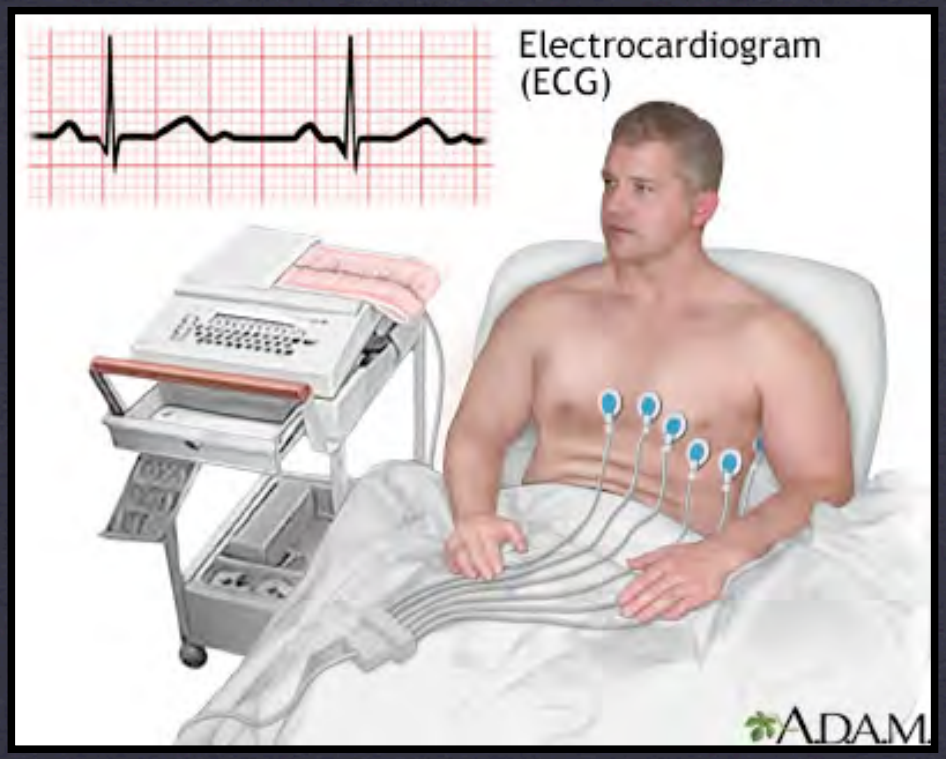

Introduction to ECGs

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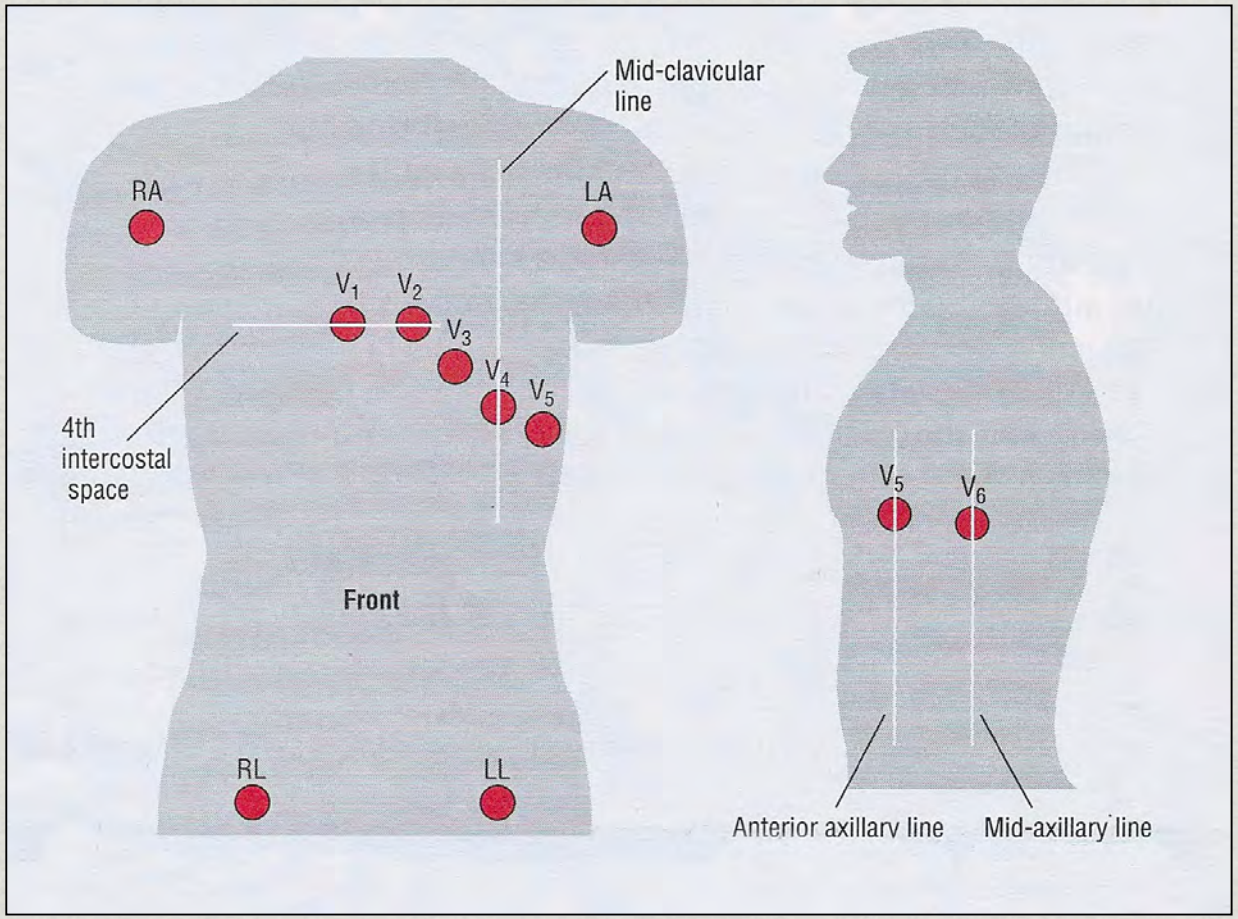
Asst. Professor
Department of Emergency Medicine

Objectives

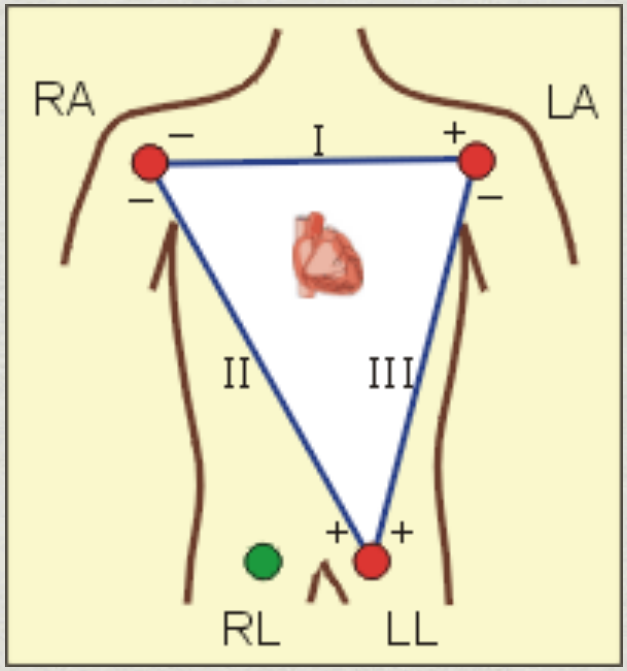
- Lead Placement
- Hexaxial System
- ECG Paper
- Systematic Approach to Reading an ECG

Lead Placement



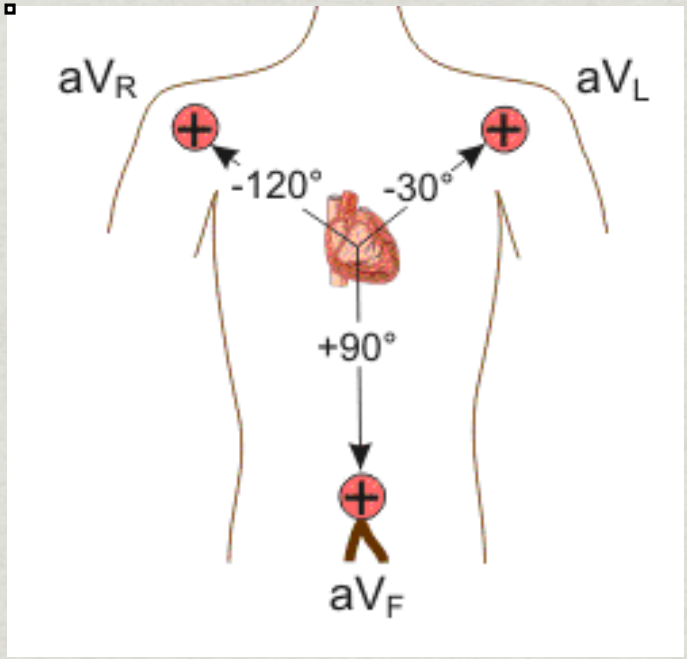
Hexaxial System

- Limb Leads (Bipolar): RA, LA, RL, LL
  - Forms Einthoven's Triangle
  - I : 0°
  - II : 60°
  - III : 120°

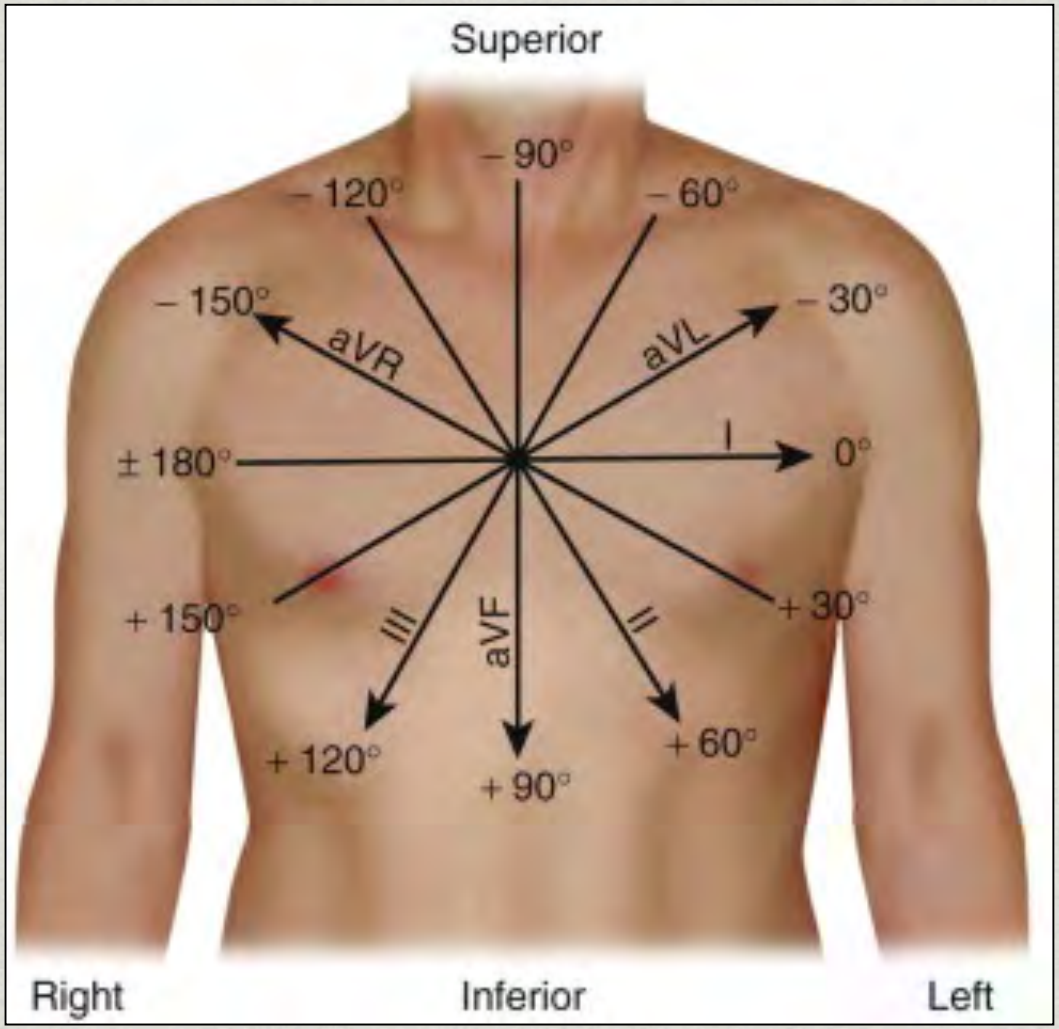


Hexaxial System

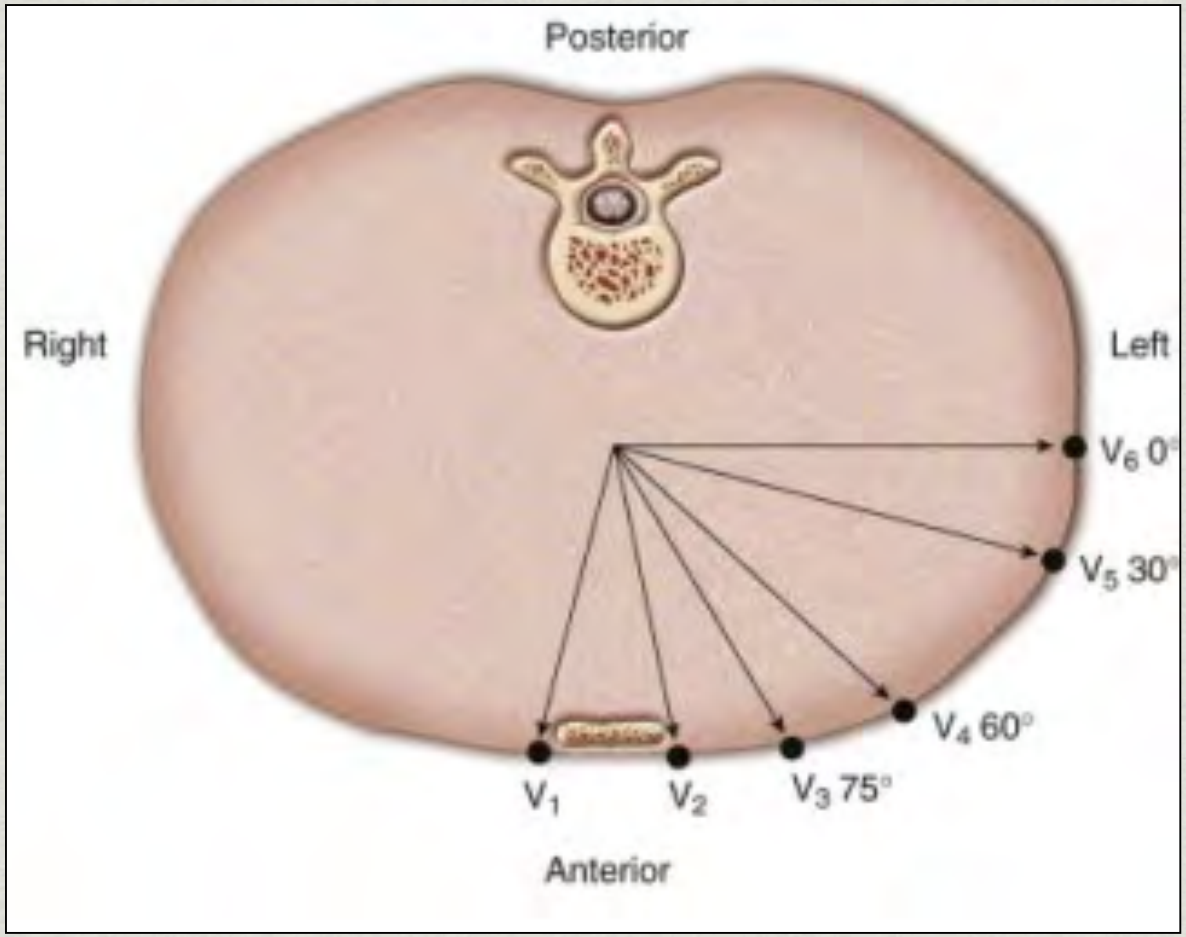
- Augmented Leads (Unipolar)
  - Utilize a central negative terminal
  - aVL : -30°
  - aVF : 90°
  - aVR : -120°



Hexaxial System



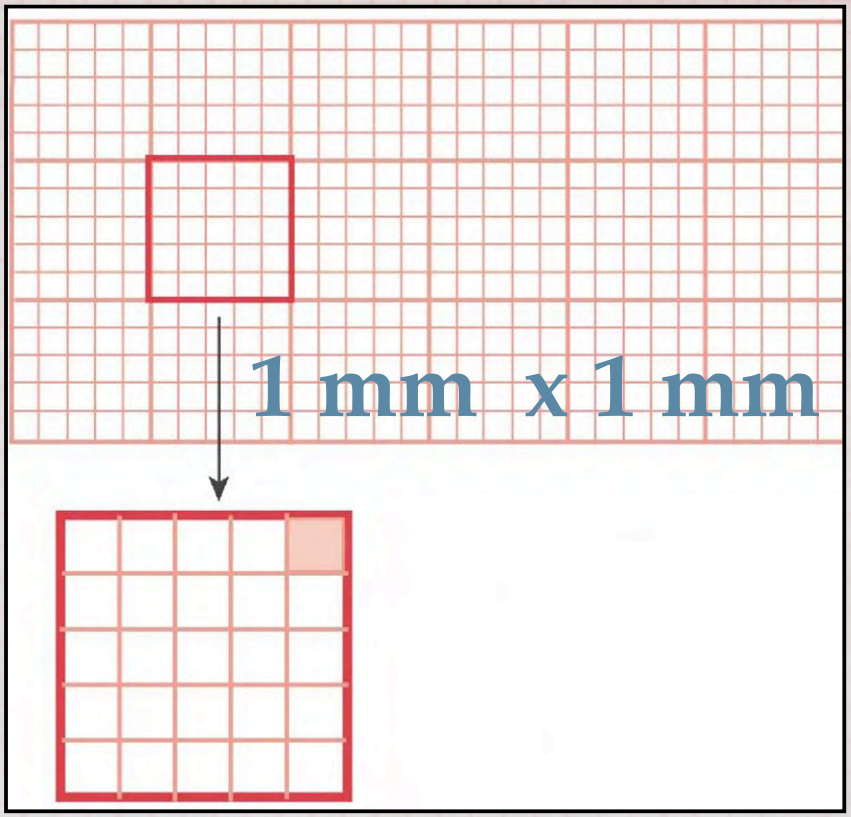
Precordial Leads

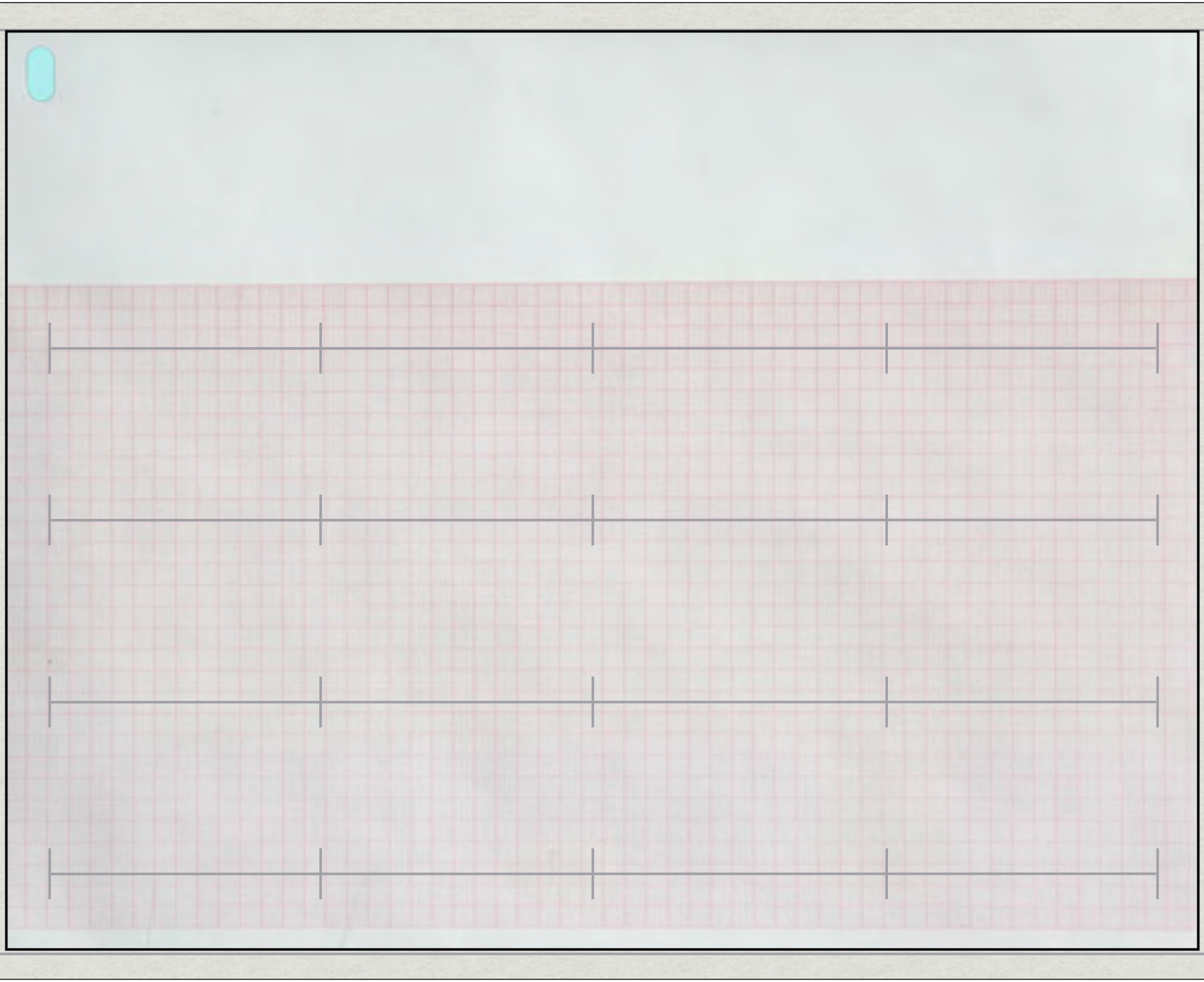


ECG Paper

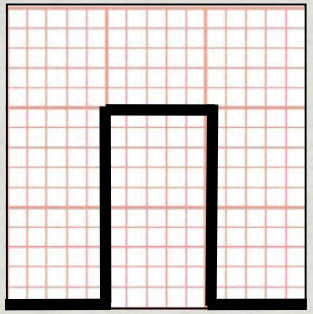
Height = millivolts

Width = Time



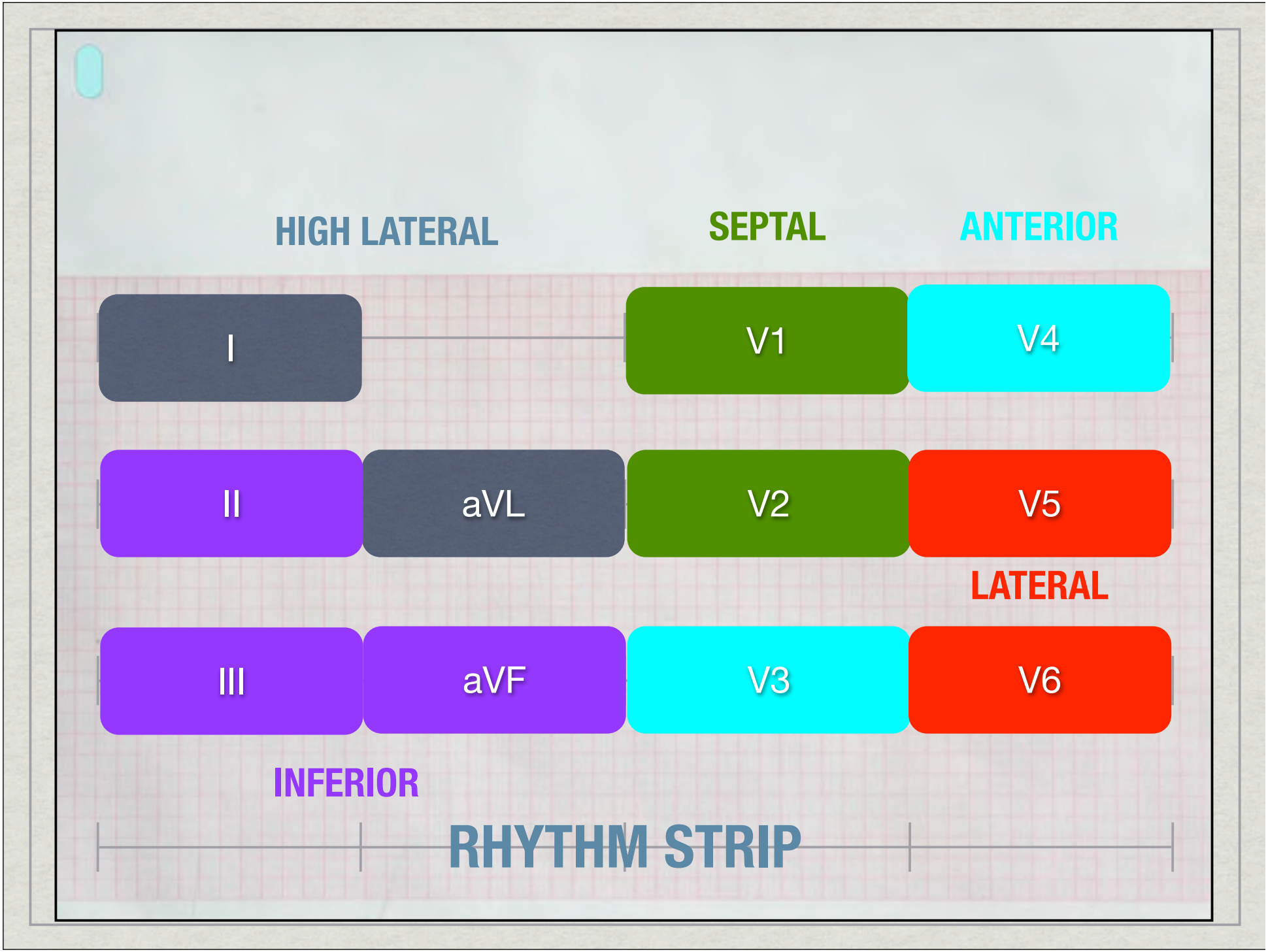


Calibration

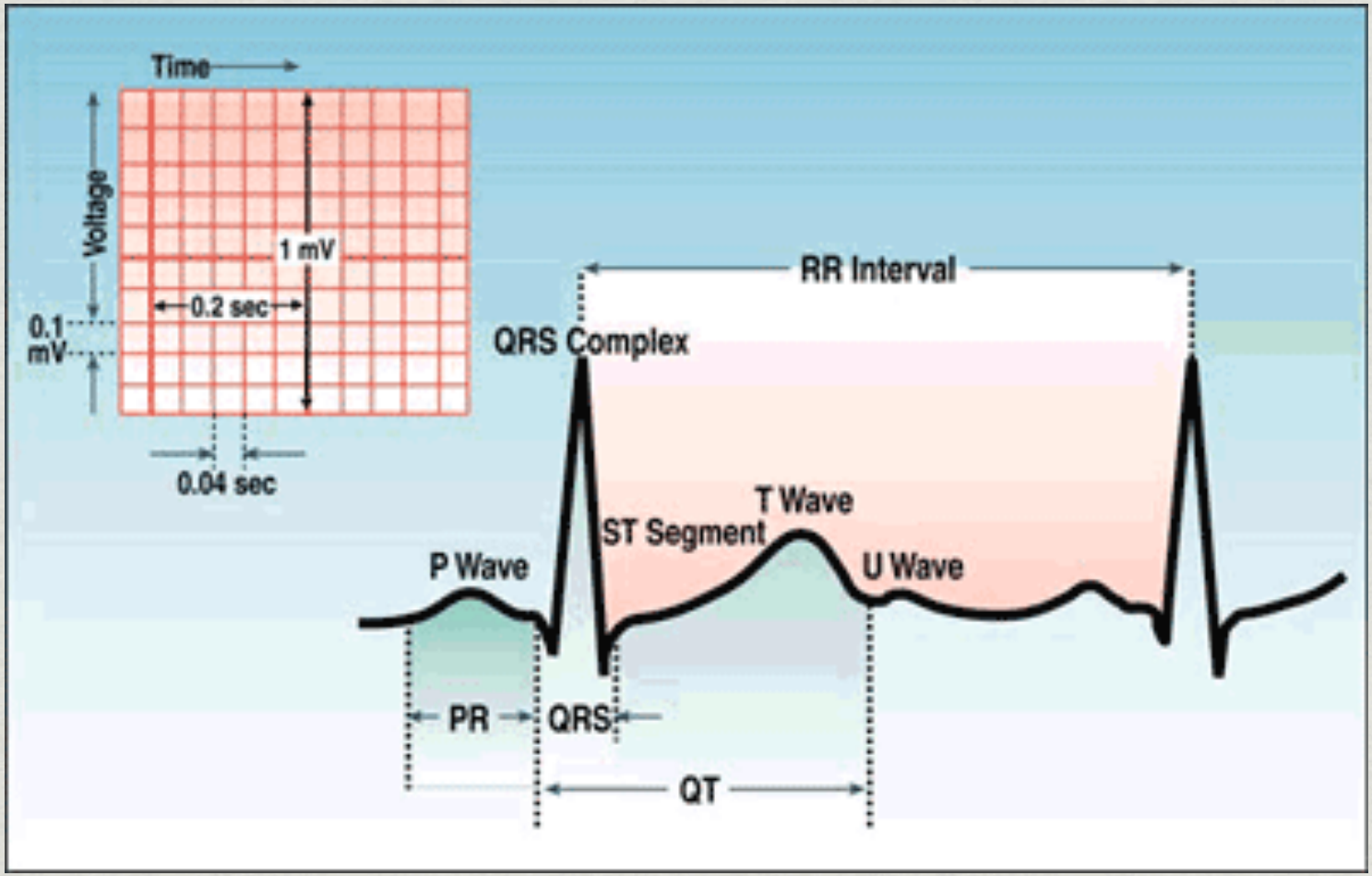


Vertical Axis 'y'	1 Small Square = 1 mm (0.1 mV)
	1 Large Square = 5 mm (0.5 mV)
	2 Large Squares = 10 mm (1 mV)

Horizontal Axis 'x'	1 Small Square = 0.04 sec
	1 Large Square = 0.2 sec
	5 Large Squares = 1 sec


HIGH LATERAL
SEPTAL
ANTERIOR
I
V1
V4
II
aVL
V2
V5
LATERAL
III
aVF
V3
V6
INFERIOR
RHYTHM STRIP

ECG Complex

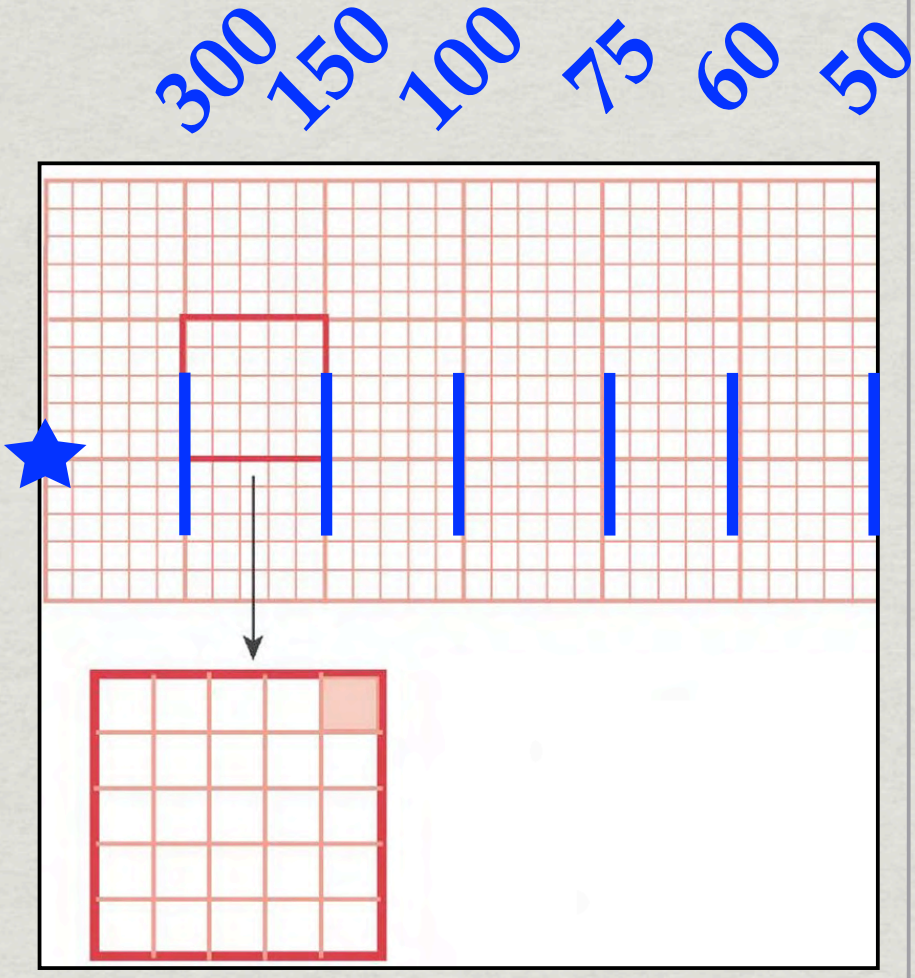

Time
Voltage
1 mV
0.2 sec
0.1 mV
0.04 sec
RR Interval
QRS Complex
T Wave
ST Segment
P Wave
U Wave
PR
QRS
QT

Interpreting the ECG

- Rate
- Rhythm
  - Ectopic beats?
- Axis
- Intervals
  - Blocks?
- Atrial Abnormalities
- Ventricular hypertrophy
- ST/T changes

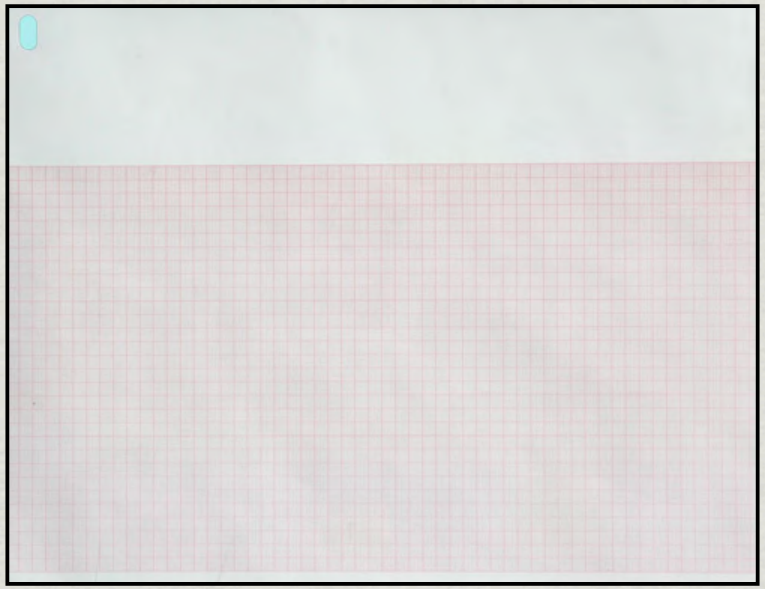
The Rate

- 5 big boxes = 1 sec
- 300 big boxes = 60 sec
- Rate = 300 / # big boxes



The Rate

- Multiply # beats on rhythm strip x 5



The Rhythm

- Is it fast or slow?
- Is it regular or irregular?
- Are there p waves present?
    - Are all p waves the same?
    - Does each QRS have a p wave?
    - Is the PR interval constant?

The Rhythm

- Are the p waves and QRS complexes associated with each other?
- Are the QRS complexes narrow or wide?
- Are the QRS complexes grouped or not?
- Are there dropped beats?

The Rhythm

Supraventricular Rhythms

Normal Sinus Rhythm

- Rate: 60 - 100 bpm
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None

Sinus Bradycardia

- Rate: Less than 60
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None

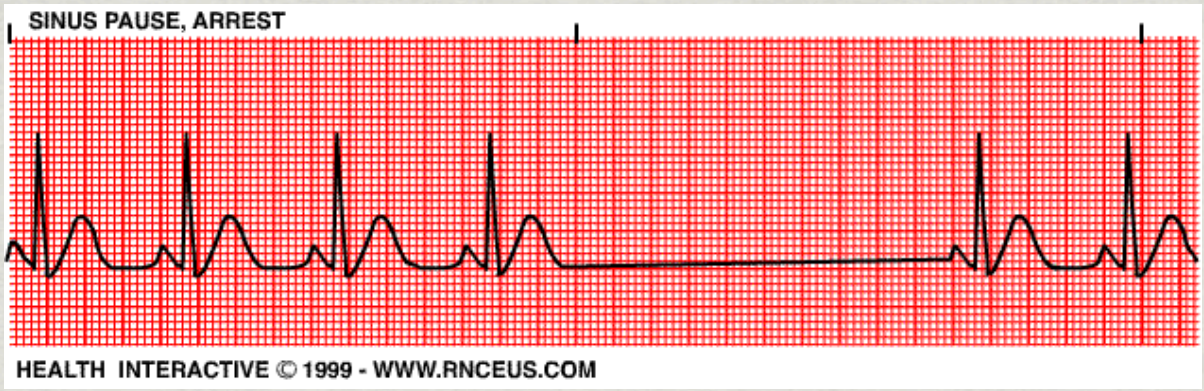
Sinus Tachycardia

- Rate: Greater than 100
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None

Sinus Arrhythmia

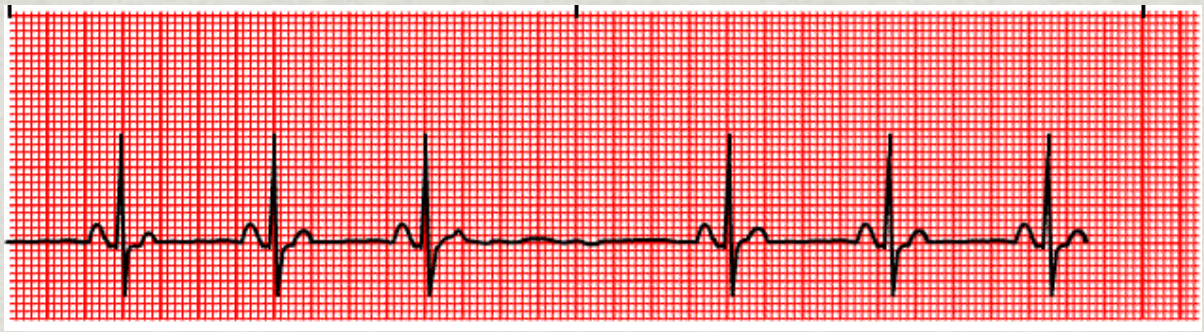
- Rate: 60 - 100
- Varies with respiration
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None

Sinus Pause / Arrest



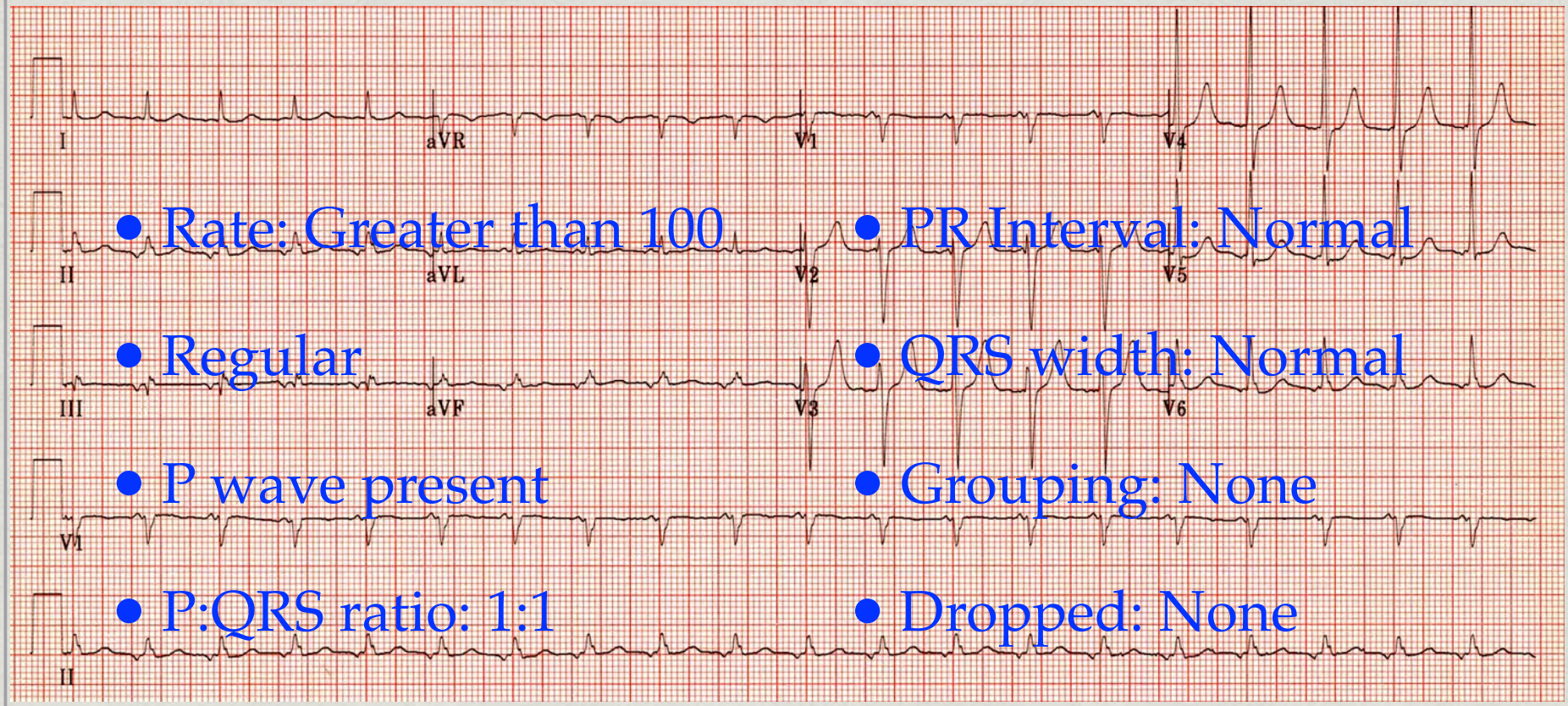
- Rate: Varies
- Irregular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None

Sinoatrial Block



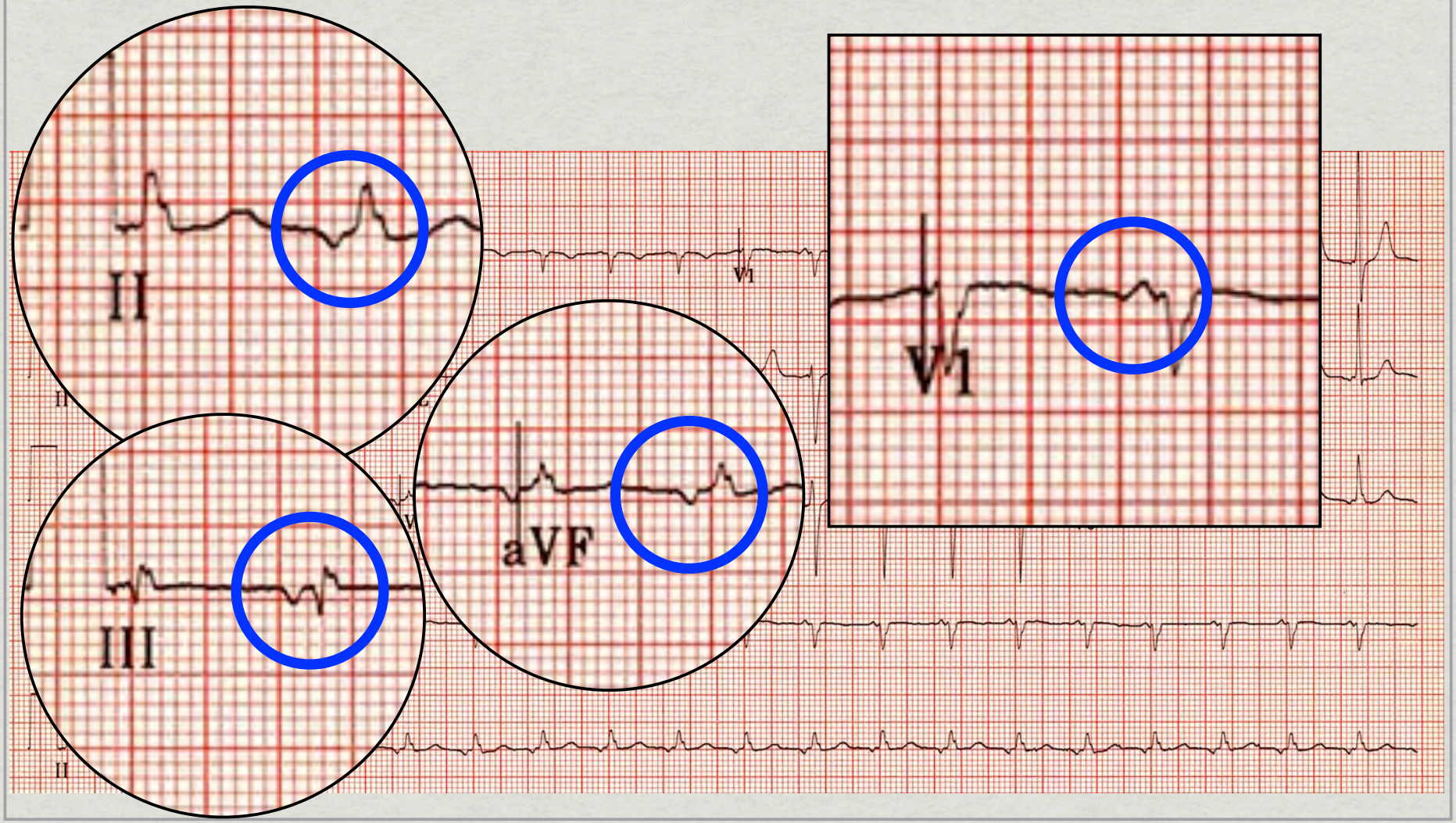
- Rate: Varies
- Irregular
- P present except in areas of dropped beat
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: Yes

Ectopic Atrial Tachycardia



- Rate: Greater than 100
- Regular
- P wave present
- P:QRS ratio: 1:1
- PR Interval: Normal
- QRS width: Normal
- Grouping: None
- Dropped: None

Ectopic Atrial Tachycardia



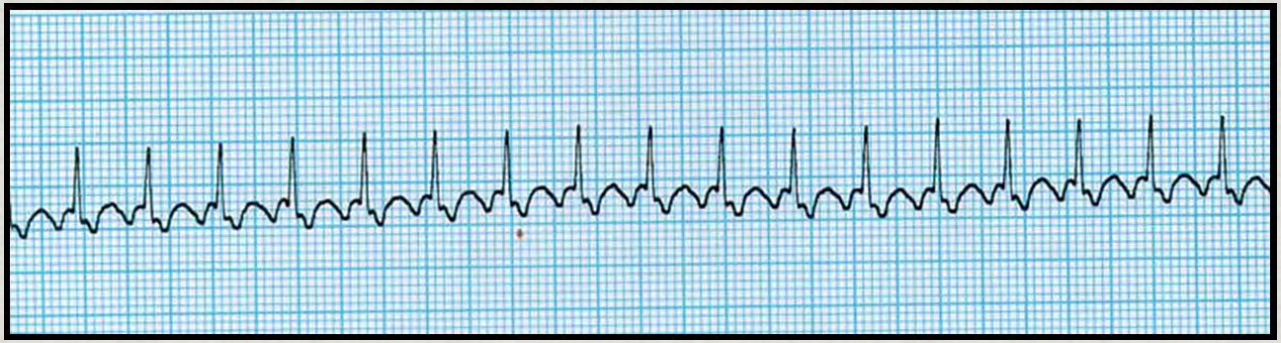
Wandering Atrial Pacemaker

- Rate: Less than 100
- Irregularly irregular
- P wave ≥ 3 morphologies
- P:QRS ratio: 1:1
- PR Interval: Varies
- QRS width: Normal
- Grouping: None
- Dropped: None

Multifocal Atrial Tachycardia

- Rate: Greater than 100
- Irregularly irregular
- P wave ≥ 3 morphologies
- P:QRS ratio: 1:1
- PR Interval: Varies
- QRS width: Normal
- Grouping: None
- Dropped: None

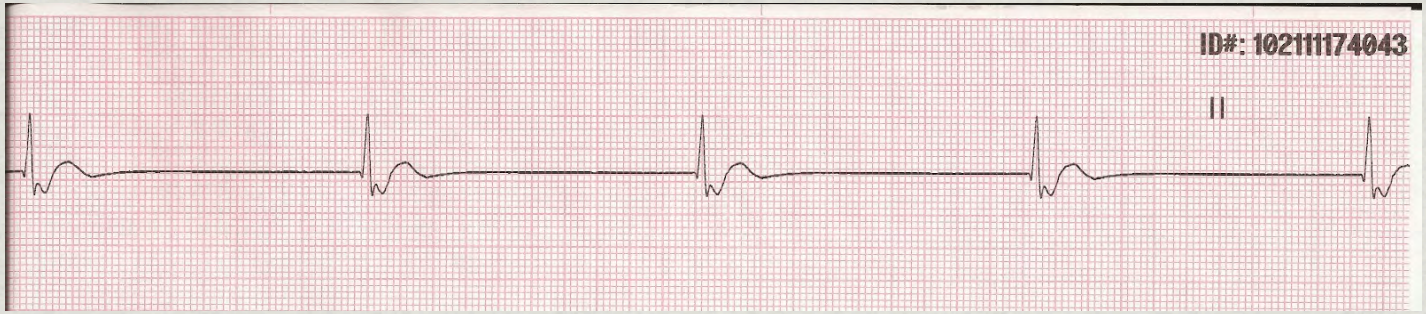
Atrial Flutter



- Rate: atrial- 250-350, ventricular 125-175
- Usually regular
- P wave- flutter waves
- P:QRS ratio: Often 2:1
- PR Interval: Variable
- QRS width: Normal
- Grouping: None
- Dropped: None

Atrial Fibrillation

- Rate: Variable
- Irregularly irregular
- P waves chaotic
- P:QRS ratio: None
- PR Interval: None
- QRS width: Normal
- Grouping: None
- Dropped: None

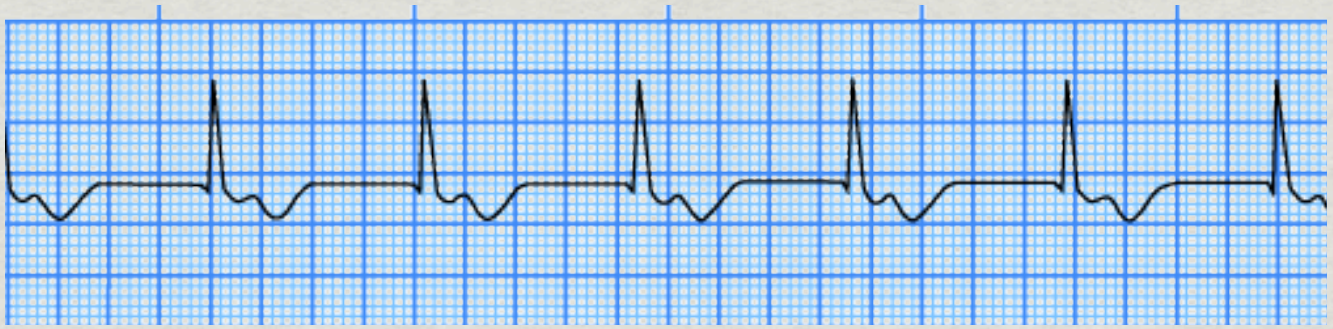


- Rate: 40-60
- Regular
- P waves- none, antegrade, retrograde
- P:QRS ratio: None or 1:1

Junctional Rhythm

- PR Interval: None, short or negative
- QRS width: Normal
- Grouping: None
- Dropped: None

Accelerated Junctional Rhythm



- Rate: 60-130 bpm
- Regular
- P waves- none, ante-, retrograde
- P:QRS ratio: none or 1:1
- PR Interval: None, short or neg
- QRS width: Normal
- Grouping: None
- Dropped: None

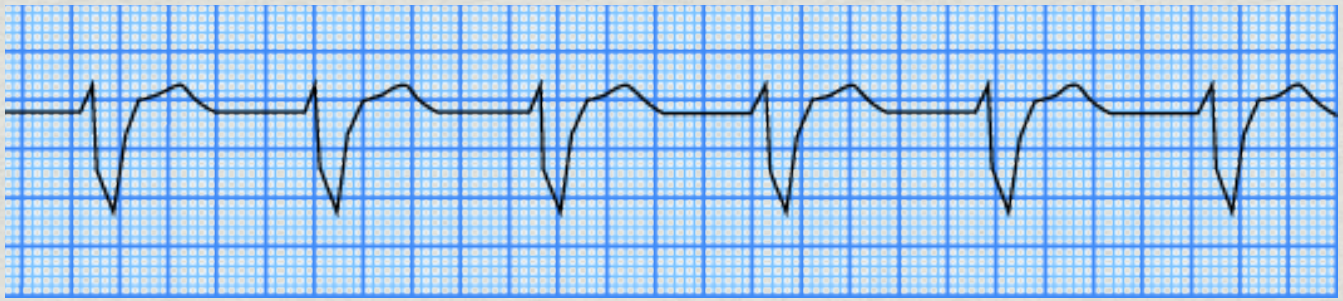
The Rhythm

Ventricular Rhythms

Idioventricular Rhythm

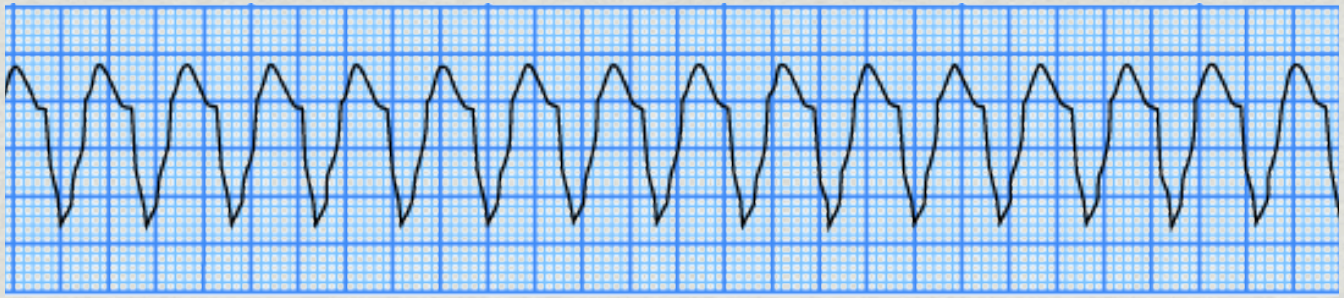
- Rate: 20 - 40 bpm
- Regular
- P wave absent
- P:QRS ratio: None
- PR Interval: None
- QRS width: Wide, bizarre
- Grouping: None
- Dropped: None

Accel. Idioventricular Rhythm



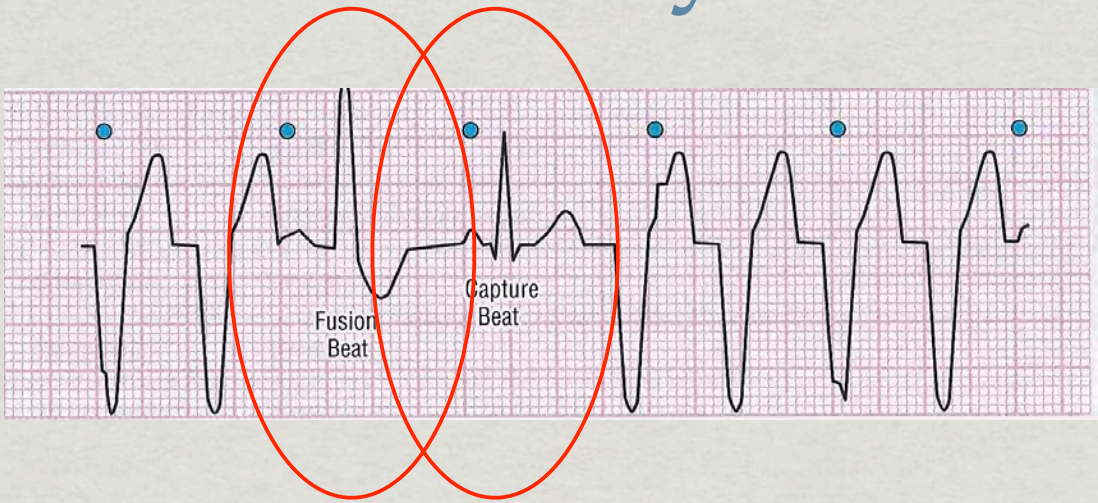
- Rate: 40 - 100 bpm
- Regular
- P wave absent
- P:QRS ratio: None
- PR Interval: None
- QRS width: Wide, bizarre
- Grouping: None
- Dropped: None

Ventricular Tachycardia



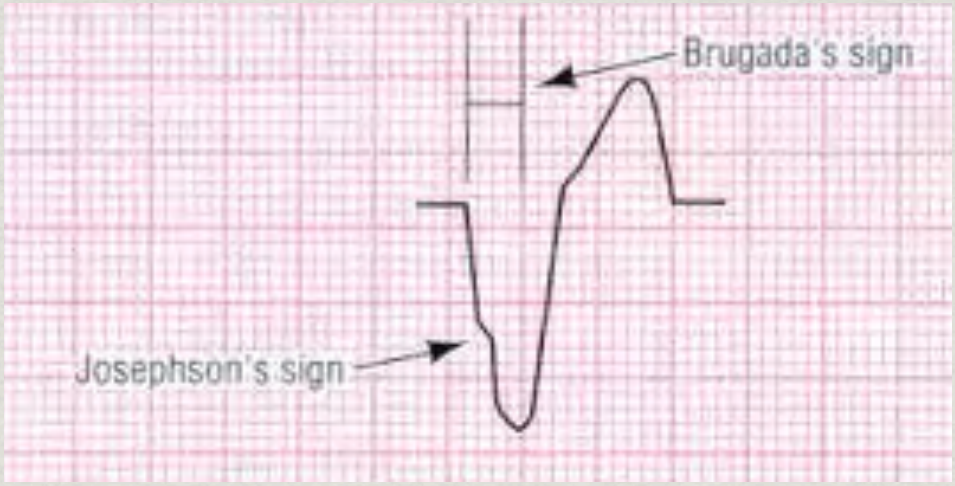
- Rate: 100 - 200 bpm
- Regular
- P wave ?buried
- P:QRS ratio: None
- PR Interval: None
- QRS width: Wide, bizarre
- Grouping: None
- Dropped: None

Ventricular Tachycardia



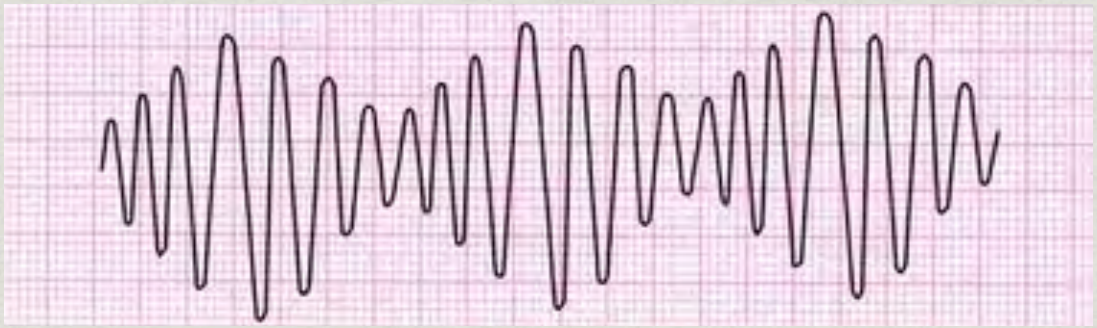
- Fusion Beats
  - Mix between V-tach and sinus morphologies
- Capture Beats
  - Sinus morphology

Ventricular Tachycardia



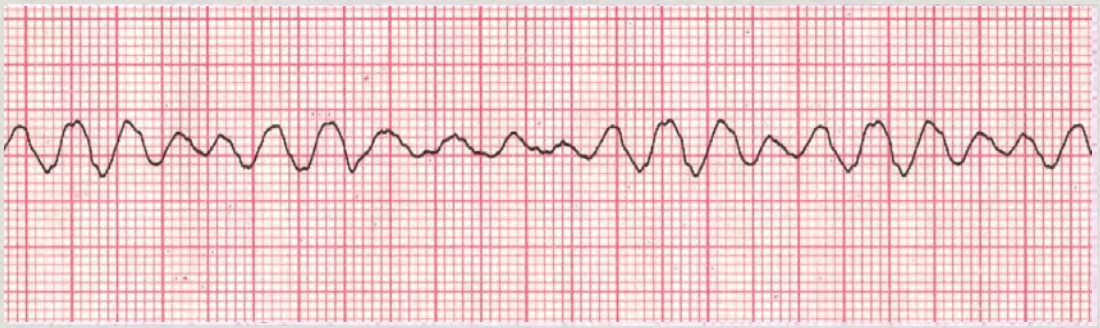
- Josephson's Sign
  - Small notching near the low point of S wave
- Brugada's Sign
  - Interval from R wave to bottom of S wave is ≥ 0.10 seconds

Torsades de Pointes



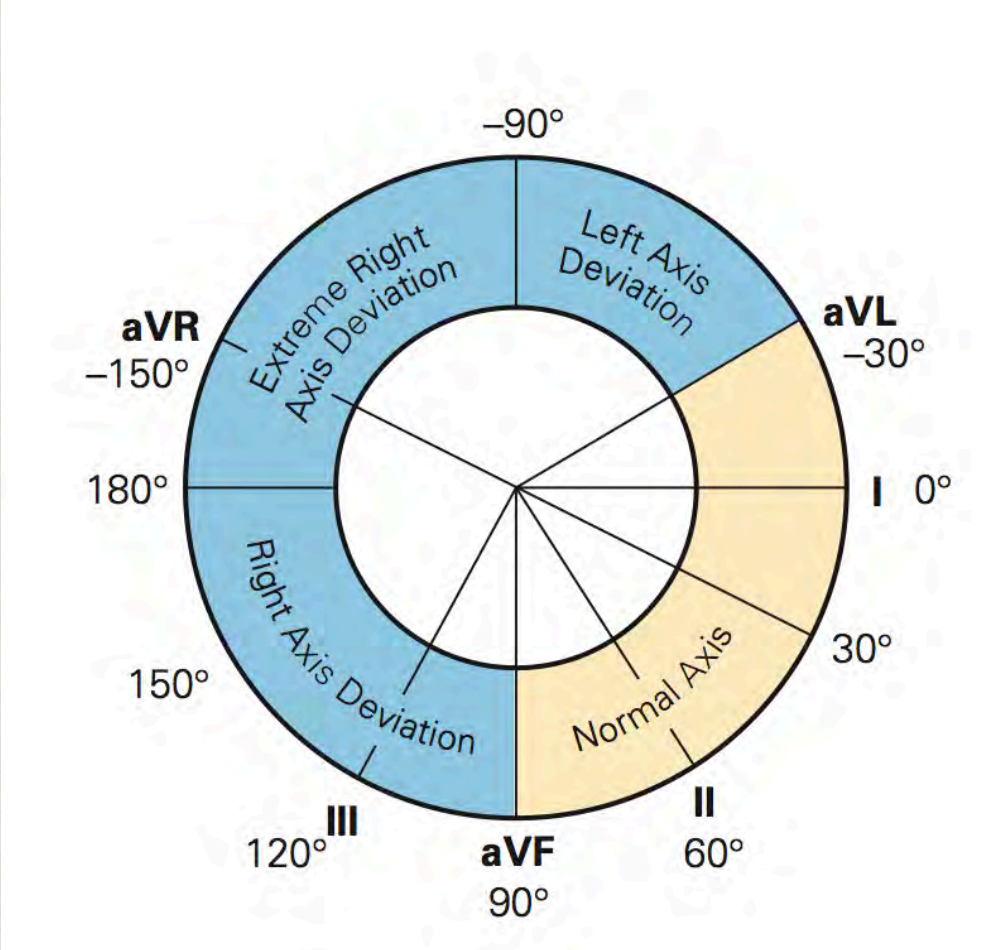
- Rate: 200 - 250 bpm
- Irregular
- P wave: None
- P:QRS ratio: None
- PR Interval: None
- QRS width: Variable
- Grouping: N/A
- Dropped: None

Ventricular Fibrillation



- Rate: Indeterminate
- Irregular
- P wave: None
- P:QRS ratio: None
- PR Interval: None
- QRS width: None
- Grouping: None
- Dropped: No beats

Axis

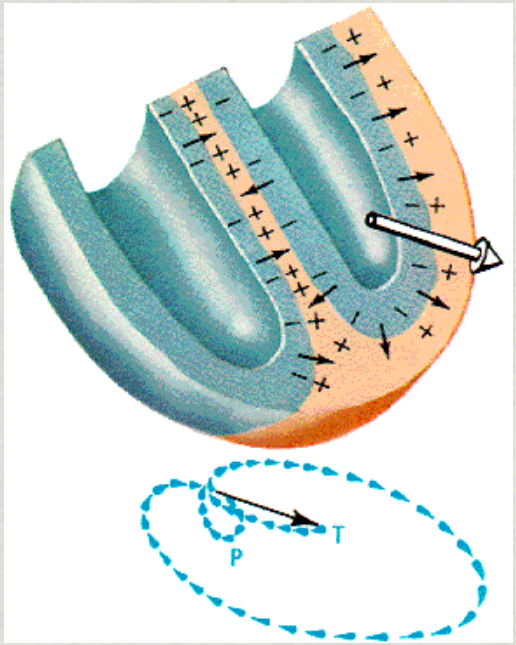

–90°
Left Axis Deviation
aVL
–30°
I
0°
30°
Normal Axis
II
60°
aVF
90°
III
120°
Right Axis Deviation
150°
180°
aVR
–150°
Extreme Right Axis Deviation

Axis

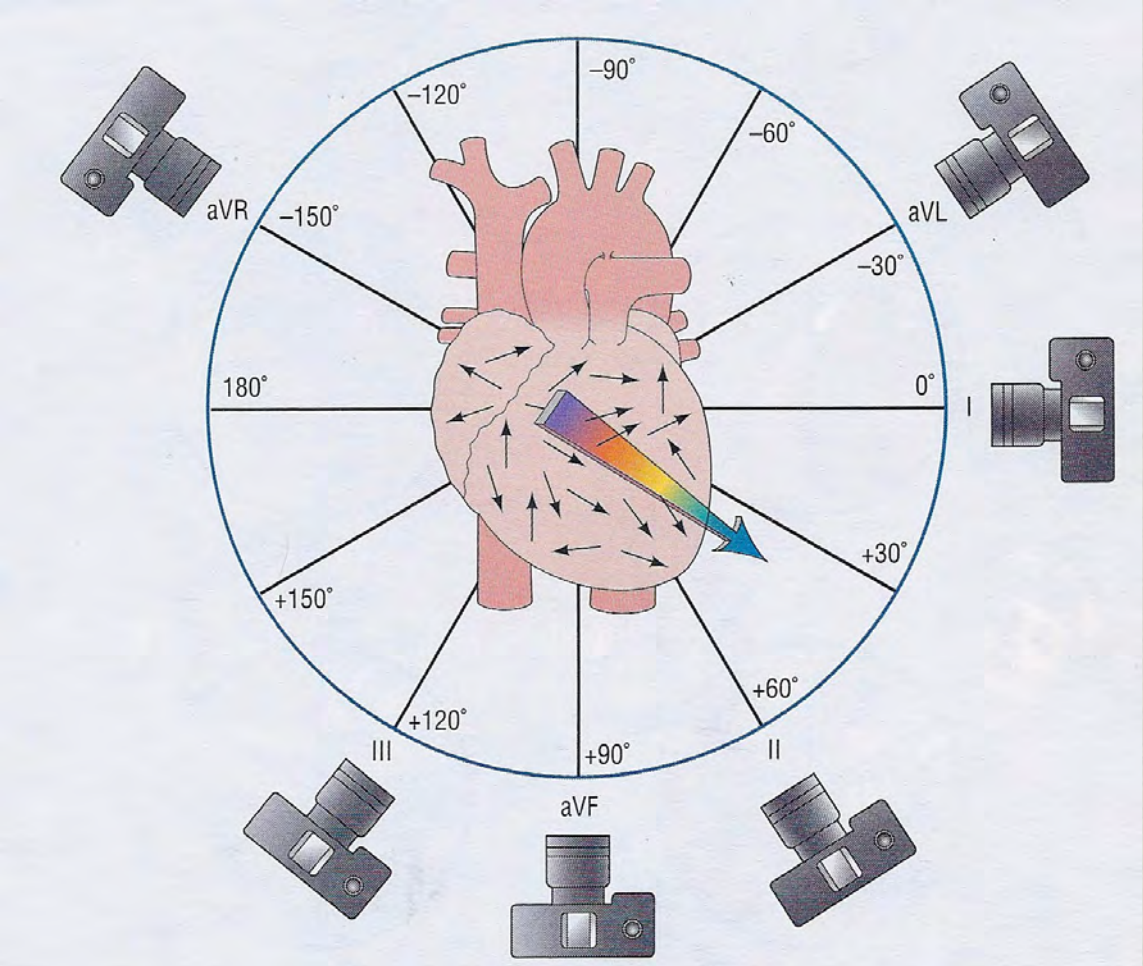
I	VR	V1	V4
II	VL	V2	V5
III	VF	V3	V6

Axis

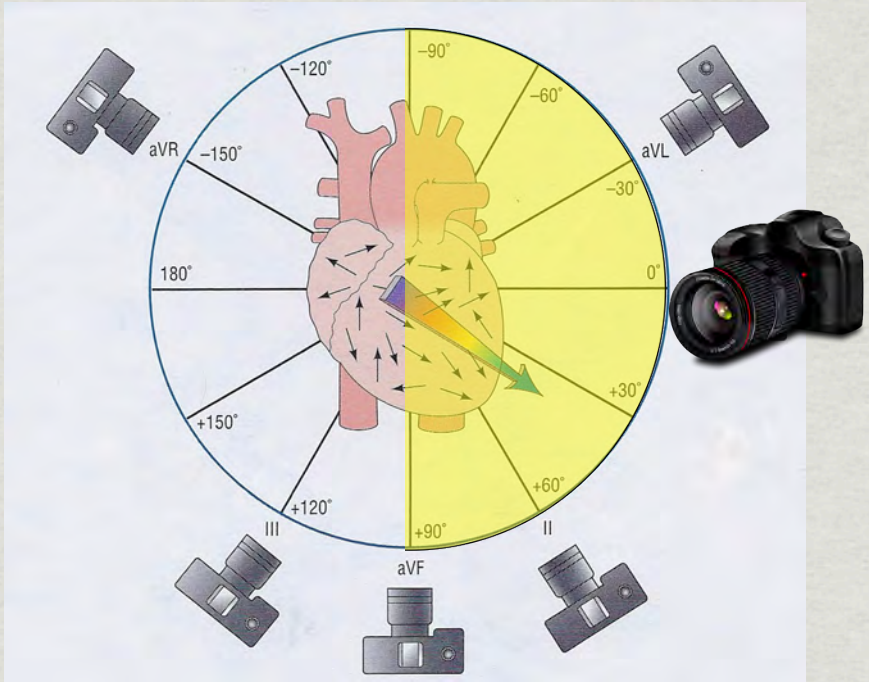
- The axis is the direction of the sum vector of ventricular depolarization



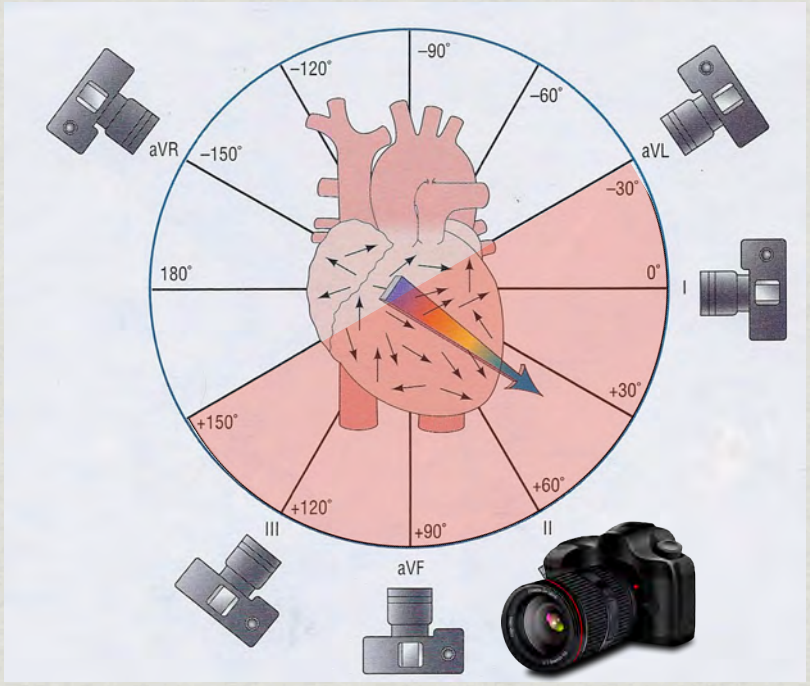
Axis



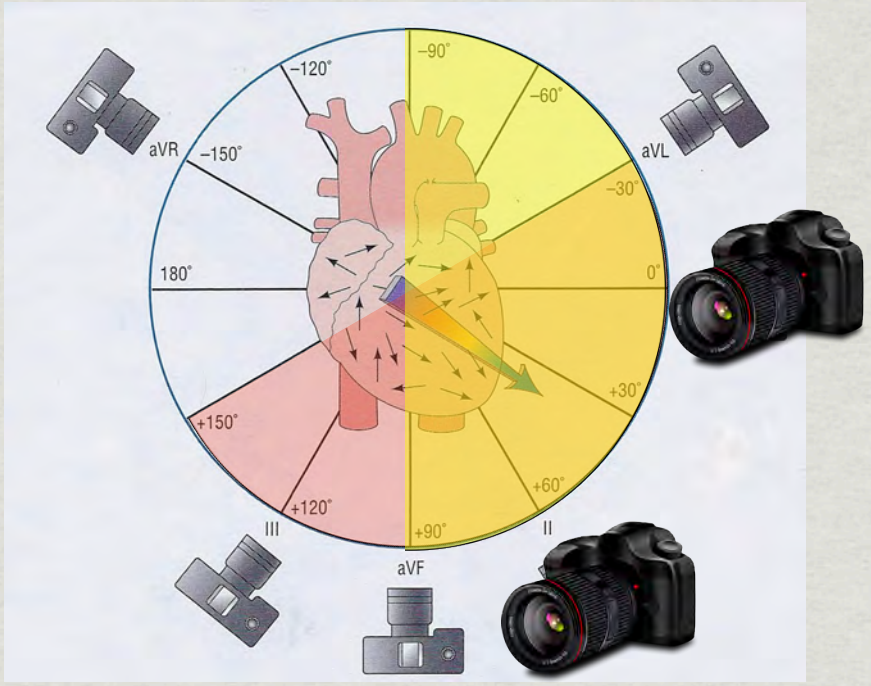
Axis



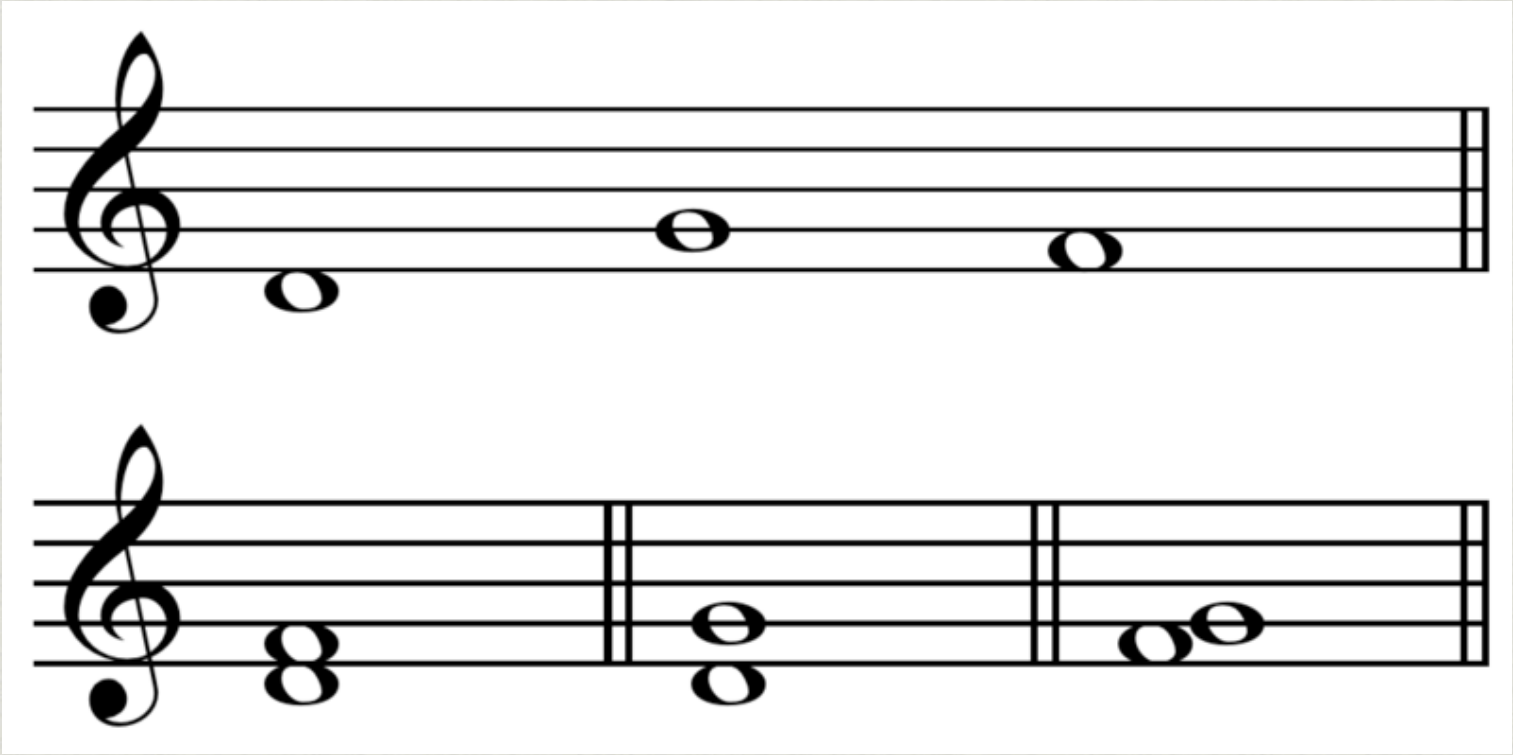
Axis



Axis



Intervals

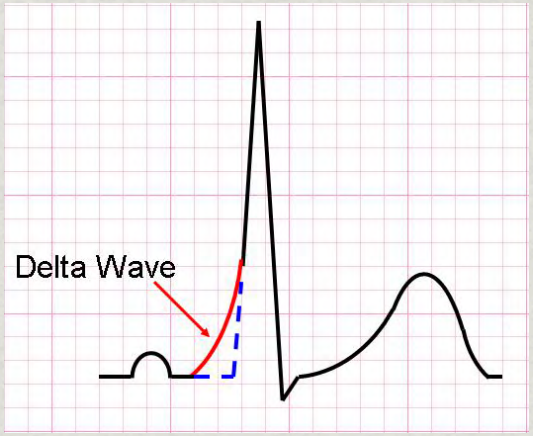


PR Interval

- Normal: 0.12 to 0.20 sec
  - Short PR interval
    - Wolff-Parkinson-White
    - Lown-Ganong-Levine
    - AV Junctional Rhythm (see arrhythmia lecture)

Wolff-Parkinson-White

- Defined by:
  - Short PR (<0.12 sec) with normal P wave
    - May be normal in 12%
  - Wide QRS complex (≥0.11 sec)
  - Presence of a delta wave
- ST-T wave changes
- Association with paroxysmal tachycardias



PR Interval

- Normal: 0.12 to 0.20 sec
  - Long PR interval – 1st Degree AV Block
    - AV nodal disease
    - Enhanced vagal tone
    - Myocarditis
    - Myocardial infarction (especially inferior MIs)
    - Electrolyte imbalance
    - Drugs (Beta Blockers, CCBs, cardiac glycosides)

QRS Duration

- Normal : 0.06 to 0.10 sec
  - Hyperkalemia
  - Ventricular tachycardia
  - Idioventricular rhythms
  - Drug effects and overdoses
  - Wolff-Parkinson-White
  - BBBs and Intraventricular conduction delay
  - PVCs
  - Aberrantly conducted complexes

QT Interval

- Must be corrected for rate = QT_c
  - Bazett's Formula
  - Fridericia's Formula
  - Hodge's Formula
- Normal is < 440

$$QT_c = QT + 1.75\,(HR - 60)$$

$$QT_c = \frac{QT}{\sqrt[3]{R\text{-}R}}$$

QT_C

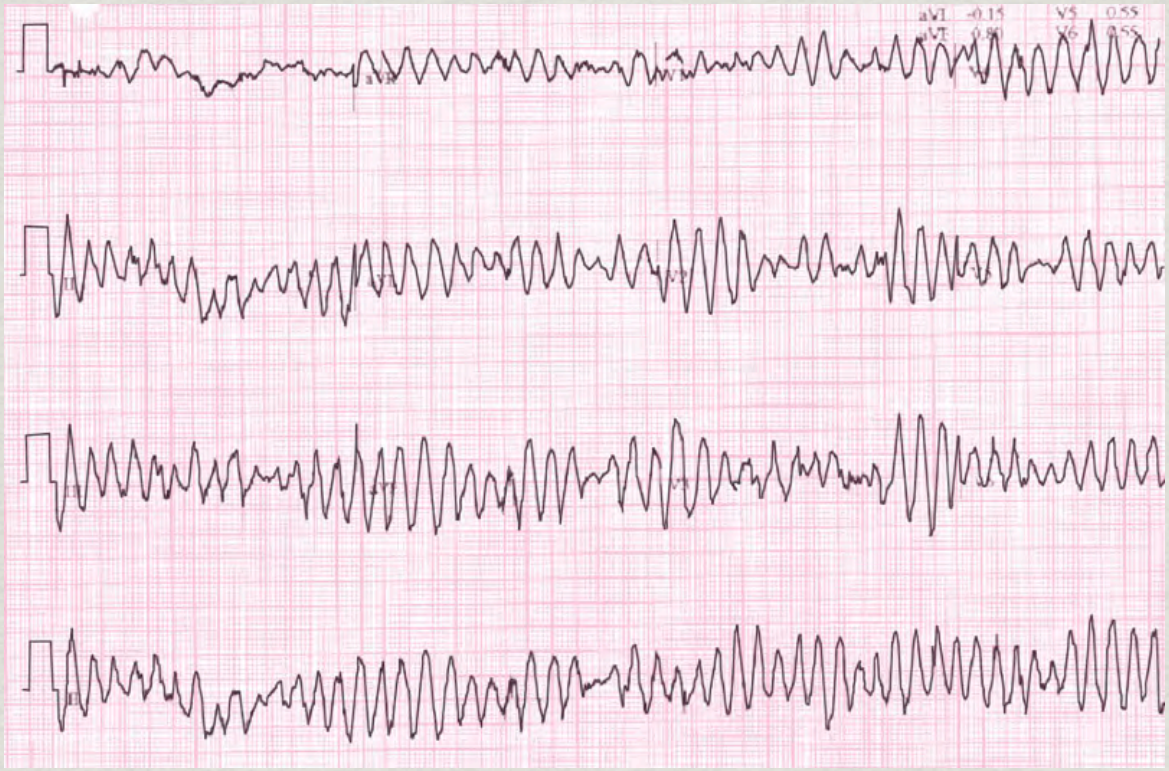
- Causes of shortened QT_c
  - Hypercalcemia
  - Digitalis
  - Tachycardia

QT_C

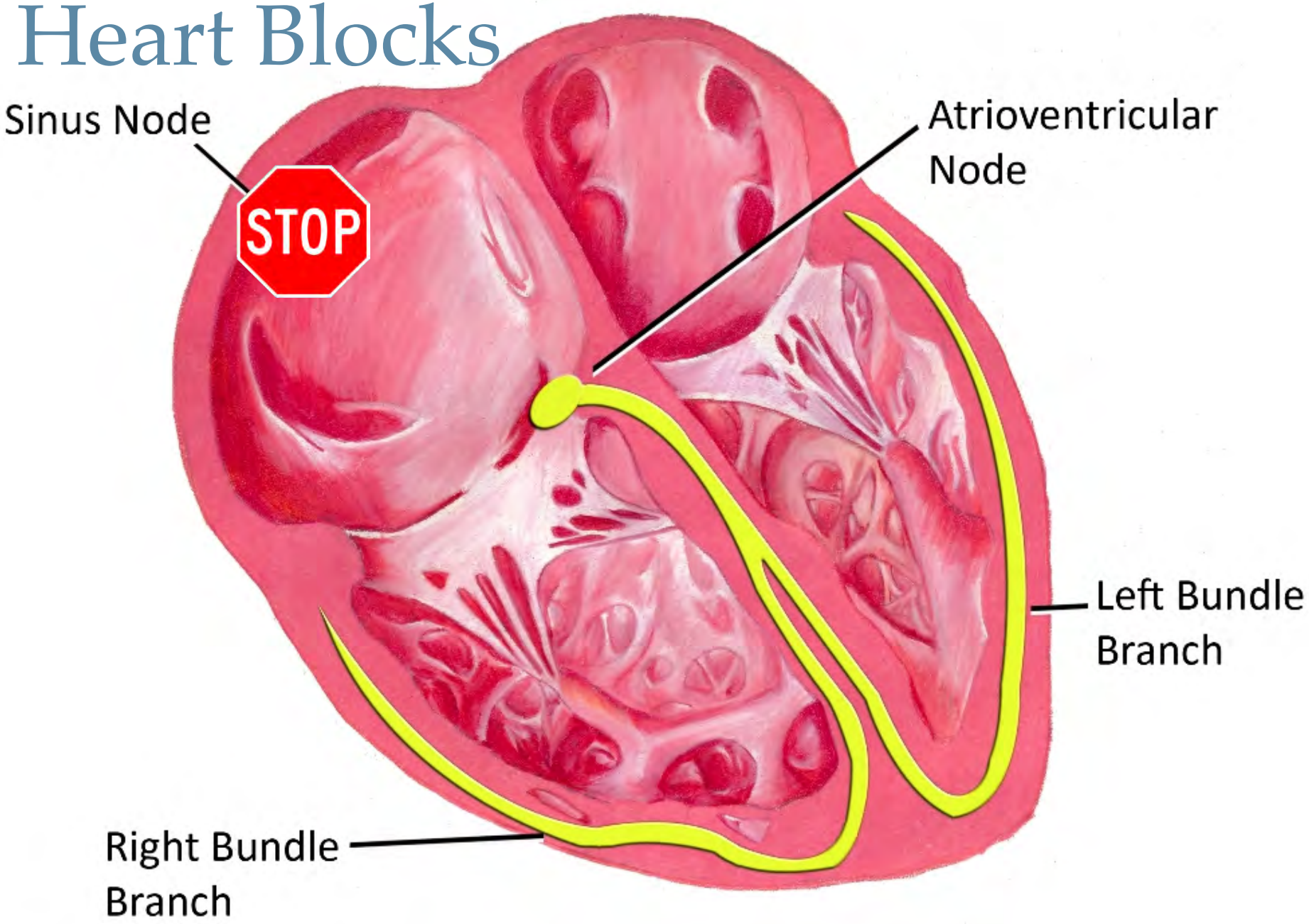
- Causes of prolonged QT_c
  - Hypocalcemia
  - Drugs (Quinidine, Procainamide, Psychotropics, Tricyclics, Pentamidine)
  - CNS
  - Hypothermia
  - Hypothyroidism
  - Ischemic Heart Disease
  - Genetic (Long QT Syndrome)

Torsades de Pointes

- Increased risk when QTc > 500 msec



Heart Blocks



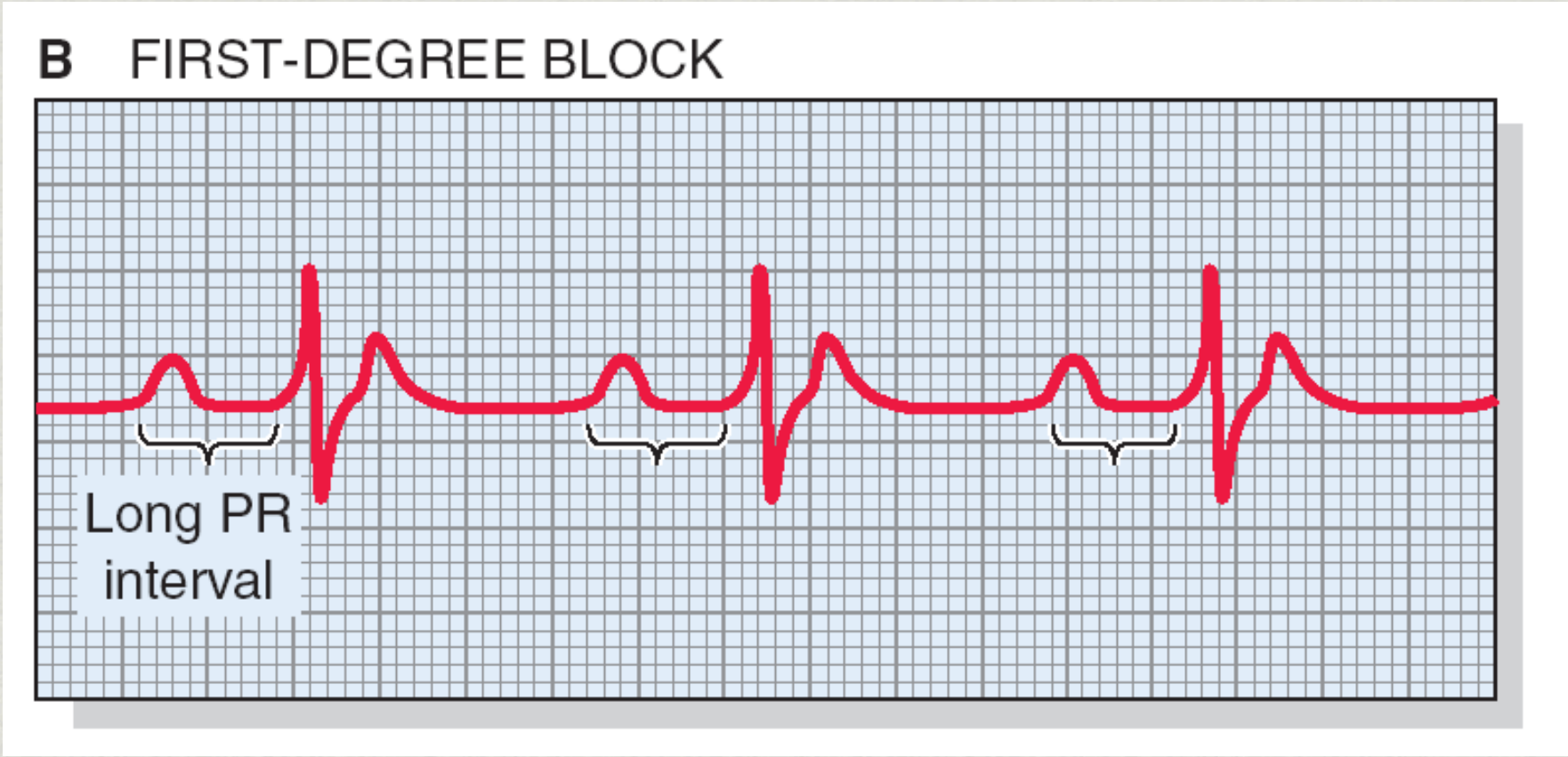
Atrioventricular (AV) Block

- Conduction between the atria and ventricles is altered
- Abnormality can be located anywhere in the AV node, His bundle, or bundle branches
- May result in either a partial or complete block

1st Degree AV Block

- Every atrial impulse conducts to the ventricles and a regular ventricular rate is produced
- PR interval exceeds 0.20 sec (5 boxes) in adults
- Almost always asymptomatic
- Etiology
  - Medications
  - Age
  - Increased vagal tone

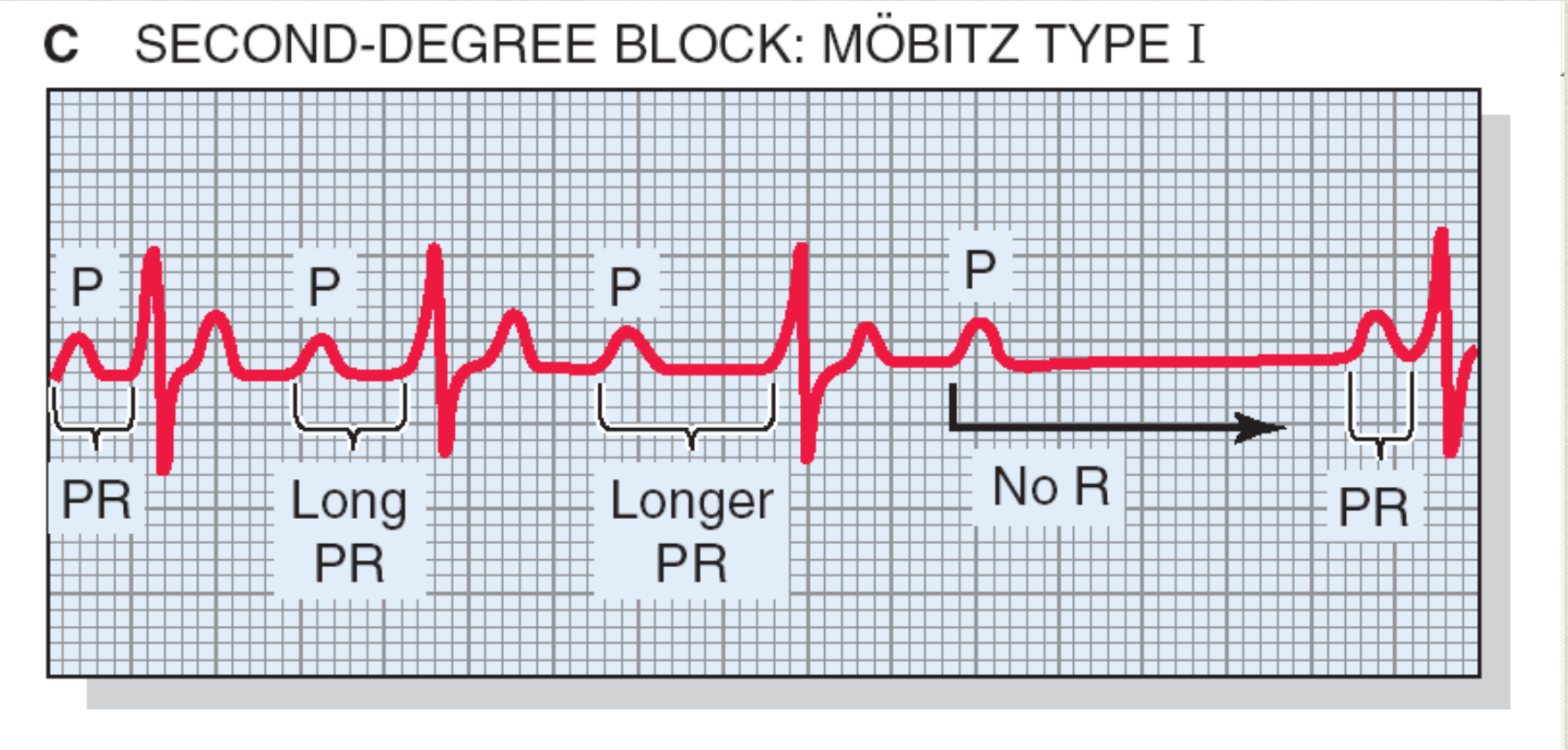
1st Degree AV Block



2nd Degree AV Block (Mobitz I- Wenckebach)

- Progressive prolongation of AV conduction (and the P-R interval) until an atrial impulse is completely blocked
- Conduction ratios are used to indicate the ratio of atrial to ventricular depolarizations
    - 3:2 indicates that two of three atrial impulses are conducted into the ventricles

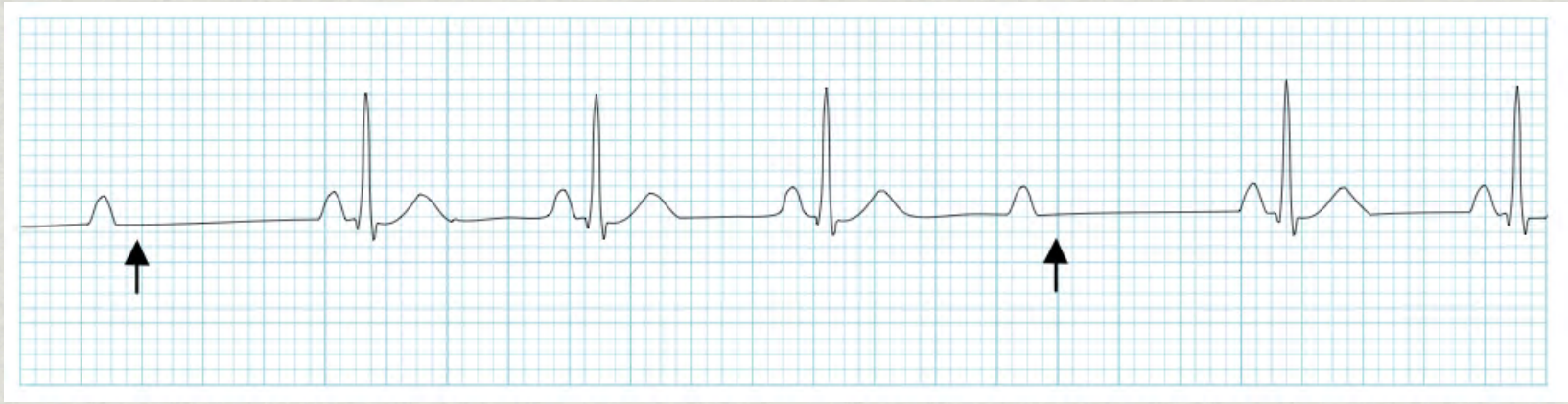
2nd Degree AV Block (Mobitz I- Wenckebach)



2nd Degree AV Block (Mobitz II)

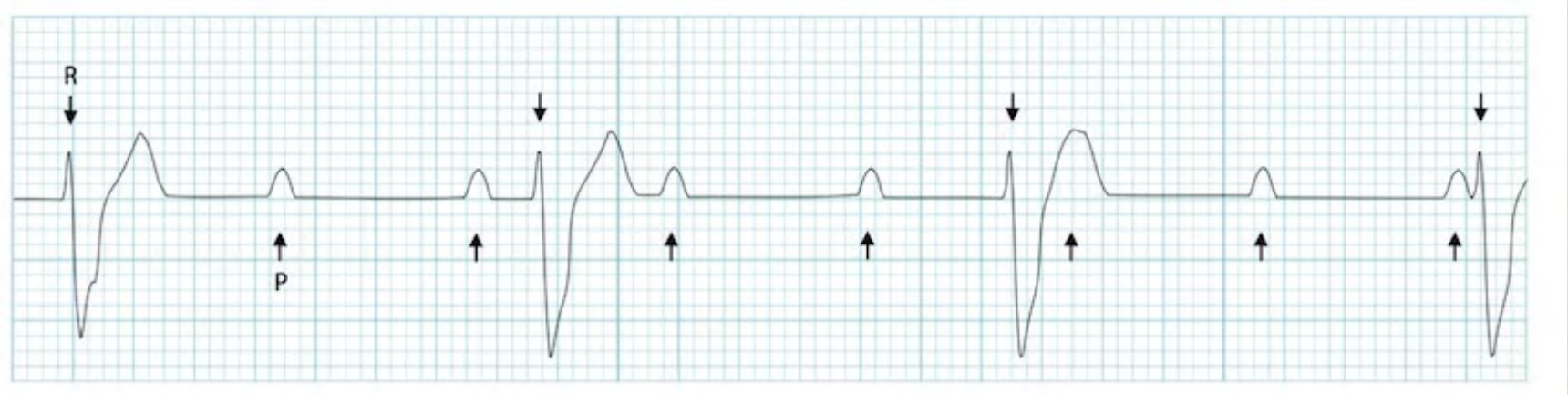
- P-R interval remains constant before and after the non-conducted atrial beats
- Usually occur in the infranodal conducting system
- Often have co-existing fascicular or BB blocks
- Often due to permanent structural defects in the infranodal conducting system
- May progress suddenly to complete heart block

2nd Degree AV Block (Mobitz II)



- RR interval surrounding the dropped beat(s) is an exact multiple of the preceding RR interval
- If there is 2:1 conduction, one cannot differentiate between Mobitz I and II

3rd Degree AV Block (Complete Heart Block)

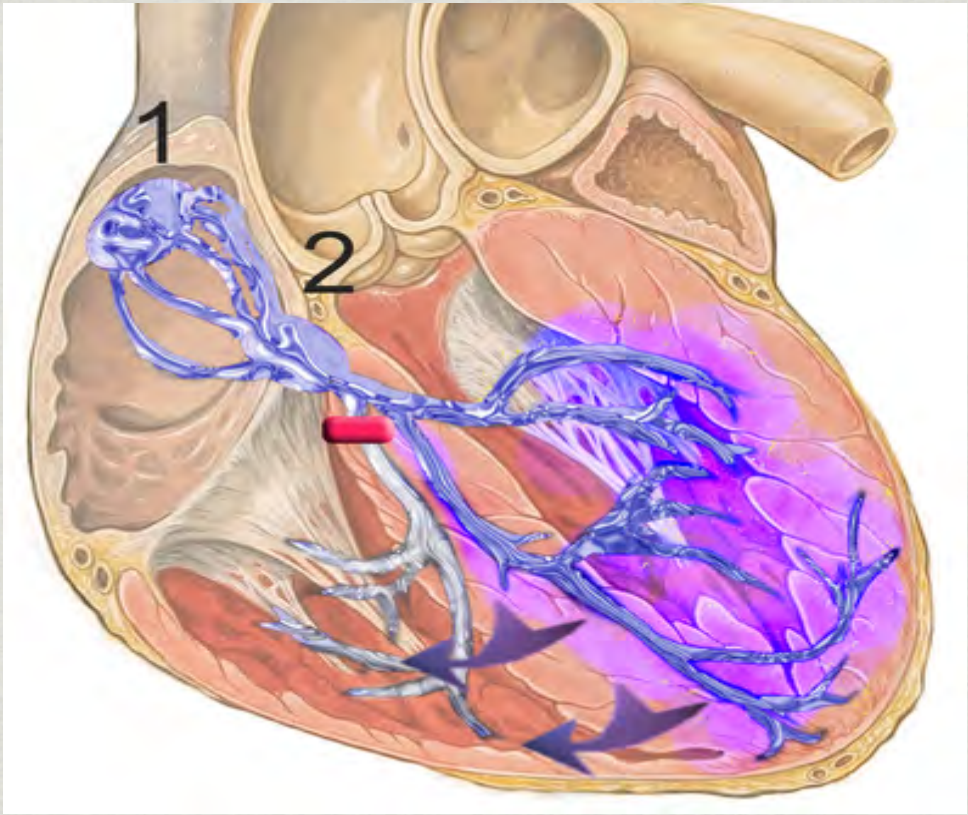


- Complete absence of AV conduction
- Perfusing rhythm is maintained by a junctional or ventricular escape rhythm
- Regular P-P intervals, R-R intervals
- Variable P-R intervals

AV Dissociation

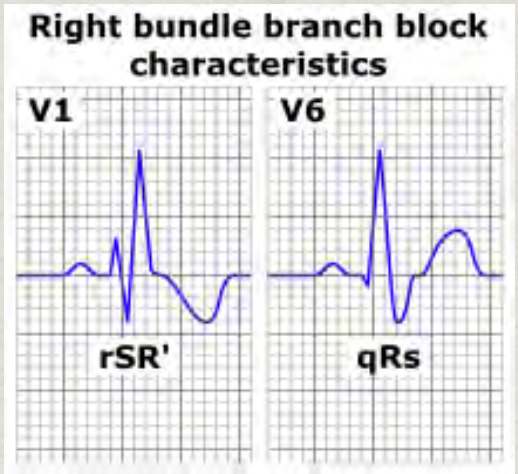
- Term indicates only the occurrence of independent atrial and ventricular contractions
  - Passive Type- default or "escape" like in third-degree AV block
  - Active Type- when the ventricular rhythm usurps control
- May be caused by entities other than complete heart block
  - Accelerated Idioventricular Rhythm
  - Ventricular Tachycardia

Right Bundle Branch Block

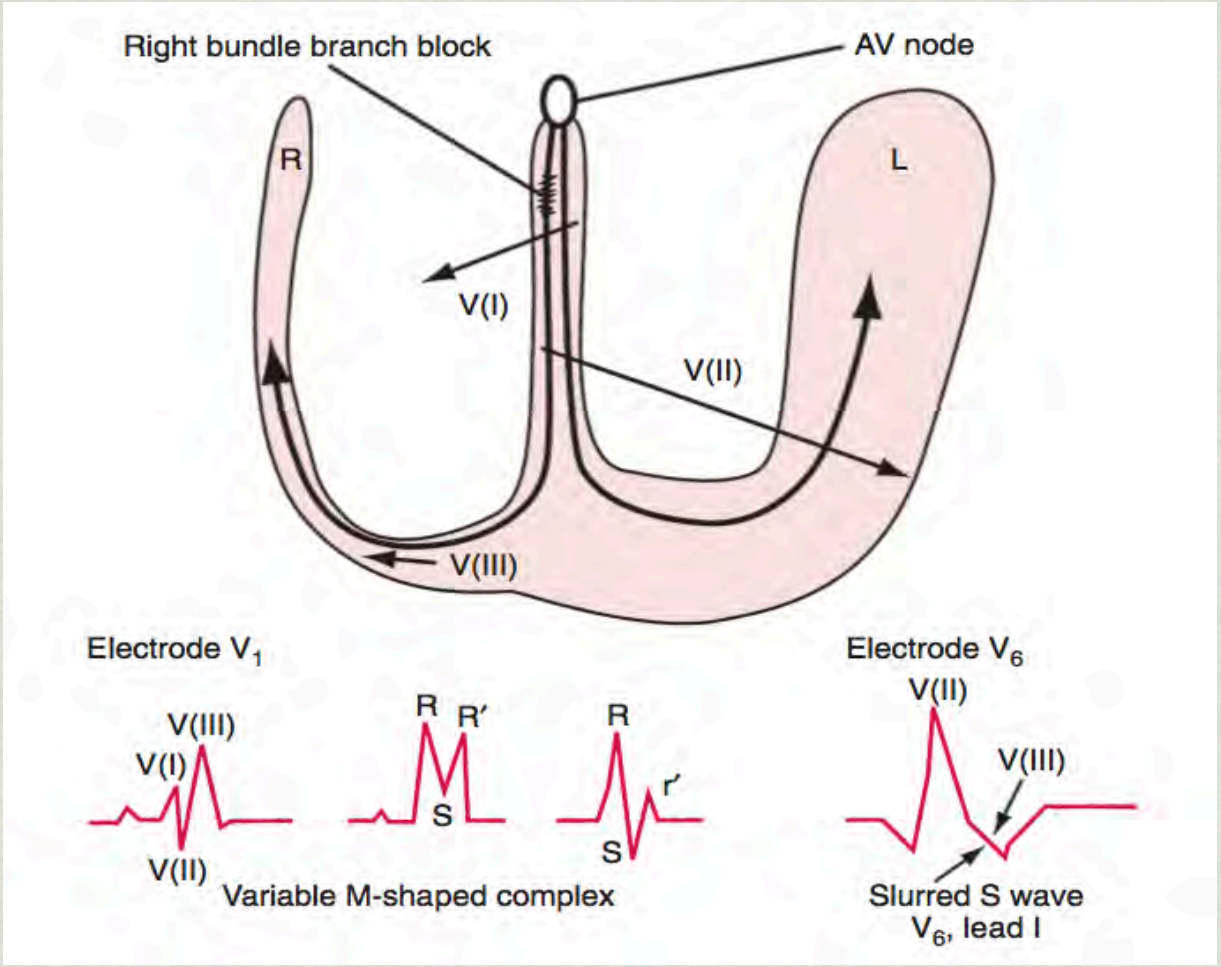


Right Bundle Branch Block

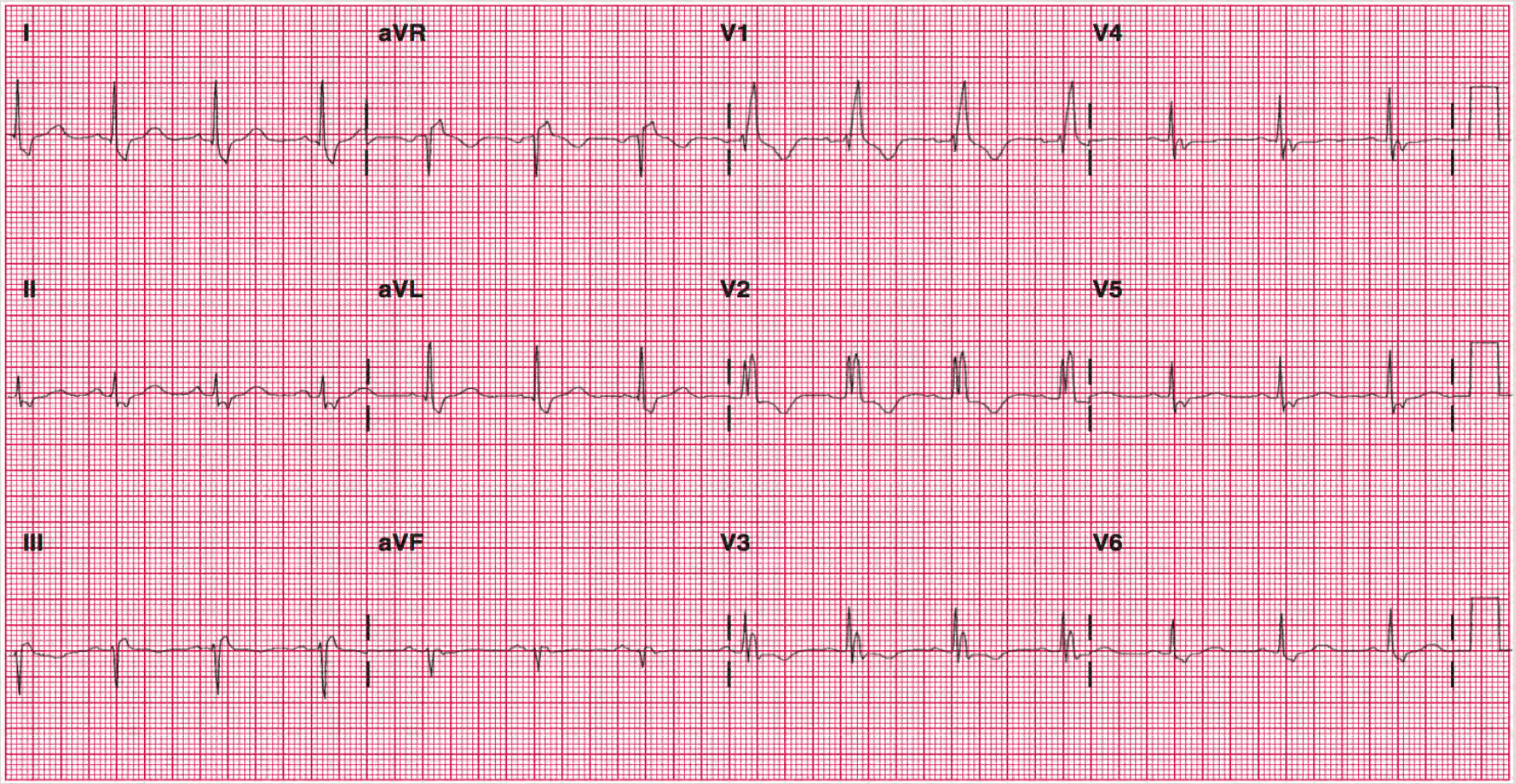
- Major Criteria
  - QRS ≥ 0.12 sec
  - Slurred S wave in leads I and V6
  - RSR’ pattern in V1
    - May get a QR’ pattern if there is previous anteroseptal infarct



Right Bundle Branch Block



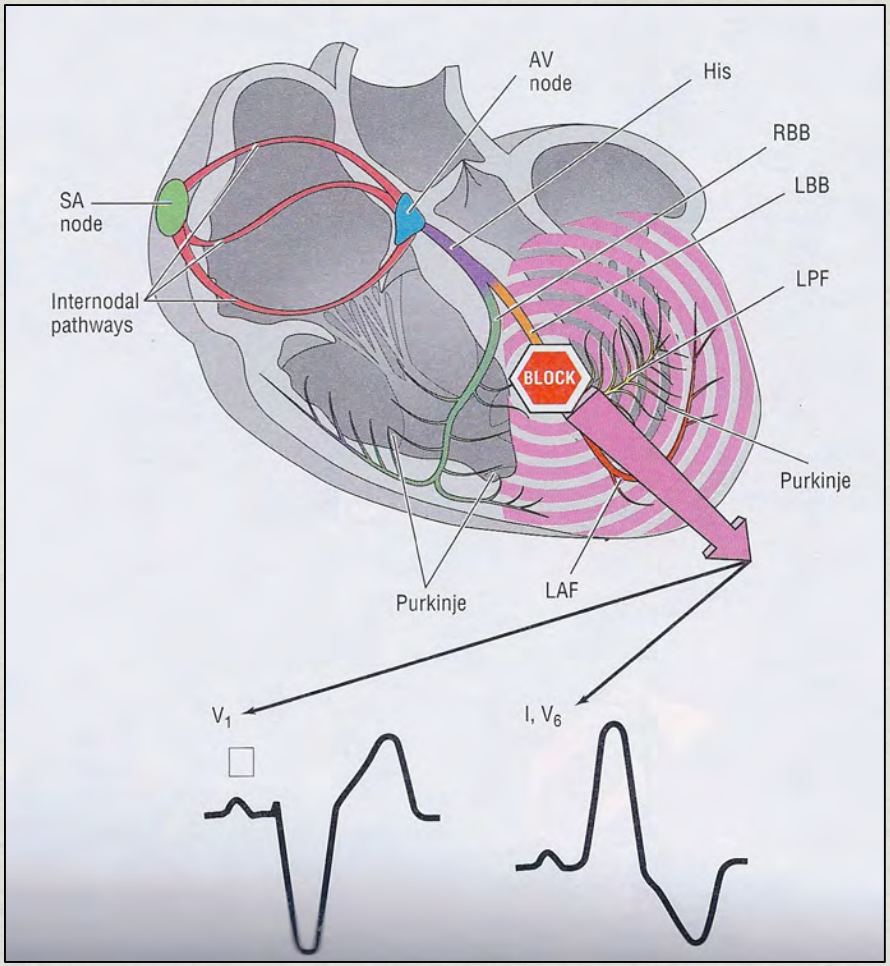
Right Bundle Branch Block



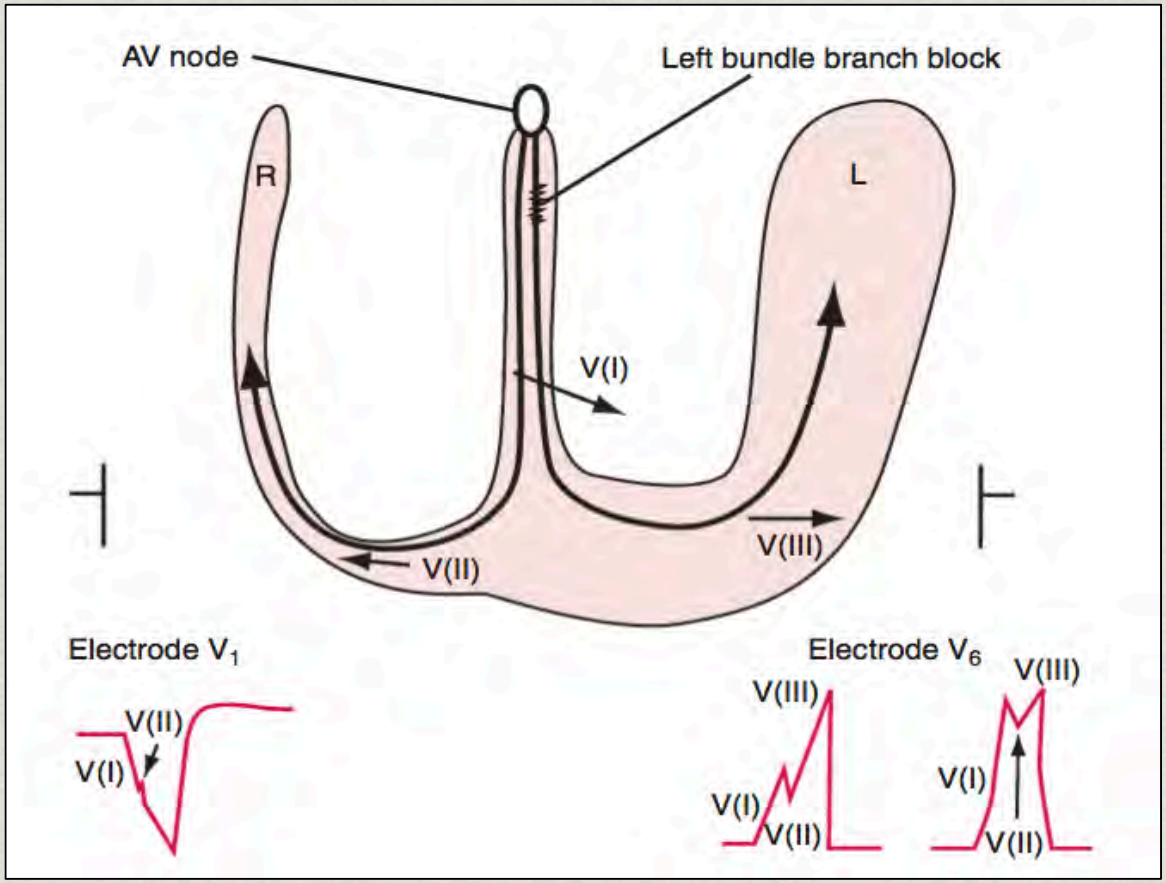
Left Bundle Branch Block

- Major Criteria
  - QRS ≥ 0.12 sec
  - Broad, monomorphic R waves in I and V6 with no Q waves
  - Broad, monomorphic S waves in V1
    - May have a small r wave

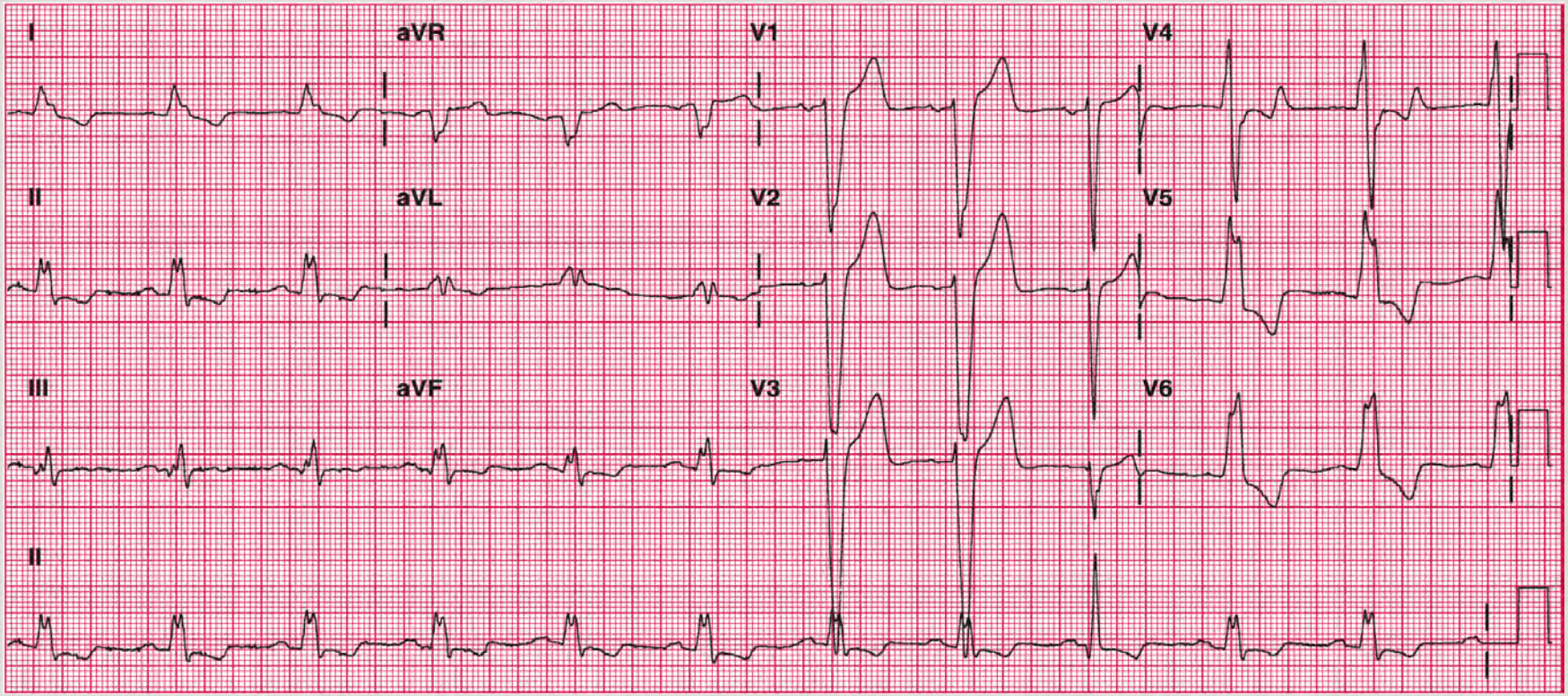
Left Bundle Branch Block



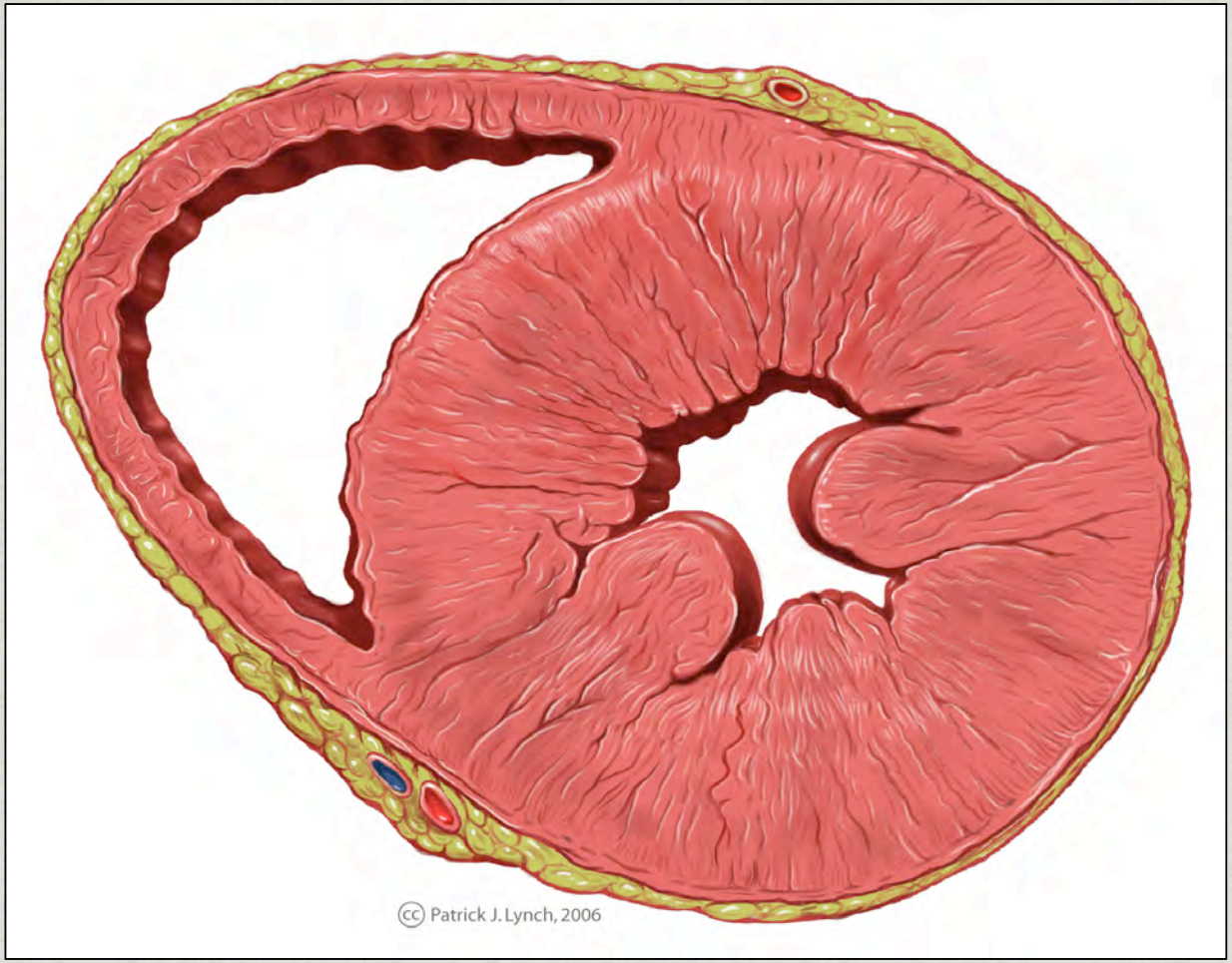
Left Bundle Branch Block



Left Bundle Branch Block

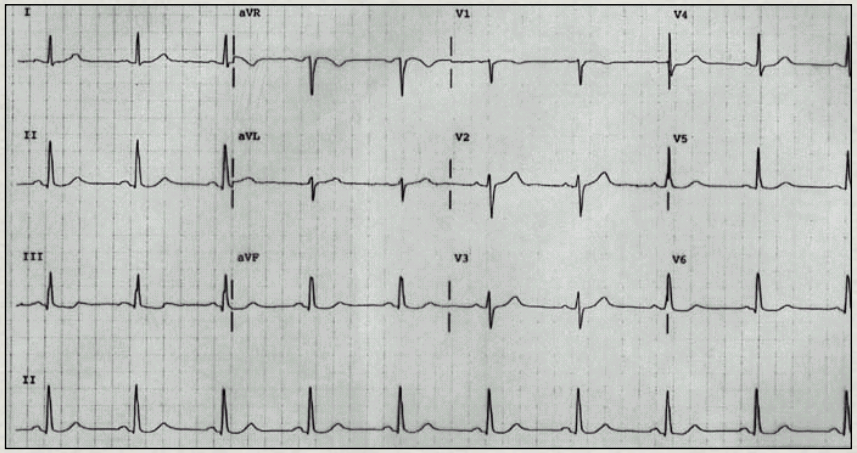


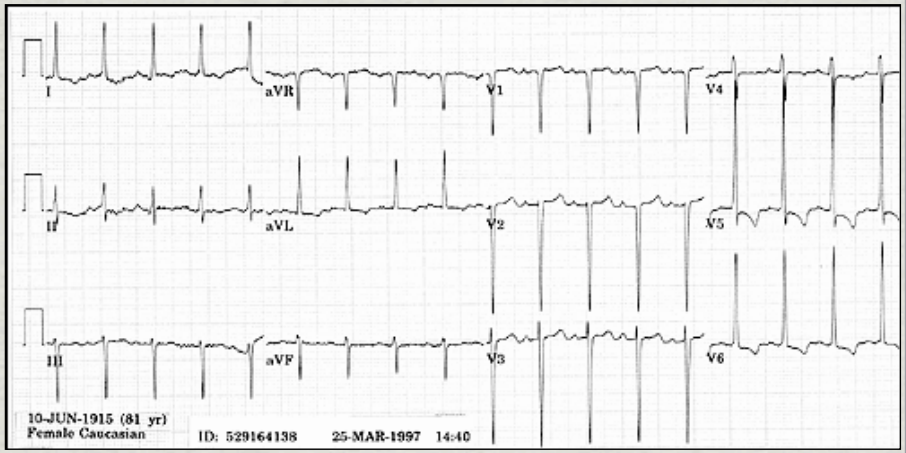
Left Ventricular Hypertrophy



Left Ventricular Hypertrophy

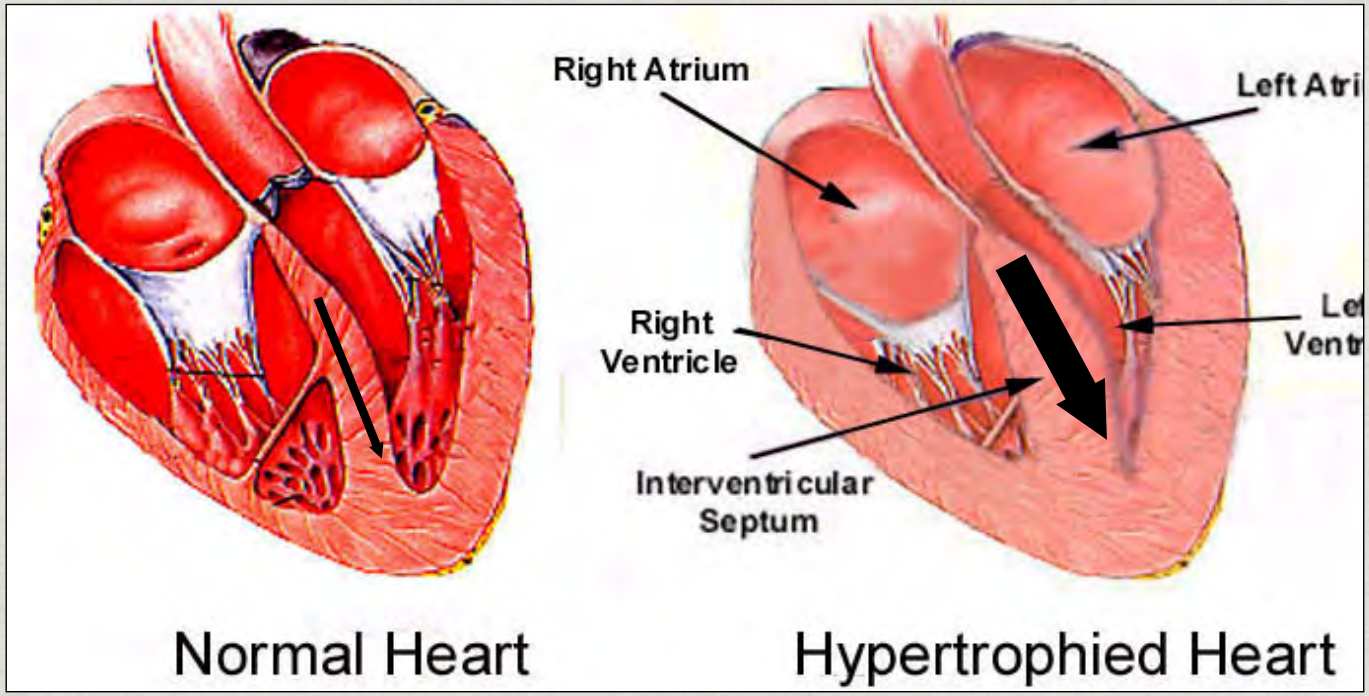
Compare these two 12-lead ECGs. What stands out as different with the second one?





Left Ventricular Hypertrophy

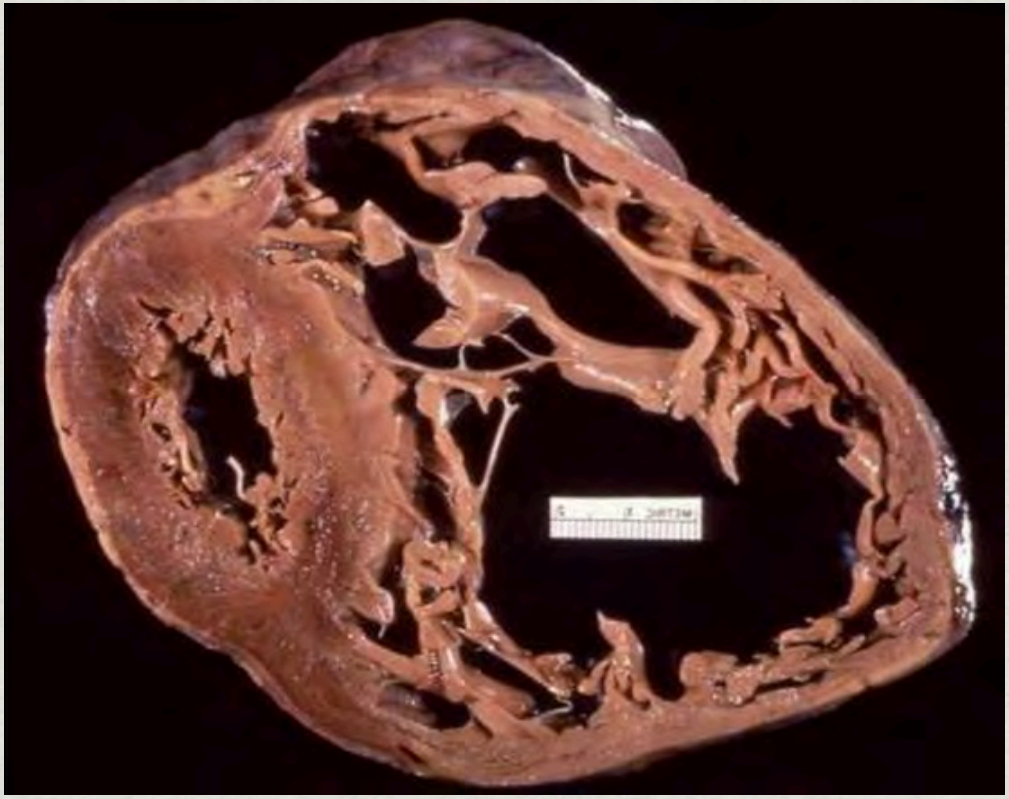
As the heart muscle wall thickens there is an increase in electrical forces moving through the myocardium resulting in increased QRS voltage



Criteria for LVH

Gubner-Ungerleider	1943	$R_I > 15$
		$R_I + S_{III} > 25$
Sokolow-Lyon	1949	$S_{V1} + R_{(V5 \text{ or } V6)} > 35$
		$R_{aVL} > 11$
Siegel	1982	Total 12-Lead voltage > 175
Murphy	1984	$S_{(V1 \text{ or } V2)} + R_{(V5 \text{ or } V6)} > 35$
Cornell (Casale)	1985	$S_{V3} + R_{aVL} > 28$ (♂) 20 (♀)

Right Ventricular Hypertrophy



Right Ventricular Hypertrophy

- Right Axis Deviation
- R > S in V1
- Deep S in left precordial leads
- Slight prolongation of QRS up to 120 msec
- Strain pattern in V1-3
- May have right atrial abnormality

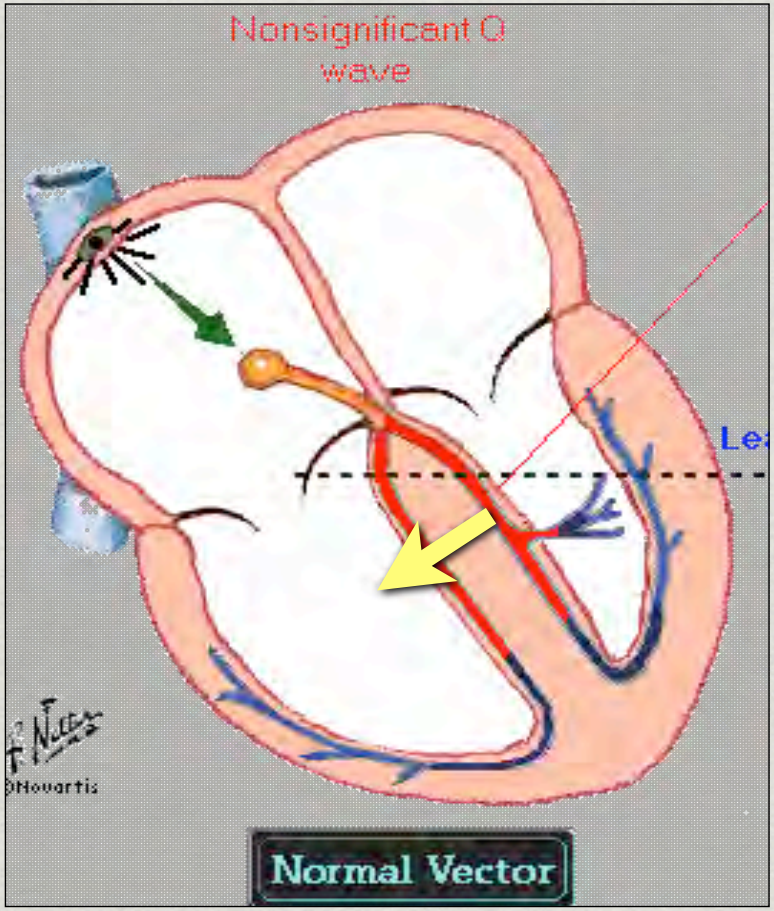
Causes of R > S in V1

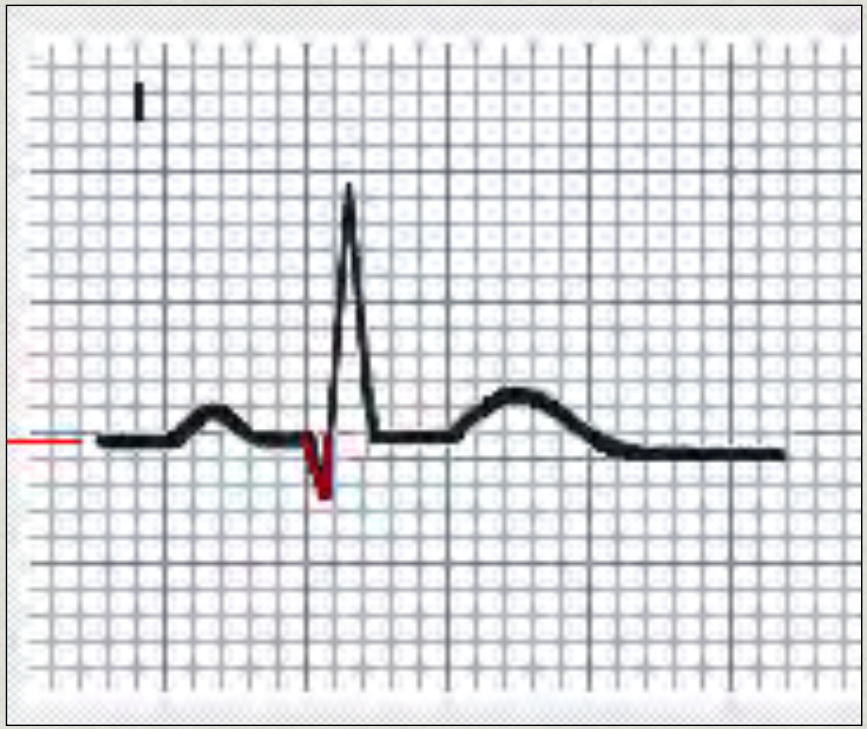
- Right Ventricular Hypertrophy
- True Posterior MI
- Lead Misplacement
- RBBB
- WPW Type A
- Normal variant

Q Waves

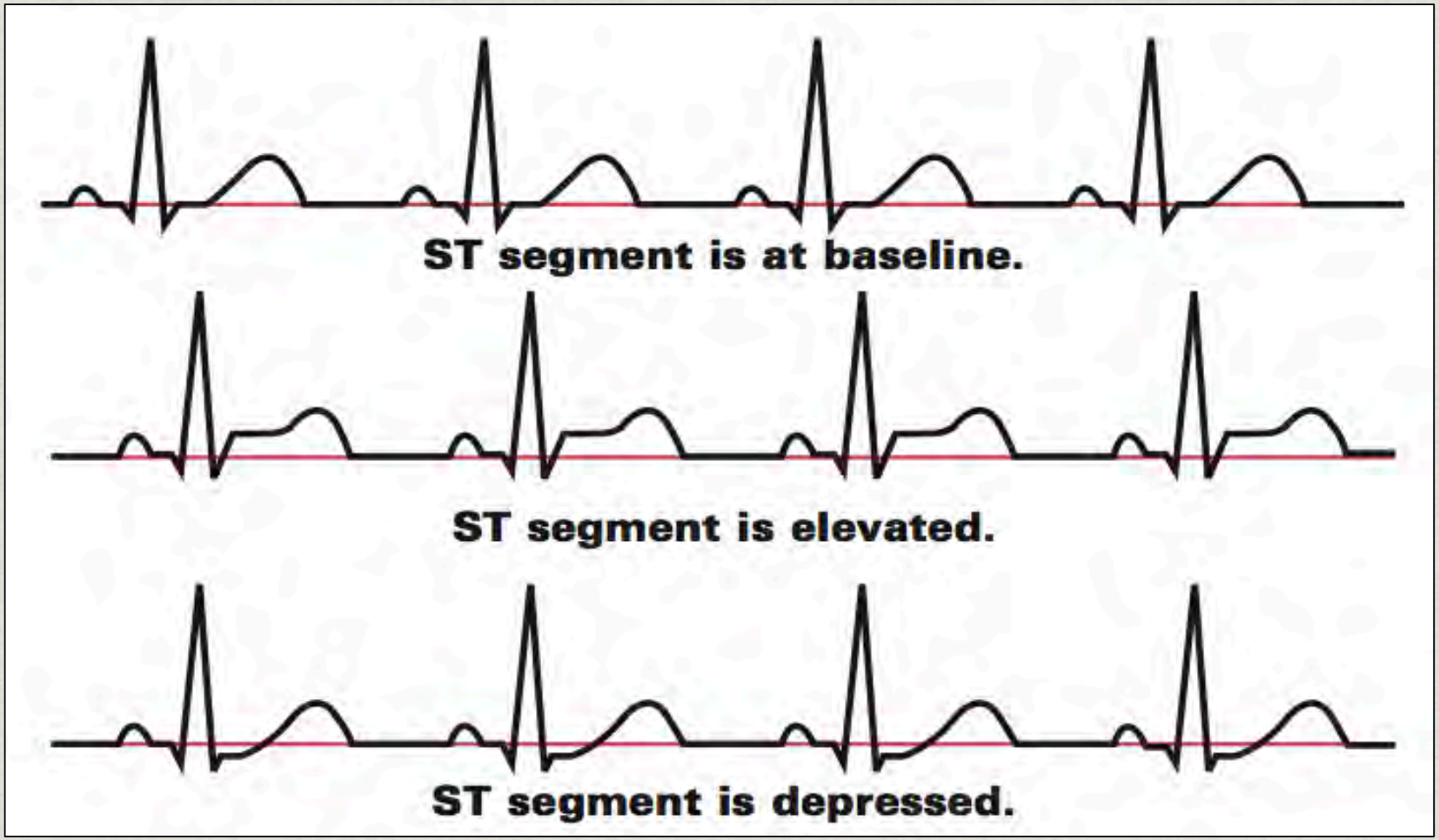
- Significant if:
  - More than 1/3 height of QRS
  - Wider than 0.03 sec
- Septal Qs (normal variant)
  - Result of initial depolarization occurring in the septum from left to right
  - Often found in left sided leads: I, aV_L and V6

Q Waves





ST Segment


ST segment is at baseline.
ST segment is elevated.
ST segment is depressed.

ST Segment Elevation

- ST elevation > 1 mm in limb leads and > 2 mm in chest leads indicates an evolving acute MI until proven otherwise.
- Other primary causes:
  - Early repolarization (normal variant)
  - Pericarditis
  - Ventricular aneurysm
  - Pulmonary embolism

STEMI Localization

Location of MI by ECG Leads

I lateral	aVR	V_1 septal	V_4 anterior
II inferior	aVL lateral	V_2 septal	V_5 lateral
III inferior	aVF inferior	V_3 anterior	V_6 lateral

ST Segment Depression

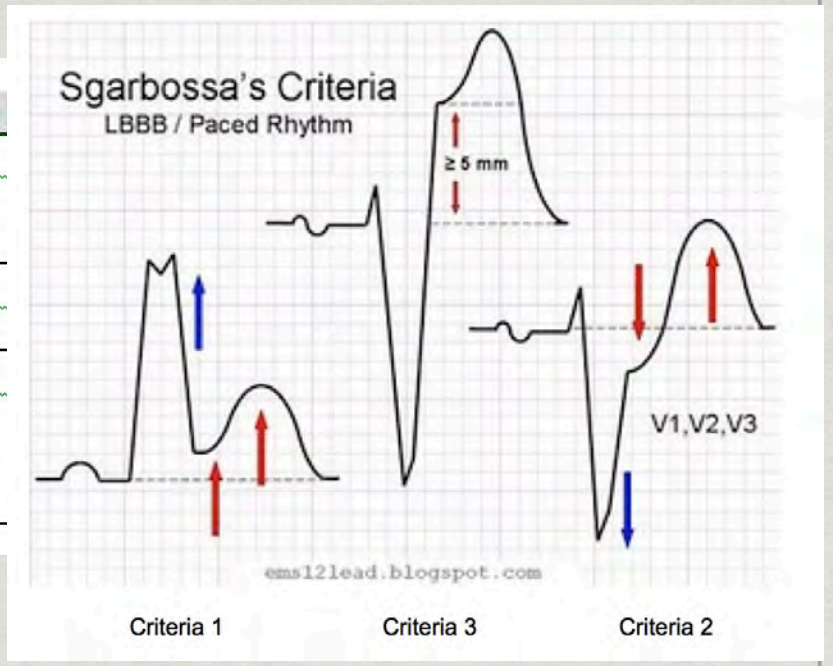
- Primary Causes
  - Myocardial Ischemia
  - LVH
  - Intraventricular conduction defects
  - Medication (digitalis)
  - Reciprocal changes in leads opposite area of acute MI

Sgarbossa Criteria

- For detecting an AMI in the setting of LBBB
- Derived from the GUSTO-1 trial
- Not perfect in screening for AMI. Use as another data point for risk-stratifying.
- Sgarbossa criteria hold true for LBBB pattern seen in pacemaker patients

Sgarbossa Criteria

Sgarbossa Criteria	Positive LR (95% CI)
1. ST elevation ≥ 1 mm concordant with QRS complex [Most predictive of AMI]	**9.54** (3.1-17.3)
2. ST depression ≥ 1 mm in lead V1, V2, or V3	**6.58** (2.6-16.1)
3. ST elevation ≥ 5 mm where discordant with QRS complex [Positive LR crosses 1.0 – may not be significant critieria]	**3.42** (0.18-6.5)

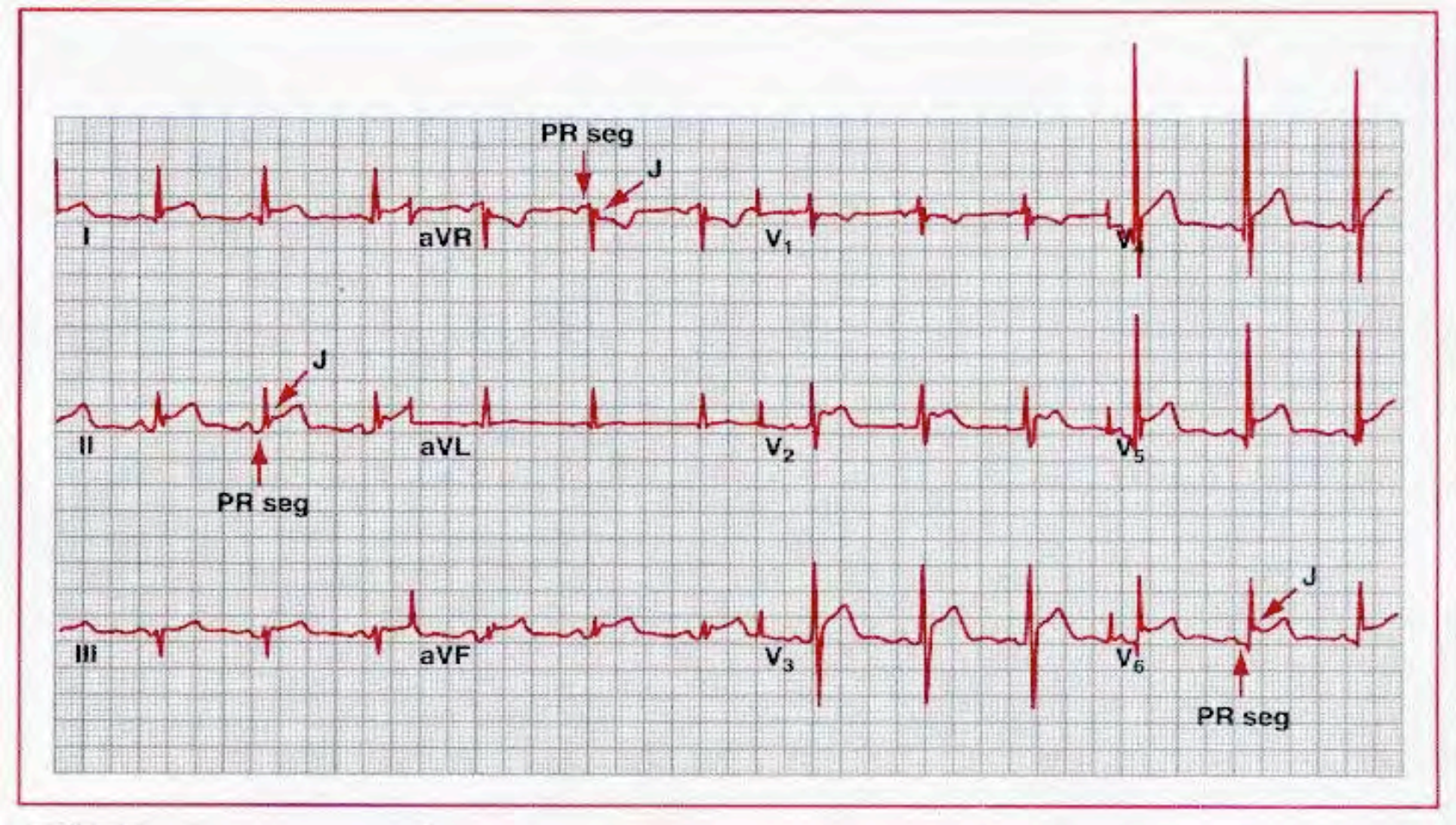


Pericarditis

Pericarditis

- Stage I
  - First few days → 2 weeks
  - ST elevation, PR depression
  - Up to 50% of pt with symptoms / rub do NOT have or evolve into stage I

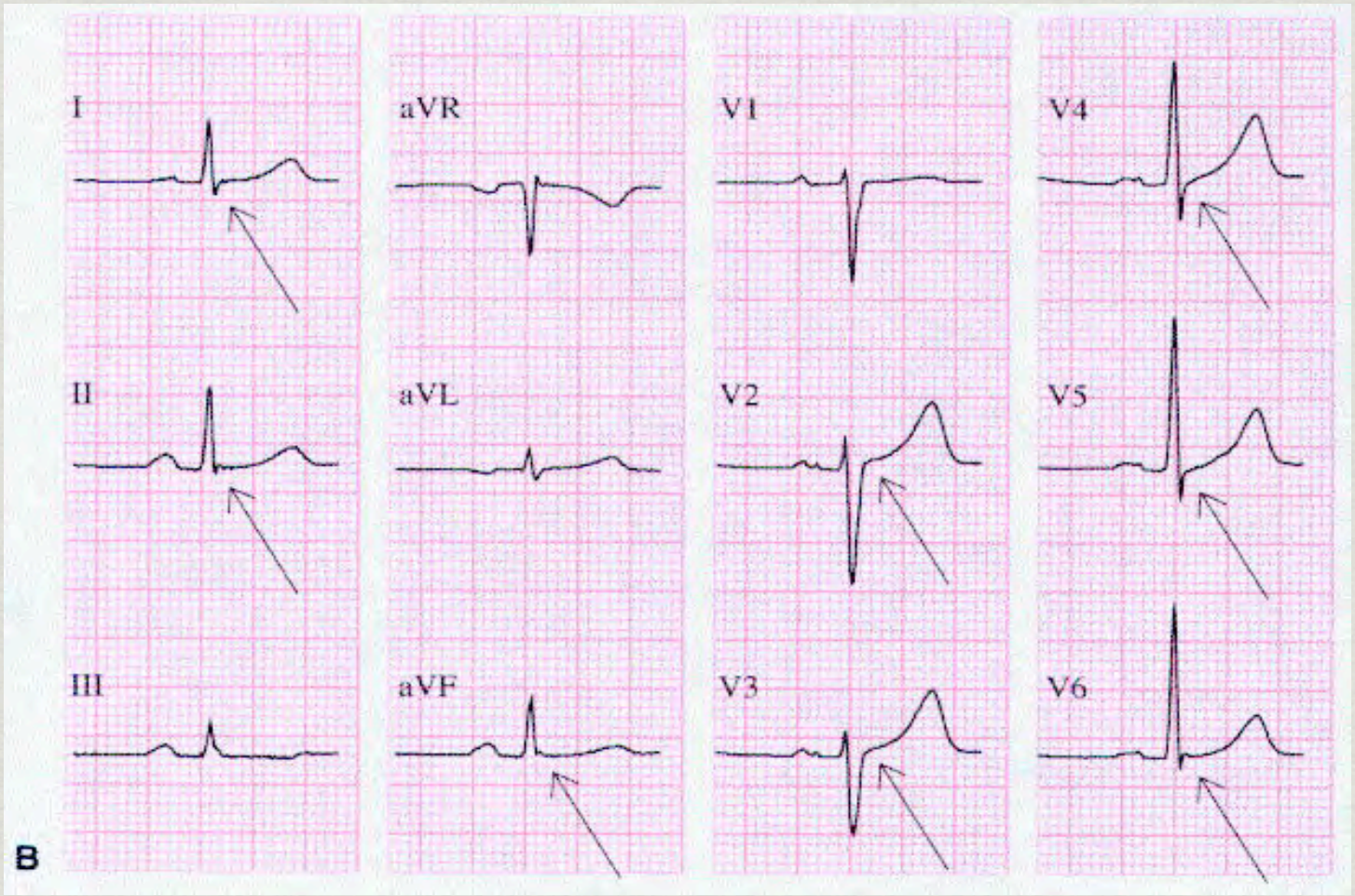
Pericarditis – Stage I



Pericarditis – Stage II

- Stage II
  - Lasts days → weeks
  - Normalization of ST and PR segments
  - ST returns to baseline, flat T waves

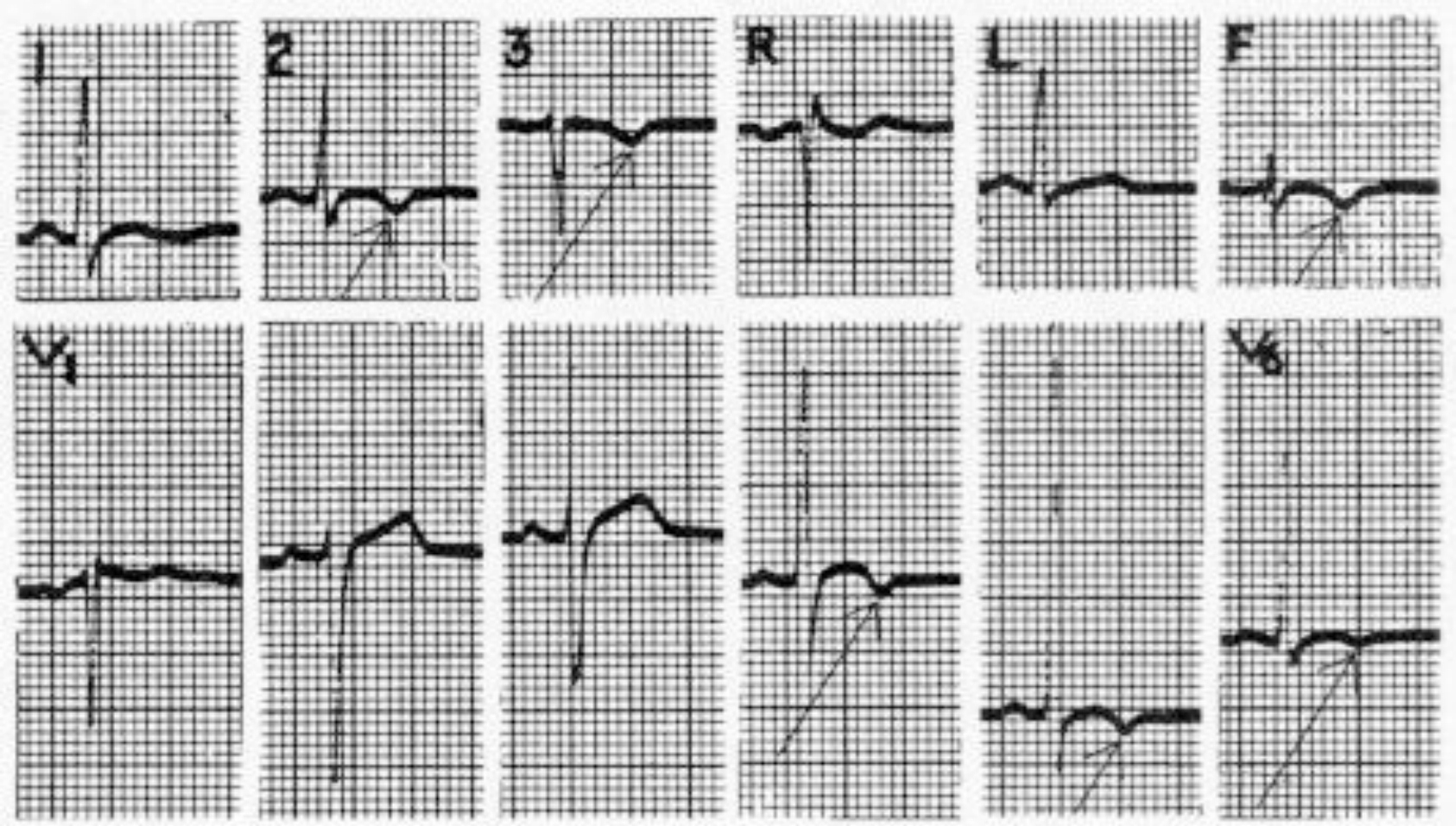
Pericarditis – Stage II



Pericarditis – Stage III

- Stage III
  - Begins after 2-3 weeks, lasts several weeks
  - Widespread T wave inversion

Pericarditis – Stage III



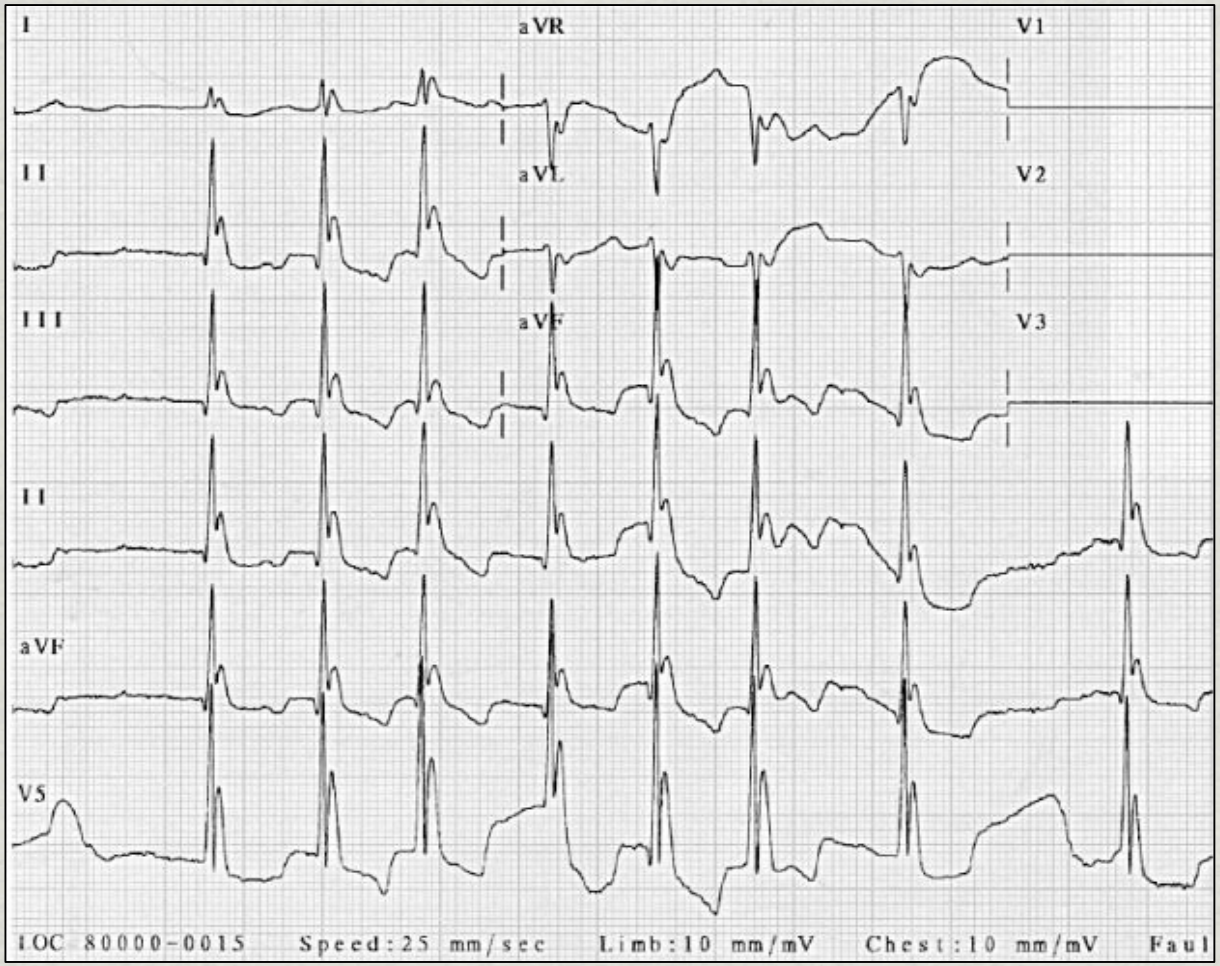
Pericarditis – Stage IV

- Stage IV
  - Lasts up to several months
  - Gradual resolution of T wave changes

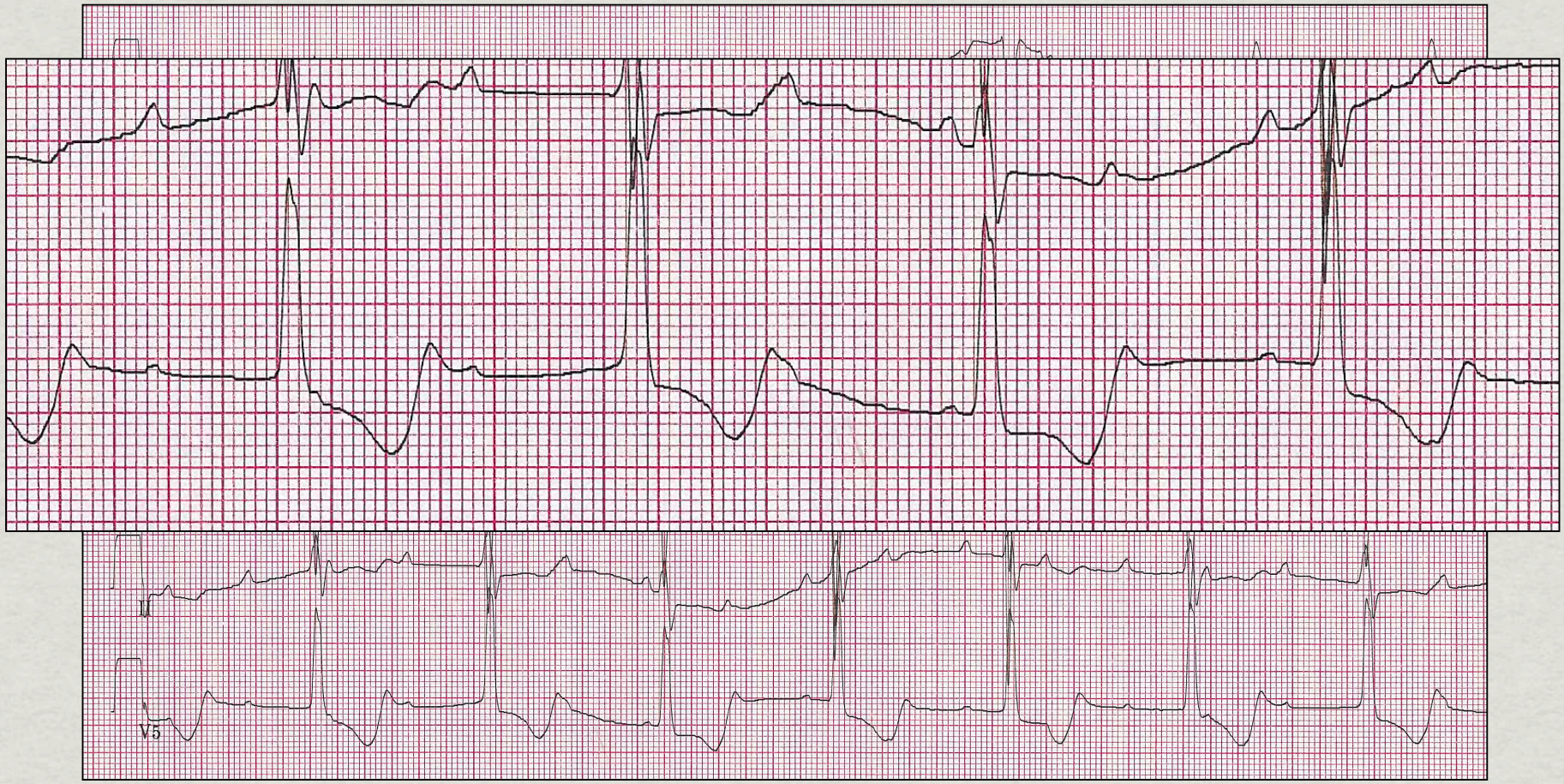
Osborn Waves

- Positive deflections occurring at the junction between the QRS complex and the ST segment, the J point, has a myocardial infarction-like elevation
- Associated with hypothermia

Osborn Waves



Last night....



Questions?