriate clinical presentation

EXPERT CONSENSUS DECISION PATHWAY

2022 ACC Expert Consensus Decision Pathway on the Evaluation and Disposition of Acute Chest Pain in the Emergency Department

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TABLE 1 Electrocardiogram Findings Suggestive of Ischemia

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Hyperacute T waves	Broad, asymmetric, peaked T waves may be seen early in STEMI Serial ECGs over very short intervals are useful to assess for progression to STEMI
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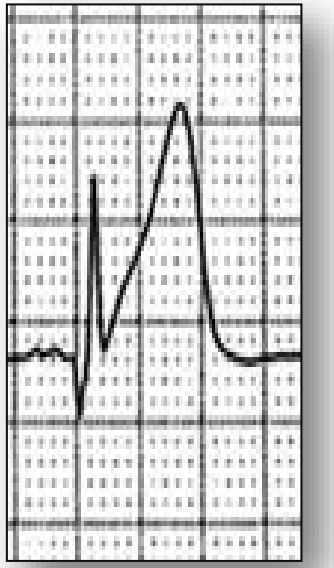
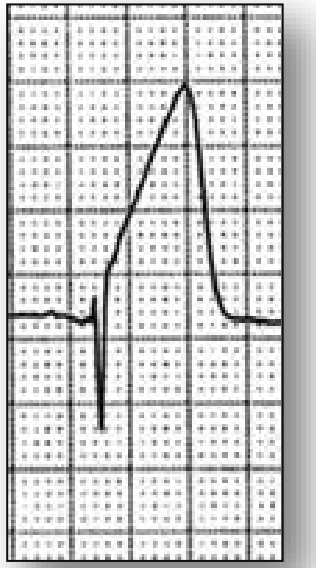
Inverted T waves	May be seen in ischemia (subacute) or infarction (may be fixed and associated with Q waves) in continuous leads

J Am Col Cardiol 2022;80:1925-60

Hyperacute T Wave

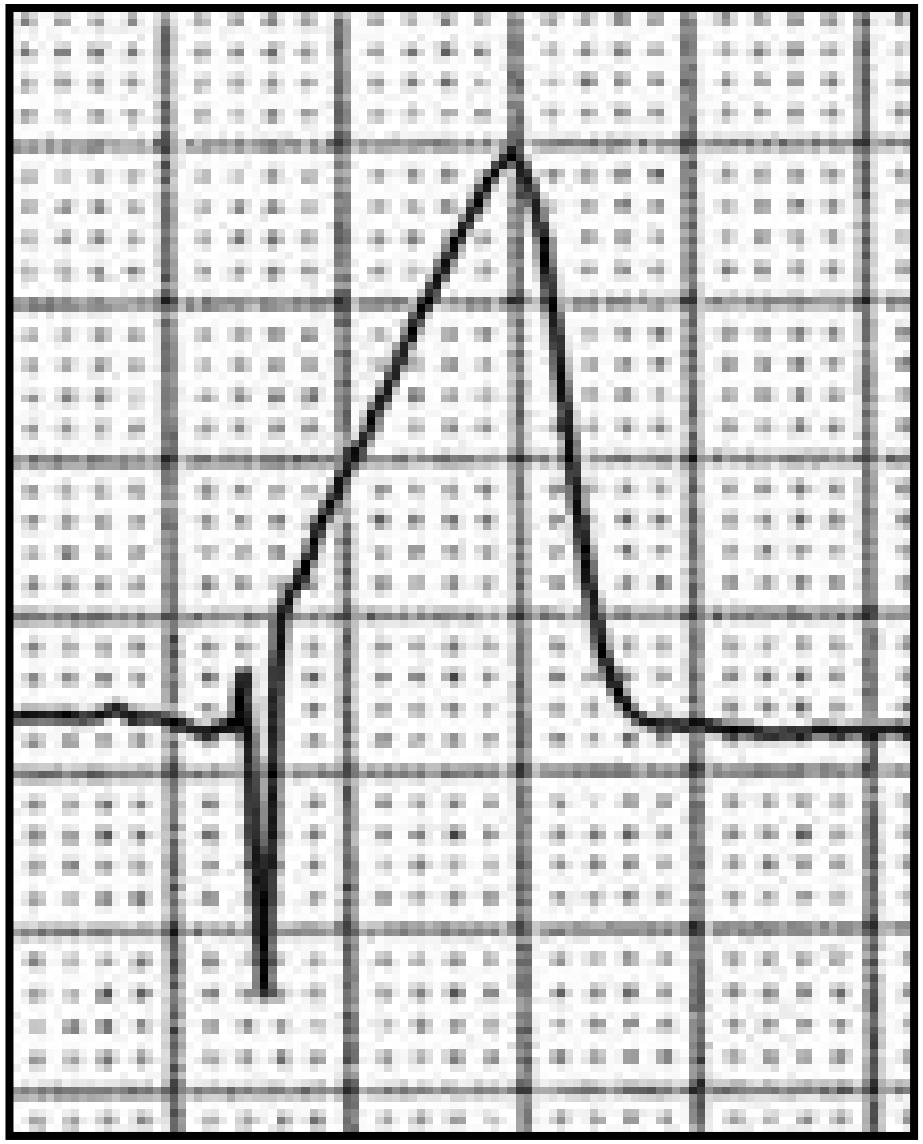
- Tall & prominent
- Broad base
- Asymmetric shape
- J point elevation
- Dynamic





Comparison of Prominent T Waves

Early STEMI



Tall & Prominent

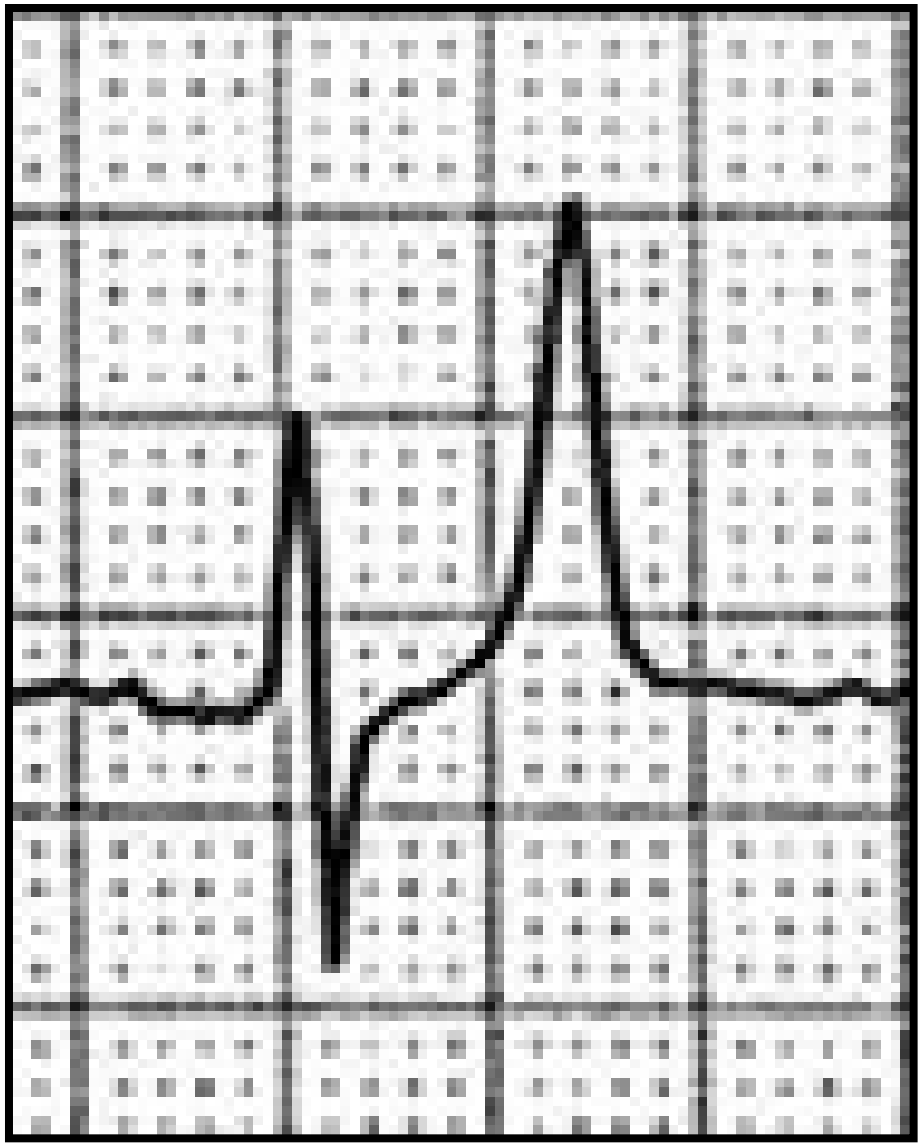
Width
Broad vs Narrow

Symmetry
Asymmetric vs Symmetric

ST Segment Elevation (J Point)
Elevated vs None

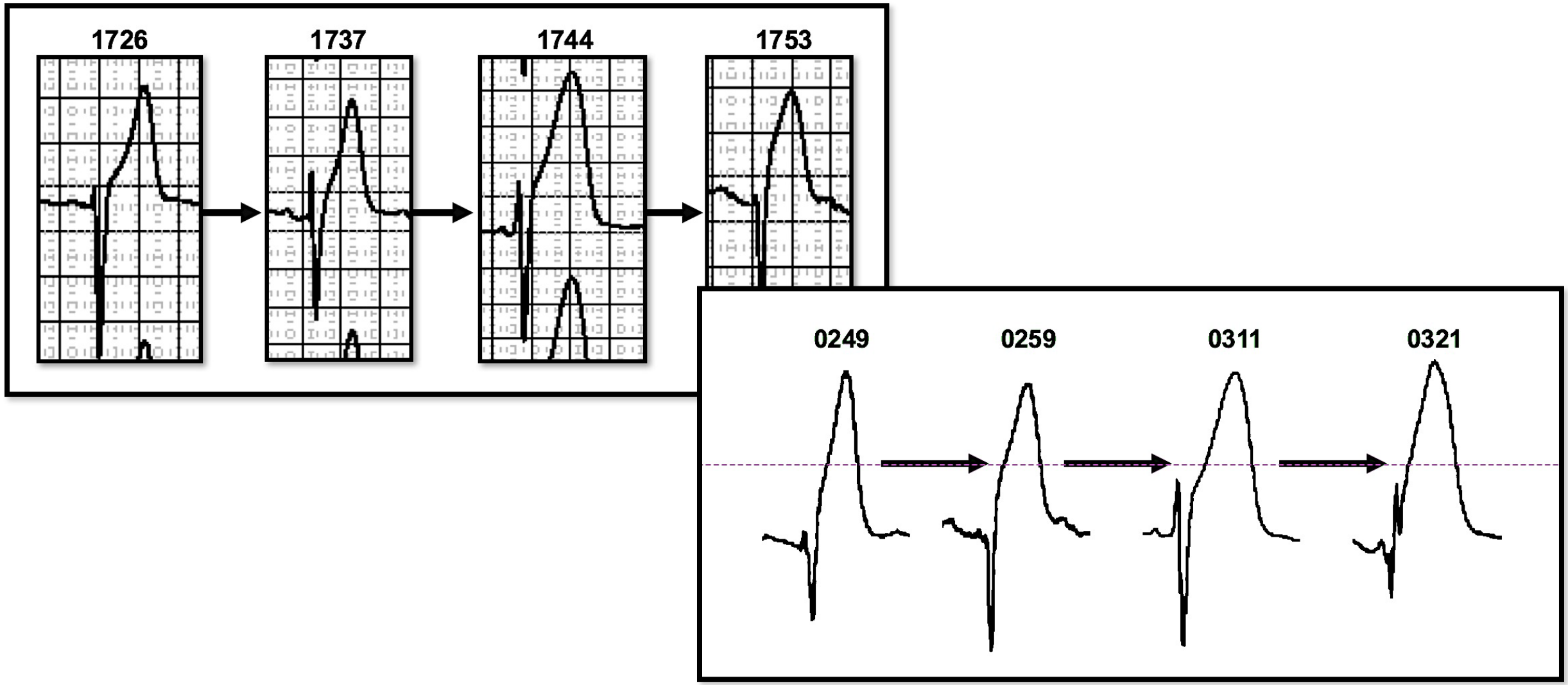
Both Dynamic

Hyperkalemia



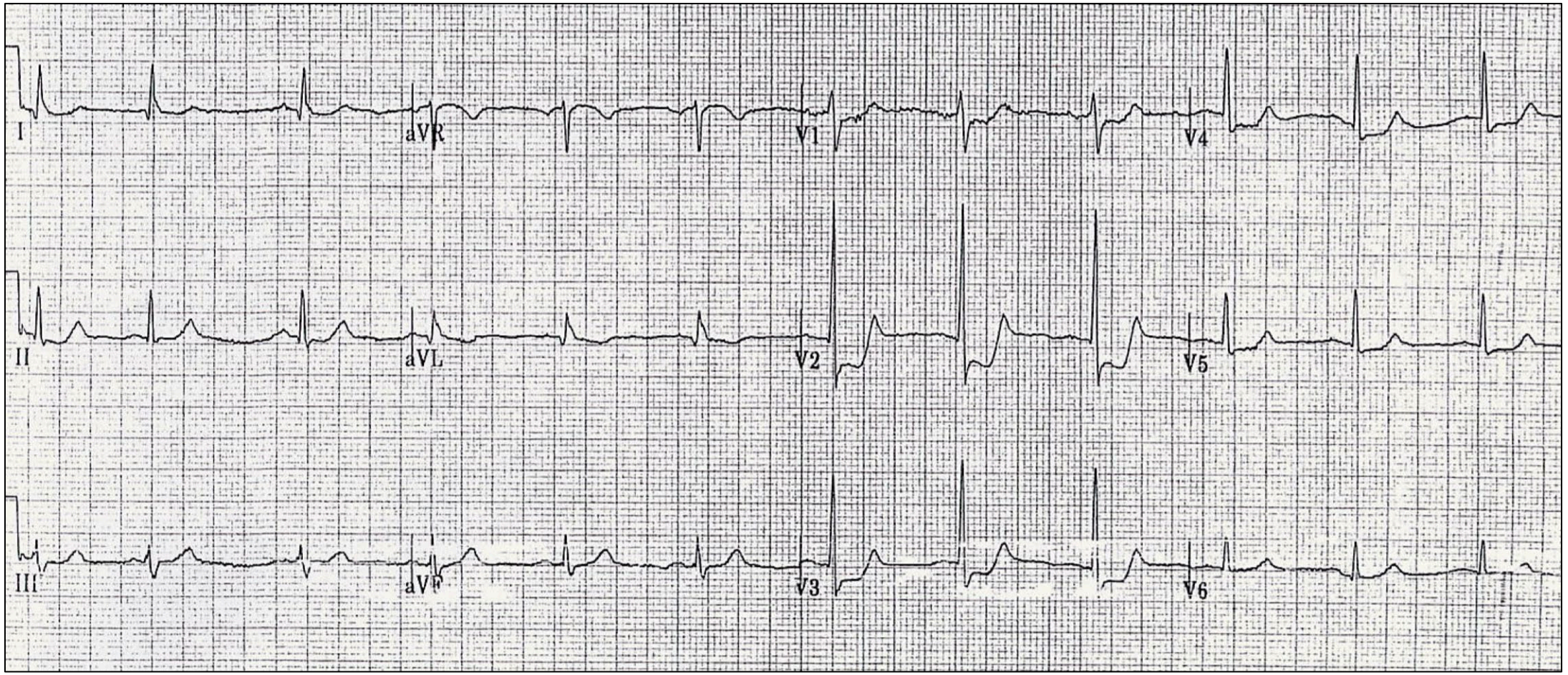
Dynamic Nature of ECG in ACS…Serial ECGs

Evolution from Hyperacute T Wave to ST Segment Elevation

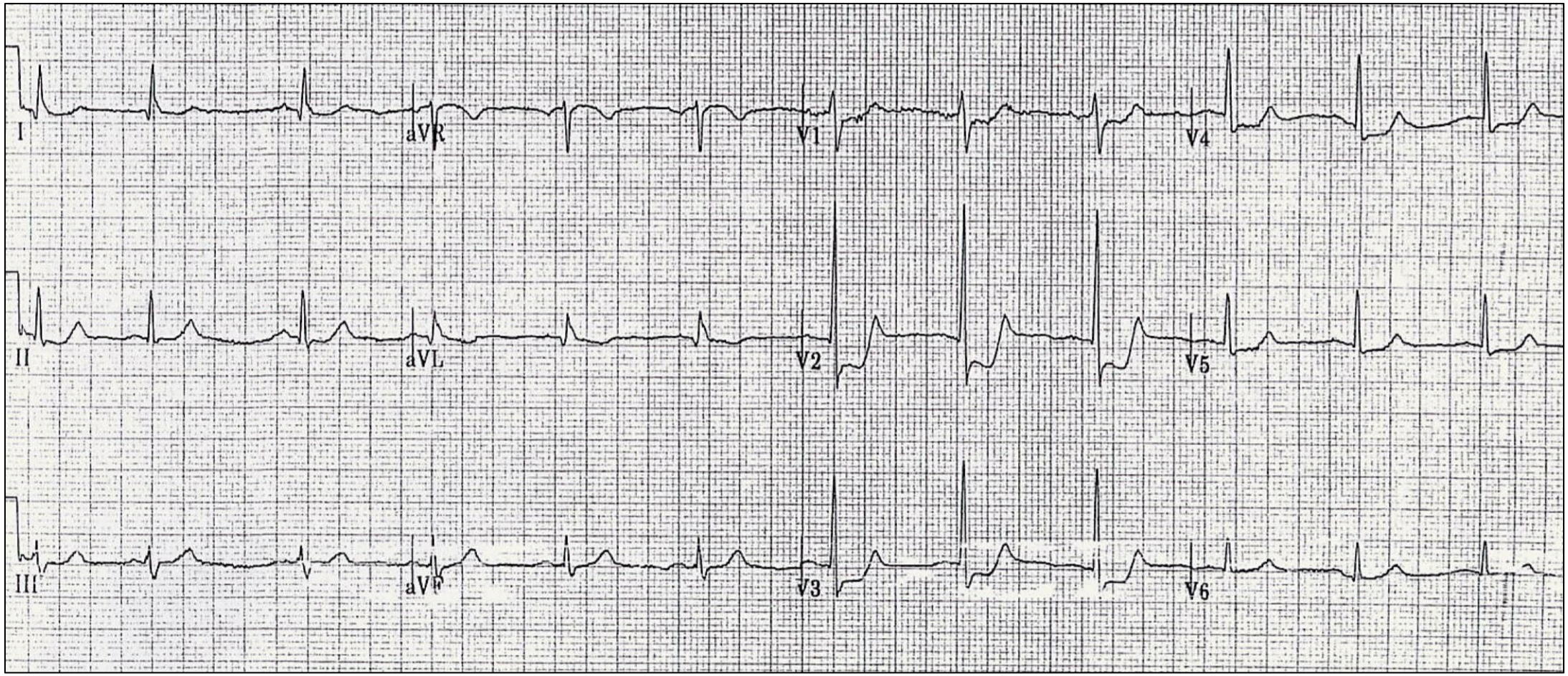


56 male with chest pain

anxious & diaphoretic -- 100/70, 70, 28, Sat 95% (RA)

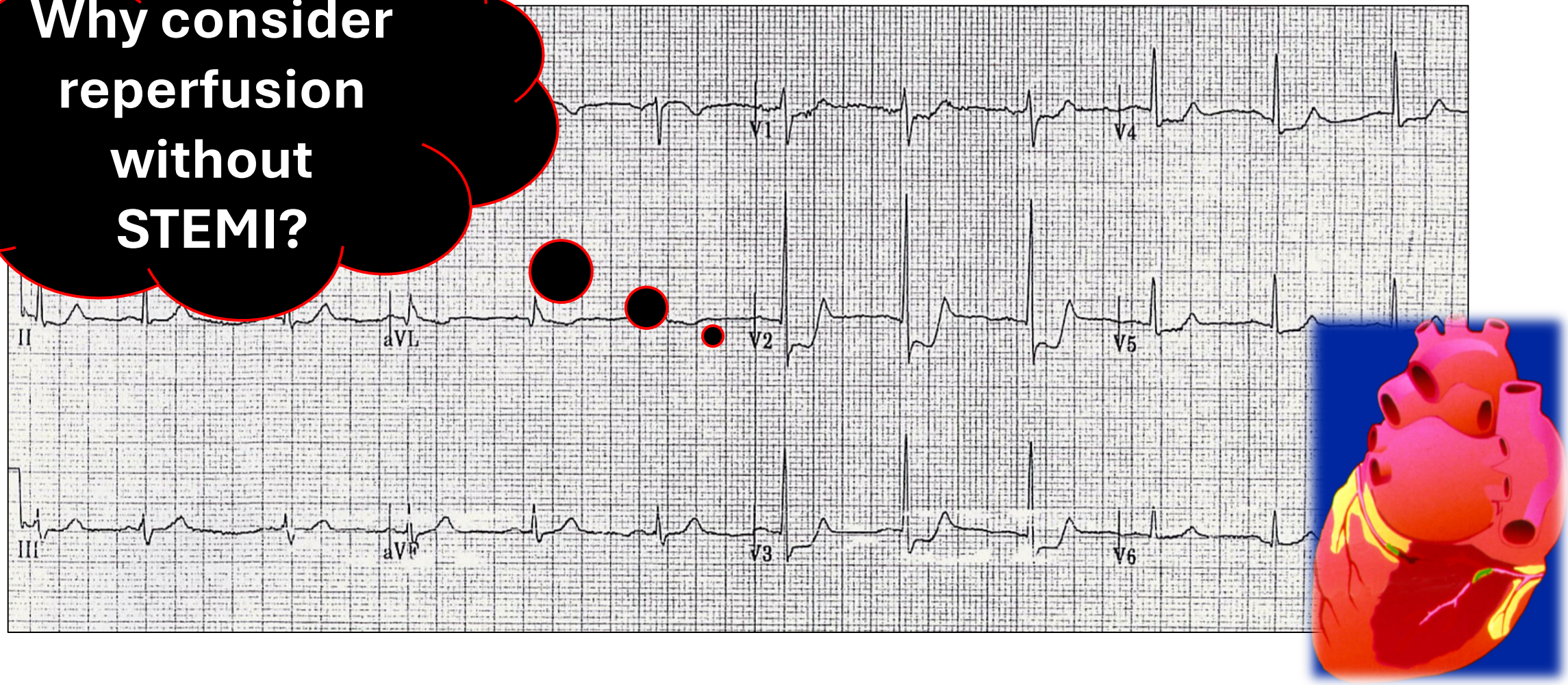


Acute Posterior Wall Myocardial Infarction



“Isolated” Acute Posterior Wall Myocardial Infarction

Why consider reperfusion without STEMI?



Posterior Wall AMI

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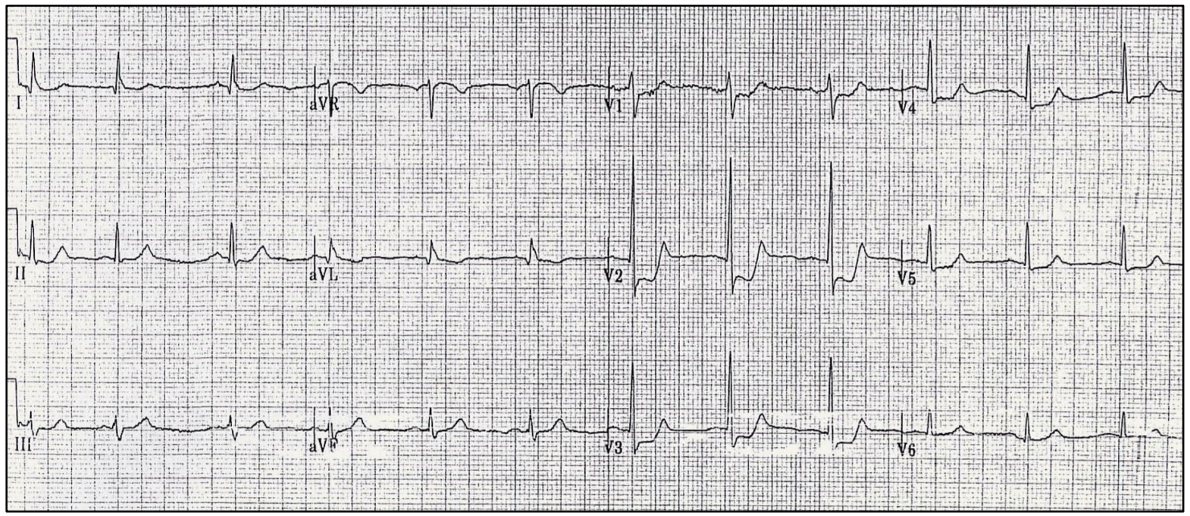


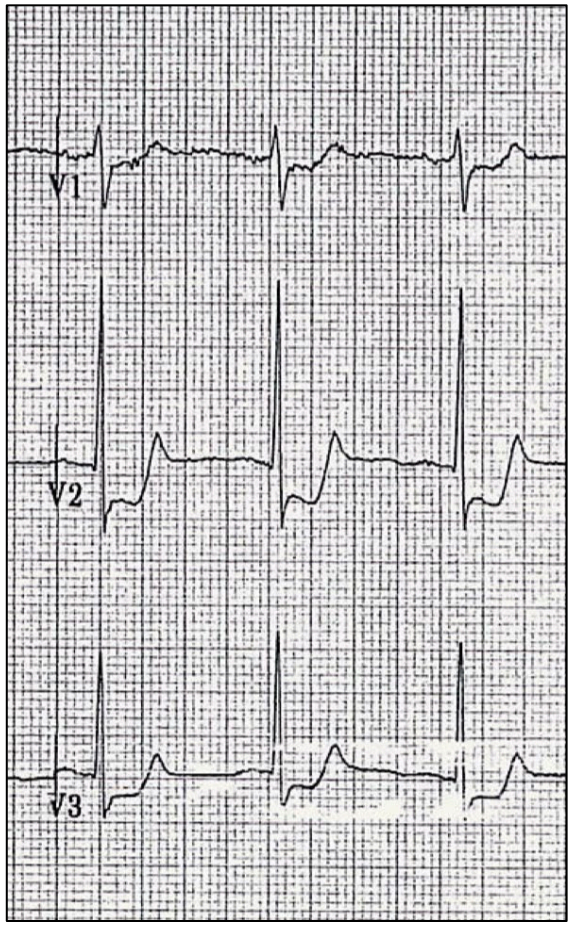
- **Considered STEMI Equivalent**
- **Indication for Urgent Reperfusion**

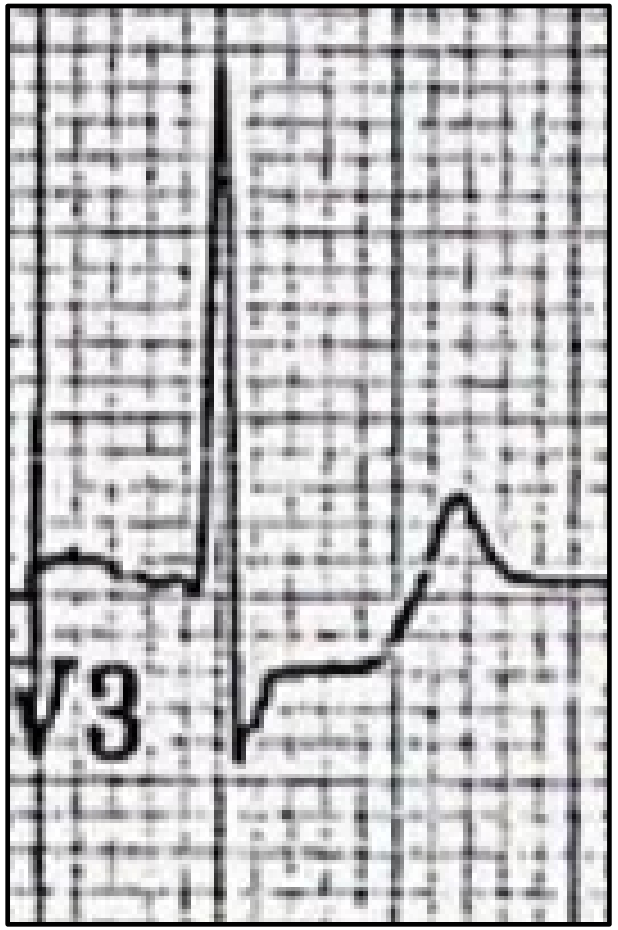
J Am Col Cardiol 2022;80:1925-60

“Isolated” Acute Posterior Wall Myocardial Infarction

- **Leads V1-V3 (…V4)**
- **Large R wave**
  - Any R wave V1
  - R/S ≥ 1.0
- **ST segment depression**
  - Horizontal
- **Upright T wave**

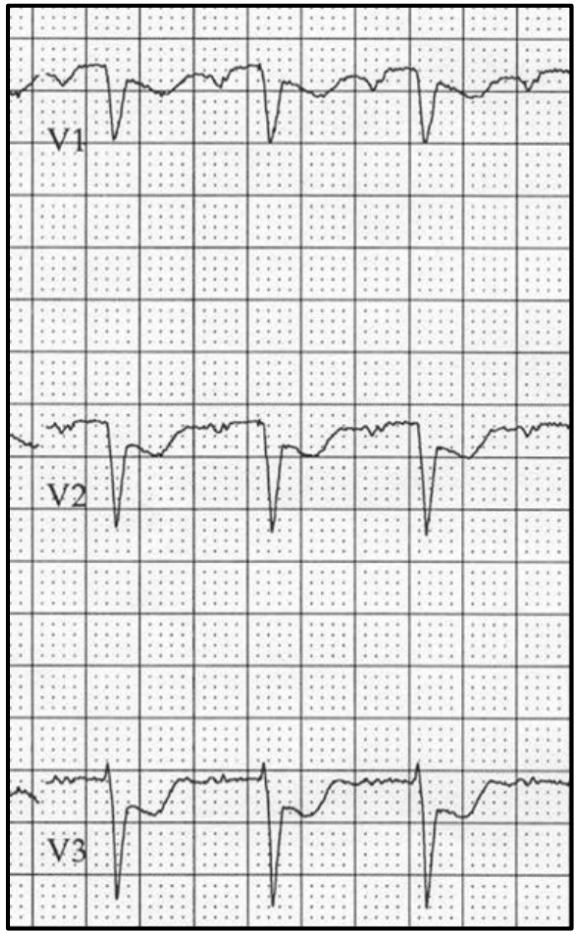
- **All 3 criteria present?**
  - 90+% posterior AMI

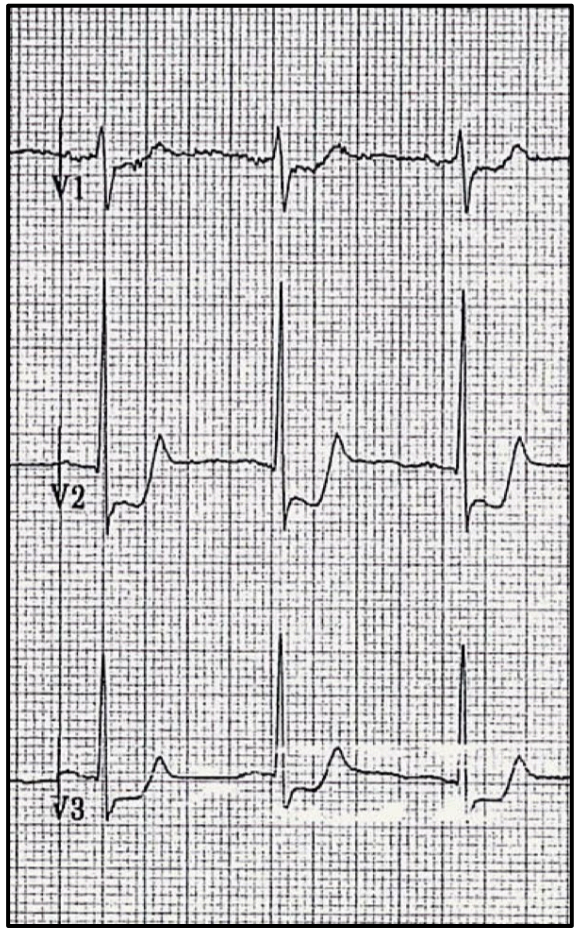




Comparison of ST Segment Depression Anterior Leads

Anterior Wall Ischemia *vs* *Acute Posterior Wall MI*

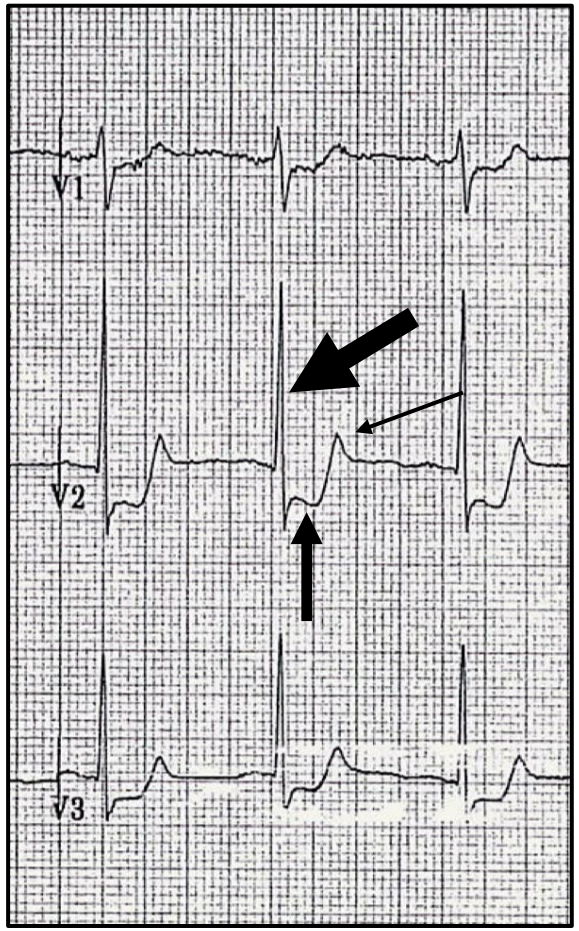




Comparison of ST Segment Depression Anterior Leads

Anterior Wall Ischemia *vs* *Acute Posterior Wall MI*

X Large R wave
X Flat ST depression
X Upright T wave

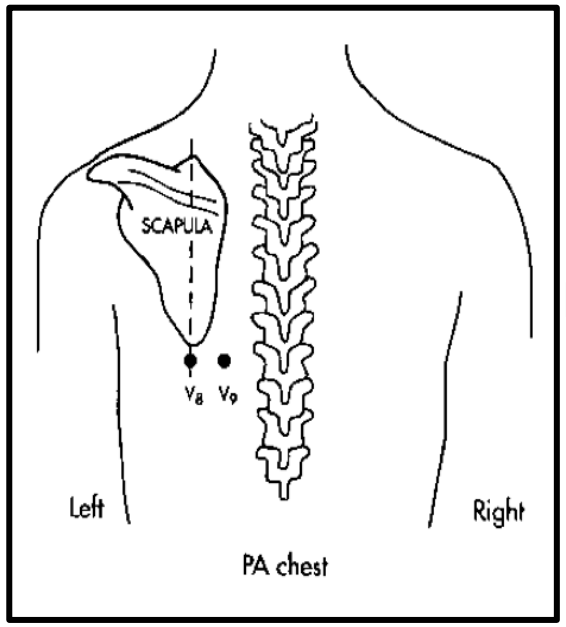


✓ Large R wave
✓ Flat ST depression
✓ Upright T wave

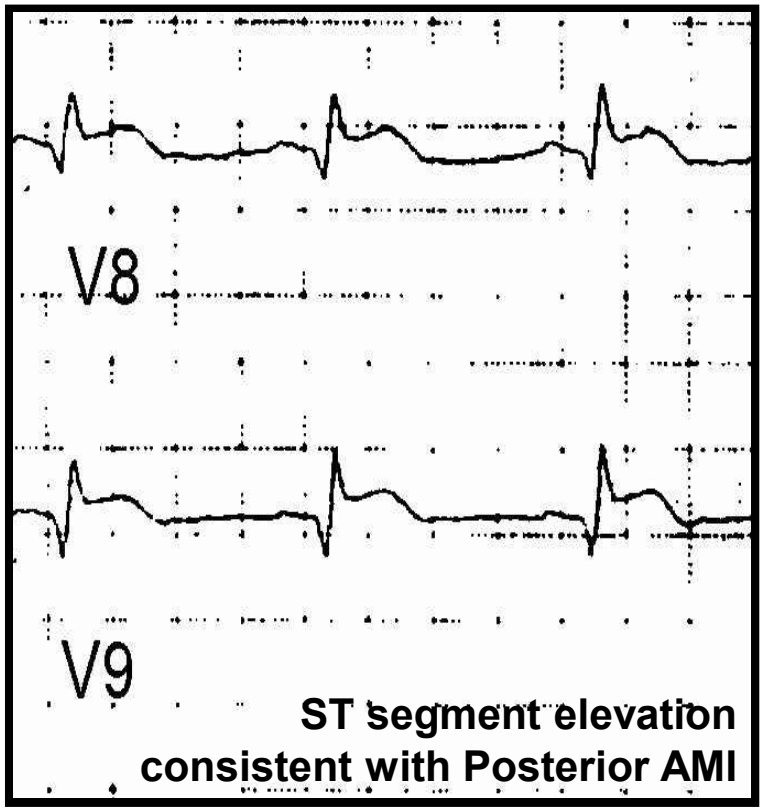
Additional Leads?

Posterior ECG Leads

Posterior ECG leads directly image the



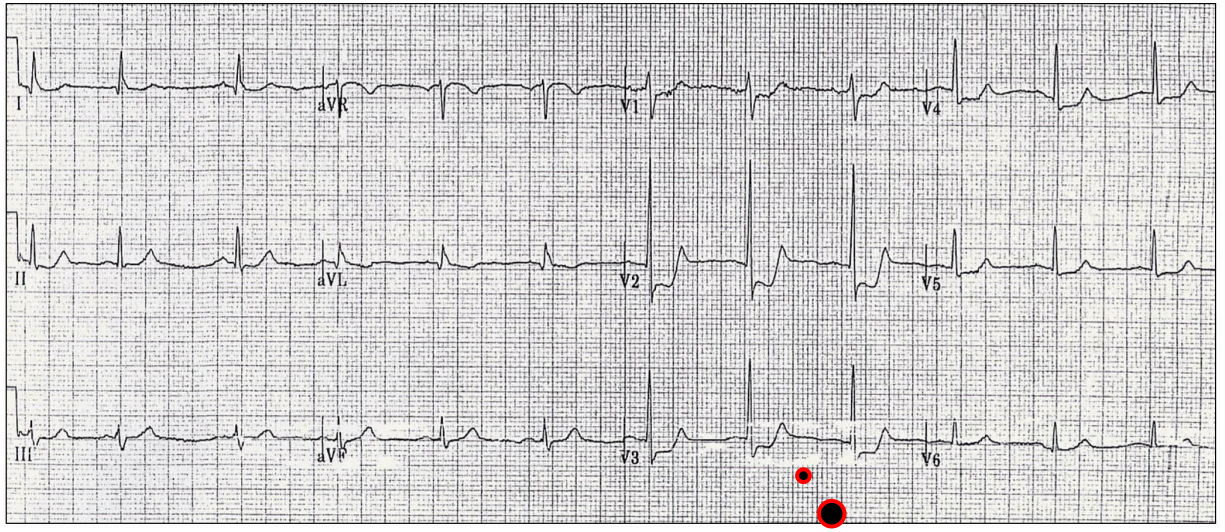
Leads V_8 & V_9



Most often, posterior AMI presents concurrently with inferior +/- lateral STEMI

Isolated Posterior AMI

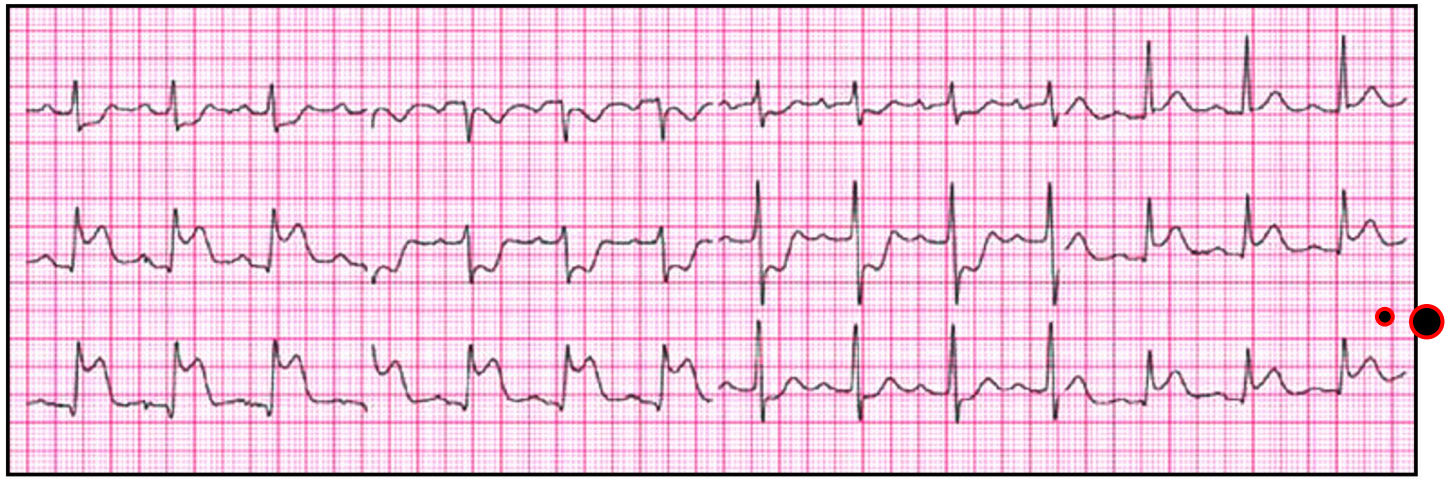
ST Depression V_1, V_2, V_3 & V_4 with Tall R Waves & Upright T Waves



5-10% of all AMIs

Posterior AMI

[ST Depression V_1, V_2, +/- V_3]
with
Inferior & Lateral STEMI
[ST Elevation II, III, AVF & V_5 / V_6]



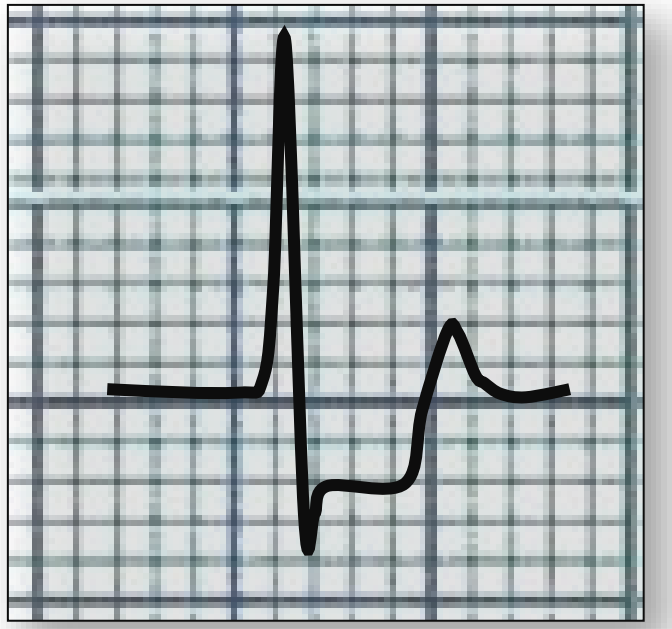
15-20% of inferior or lateral STEMIs

Why Recognize Posterior AMI?

- **Acute infarction of LV wall**

- **Rx similar to inferior STEMI**
  - Aspirin, heparin, nitrates, etc
  - Candidate for fibrinolytics or PCI

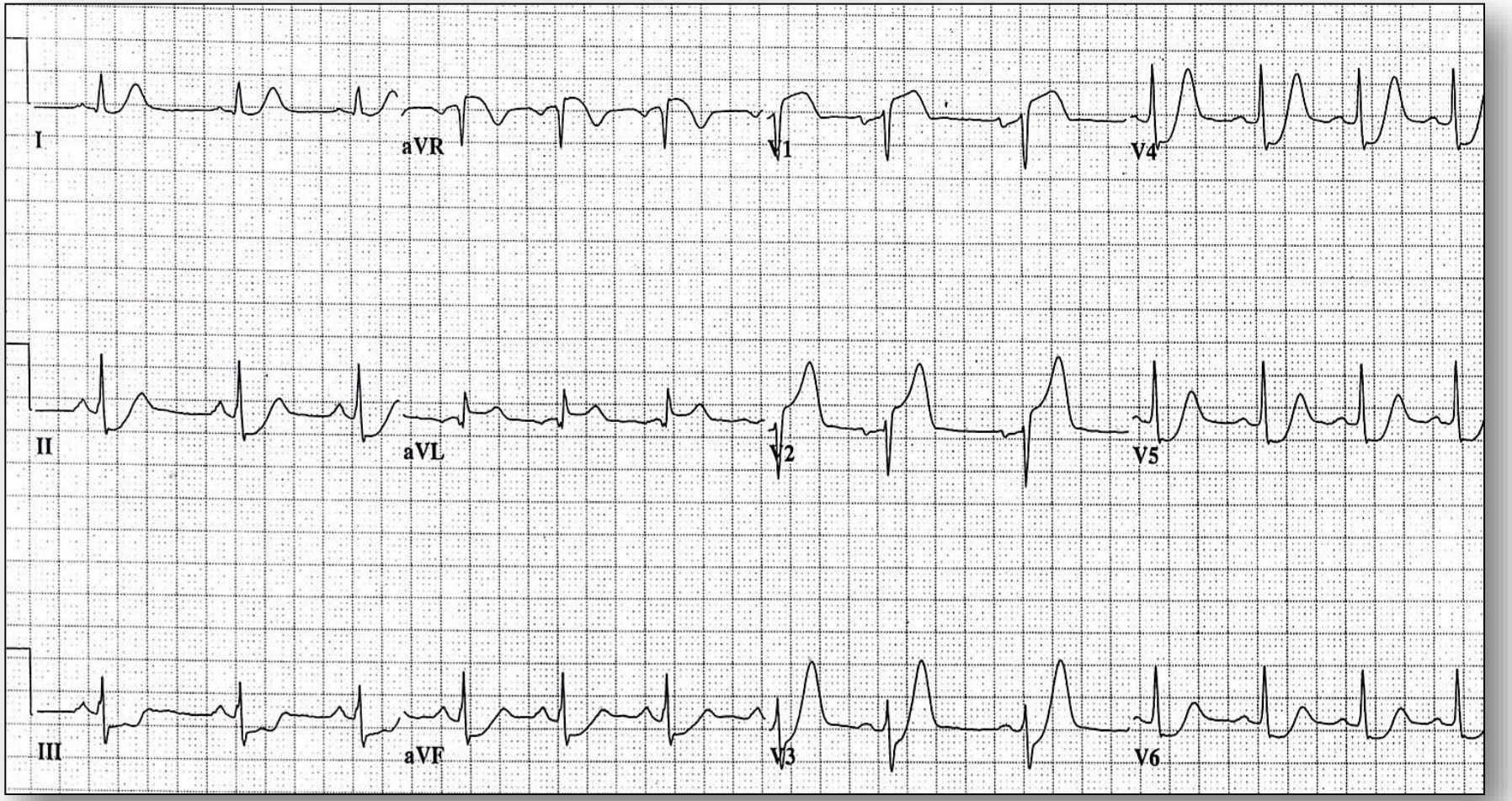
    [AHA/ACC Guidelines]



- **Risk of acute CV complications, poor LV function, & death similar to inferior STEMI**

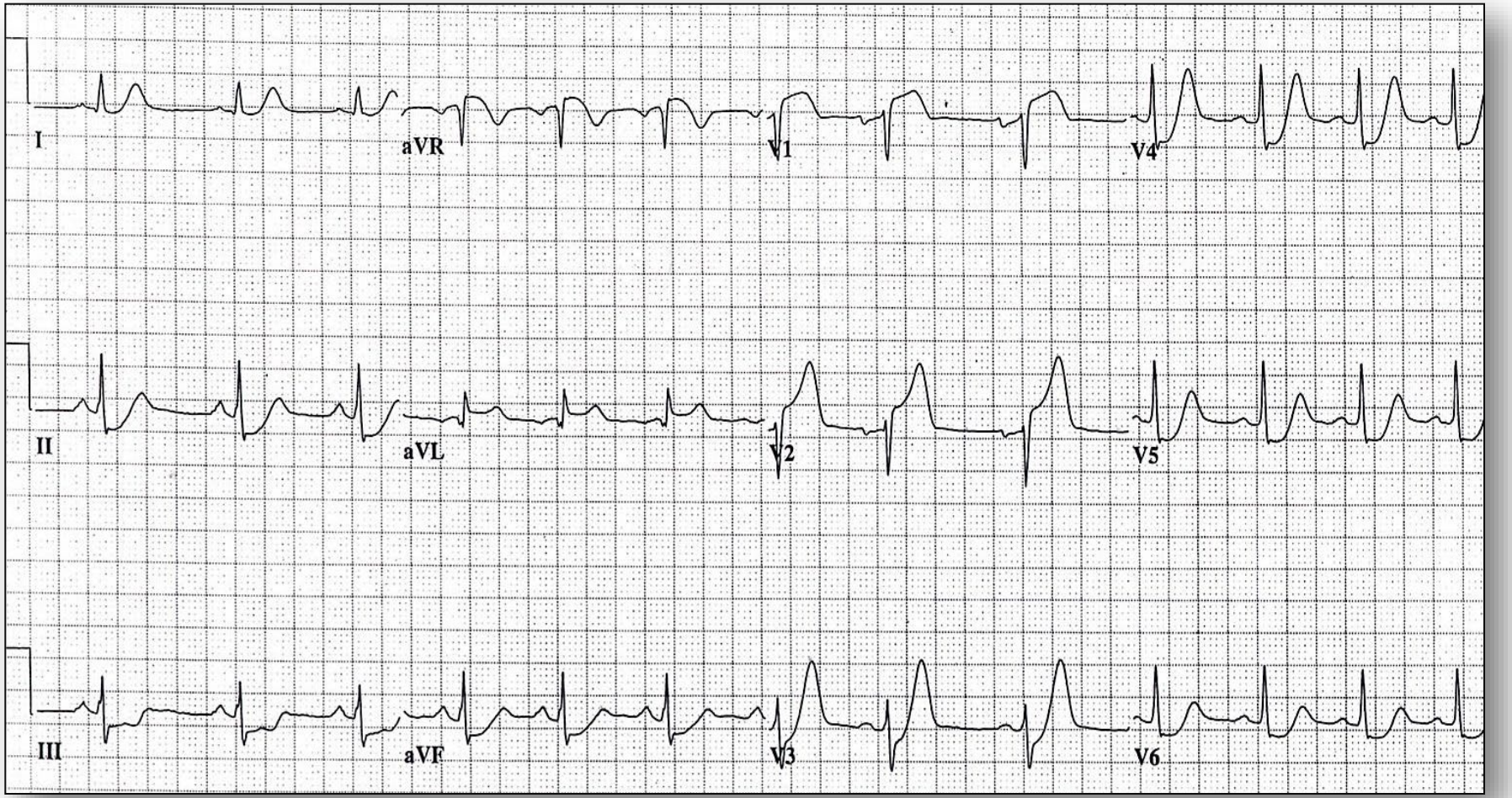
58 year-old Female with Chest Pain

“my chest hurts really bad …just like my heart attack!”



Anterior STEMI

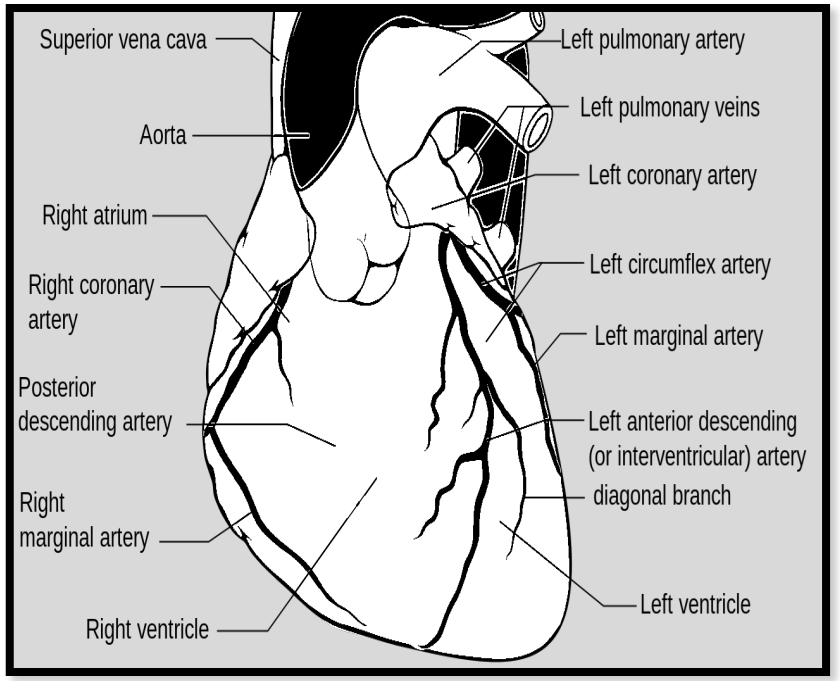
Likely due to Left Main Coronary Lesion



left main lesion noted with successful PCI

Left Main Coronary Artery Obstruction*

- **Very high mortality**
- **Reperfusion therapy**
  - Lytic Rx NOT particularly useful
  - PCI reduces mortality
- **Time to PCI = major survival predictor**



* near complete obstruction

So, how do we recognize LMCA obstruction?

STE > 0.5 mm lead aVR

…+/- STE in lead aVL

…+/- widespread STD

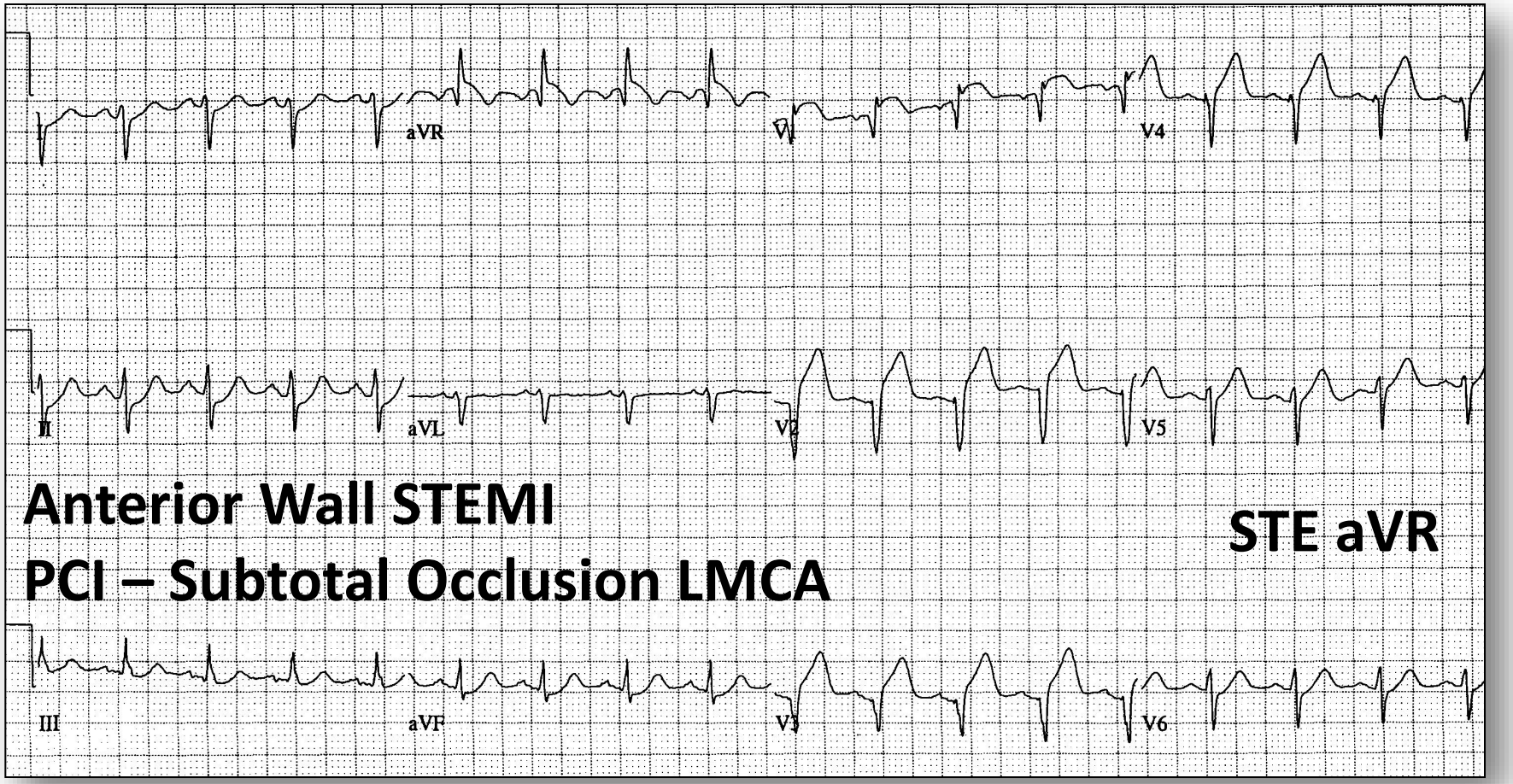
…with appropriate clinical presentation

Left Main Coronary Artery Obstruction

- **Seen in all forms of ACS**
  - STEMI
  - NSTEMI
  - Unstable angina
- **Treatment focuses on ACS type + early coronary angiography**

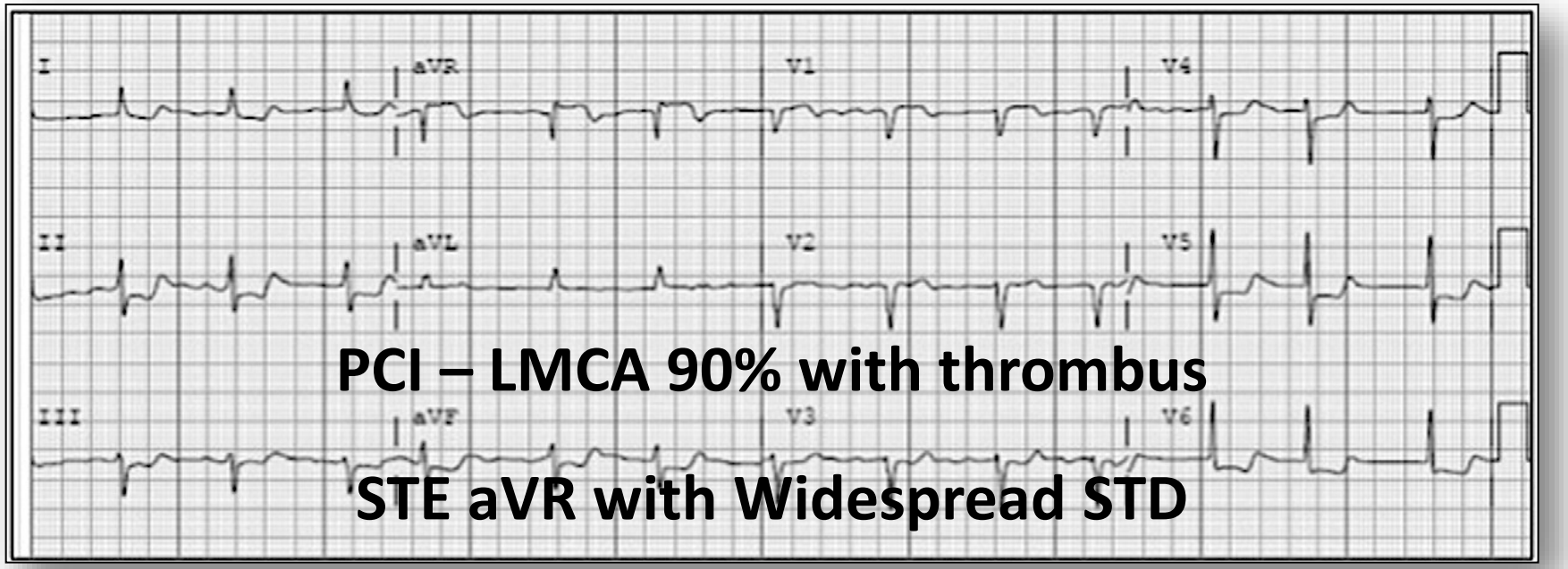
Left Main Coronary Artery Obstruction
Anterior STEMI

47 year-old Male with Chest Pain & Diaphoresis



Left Main Coronary Artery Obstruction
NSTEMI - Chest Pain with Troponin +++

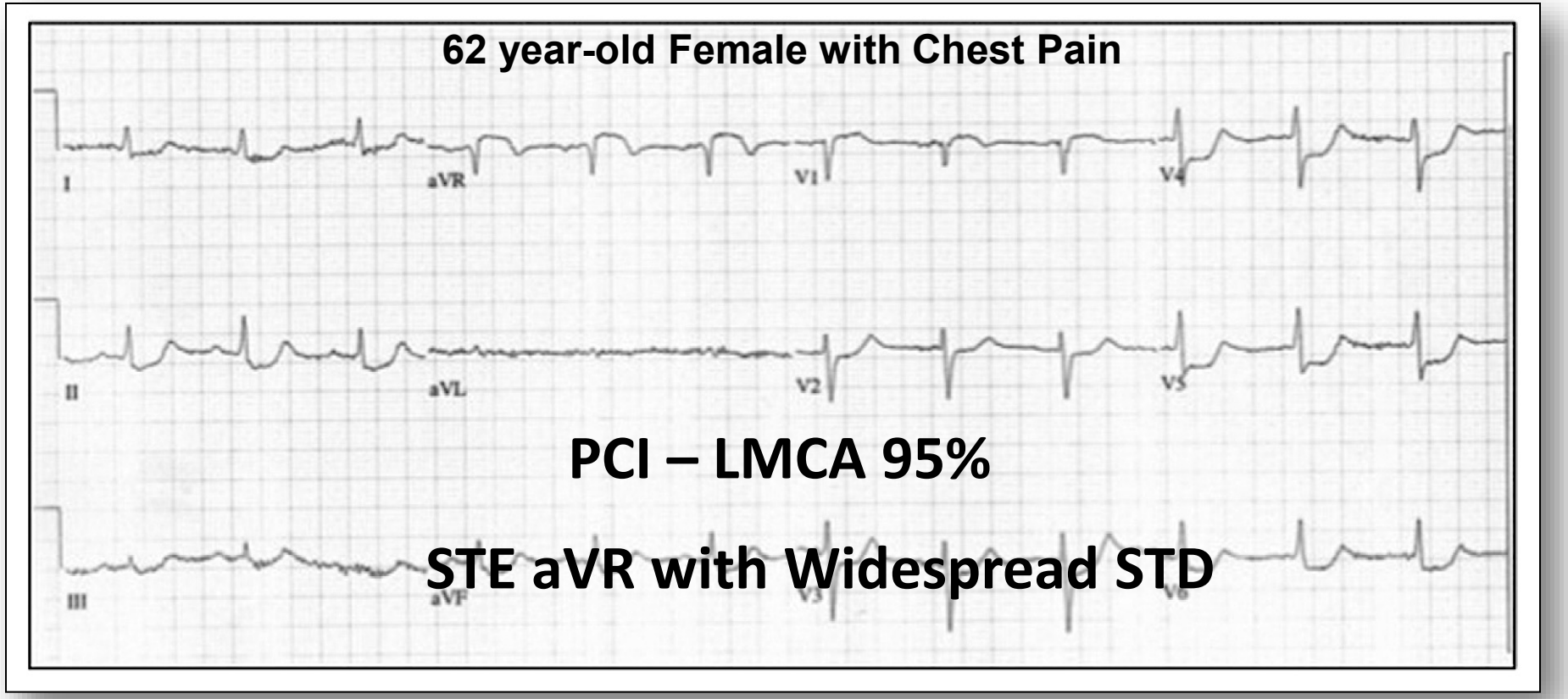
61 year-old Male with Chest Pain



ECG Courtesy of Amal Mattu, MD

Left Main Coronary Artery Obstruction

Unstable Angina - Chest Pain with Negative Troponin @ 8 hours



ECG Courtesy of Amal Mattu, MD

55 Female - Chest Pain, Now Resolved

well-appearing "…it's my husband's cooking"

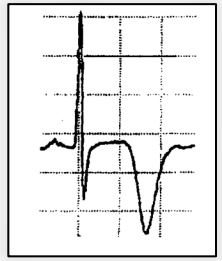
Wellen's Syndrome

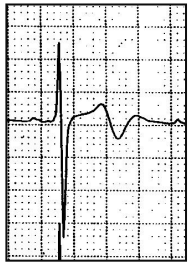
to cath lab for coronary angiography & PCI

Wellens' Syndrome

- **Pattern of ECG changes associated with critical, proximal LAD stenosis**

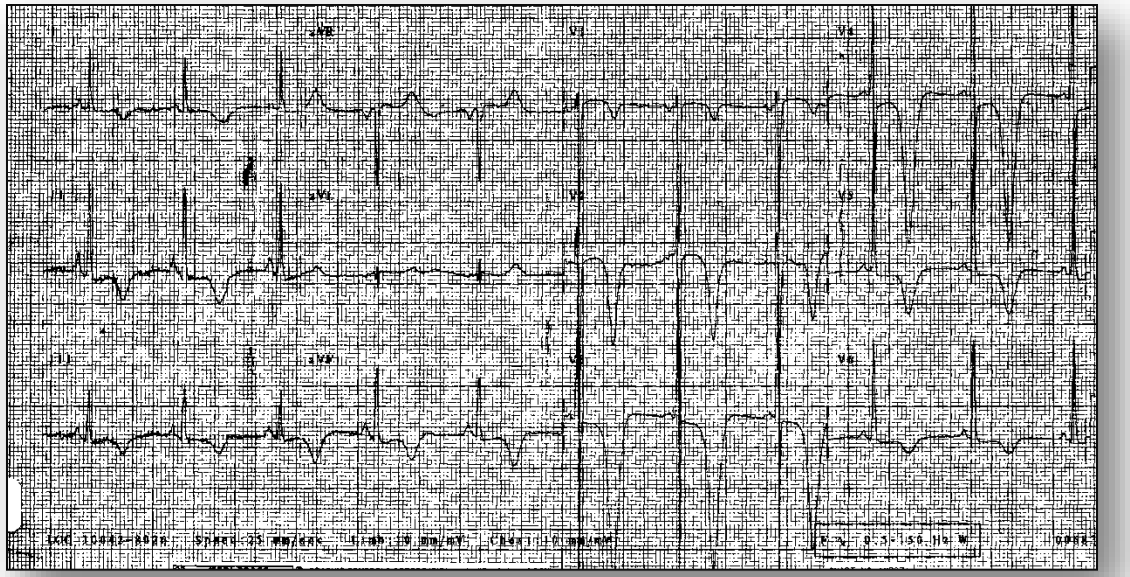
Deeply inverted T waves





Biphasic T waves

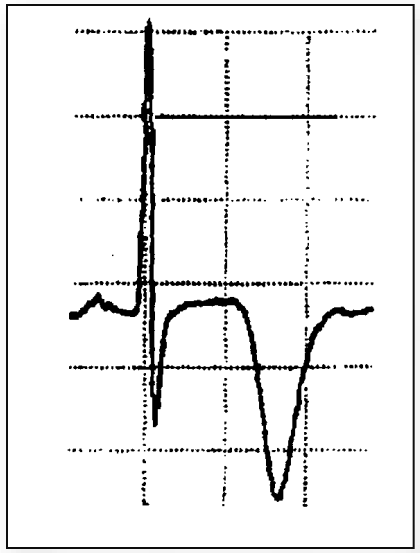
- **Syndrome criteria: T waves changes plus…**
  - History of chest pain, active or resolved
  - No Q waves / loss of R wave / ST elevation
  - No marker changes
- **If suspected, avoid stress testing**



Wellens' Syndrome

Deeply Inverted T Waves

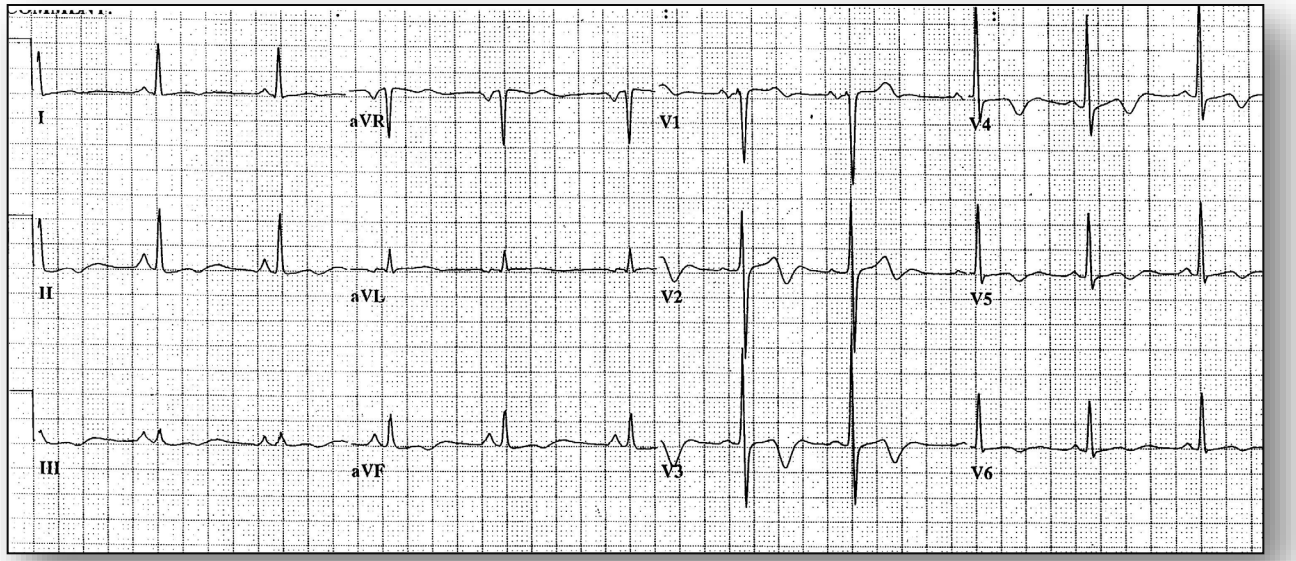
75%

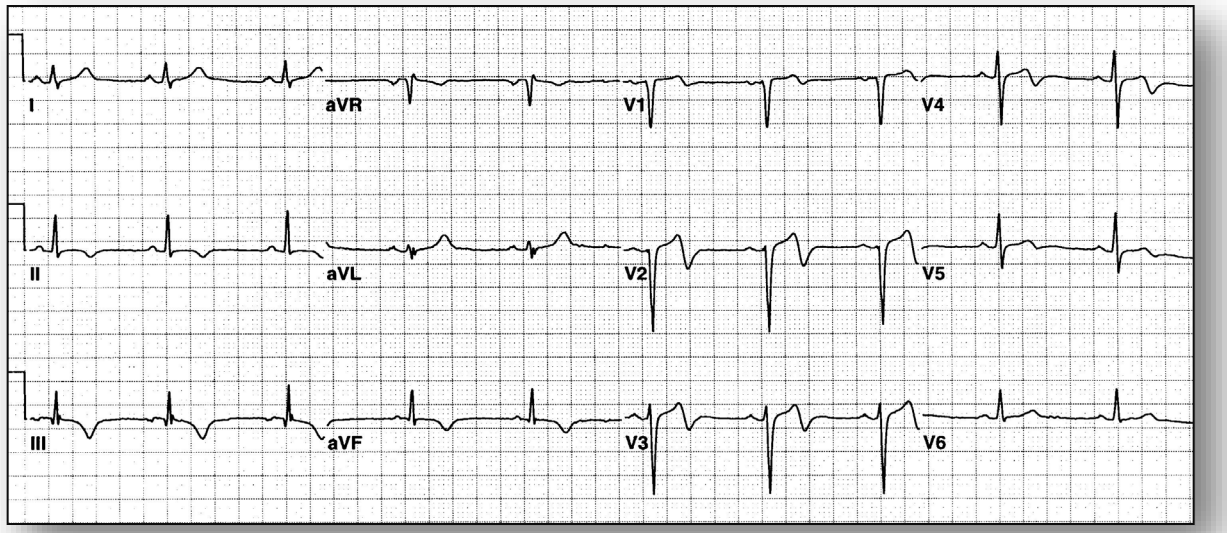


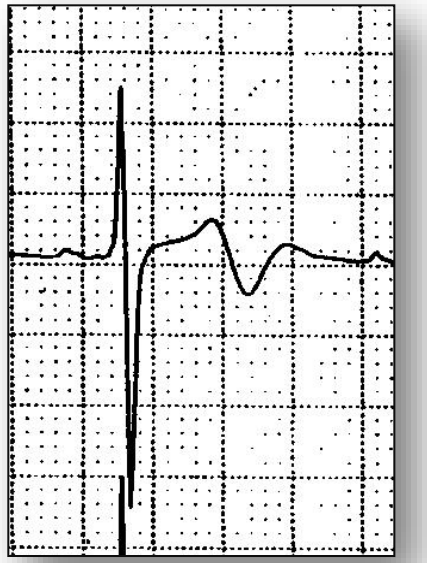
Wellens' Syndrome

Biphasic T Waves

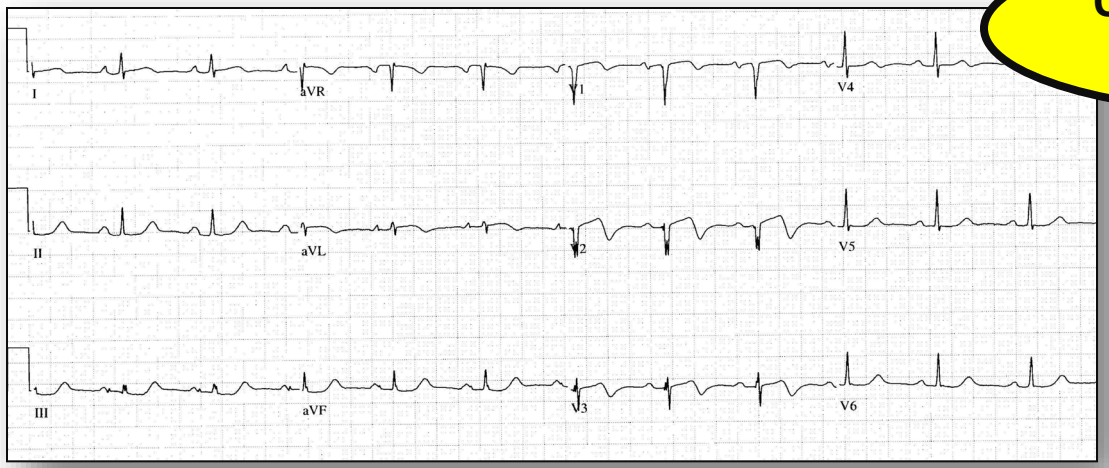
25%







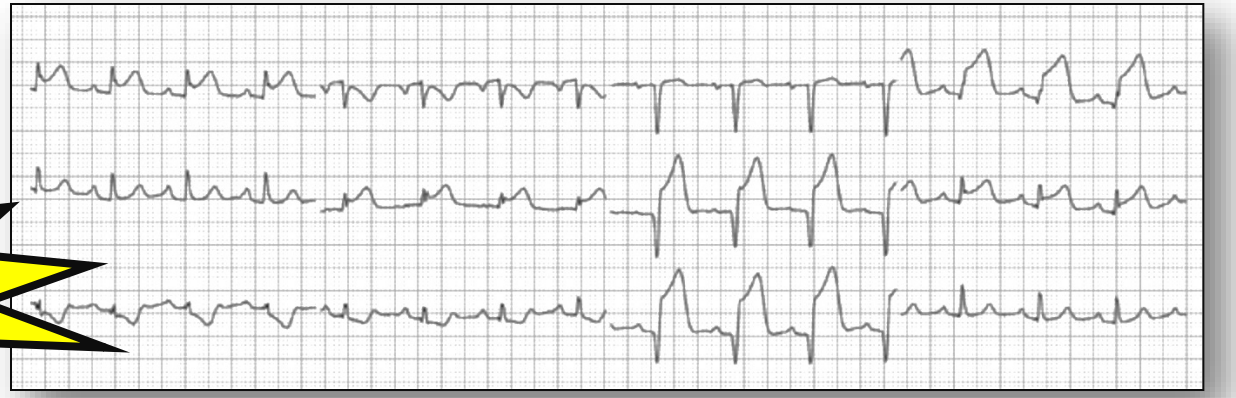
Wellens' Syndrome Natural History STEMI



On Presentation…
Painfree

Biphasic T waves V_1-V_3

9 hours later.
Chest pain and …

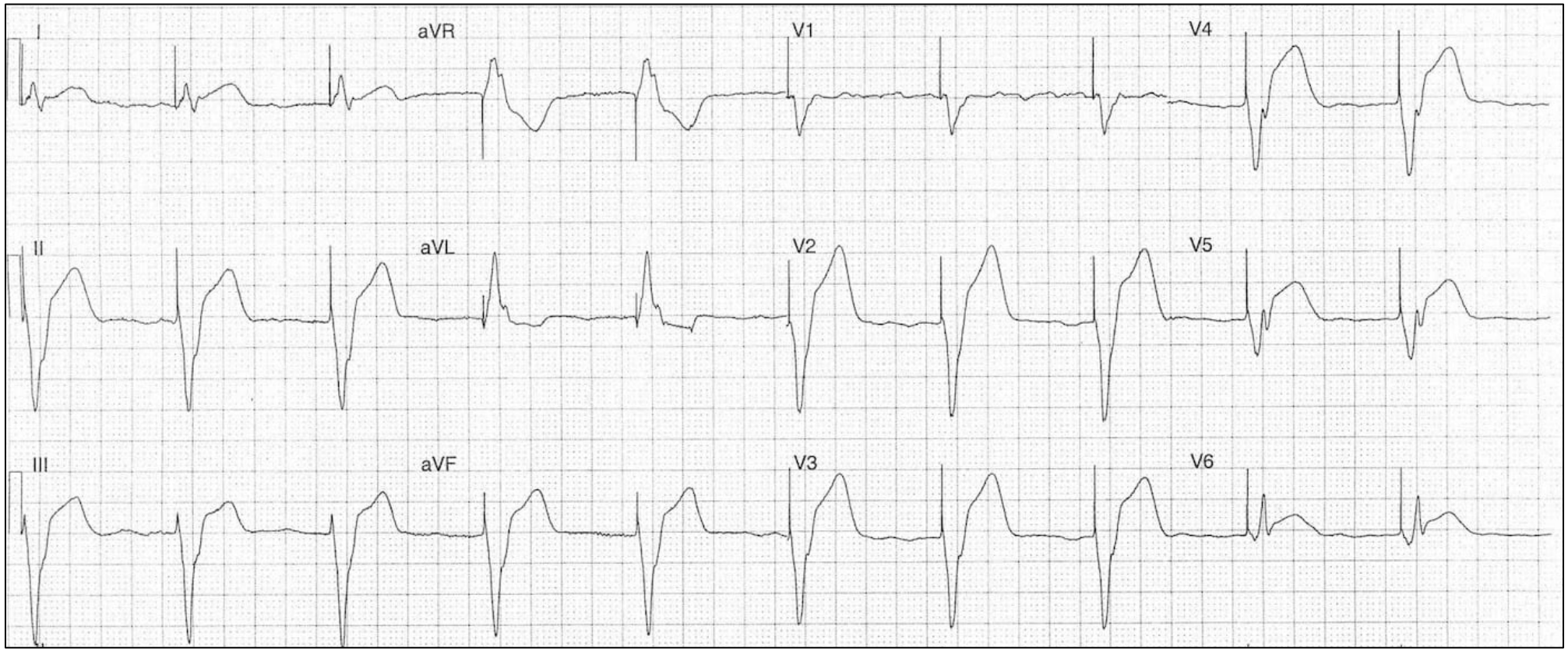


Anterolateral STEMI

72 male with history of heart block & implanted pacemaker

c/o substernal chest pain

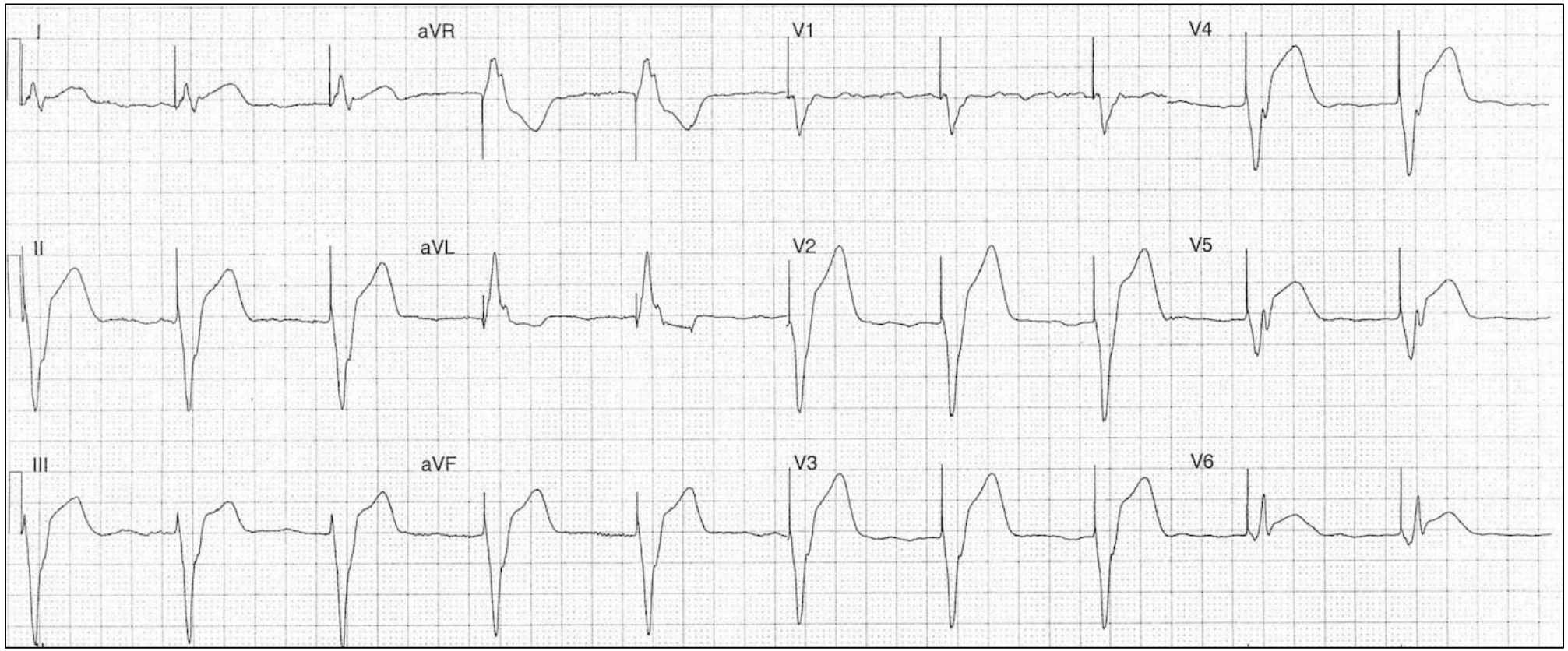
Pale, anxious, & diaphoretic -- 85/60, 70, 28, Sat 92% (RA)



ECG - LTFL: https://litfl.com/ecg-case-084

Ventricular Paced Rhythm with ECG Evidence of AMI

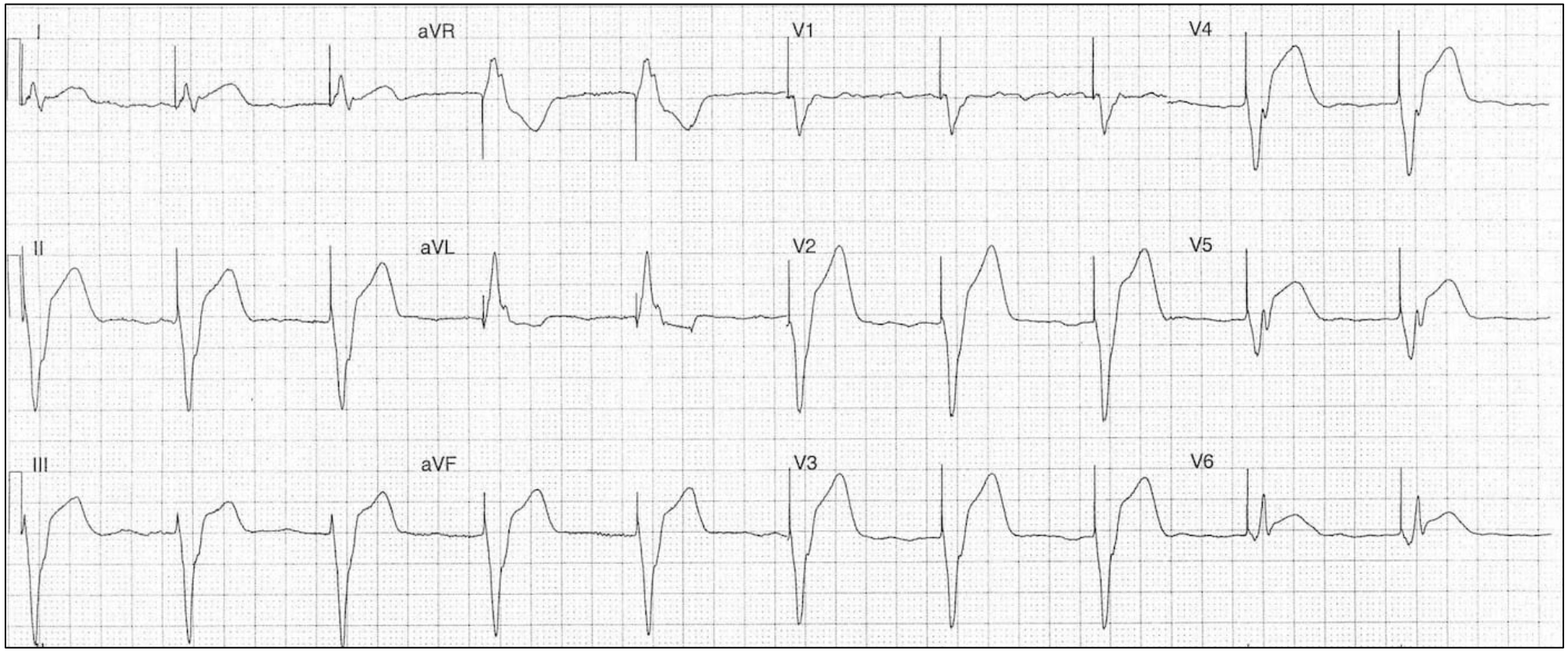
Concordant ST Elevation I / V6 & Excessive Discordant ST Elevation V2-V5



ECG - LTFL: https://litfl.com/ecg-case-084

Ventricular Paced Rhythm with ECG Evidence of AMI

to cath lab for PCI



ECG - LTFL: https://litfl.com/ecg-case-084

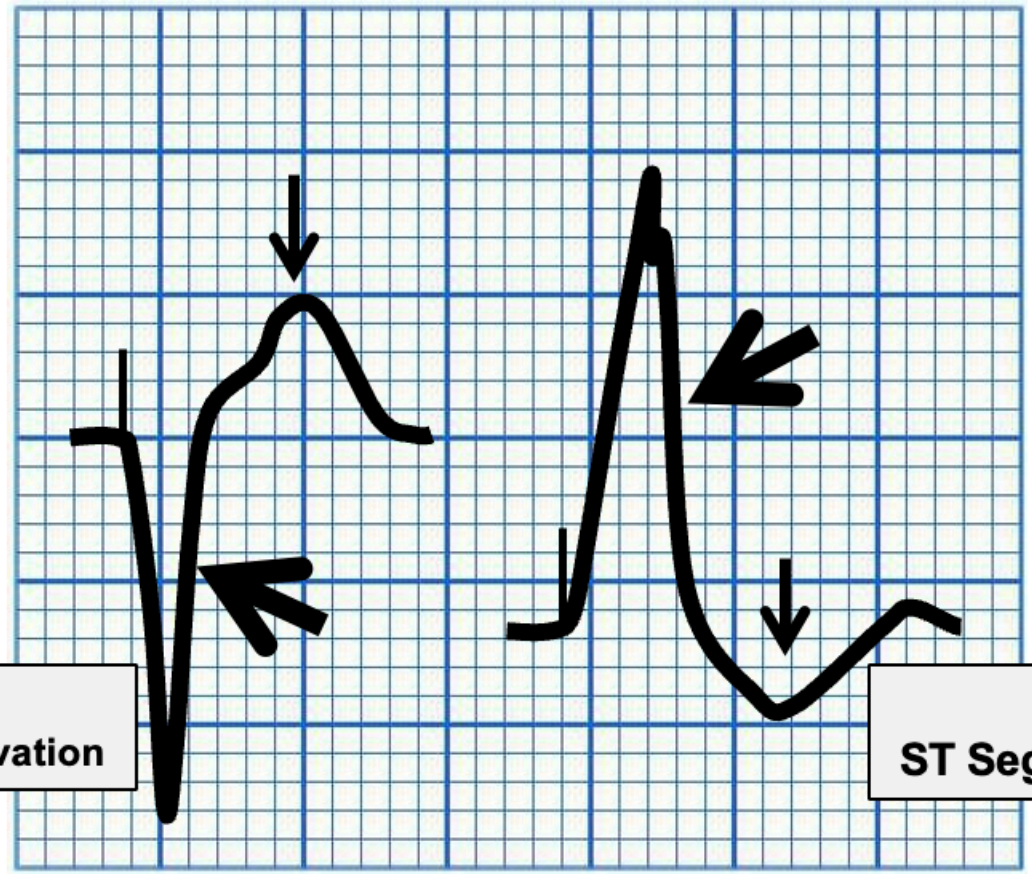
Ventricular Paced Rhythm & AMI ECG Diagnosis

- **Confounds ability to demonstrate AMI**
- **Mimics AMI findings**
- **Similar ECG approach to *Modified Sgarbossa Criteria* in LBBB**

Ventricular Paced Rhythms

Appropriate Discordance

"Anticipated" ST Segment & T Wave Configurations

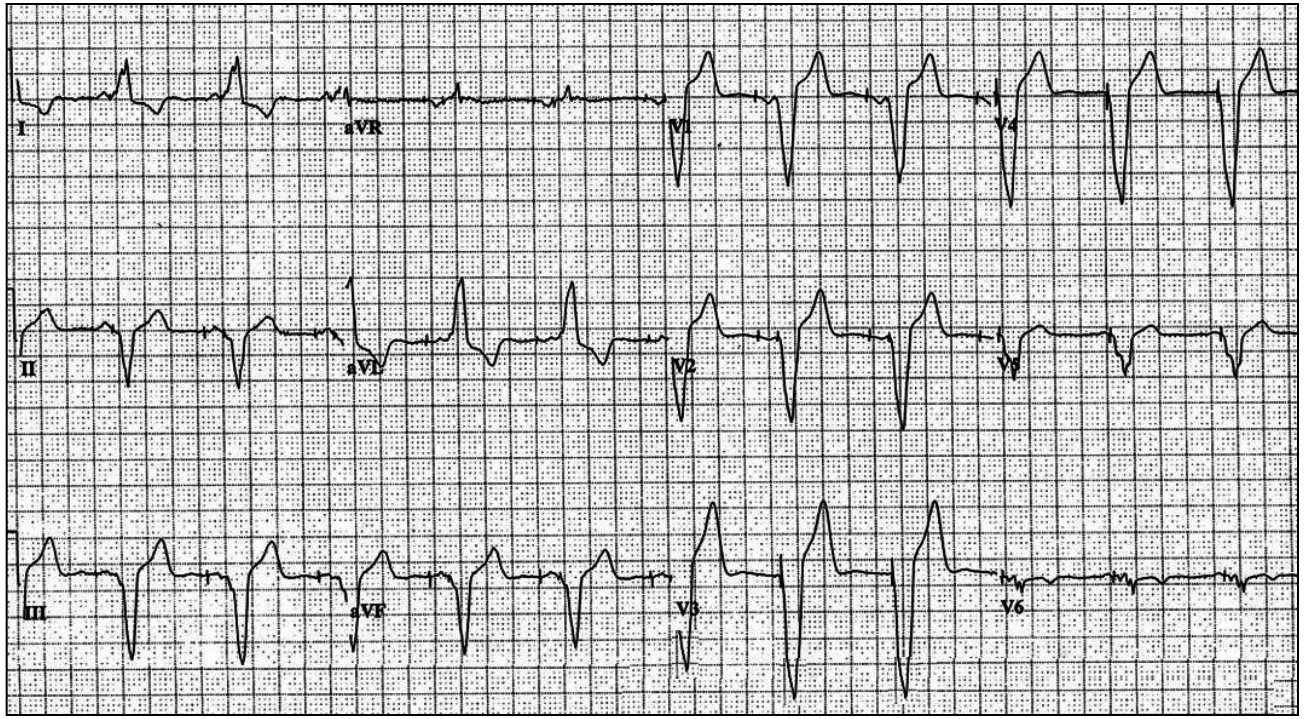


Discordant
ST Segment Elevation

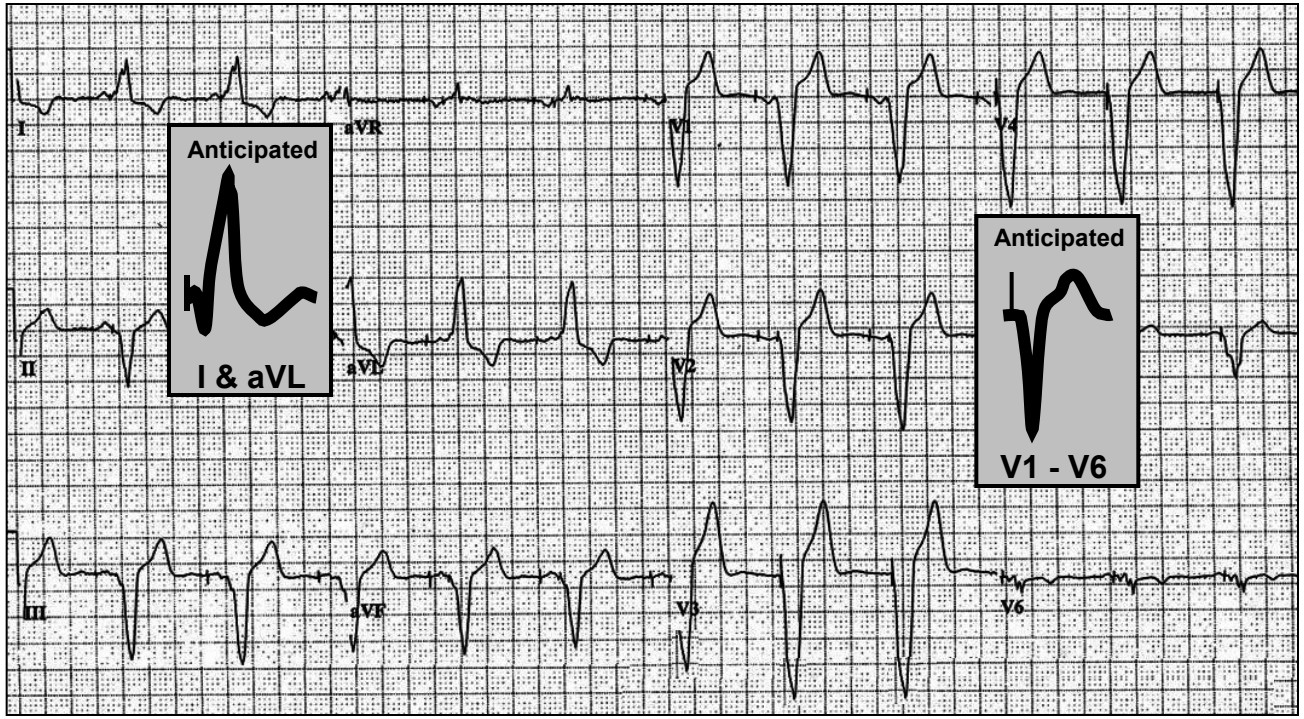
Discordant
ST Segment Depression

Proportional

Ventricular Paced Pattern
"Anticipated" ST Segment & T Wave



Ventricular Paced Pattern
"Anticipated" ST Segment & T Wave



Approach to Suspected AMI in Ventricular Paced Rhythm

Electrocardiographic Diagnosis of Acute Coronary Occlusion Myocardial Infarction in Ventricular Paced Rhythm Using the Modified Sgarbossa Criteria

Kenneth W. Dodd, MD*; Deborah L. Zvosec, PhD; Michael A. Hart, MD; George Glass III, MD; Laura E. Bannister, MBChB; Richard M. Body, MBBS; Brett A. Boggust, BA; William J. Brady, MD; Anna M. Chang, MD; Louise Cullen, MBBS, PhD; Rafael Gómez-Vicente, MD; Maite A. Huis in 't Veld, MD; Rehan M. Karim, MD; H. Pendell Meyers III, MD; David F. Miranda, MD; Gary J. Mitchell, MD; Charles Reynard, MBBS; Clifford Rice, MD; Bayert J. Salverda, BA; Samuel J. Stellpflug, MD; Vaishal M. Tolia, MD; Brooks M. Walsh, MD; Jennifer L. White, MD; Stephen W. Smith, MD; on behalf of the PERFECT study investigators (the complete list of PERFECT study investigators is provided in Appendix E1, available at http://www.annemergmed.com)

Can use very similar strategy to LBBB AMI diagnosis

Ann Emerg Med 2021

"Modified Sgarbossa Criteria"

ST Segment & T Wave Configurations Suggestive of AMI in Ventricular Paced

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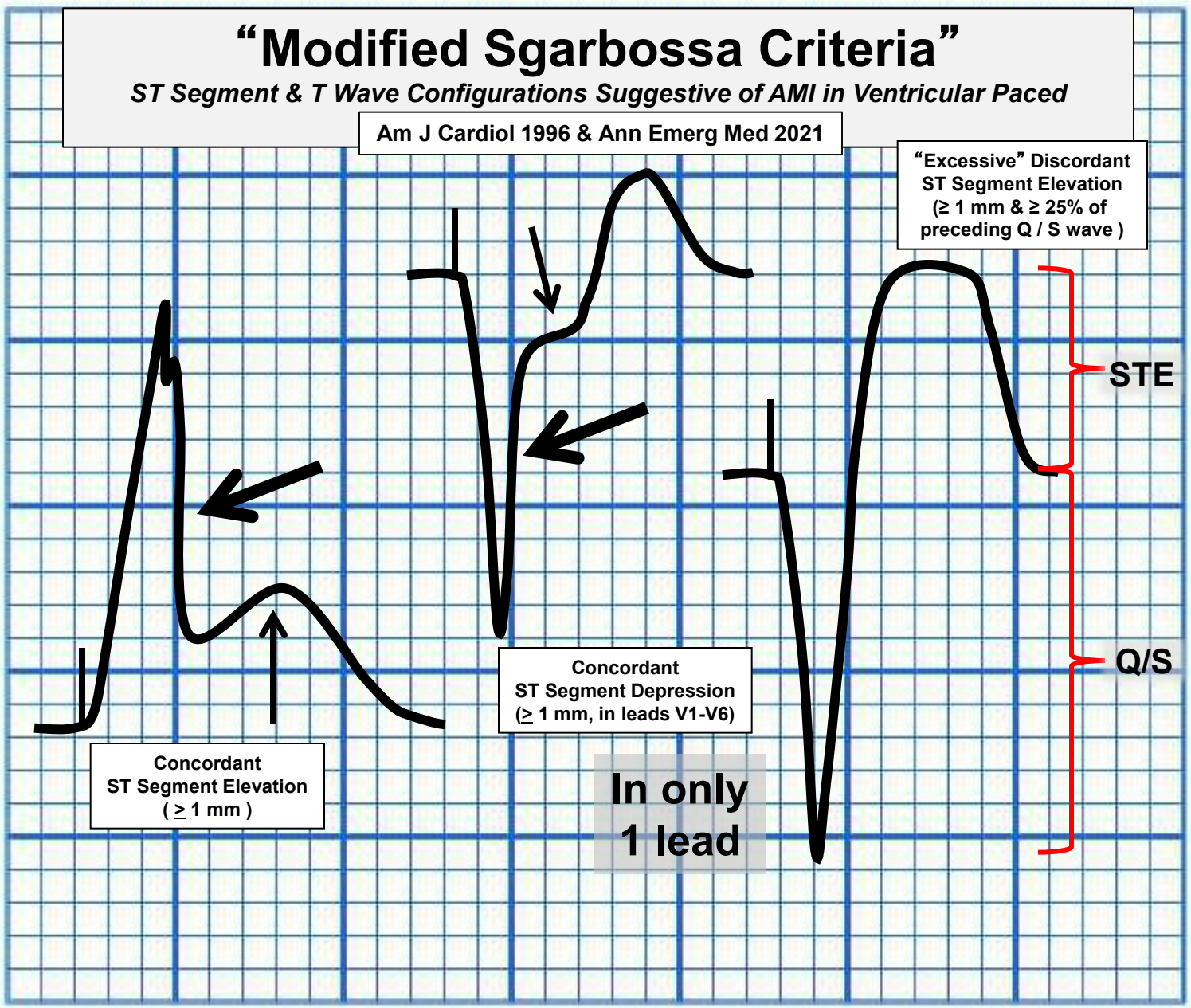
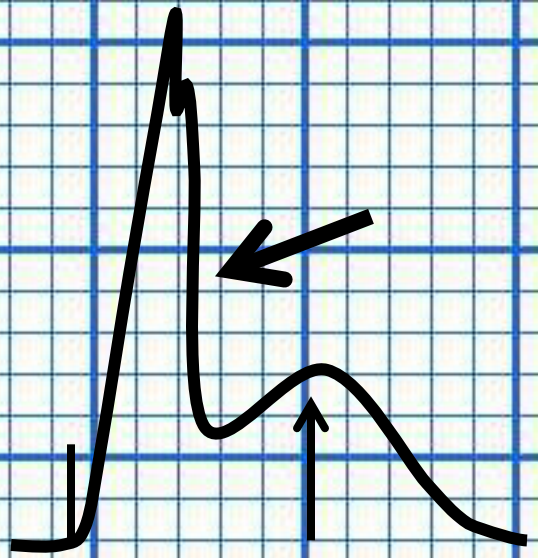


Concordant ST Segment Elevation

(≥ 1 mm)

Suggestive of AMI



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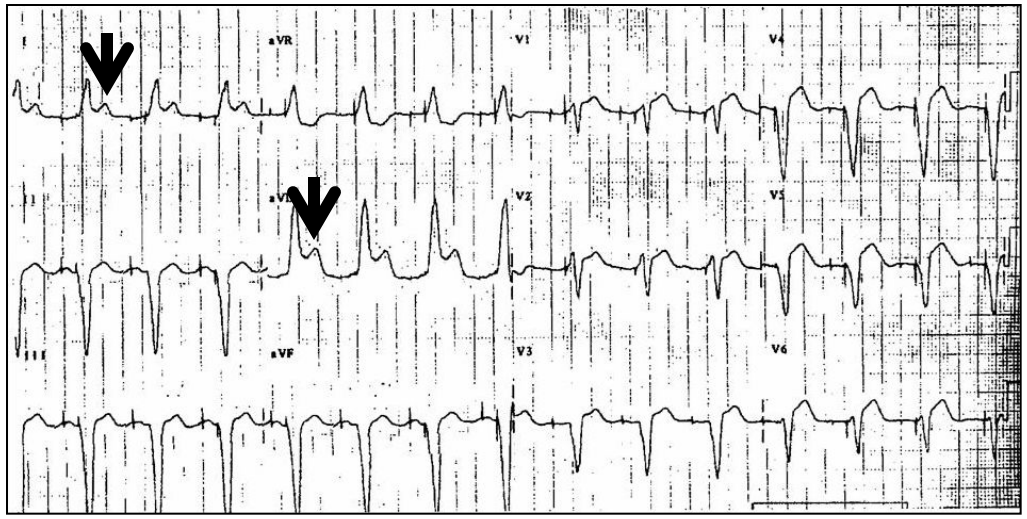
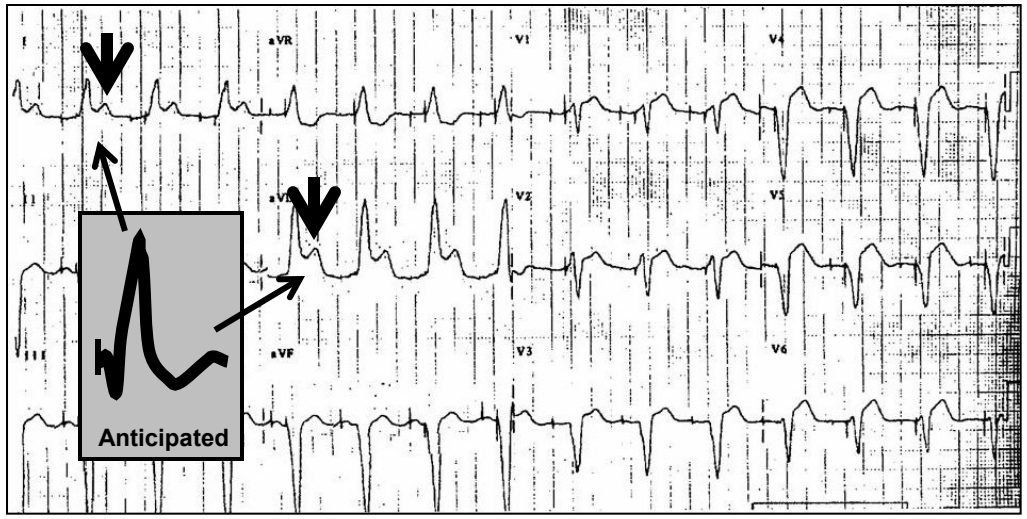
Ventricular Paced Pattern with AMI

Concordant ST Segment Elevation



Ventricular Paced Pattern with AMI

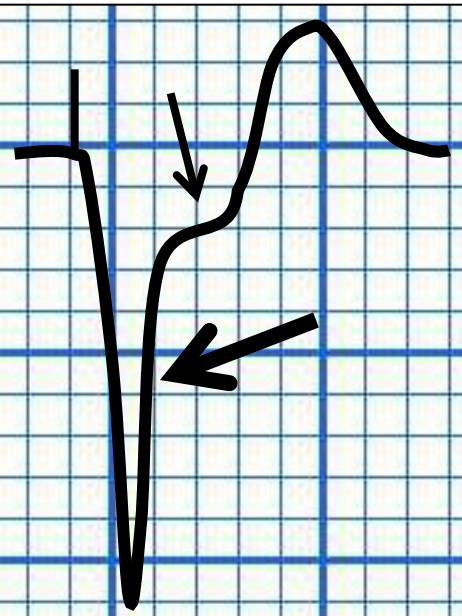
Concordant ST Segment Elevation



Concordant ST Segment Depression

(≥ 1 mm & limited to V1-V6)

Suggestive of AMI



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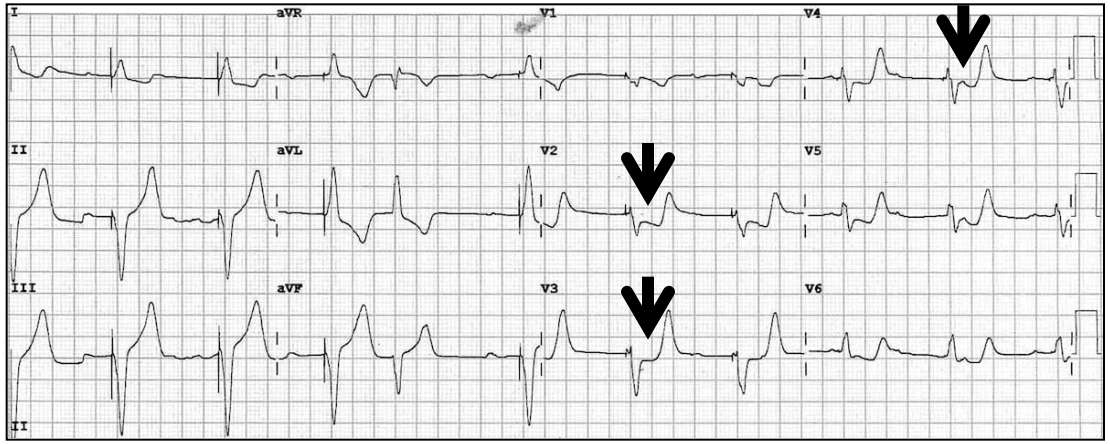
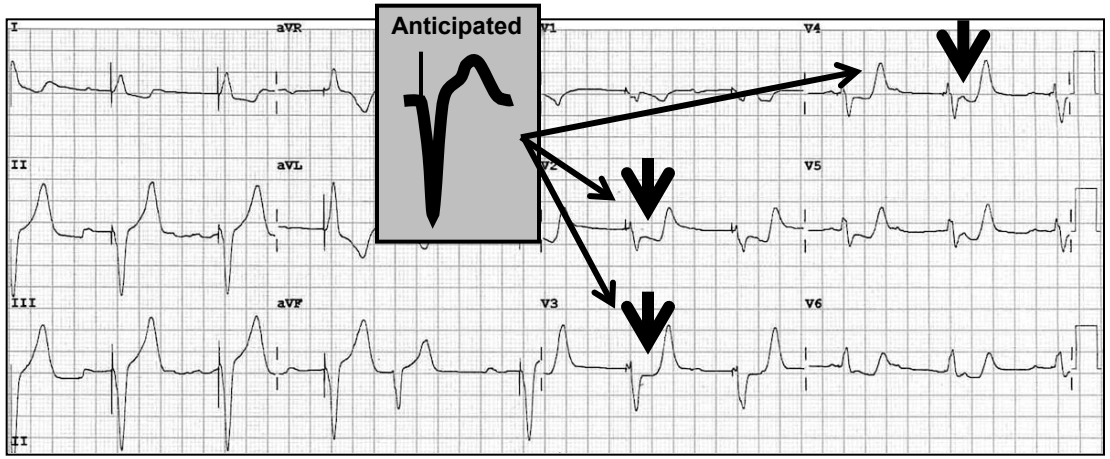
Ventricular Paced Pattern with AMI

Concordant ST Segment Depression



Ventricular Paced Pattern with AMI

Concordant ST Segment Depression



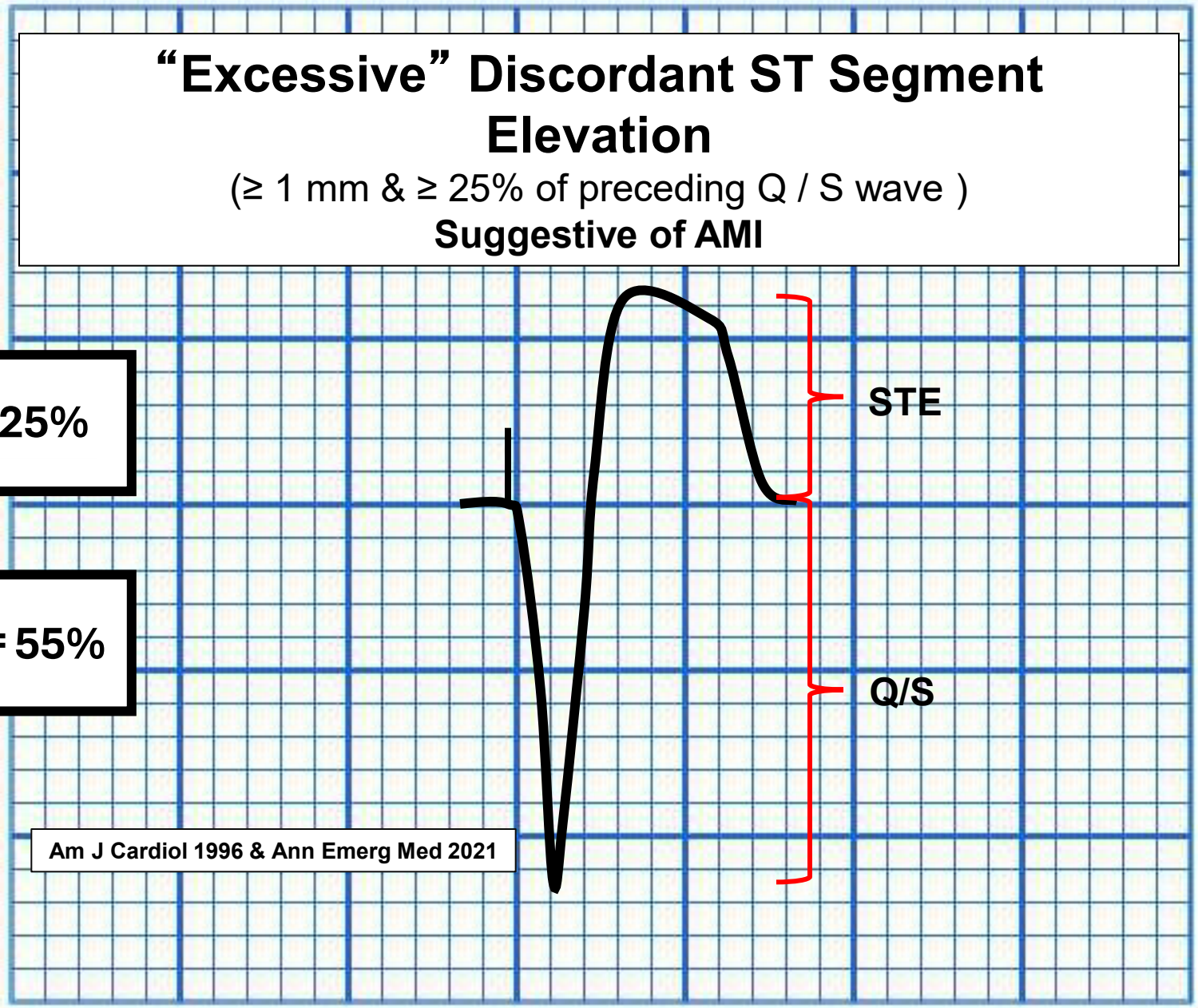
"Excessive" Discordant ST Segment Elevation

(≥ 1 mm & ≥ 25% of preceding Q / S wave)

Suggestive of AMI

$$\frac{\text{STE}}{\text{Q(S)}} \geq 25\%$$

$$\frac{6\text{ mm}}{11\text{ mm}} = 55\%$$

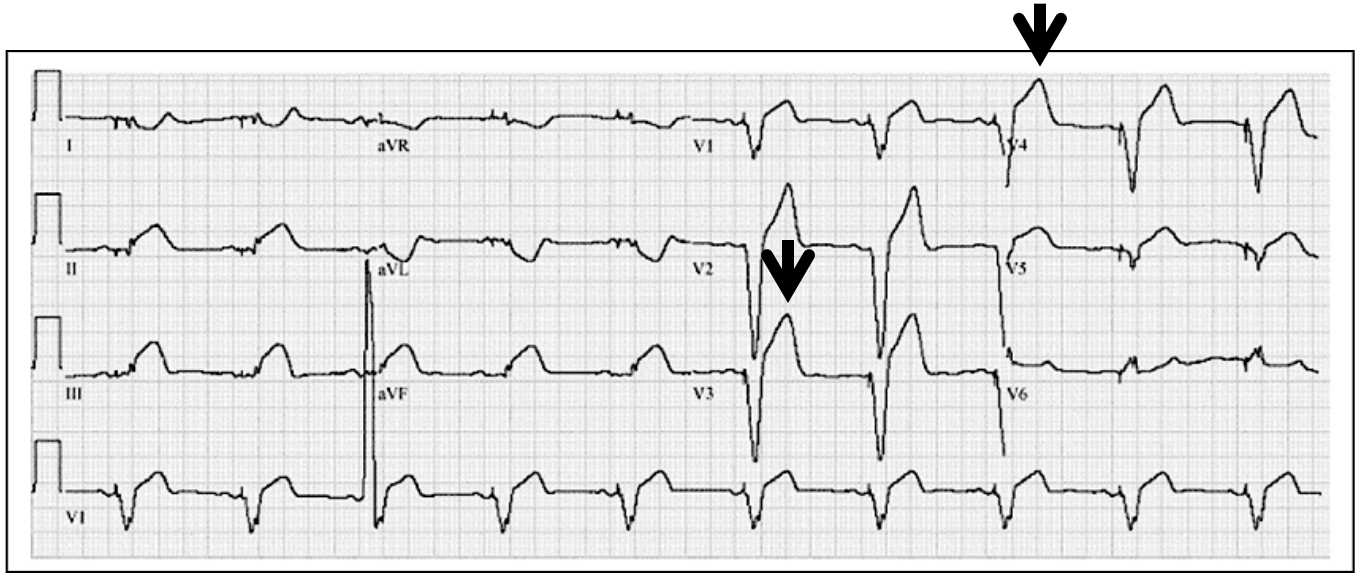


Am J Cardiol 1996 & Ann Emerg Med 2021

Ventricular Paced Pattern with AMI

"Excessive" Discordant ST Segment Elevation

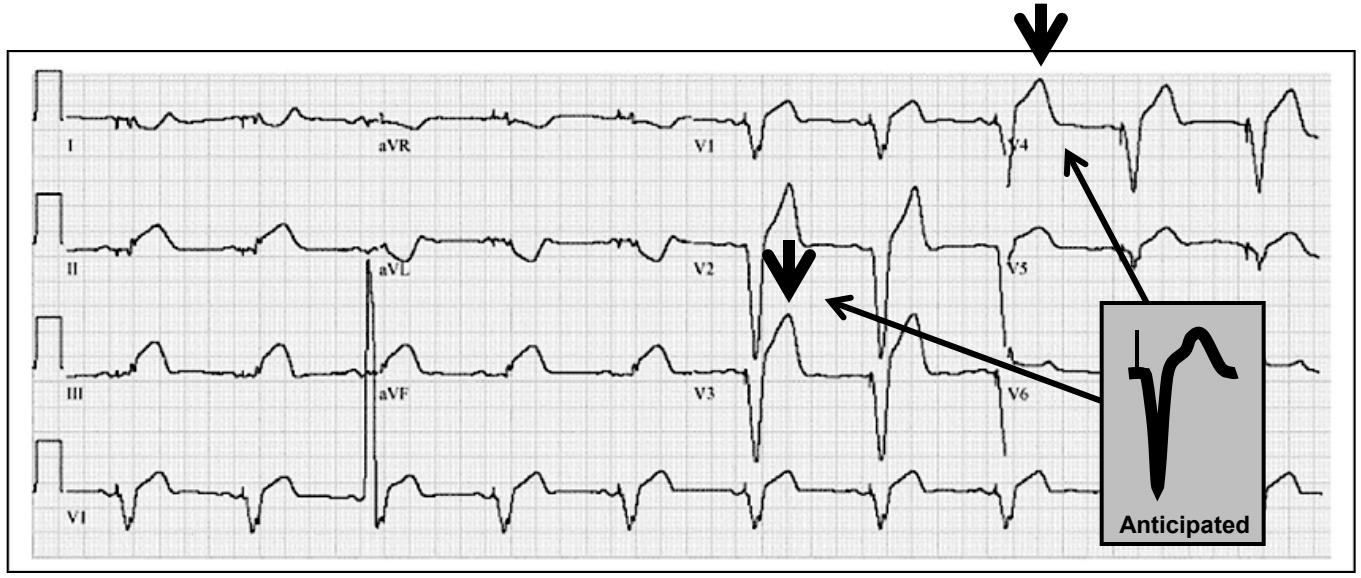
≥ 25% of preceding Q / S wave



Ventricular Paced Pattern with AMI

"Excessive" Discordant ST Segment Elevation

≥ 25% of preceding Q / S wave

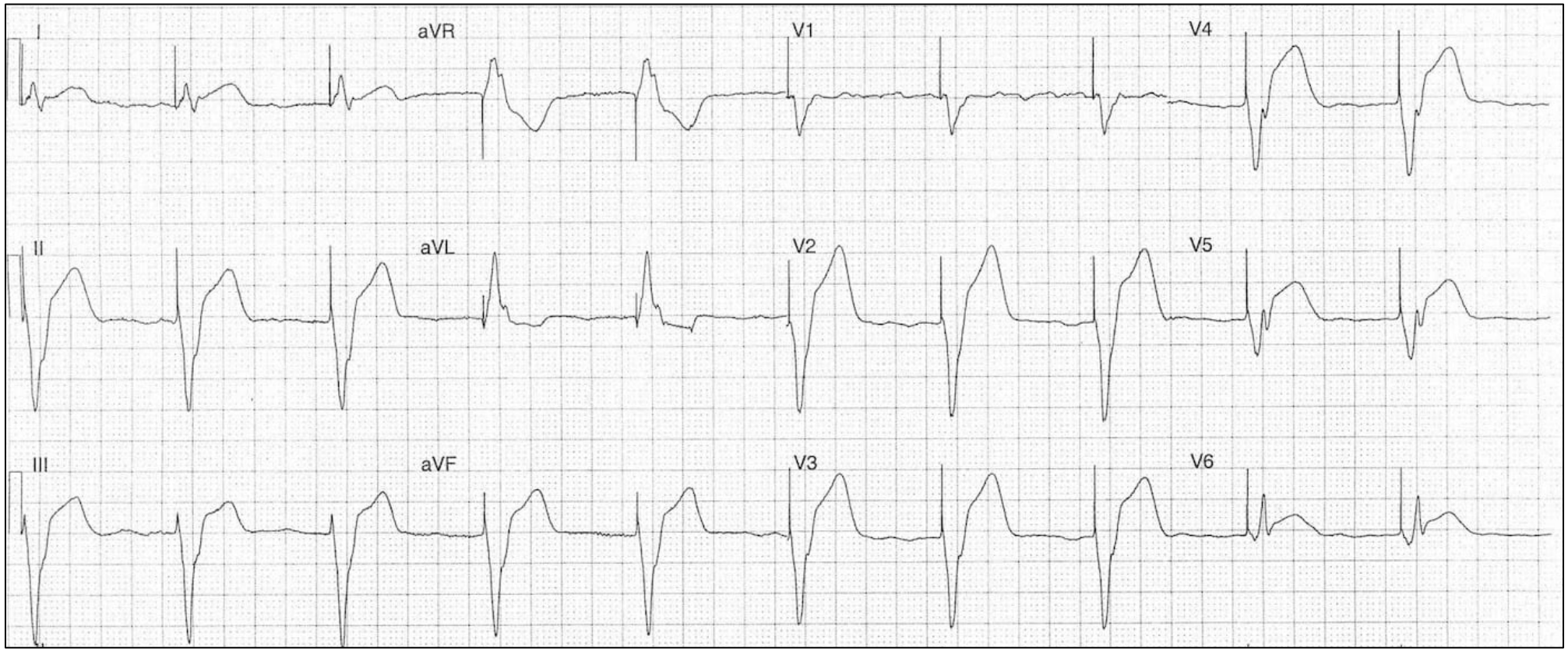


…*back to our patient*

72 male with history of heart block & implanted pacemaker

c/o substernal chest pain

Pale, anxious, & diaphoretic -- 85/60, 70, 28, Sat 92% (RA)



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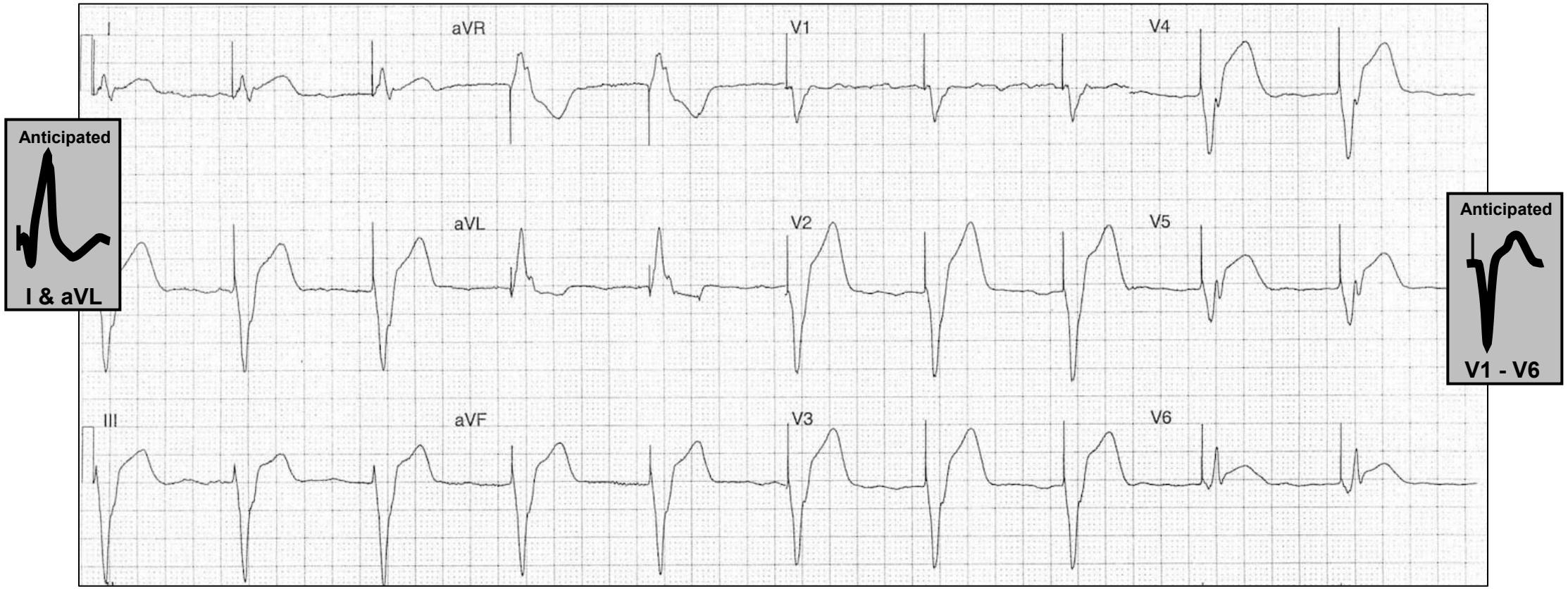
Ventricular Paced Rhythm with ECG Evidence of AMI

Concordant ST Elevation I / V6 & Excessive Discordant ST Elevation V2-V5



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