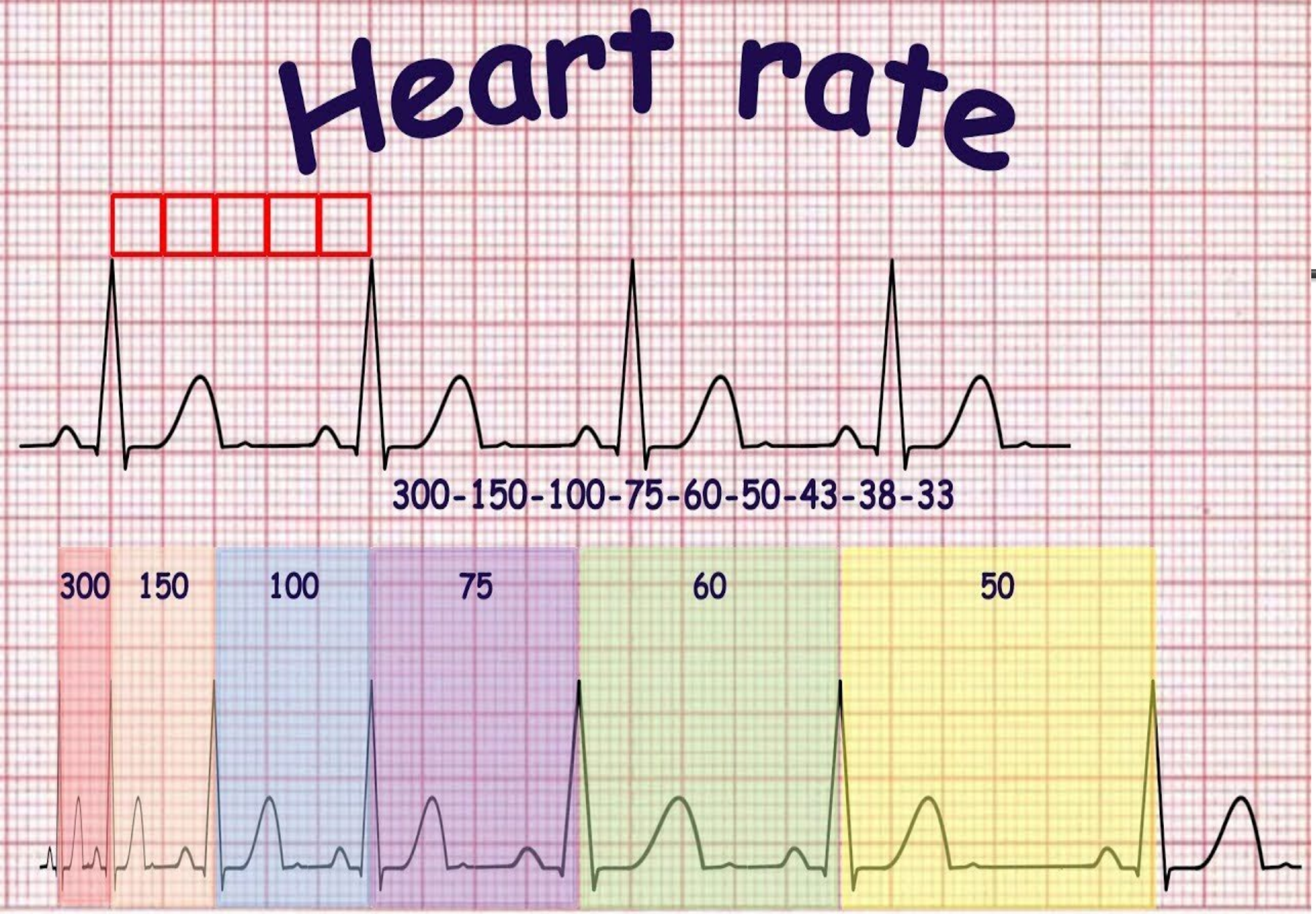


EKG
The normal and abnormal
2024 UPDATE

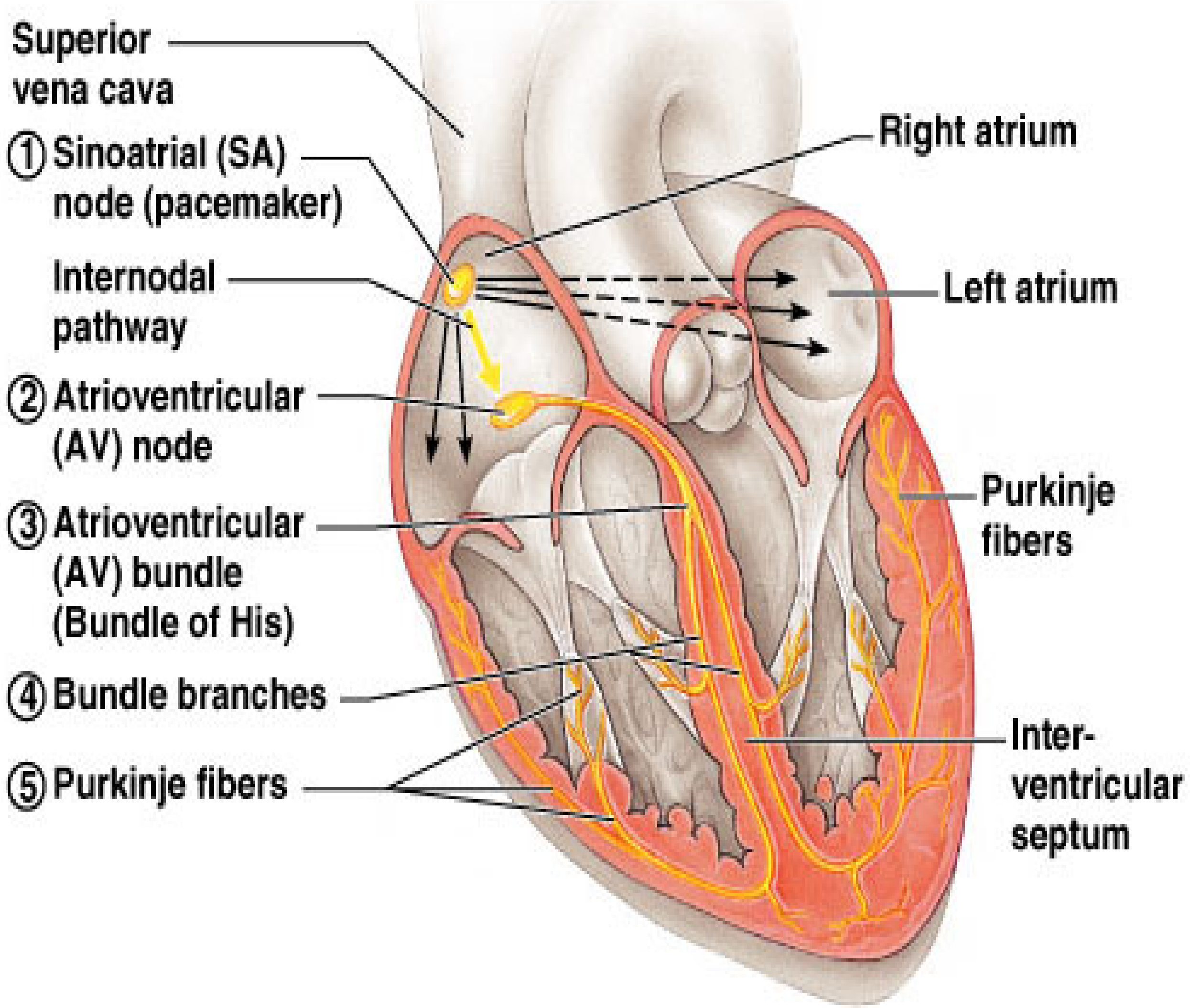
D.HAMMOUDI .MD

The Cardiac Cycle

- Heart at rest
  - Blood flows from large veins into atria
  - Passive flow from atria into ventricles
- Atria (R & L) contract simultaneously
  - Blood forced into ventricles
- Ventricles (R & L) contract simultaneously
  - Atrioventricular valves close → "lubb" sound
  - Blood forced into large arteries
- Ventricles relax
  - Semilunar valves close → "dub" sound
- Heart at rest

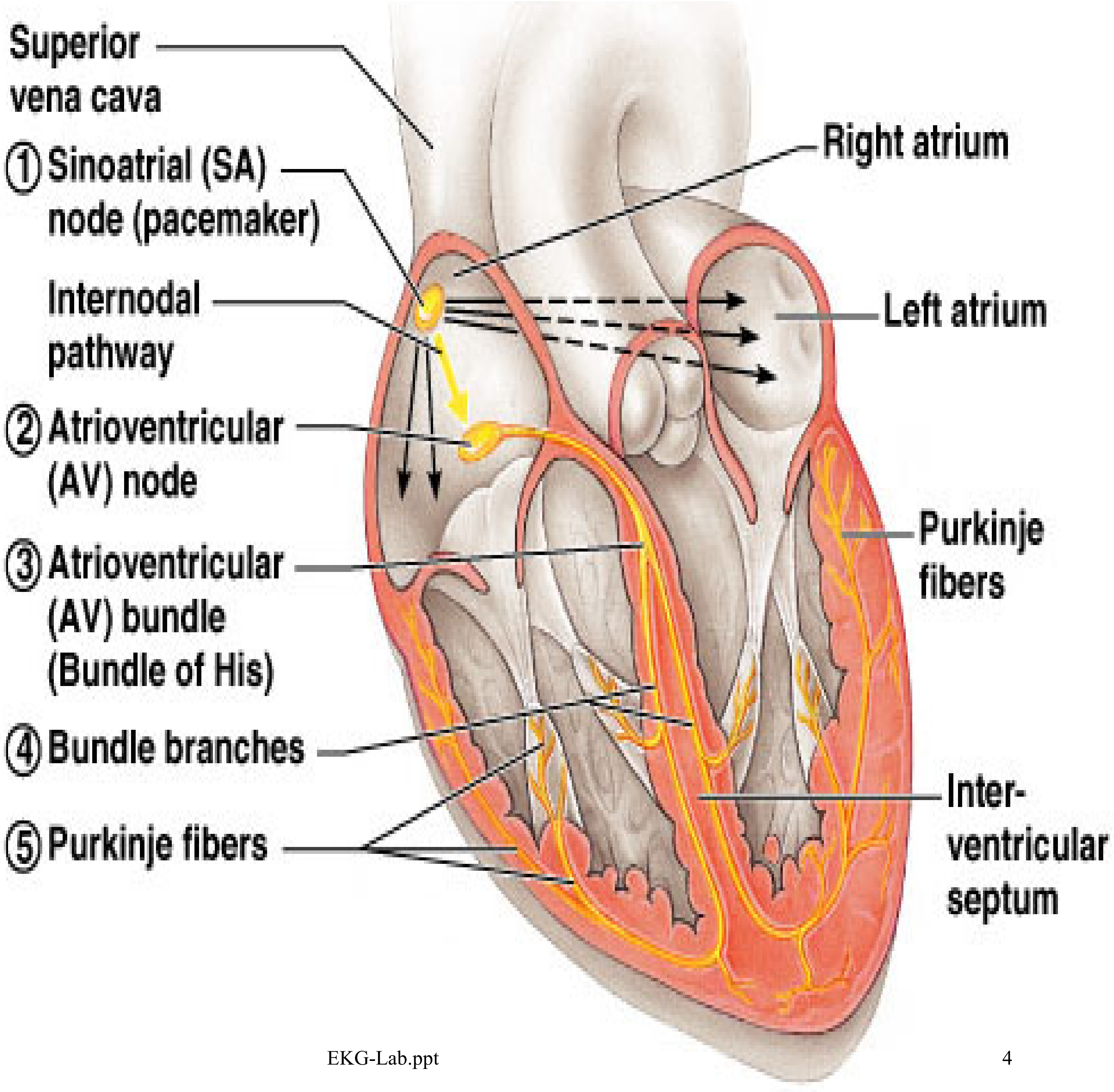
Depolarization and Impulse Conduction

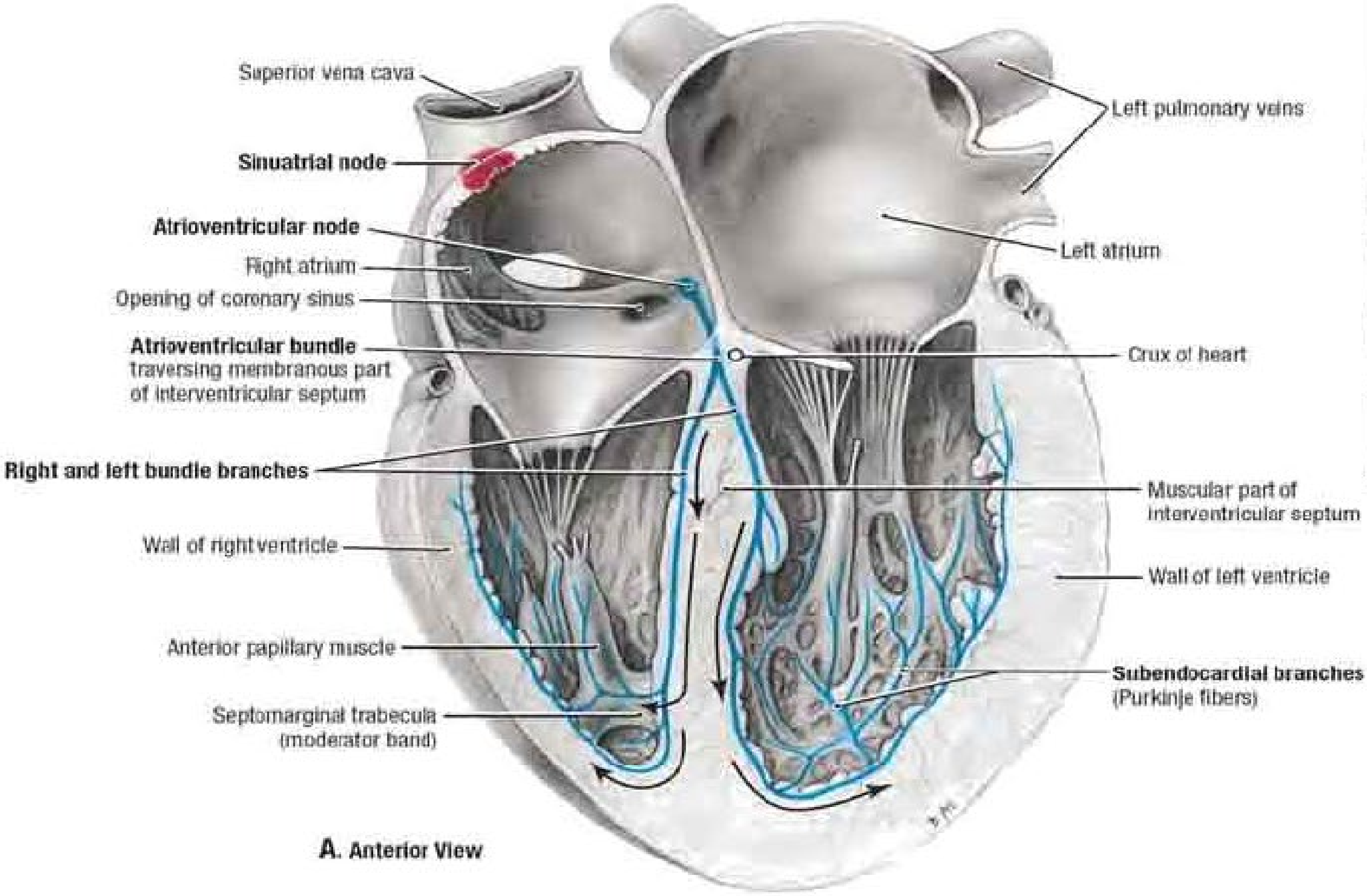
- Heart is autorhythmic
- Depolarization begins in sinoatrial (SA) node
- Spread through atrial myocardium
- Delay in atrioventricular (AV) node



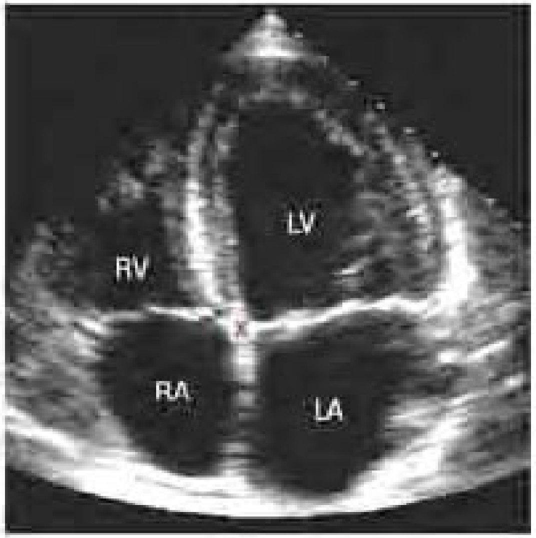
Depolarization and Impulse Conduction

- Spread from atrioventricular (AV) node
  - AV bundle
  - Bundle branches
  - Purkinje fibers



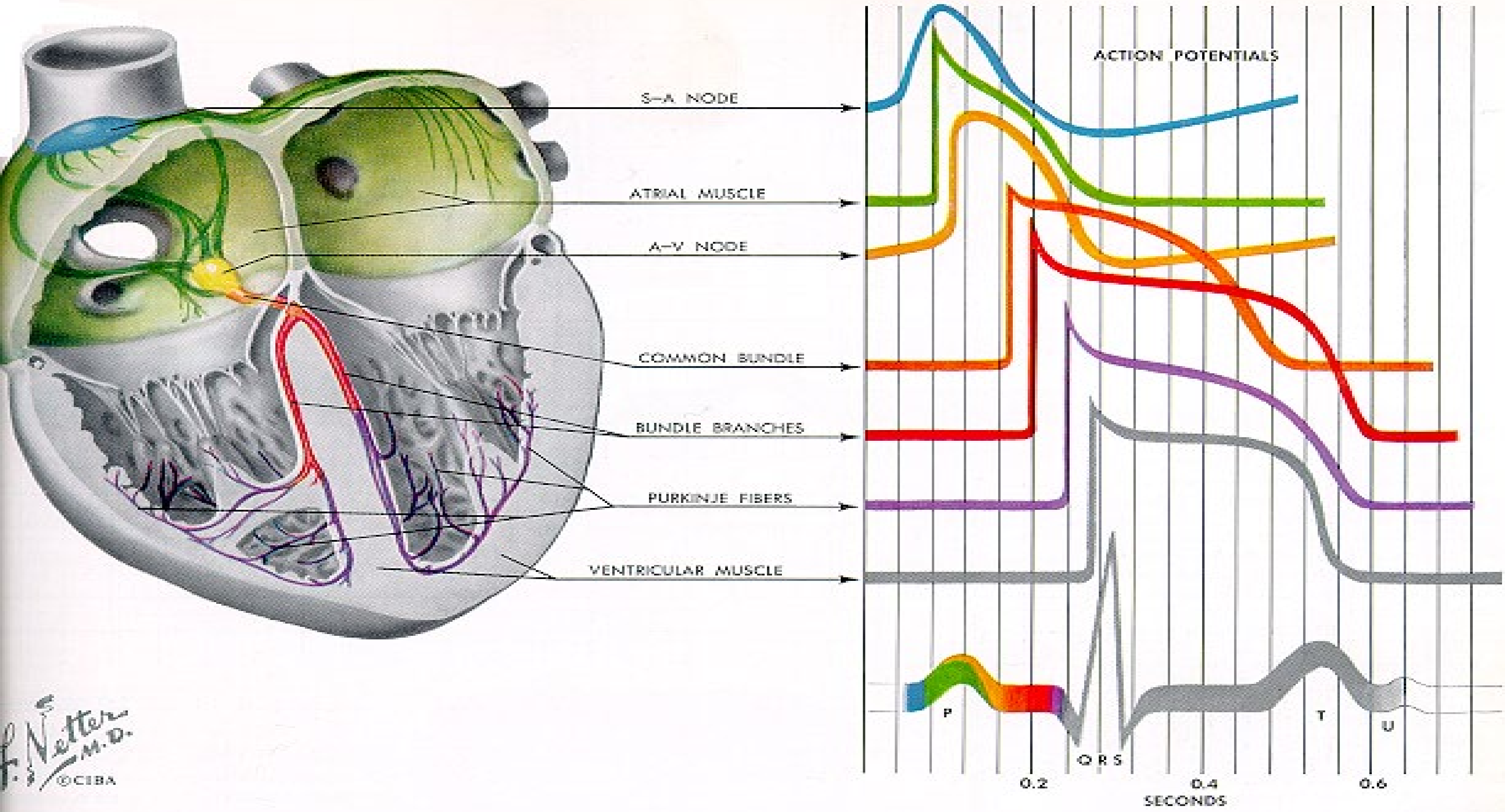


A. Anterior View



B. Echocardiogram, Apical Four-chamber View

RV	Right ventricle	LV	Left ventricle
	x Crux of heart		
RA	Right atrium	LA	Left atrium



ACTION POTENTIALS
S–A NODE
ATRIAL MUSCLE
A–V NODE
COMMON BUNDLE
BUNDLE BRANCHES
PURKINJE FIBERS
VENTRICULAR MUSCLE
P
QRS
T
U
0.2
0.4
0.6
SECONDS
F. Netter M.D.
©CIBA

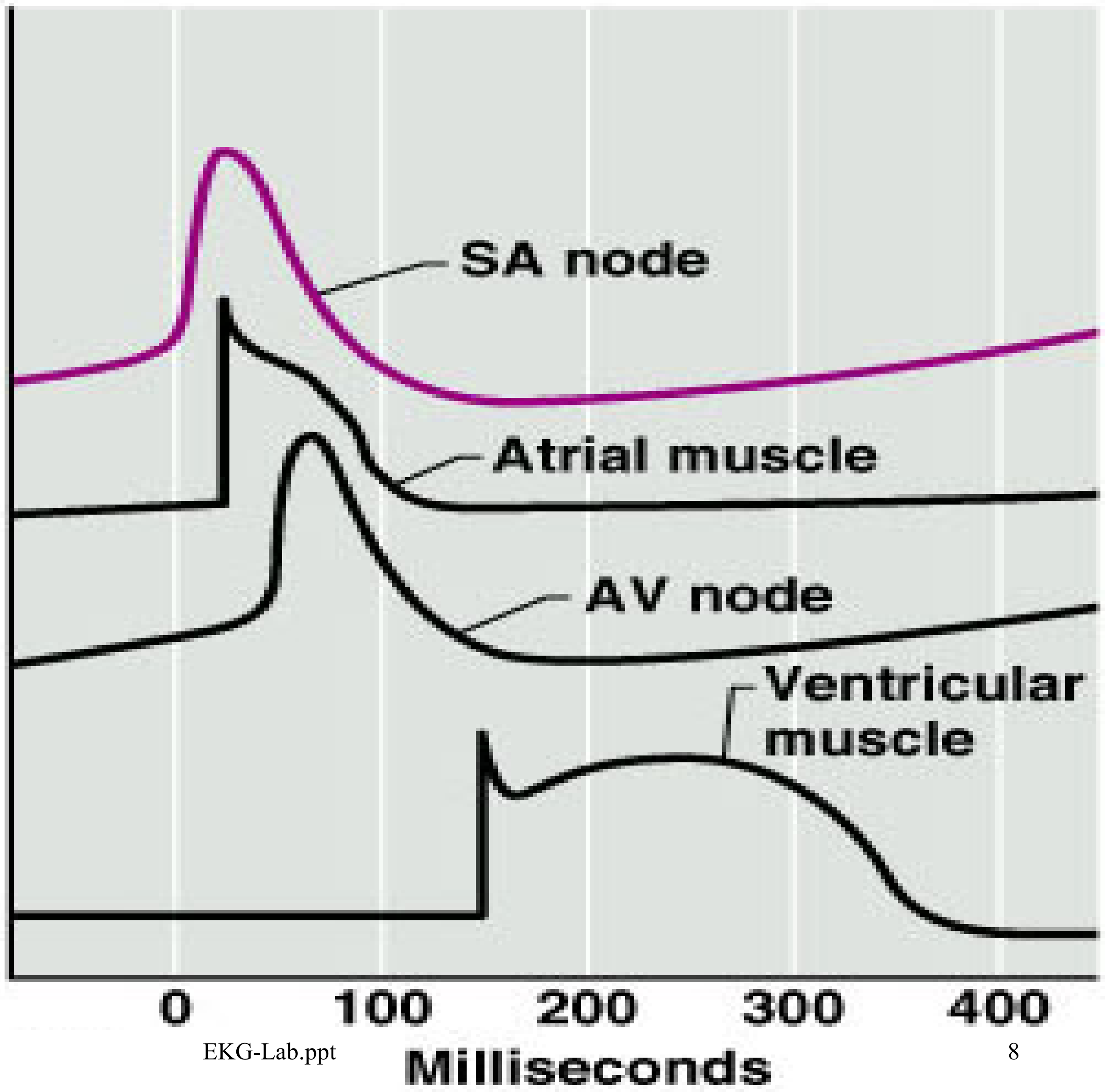
Arrhythmia Formation

Arrhythmias can arise from problems in the:

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

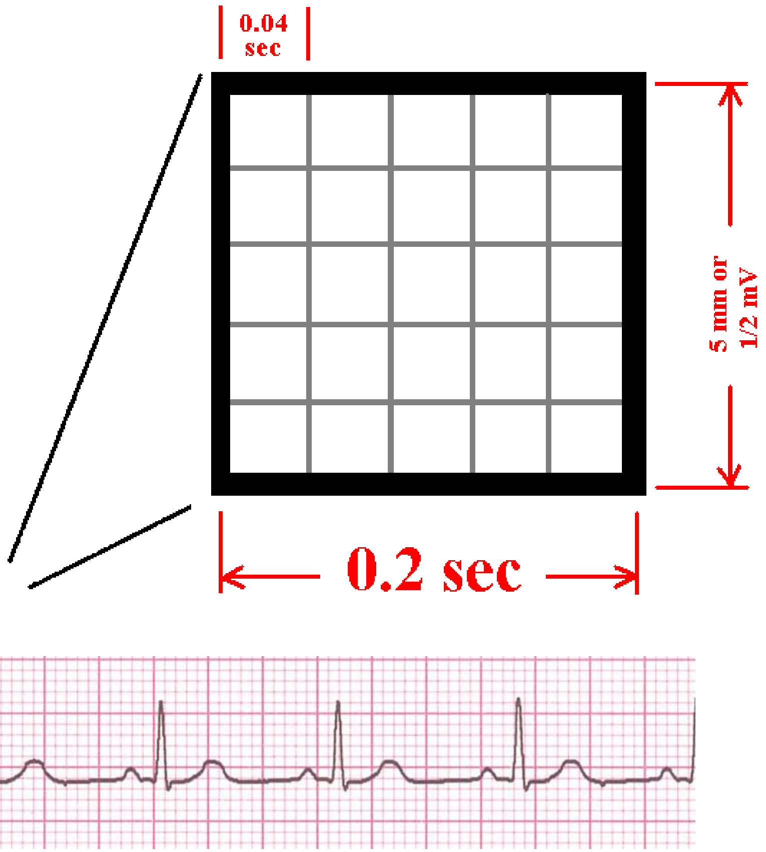
Depolarization and Impulse Conduction

- Depolarization in SA node precedes depolarization in atria, AV node, ventricles

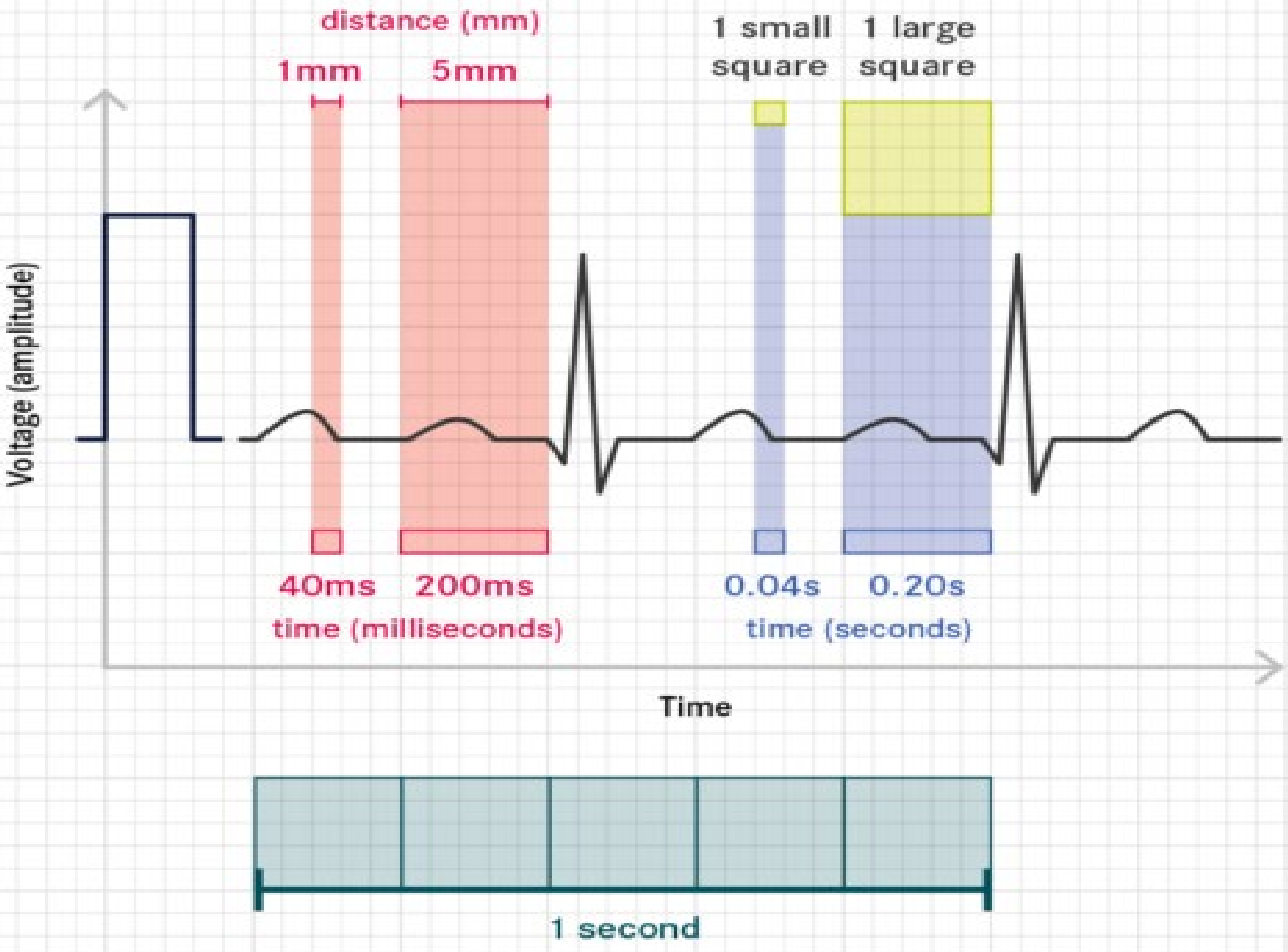


The ECG Paper

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



Understanding an ECG



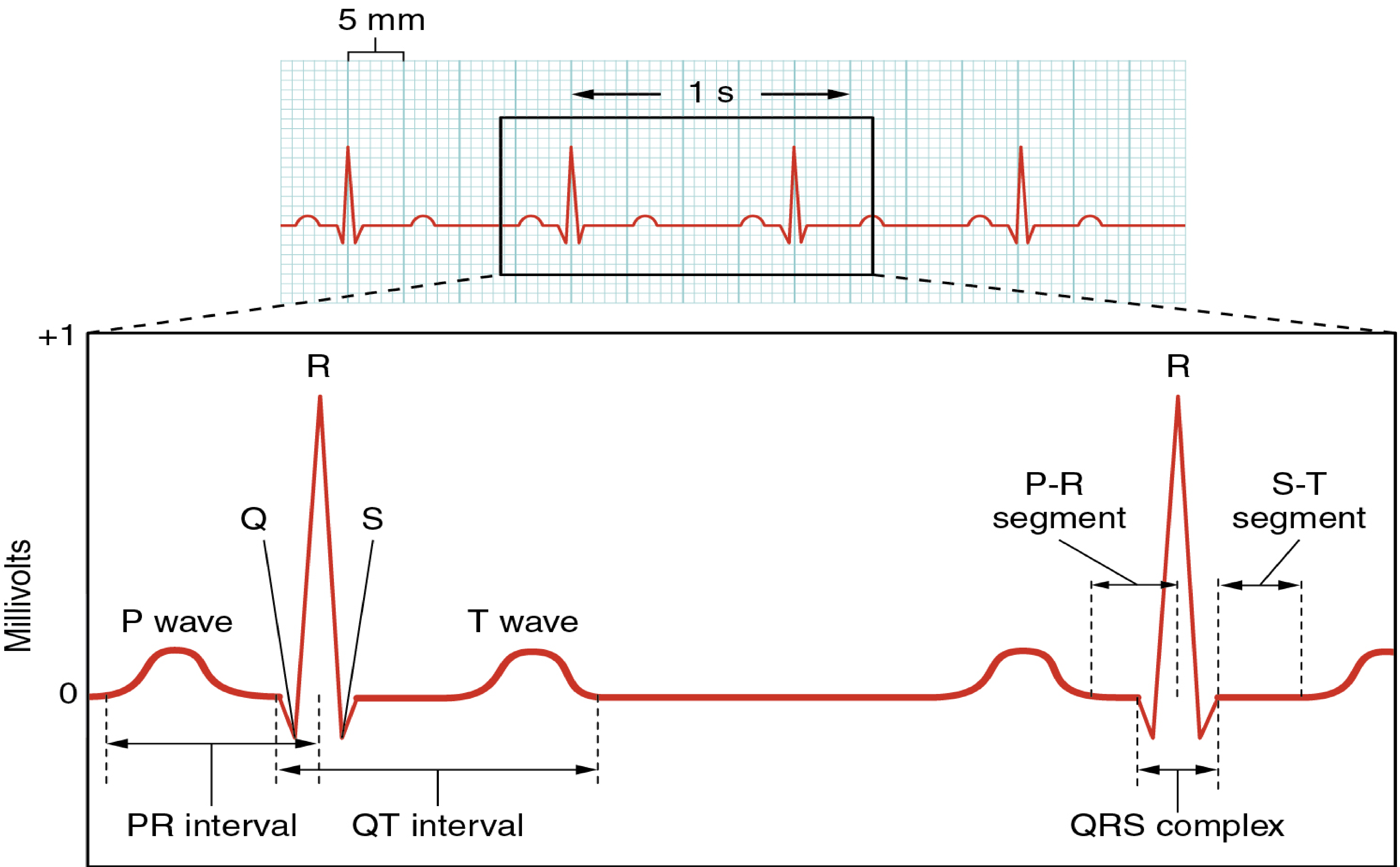
Standard calibrations: 25 mm/sec 10 mm/mV

https://seermedical.com/blog/calculate-heart-rate-ecg#:~:text=Simply%20identify%20two%20consecutive%20R,squa[illegible]ween%20consecutive%20R%20waves.

QRS Interval: measures 2 small squares (2 mm) which represents a QRS interval of 0.08 seconds. *The normal QRS interval is <0.12 seconds.*

PR Interval: measures 4 small squares (4mm) which represents a PR interval of 0.16 seconds. *The normal PR interval is <0.2 seconds.*

QT Interval: measures 9 small squares (9 mm) which represents a QT interval of 0.36 seconds. The normal QT interval is rate dependent, and reported as a corrected QT interval. Corrected QT interval = (observed QT interval) / (square root of RR interval). *In general the QT interval is normal when it is less than half of the RR interval.*



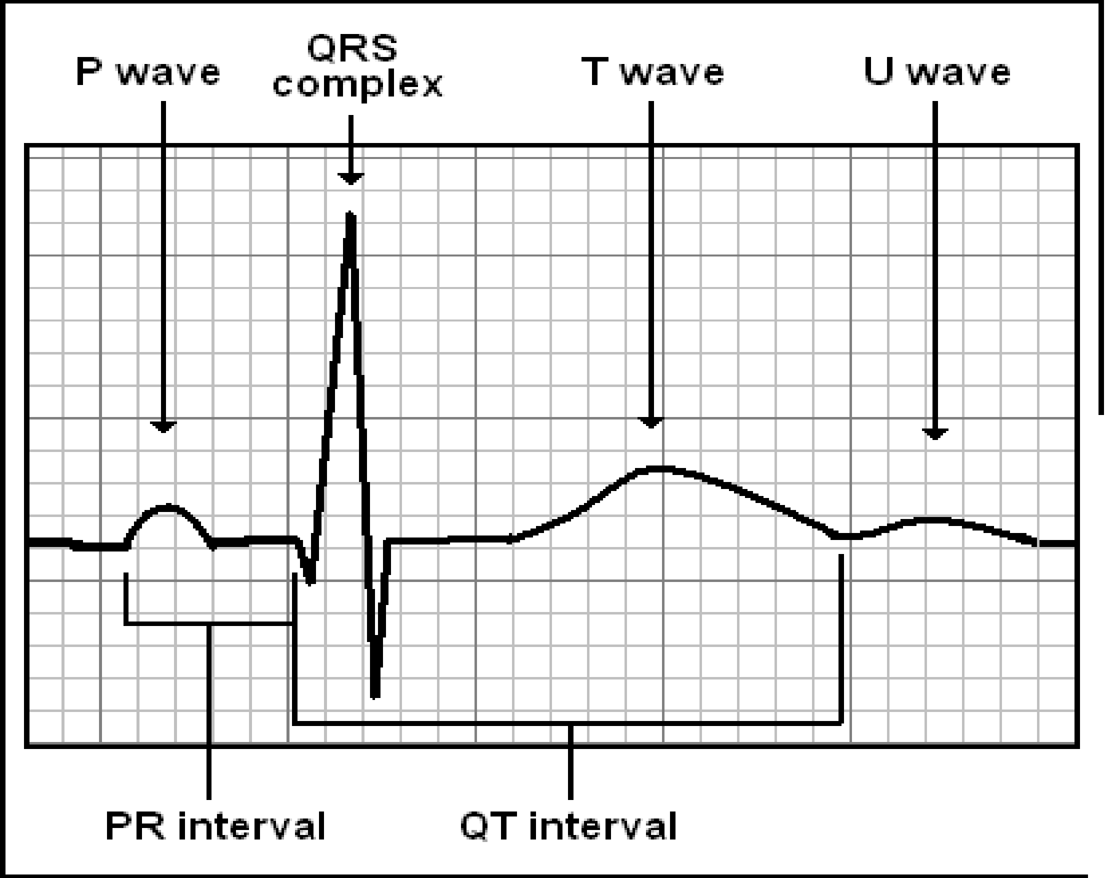
5 mm
1 s
+1
0
Millivolts
R
R
Q
S
P wave
T wave
P-R segment
S-T segment
PR interval
QT interval
QRS complex

The ECG Paper (cont)

- Every 3 seconds (15 large boxes) is marked by a vertical line.
- This helps when calculating the heart rate.

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

Waveforms and Intervals



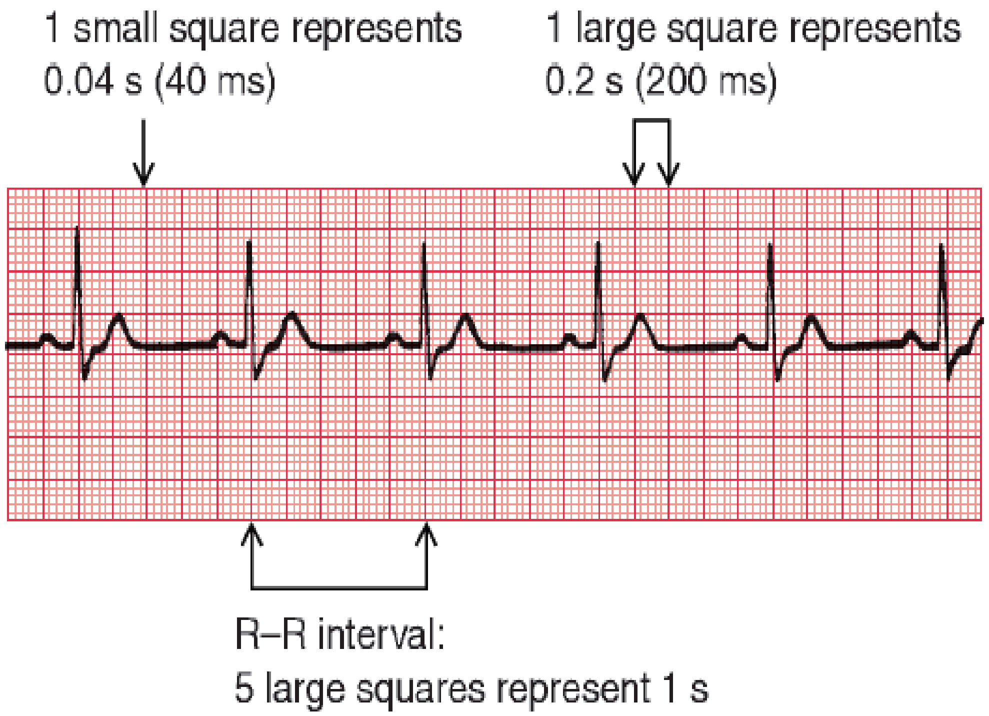
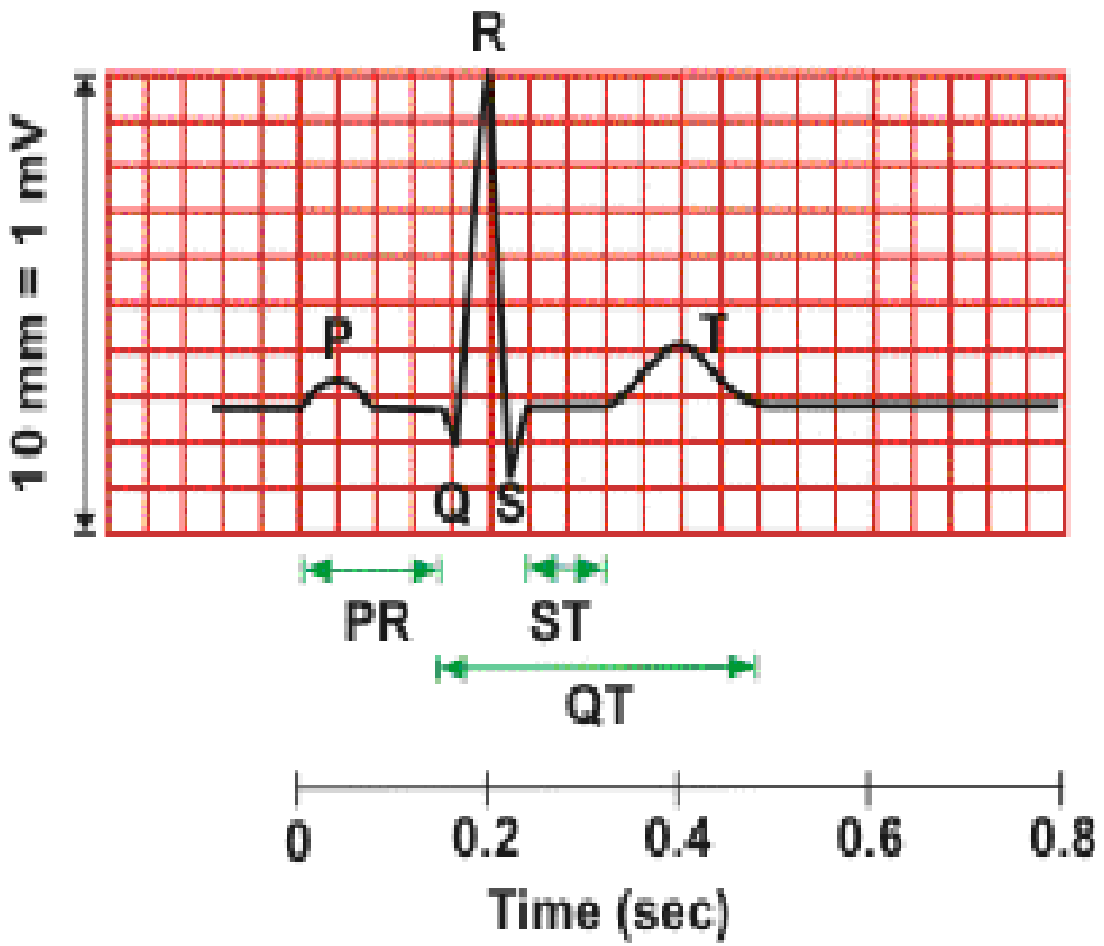


Fig. 1.4 Relationship between the squares on ECG paper and time. Here, there is one QRS complex per second, so the heart rate is 60 beats/min

- Q waves
  - Can occur normally in several leads
    - Normal Q waves called physiologic
  - Physiologic Q waves
    - < .04 sec (40ms)
  - Pathologic Q
    - >.04 sec (40ms)

Component	Characteristics
Heart Rate	60-100 bpm
PR Interval	0.12–0.20 sec
QRS Interval	0.06–0.10 sec
QT Interval	Less than half of the R-R interval
ST segment	0.08 sec



P wave (0.08 - 0.10 s)

QRS (0.06 - 0.10 s)

P-R interval (0.12 - 0.20 s)

$Q\text{-}T_C$ interval ($\leq$ 0.44 s)*

$$^{*}QT_C = QT/\sqrt{RR}$$

Suppose we measured the height of the P wave to be 2 mm. Now we'll have to convert this measurement from millimeters into millivolts. It is a standard for each machine that 10 mm = 1 mV. Thus we can set up the following:

$$\text{Amplitude of the P wave} = 2\,\cancel{\text{mm}} \times \frac{1\text{ mV}}{10\,\cancel{\text{mm}}} = 0.2\text{mV}$$

To measure the duration of an interval, we must measure its width in millimeters. Suppose we measure the width of the PR interval to be 4 mm. We'll have to convert this measurement from millimeters into seconds. The machine is set so that 25 mm of paper is used per 1 second. Thus we can set up the following:

$$\text{Duration of the PR interval} = 4\ \cancel{\text{mm}} \times \frac{1\ \text{sec}}{25\ \cancel{\text{mm}}} = 0.16\ \text{seconds}$$

To determine atrial rate, we begin by measuring the **PP interval**, the distance from the start of one P wave to the start of the next. During this span we will have one P wave and thus one atrial depolarization and one atrial contraction. Suppose the PP interval was 30 mm long. We can then set up the following:

$$\frac{1\ \cancel{\text{P wave}}}{30\ \cancel{\text{mm}}} \times \frac{1\ \text{atrial contraction}}{1\ \cancel{\text{P wave}}} \times \frac{25\ \cancel{\text{mm}}}{1\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{1\ \text{min}} = \frac{50\ \text{atrial contractions}}{1\ \text{minute}}$$

We would now assume that the ventricular rate was also 50 contractions per minute. We could verify this by measuring the **RR interval**, the distance from the peak of one R wave to the peak of the next. If it was also 30 mm long, we could set up the following:

$$\frac{1\ \cancel{\text{QRS}}}{30\ \cancel{\text{mm}}} \times \frac{1\ \text{ventricular contraction}}{1\ \cancel{\text{QRS}}} \times \frac{25\ \cancel{\text{mm}}}{1\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{1\ \text{min}} = \frac{50\ \text{ventricular contractions}}{1\ \text{minute}}$$

ECG Manifestations: Electrolyte Imbalance

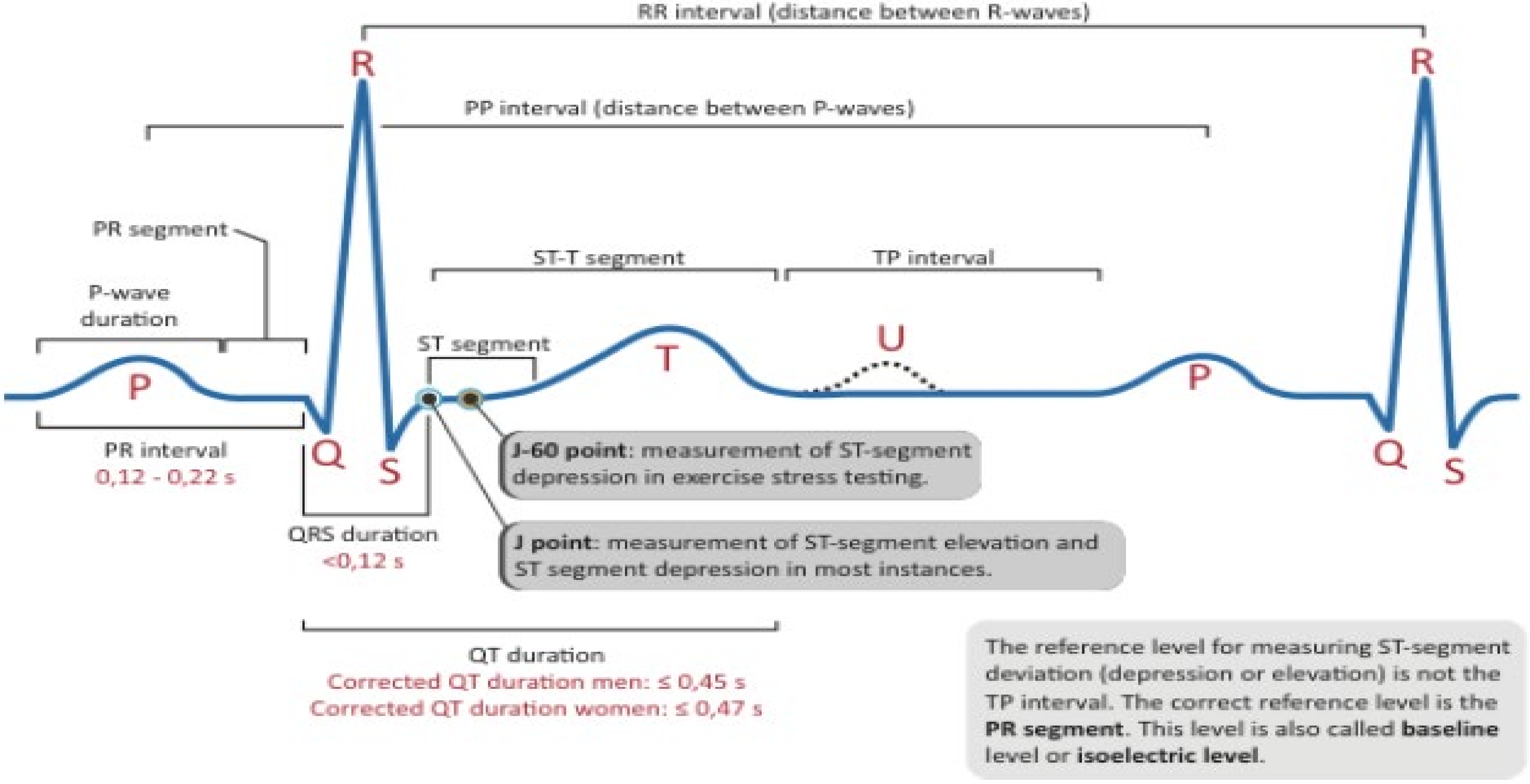
Diercks DB et al. J Emerg Med. 2004; 27(2); 153-60.
Rosen's EM: Concepts and Clinical Practice, 7th ed, 2010.
Goldberger, AL. Clinical Electrocardiography: A Simplified Approach, 7th ed, 2006.

PR interval	Short	Prolonged
	(Think pre-excitation syndromes such as Wolff-Parkinson-White)	High K Low Ca
QRS duration	Narrow	Wide (>100 msec)
	Low K Low Ca Normal	High K High Ca
QTc interval	Short (<350 msec)	Prolonged (>440 msec)
	High Ca	Low K Low Ca
ST segment	Depressed	Elevated
	Low K High Ca	High K
T wave	Peaked/tall	Flattened
	High K	Low K
U wave	Absent	Present
	Normal	Low K Low Ca
Heart rate	Slow (bradydysrhythmia, nodal block)	Fast (tachydysrhythmia)
	High K High Ca	Low K Low Ca

	Low	High
Ca	• QTc prolonged (hallmark) • U wave • Heart blocks, ventricular dysrhythmias, torsades de pointes	• QTc shortened (hallmark) • ST segment depression and shortening • QRS widening • Rare: bradydysrhythmias, bundle branch blocks, high degree AV blocks
K	Early to late findings: • T wave: decreased amplitude • T wave: flat or inverted • ST segment depression • U wave • QTc prolonged (at risk for VT or torsades de pointes)	Early to late findings: • T wave: tall, then "peaked" (symmetrical) • P wave flattening • PR interval prolonged • QRS widening • Nodal blocks, escape beats • Sine wave: fusion of QRS and T wave --> VF or asystole

Mg derangements: Nonspecific ECG findings; often co-exist with Ca derangements.
- Classic teaching: Low Mg level --> QTc prolongation --> torsades de pointes

Waves, intervals and durations on the ECG



EKG Leads

The standard EKG has 12 leads:

3 Standard Limb Leads

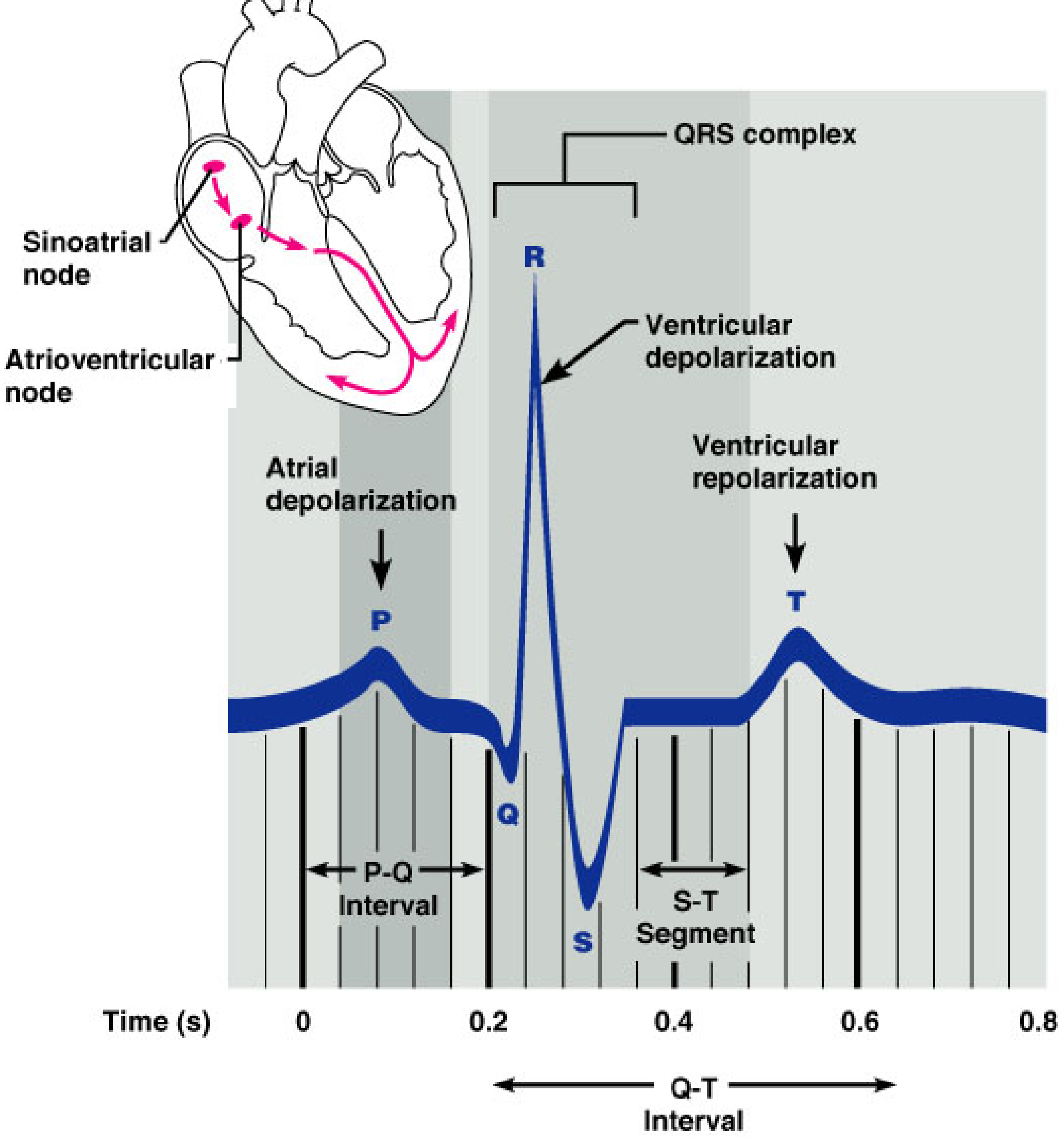
3 Augmented Limb Leads

6 Precordial Leads

The axis of a particular lead represents the viewpoint from which it looks at the heart.

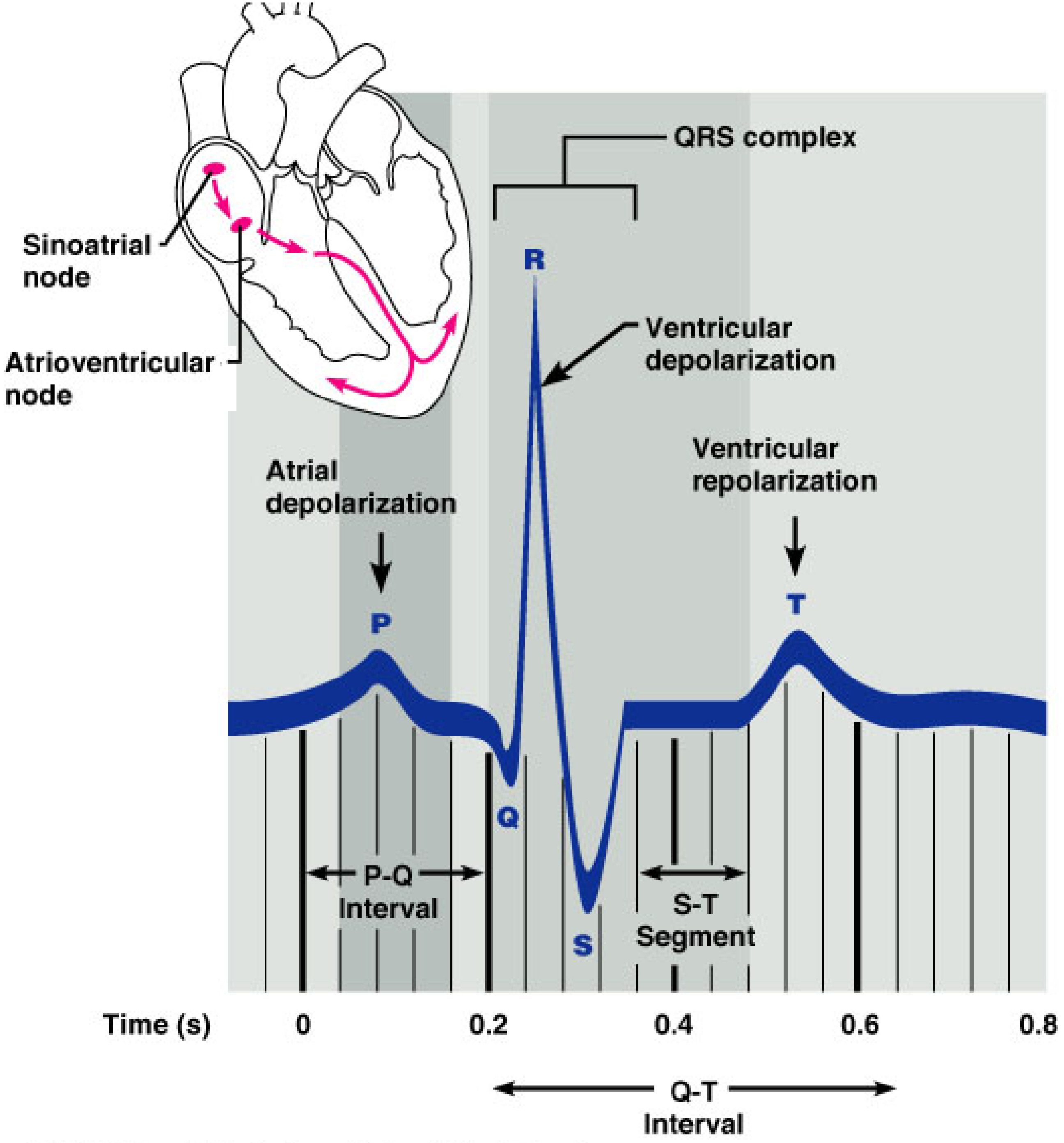
Electrocardiogram

- P wave
  - Depolarization of atria
  - Followed by contraction
- QRS complex
  - 3 waves (Q, R, & S)
  - Depolarization of ventricles
  - Followed by contraction
- T wave
  - Repolarization of ventricles



Electrocardiogram

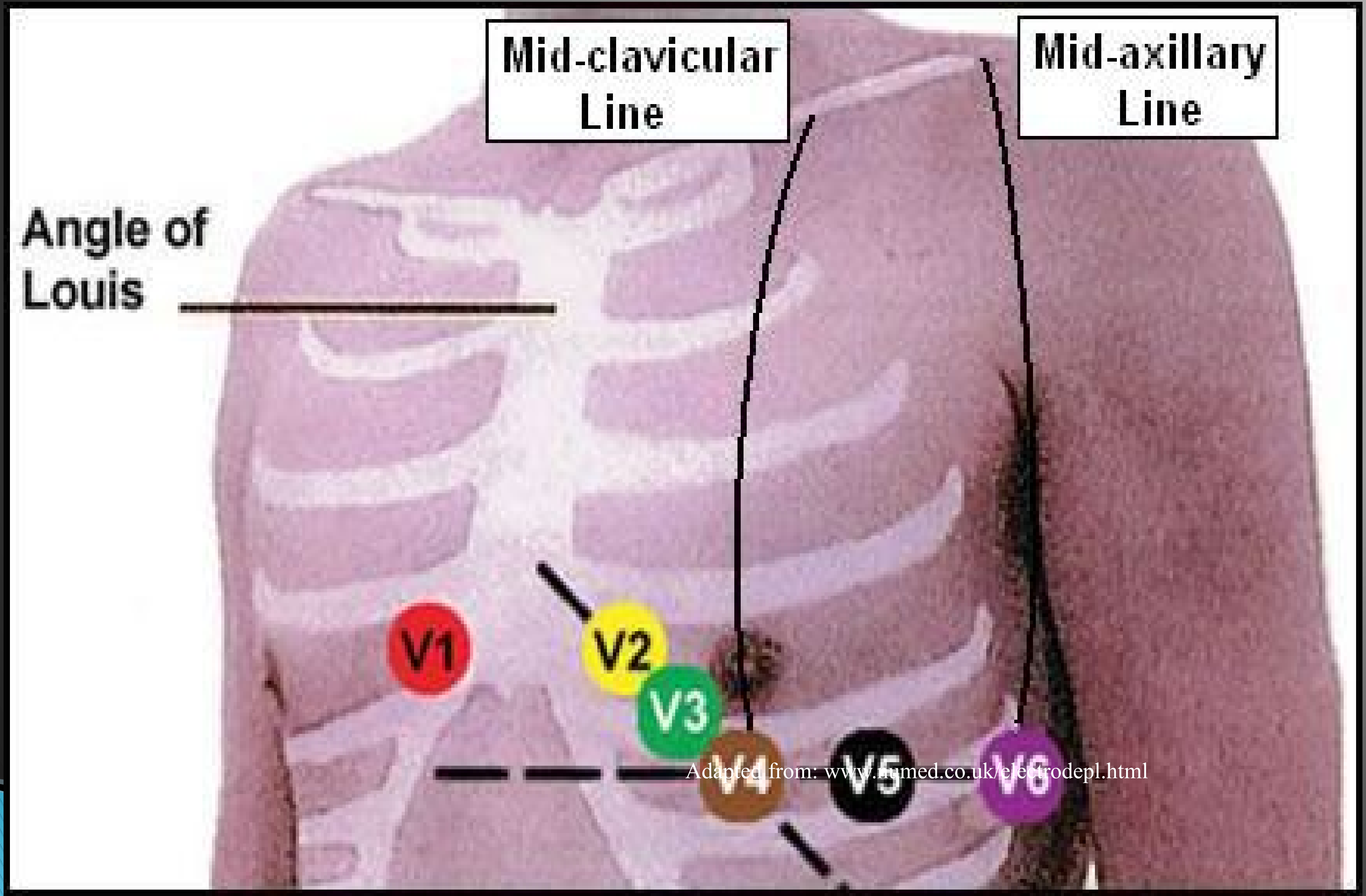
- P–Q interval
  - Time atria depolarize & remain depolarized
- Q–T interval
  - Time ventricles depolarize & remain depolarized



Intervals

- **P wave - atrial depolarization**
- **PR interval - time from sinoatrial** node (S-A) to atrioventricular node (A-Vnode)
- **QRS Complex – ventricular** depolarization
- **ST Segment - beginning of** ventricular repolarization
- **T Wave - later stages of** ventricular repolarization
- **U Wave - final component of** ventricular repolarization
- **RR Interval - represents the** time for one complete cardiac cycle

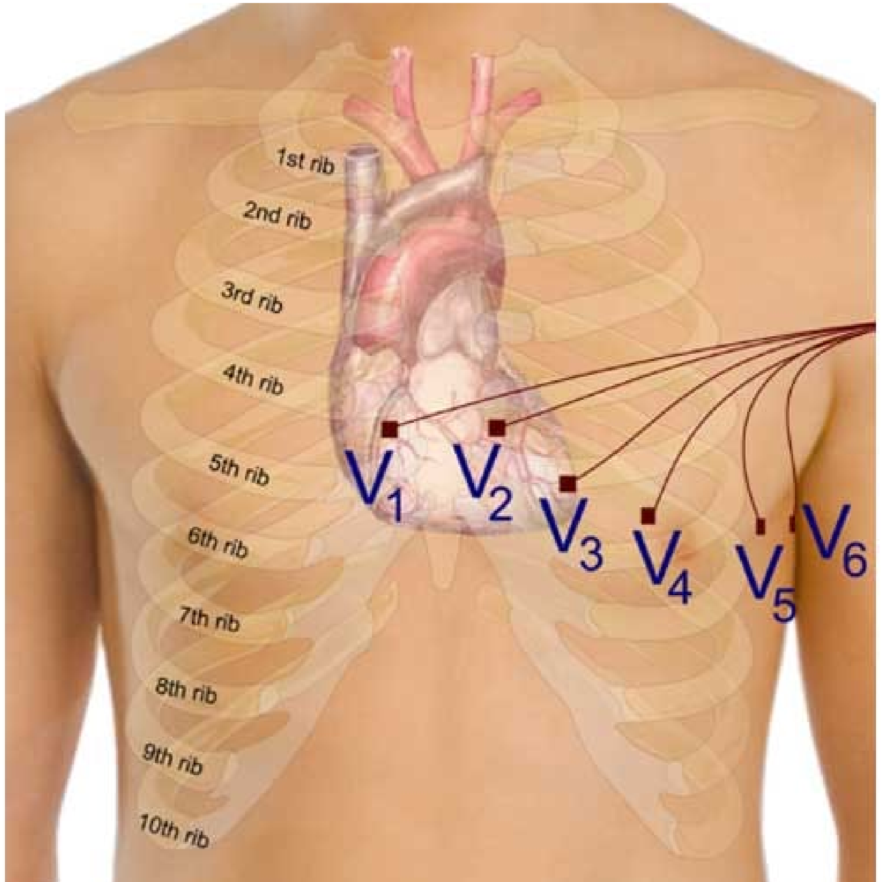
Precordial Leads

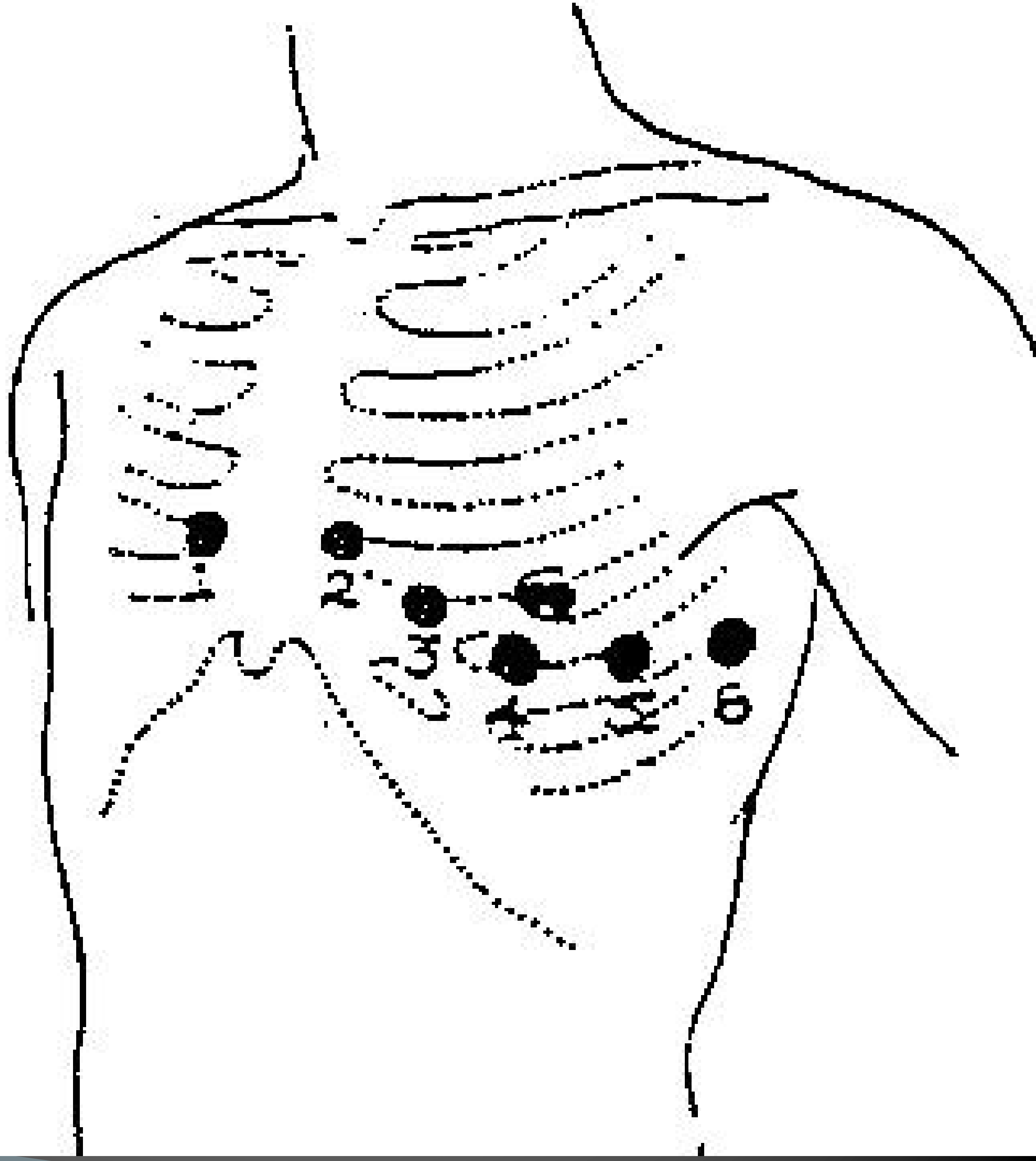


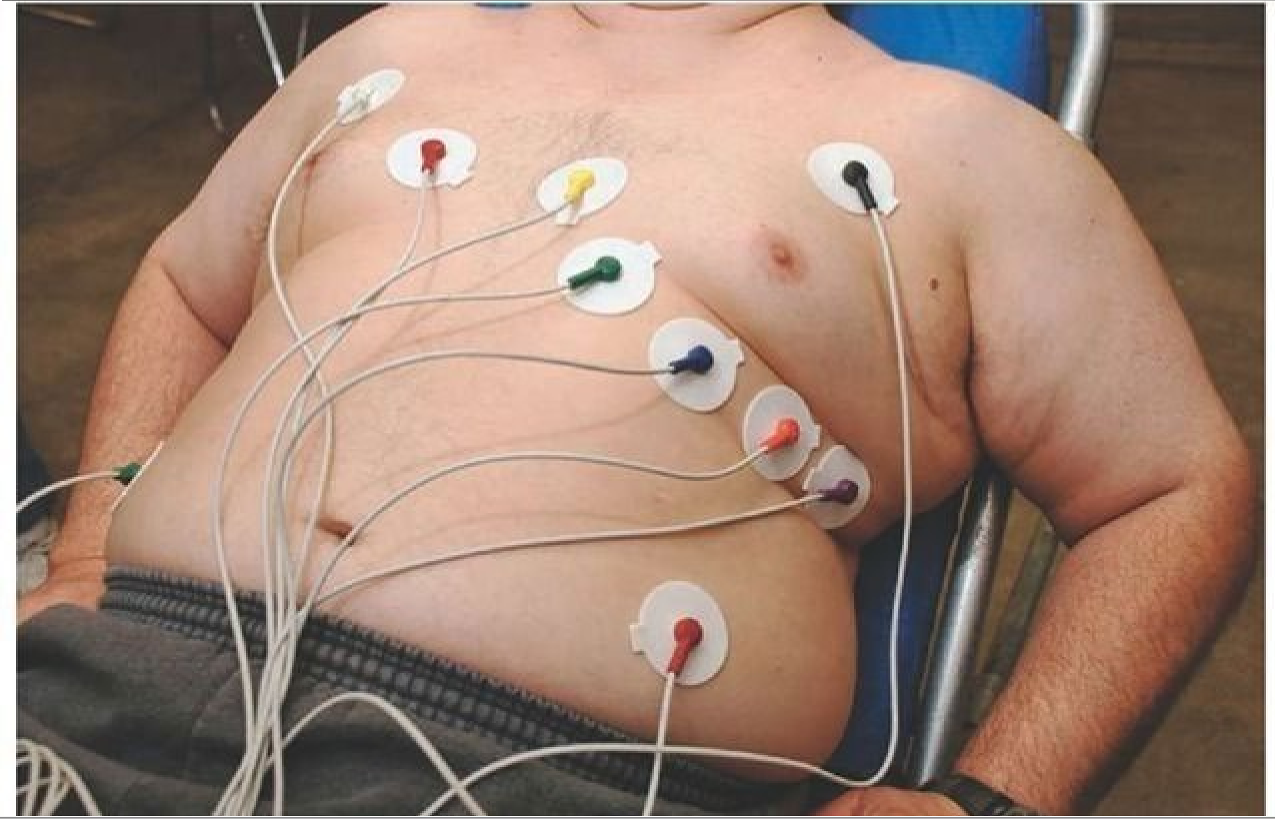
Adapted from: www.numed.co.uk/electrodepl.html

Lead Placement

V1 = 4th intercostal space, right border of sternum
V2 = 4th intercostal space, left border of sternum
V3 = midway between V2 and V4
V4 = 5th intercostal space, midclavicular line
V5 = anteroaxillary line at level of V4
V6 = midaxillary line at level of V4 and V5

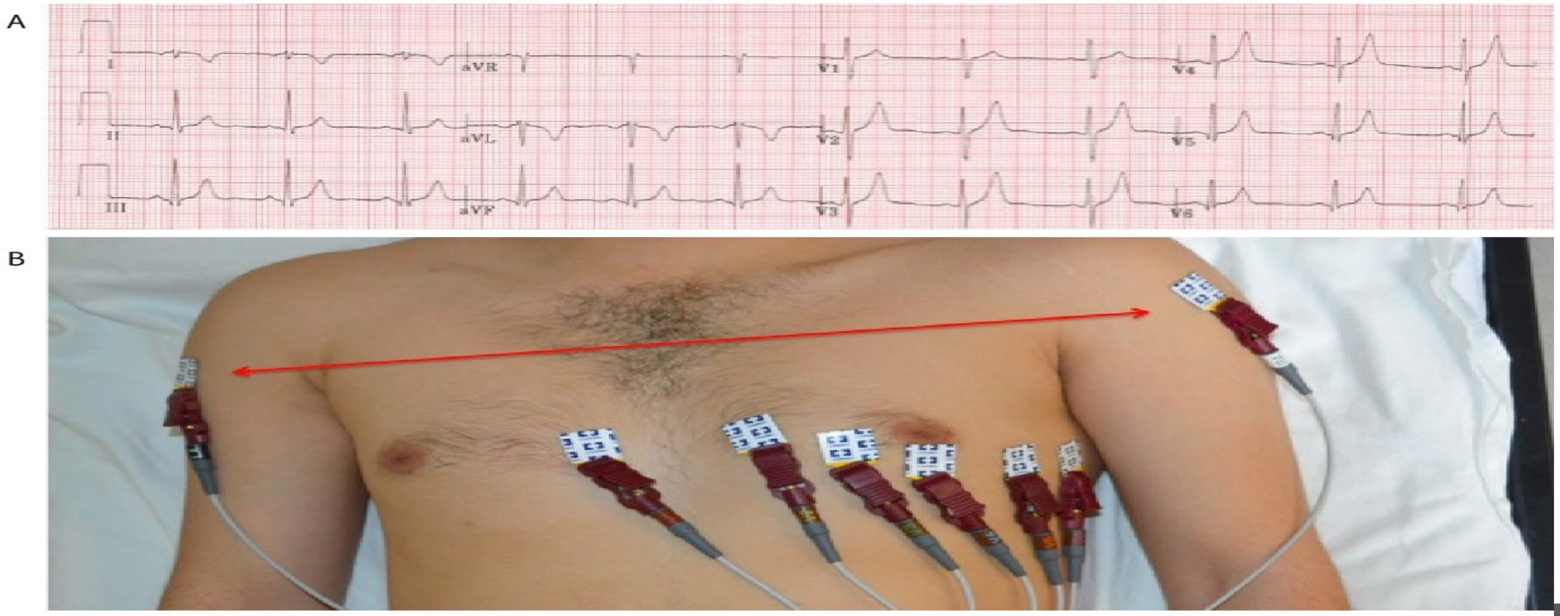


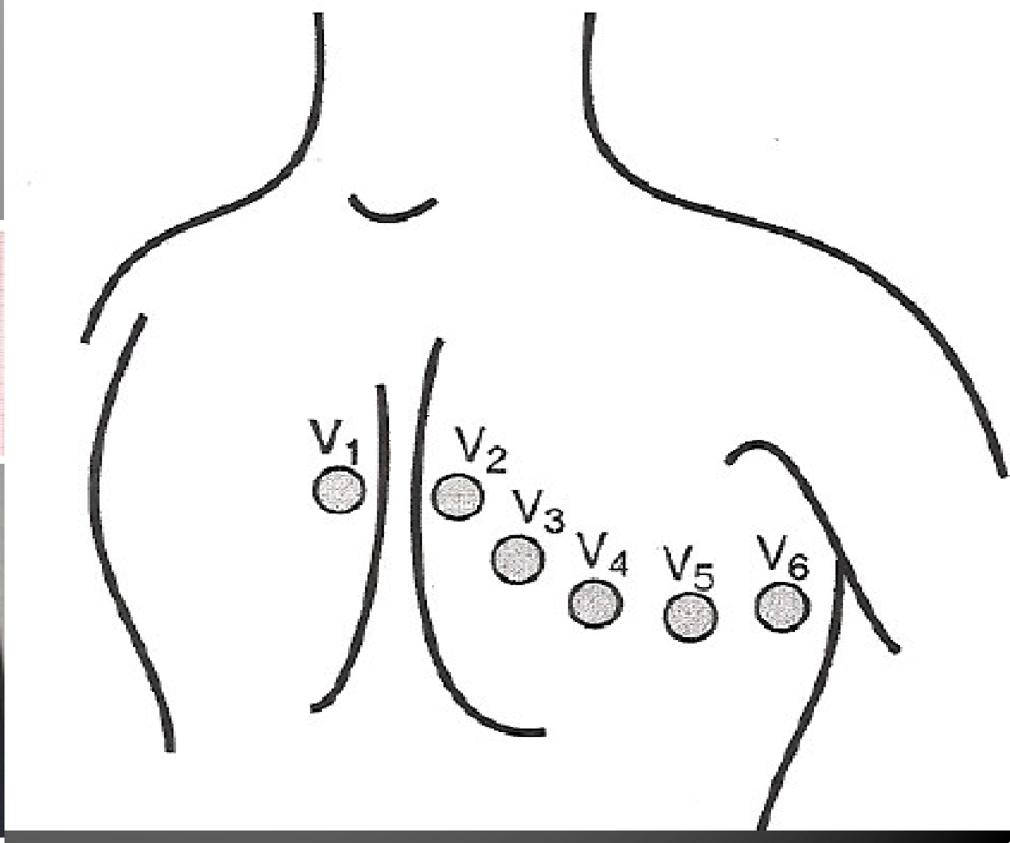




Lead Placement

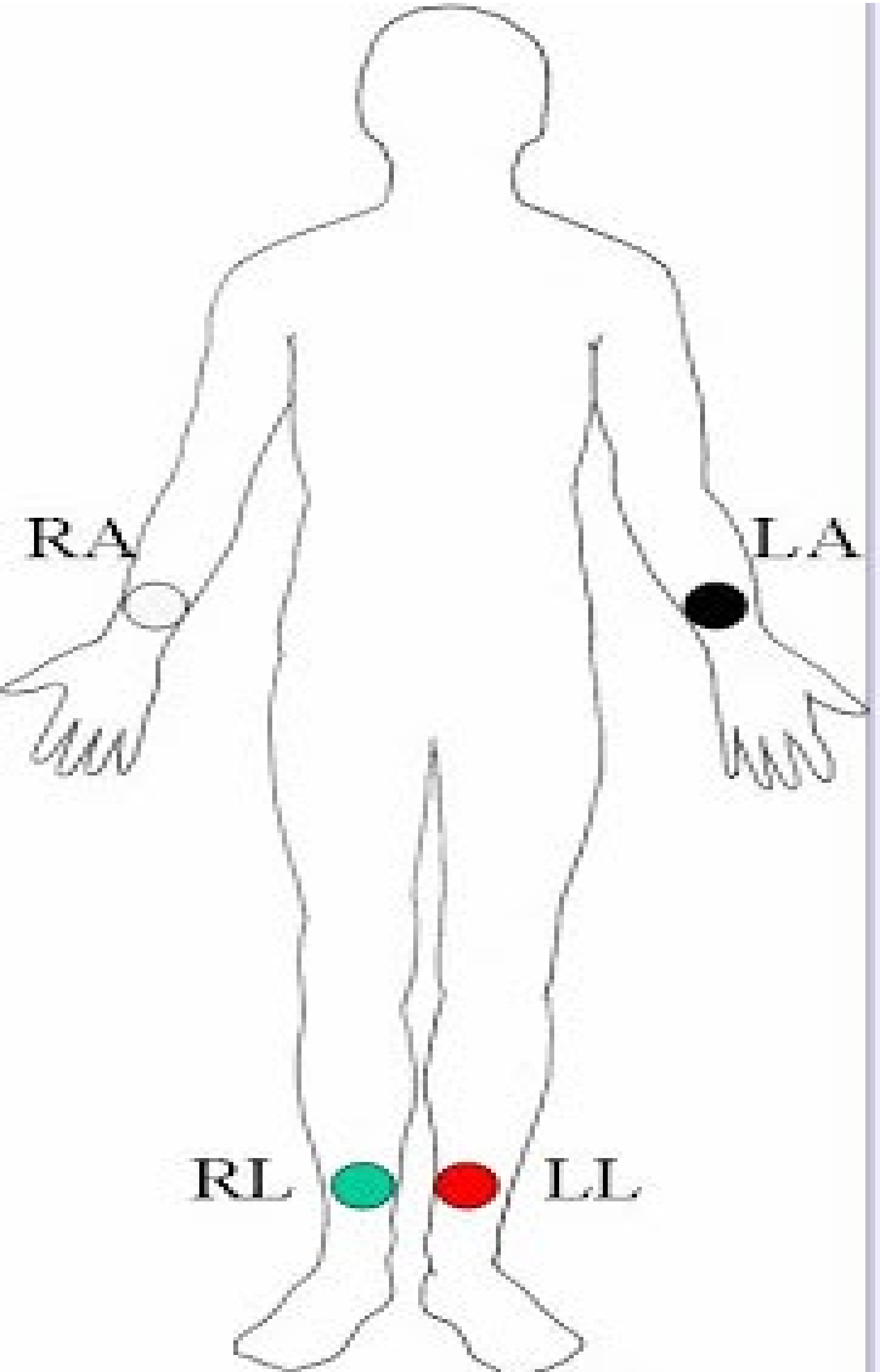
- V1 – Right Sternal Border – 4th ICS
- V2 – Left Sternal Border – 4th ICS
- V3 Midway Between V2 and V4
- V4 Midclavicular line – 5th ICS
- V5 Anterior Axillary line – 5th ICS
- V6 Mid axillary line – 5th ICS





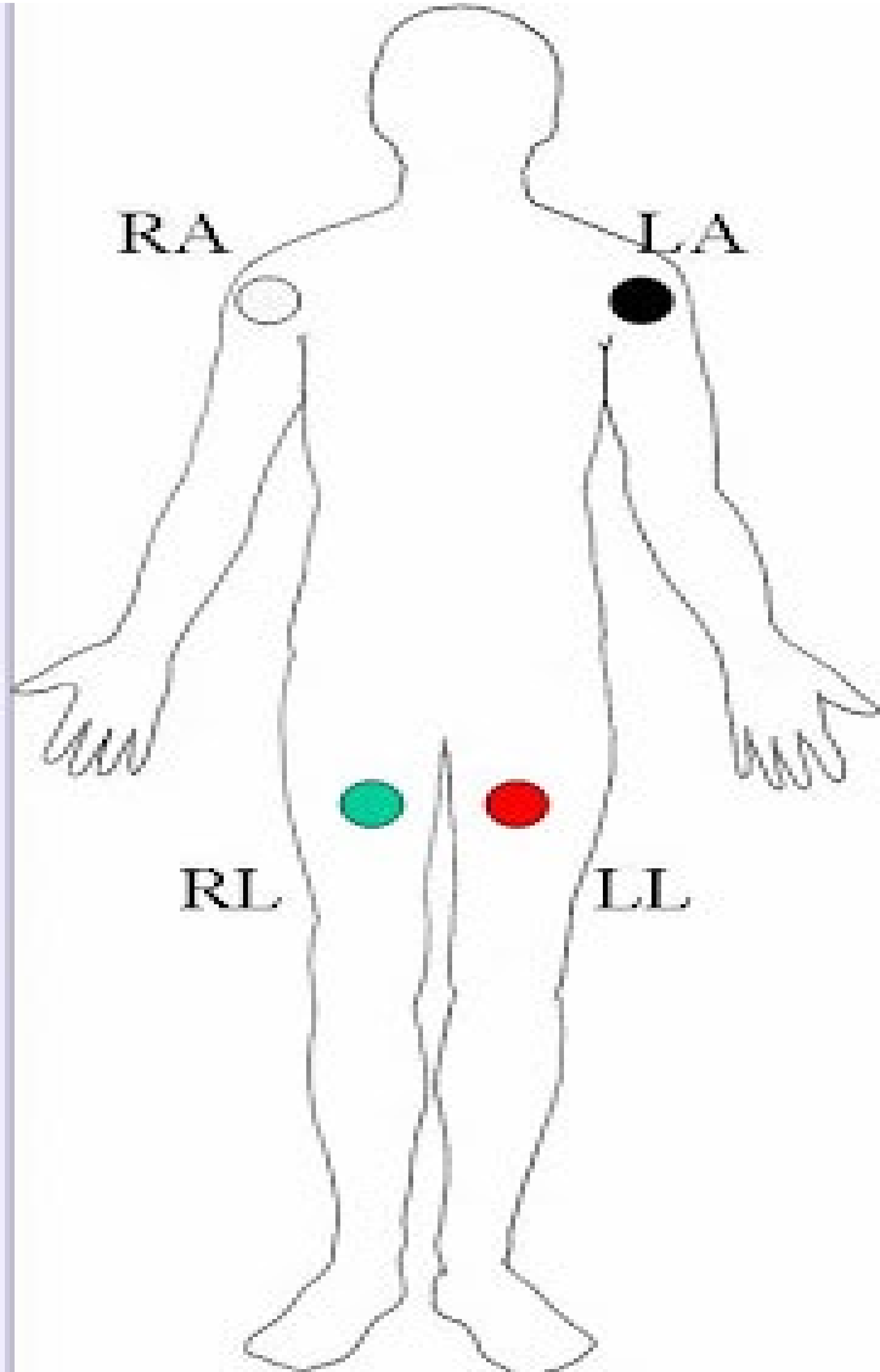
- Lead Placement
- V1 =
- V2 =
- V3 =
- V4 =
- V5 =
- V6 =

- **Lead Placement**
- V1 = 4th intercostal space, right border of sternum
- V2 = 4th intercostal space, left border of sternum
- V3 = midway between V2 and V4
- V4 = 5th intercostal space, midclavicular line
- V5 = anteroaxillary line at level of V4
- V6 = midaxillary line at level of V4 and V5



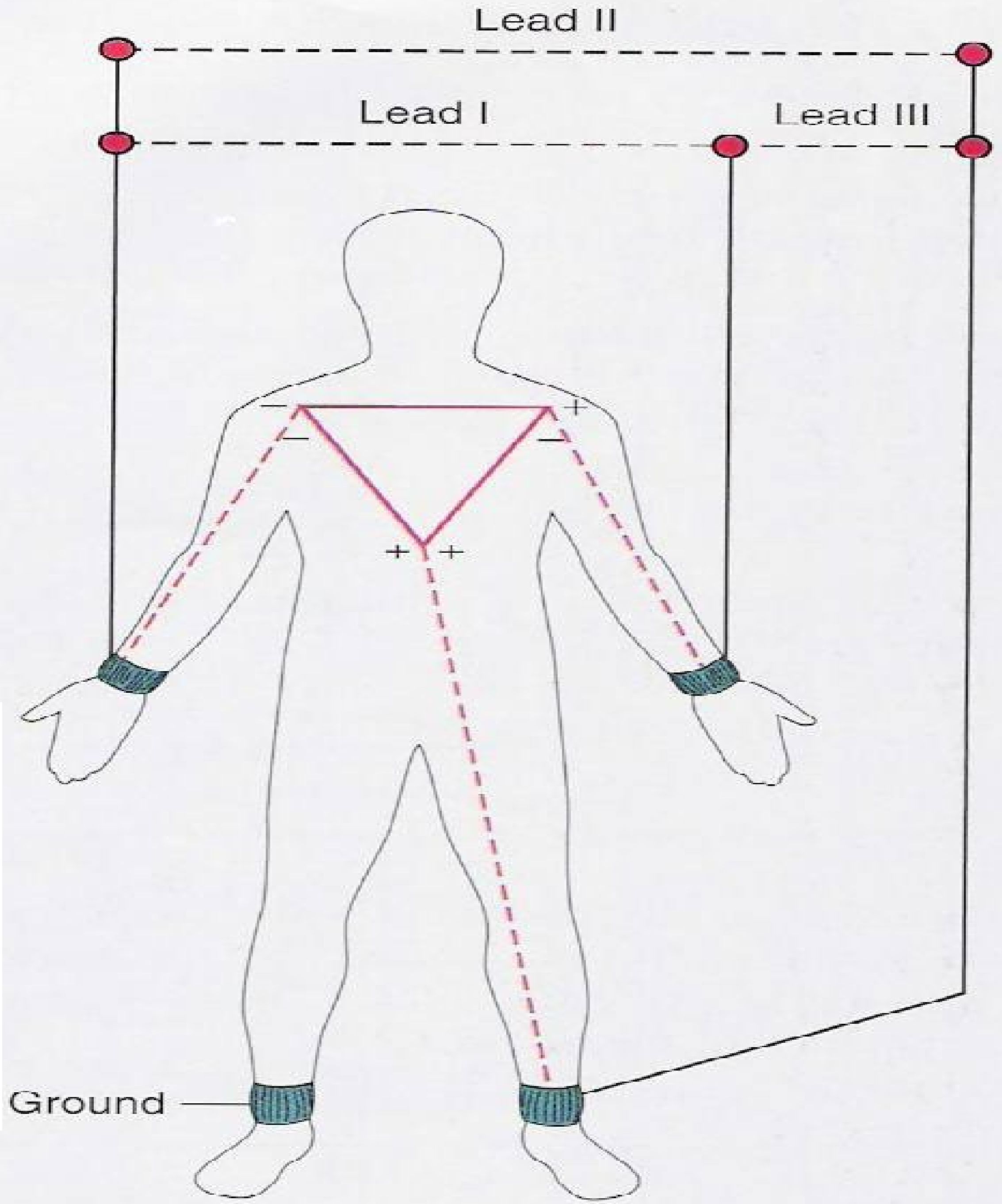
RA = Right Arm
LA = Left Arm
RL = Right Leg
LL = Left Leg

RA - White
LA - Black
RL - Green
LL - Red



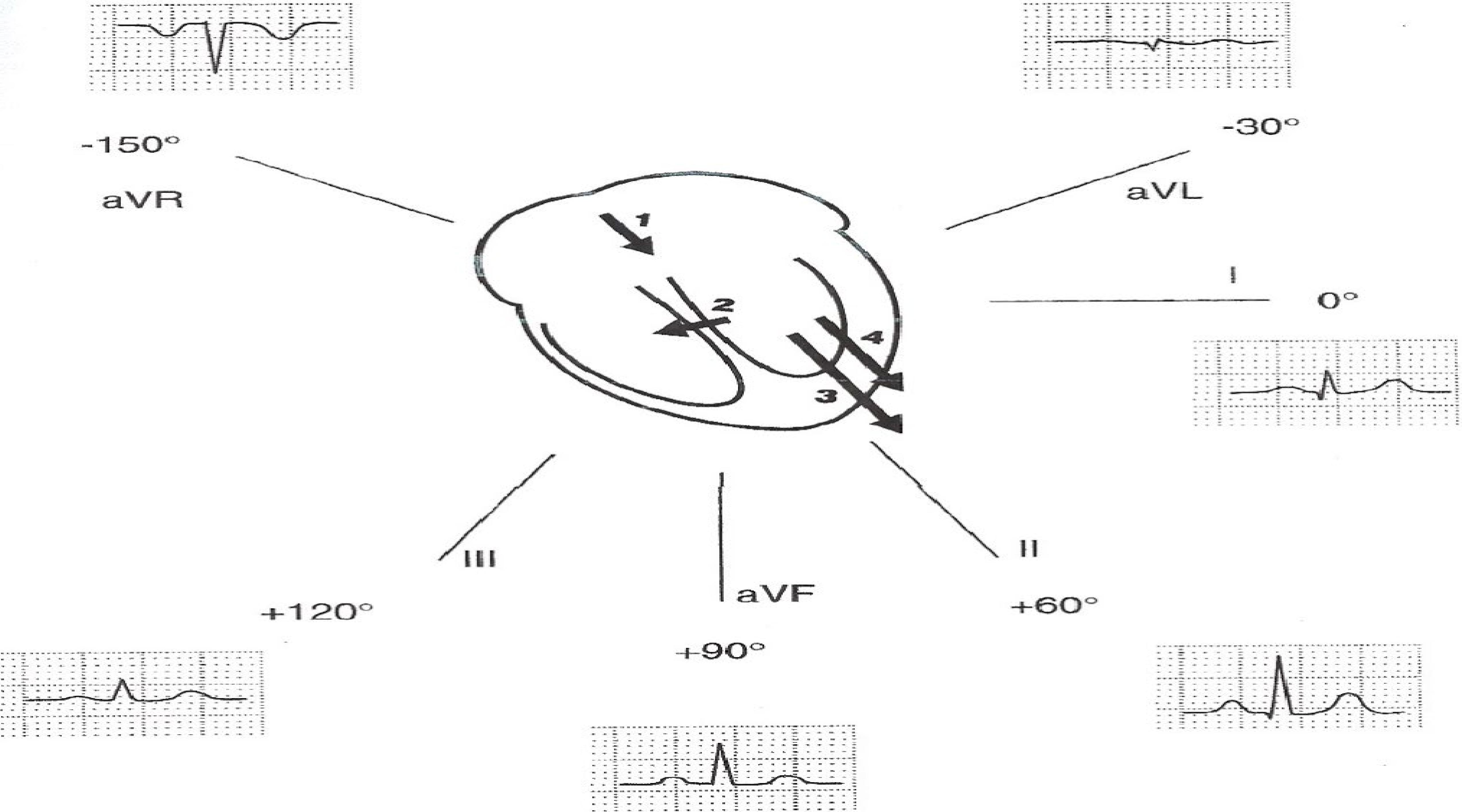
Electrocardiogram

- Einthoven's triangle
  - Three standard limb leads
  - Voltage differences between corners of triangle
  - We will use "Lead II"
    - Right shoulder to left leg



Triangle and Einthoven's law: the three bipolar leads form what is called the Einthoven's triangle (named so after the inventor of the electrocardiogram). These leads maintain a mathematical proportion explained by the Einthoven's law, which says: II = I + III.

This law is of great value when Interpreting an electrocardiogram. It allows us to determine whether the limb electrodes are correctly placed; if the position of any electrode is altered, this law would not hold, thus allowing us to realise the EKG is not correctly done



-150°
aVR
-30°
aVL
1
2
3
4
I
0°
III
+120°
aVF
+90°
II
+60°

QRS Deflection			Axis
Lead I	Lead aVF	Lead II	
+	+	NA	Normal
+	-	+	Normal
+	-	-	LAD
-	+	NA	RAD
-	-	NA	Extreme Axis

ECG Recordings: **(QRS vector---leftward, inferiorly and posteriorly**

3 Bipolar Limb Leads

I = RA vs. LA(+)

II = RA vs. LL(+)

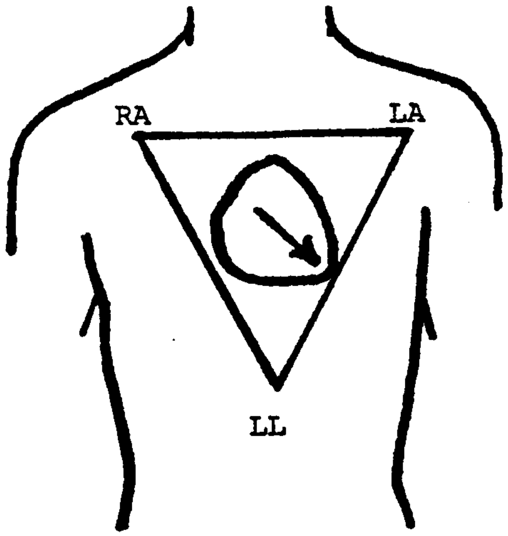
III = LA vs. LL(+)

3 Augmented Limb Leads

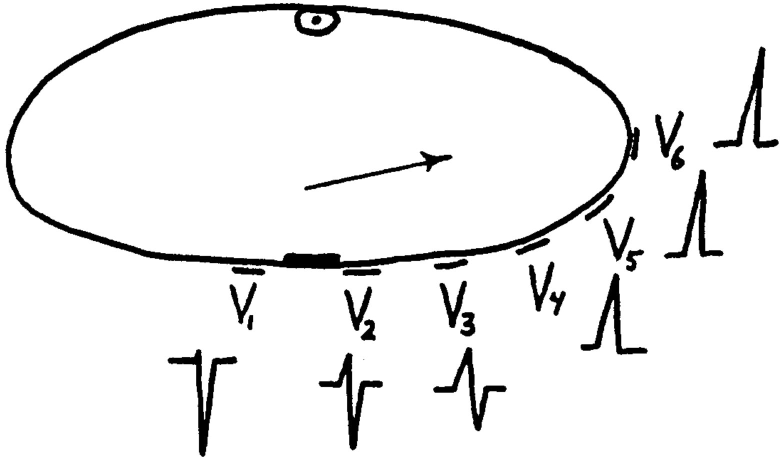
aVR = (LA-LL) vs. RA(+)

aVL = (RA-LL) vs. LA(+)

aVF = (RA-LA) vs. LL(+)



6 Precordial (Chest) Leads: Indifferent electrode (RA-LA-LL) vs. chest lead moved from position V_1 through position V_6.

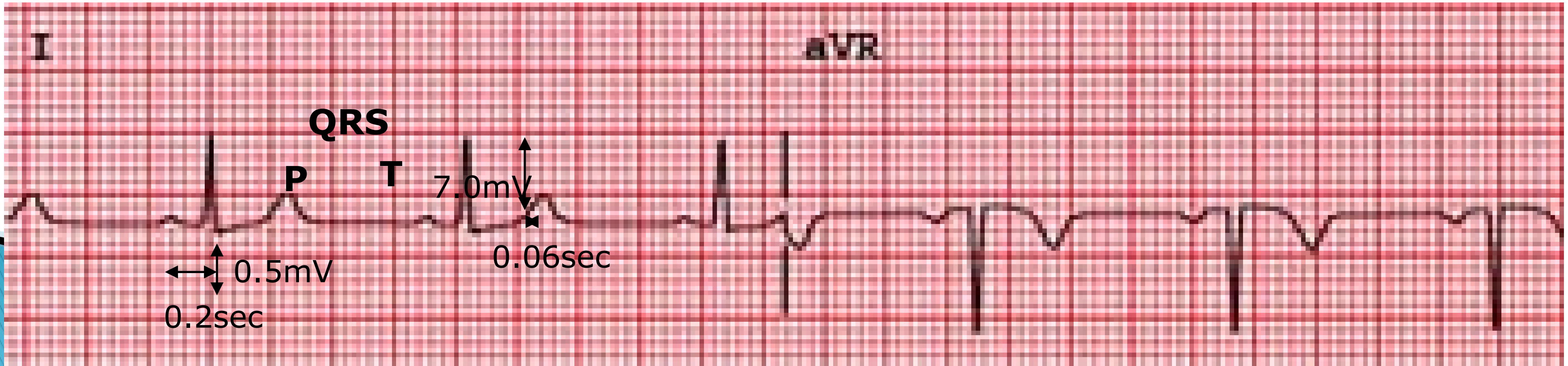


Normal EKG

- A **positive wave** form (QRS mainly above the baseline) results from the wave of depolarization moving towards the positive end of the lead.
  - e.g.
- A negative waveform (QRS mainly below the baseline) is when a wave of depolarization is moving *away* from the positive electrode (towards the negative end of the lead).
- EKG paper has 1 millimeter small squares – so height and depth of wave is measured in millimeters.

  10 mm = 1.0 mVolt
- Horizontal axis is time.
  - 0.04 seconds for 1 mm (1 small box).
  - 0.2 seconds for 1 large box = 5 small boxes = 5 x .04 seconds.

Positive QRS in Lead I.
Negative QRS in Lead aVR.
R wave = 7-8 mm high in Lead I = 7-8mV.
QRS wave = 0.06 seconds long in Lead I.

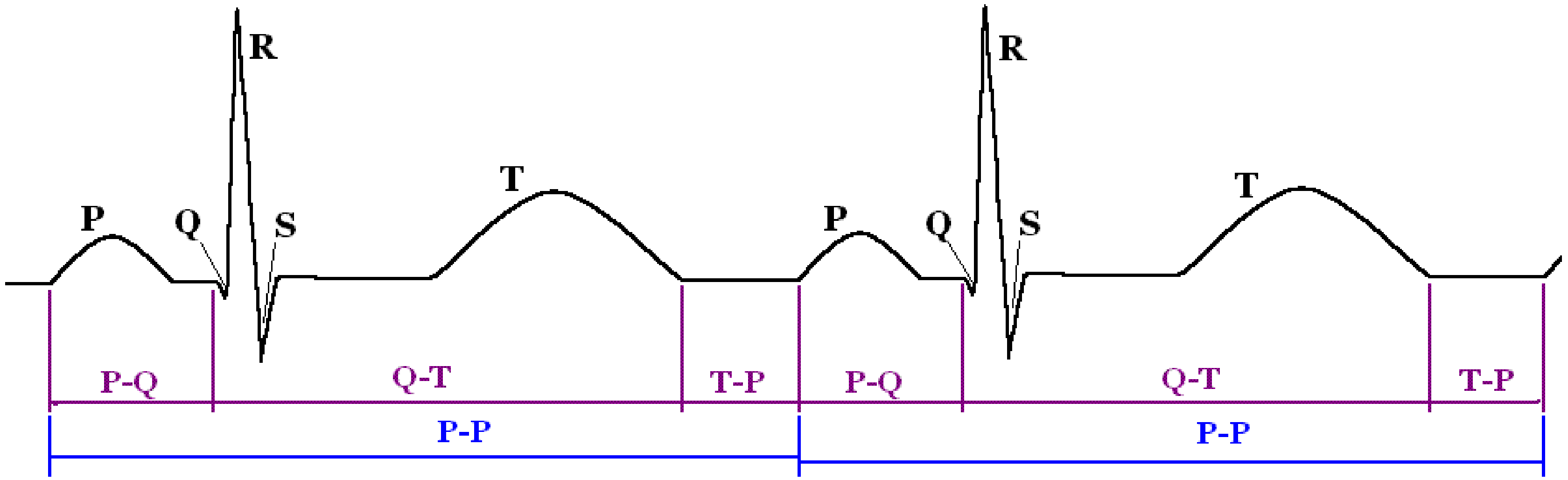


Rhythm Summary

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

Electrocardiogram

- Intervals show timing of cardiac cycle
  - P–P = one cardiac cycle
  - P–Q = time for atrial depolarization
  - Q–T = time for ventricular depolarization
  - T–P = time for relaxation



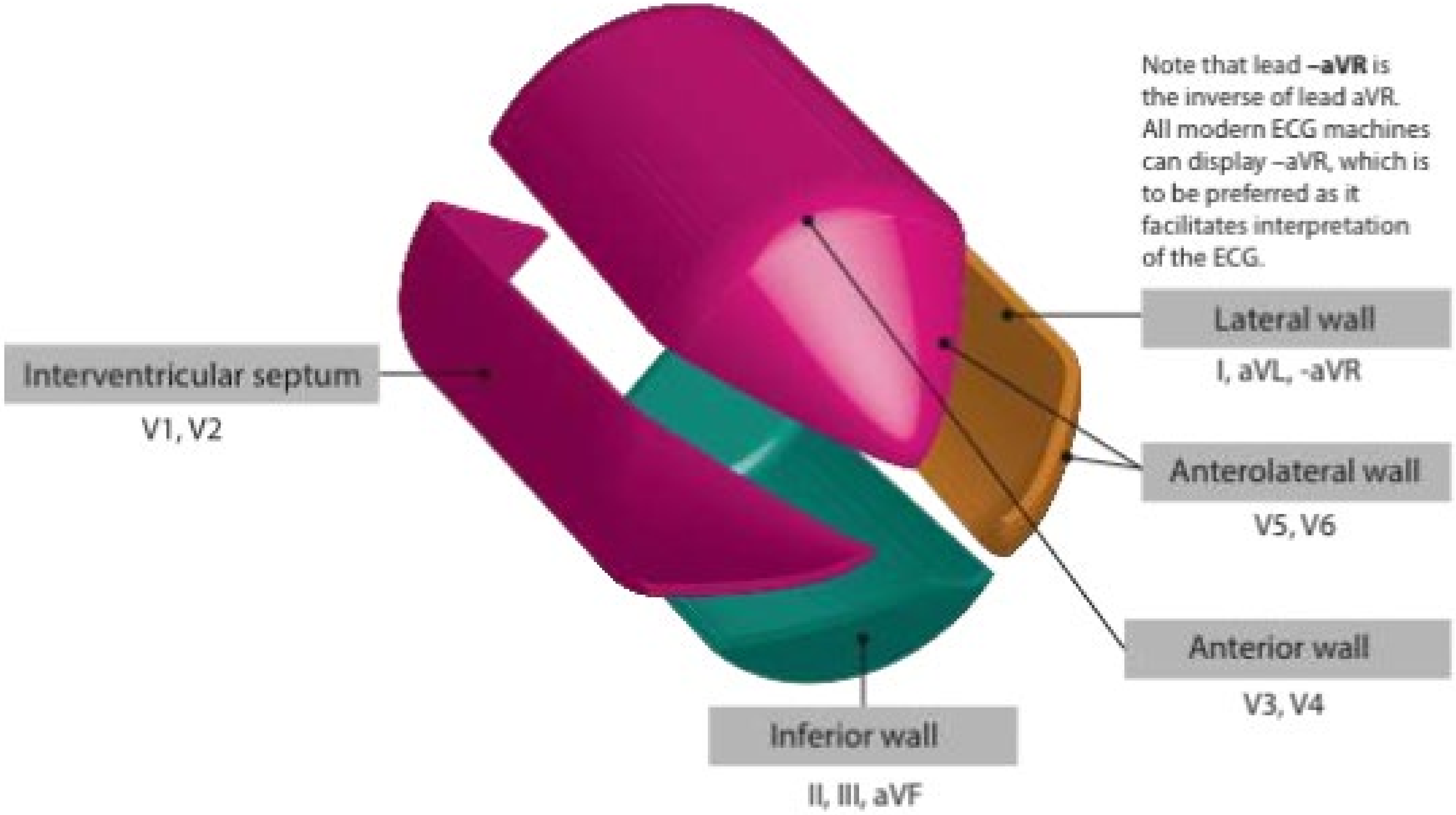
- What these intervals represents ?

- · **P wave**
- · **PR interval –**
- · **QRS Complex –**
- · **ST Segment –**
- · **T Wave –**
- · **U Wave –**
- · **RR Interval –**

- Intervals
- • **P wave – atrial depolarization**
- • **PR interval – time from sinoatrial** node (S-A) to atrioventricular node (A-Vnode)
- • **QRS Complex – ventricular** depolarization
- • **ST Segment – beginning of** ventricular repolarization
- • **T Wave – later stages of** ventricular repolarization
- • **U Wave – final component of** ventricular repolarization
- • **RR Interval – represents the** time for one complete cardiac cycle

The walls of the left ventricle and the leads that view these walls

The four walls of the left ventricle and the ECG leads that "view" these walls



Note that lead **–aVR** is the inverse of lead aVR. All modern ECG machines can display –aVR, which is to be preferred as it facilitates interpretation of the ECG.

Anatomic Groups (Septum)

I Lateral	aVR None	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

Anatomic Groups (Anterior Wall)

I Lateral	aVR None	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

Anatomic Groups (Lateral Wall)

I Lateral	aVR None	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

Anatomic Groups (Inferior Wall)

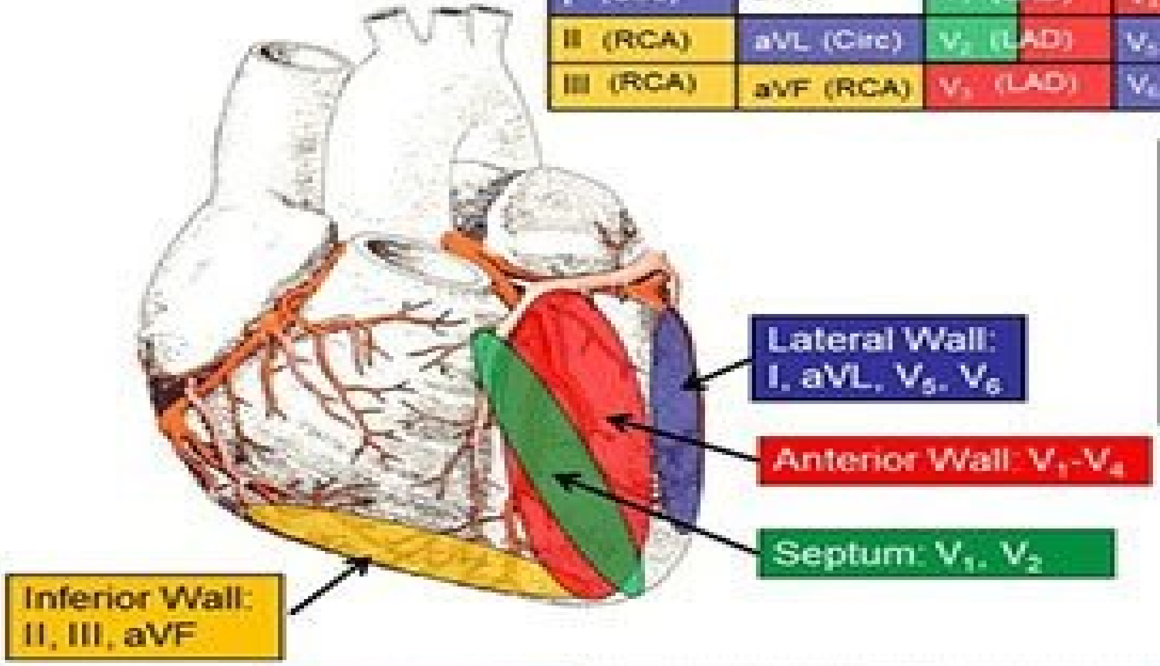
I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

Anatomic Groups (Summary)

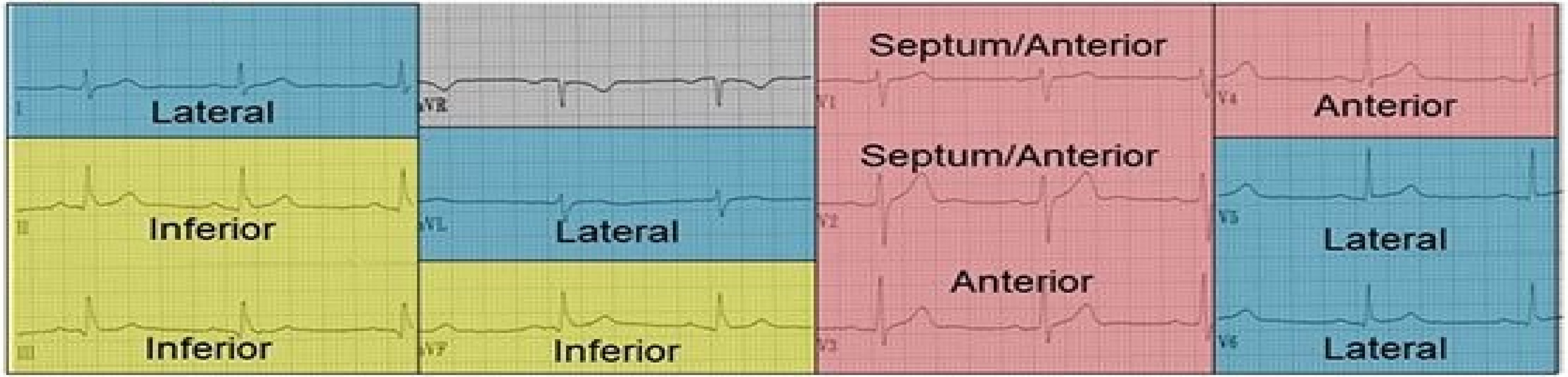
I Lateral	aVR None	V_1 Septal	V_4 Anterior
II Inferior	aVL Lateral	V_2 Septal	V_5 Lateral
III Inferior	aVF Inferior	V_3 Anterior	V_6 Lateral

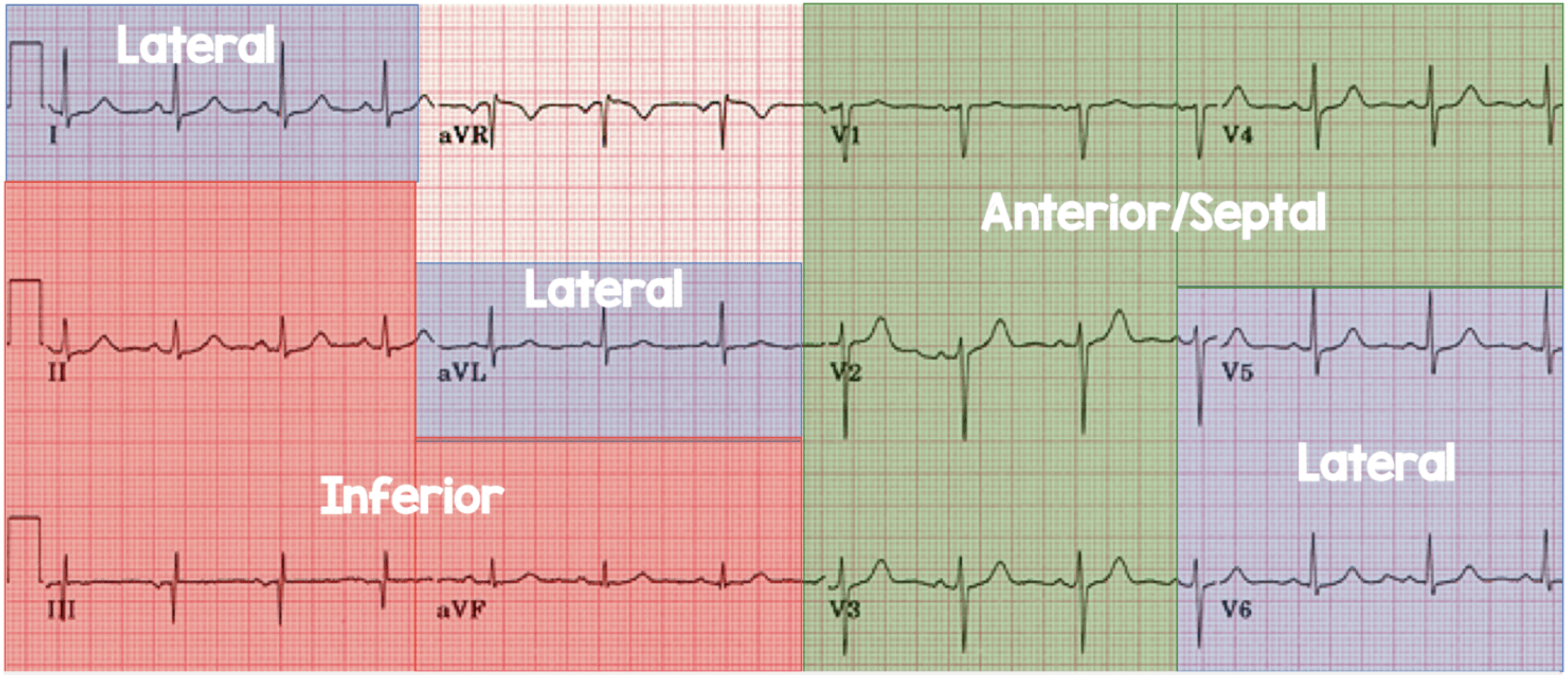
Which Leads Look Where?

I (Circ)	aVR	V_1 (LAD)	V_4 (LAD)
II (RCA)	aVL (Circ)	V_2 (LAD)	V_5 (Circ)
III (RCA)	aVF (RCA)	V_3 (LAD)	V_6 (Circ)



Inferior wall: II, III, aVF
Septum: V1, V2
Anterior wall: V3, V4
Lateral wall: I, aVL (high lateral); V5, V6 (low lateral)
Anterior wall and septum often infarct together because both supplied by LAD, so anteroseptal MI shows in V1-V4



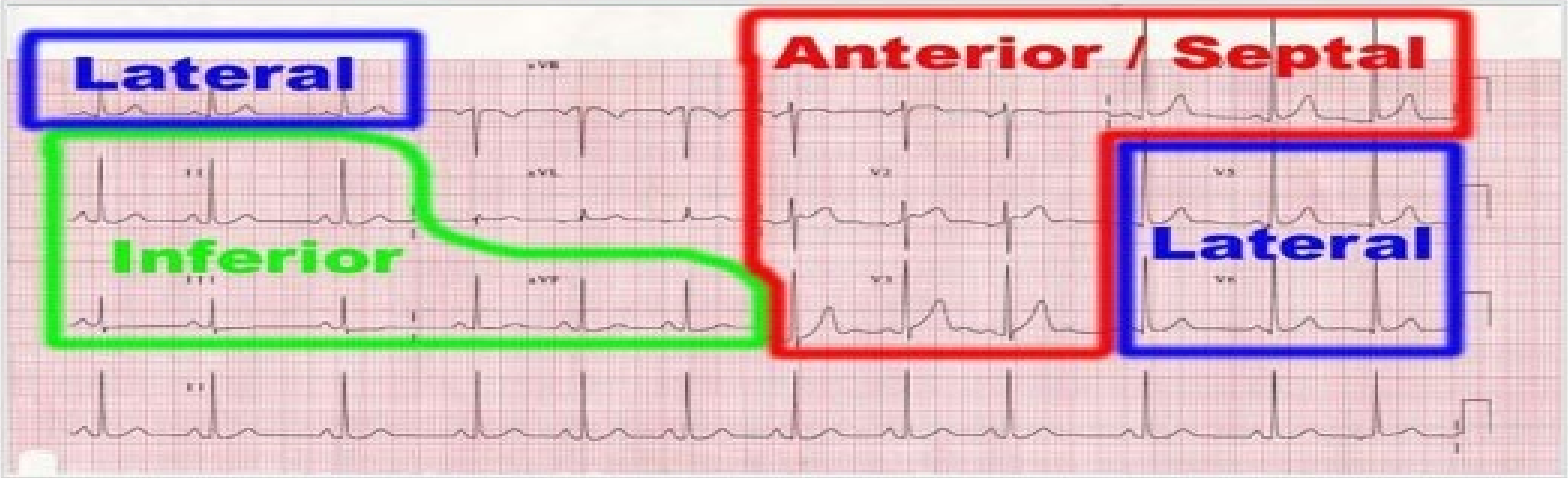


Coronary Anatomy & ECG Leads

Lateral Leads	I, aVL, V5 - V6	LCx or Diagonal of LAD
Inferior Leads	II, III, aVF	RCA and/or LCx
Anterior/Septal Leads	V1 - V4	LAD

REBEL
REVIEWS

Areas of the ECG to be concentrated upon to study the events e.g. MI



Position	Leads
Lateral	look on lead I,V5 ,V6
Inferior	look on lead II ,III ,aVF
Anterior/ Septal	look on V1,V2,V3,V4

Rule of 300

Take the number of “big boxes” between neighboring QRS complexes, and divide this into 300. The result will be approximately equal to the rate

Although fast, this method only works for regular rhythms.

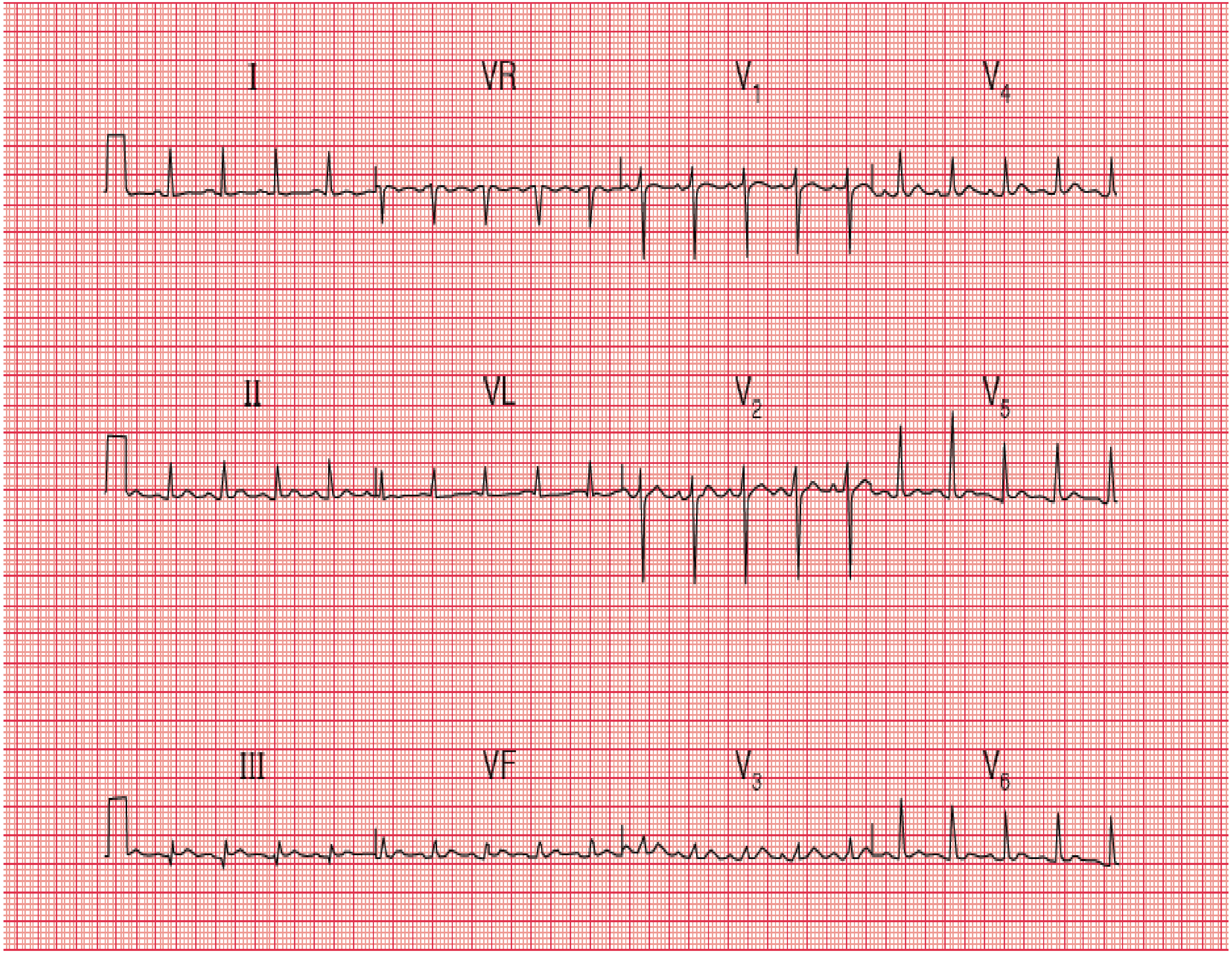


Fig. 1.23 12-lead ECG: example 1

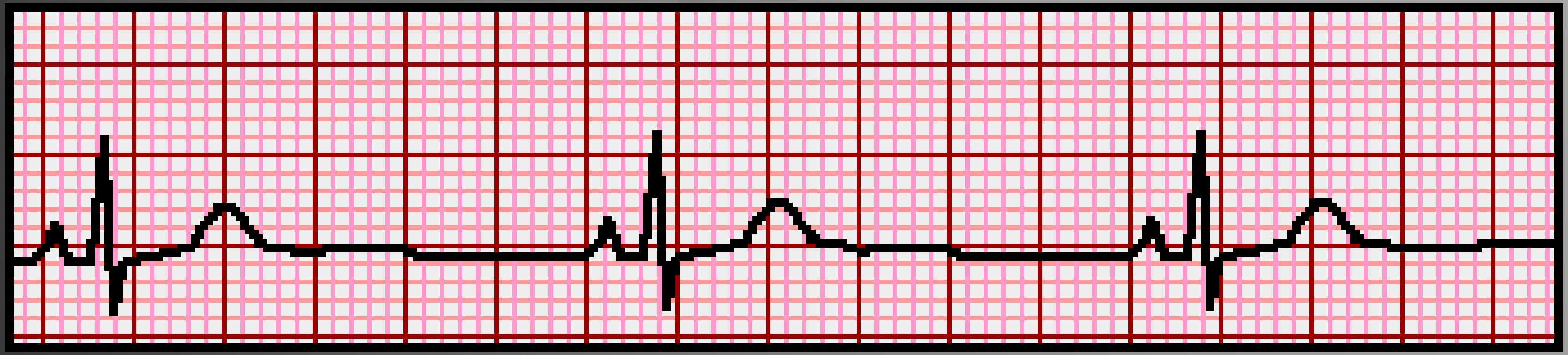
Description

- Sinus rhythm, rate 110/min
- Normal PR interval (140 ms)
- Normal QRS duration (120 ms)
- Normal cardiac axis
- Normal QRS complexes
- Normal T waves (an inverted T wave in lead VR is normal)

Interpretation

- Normal ECG

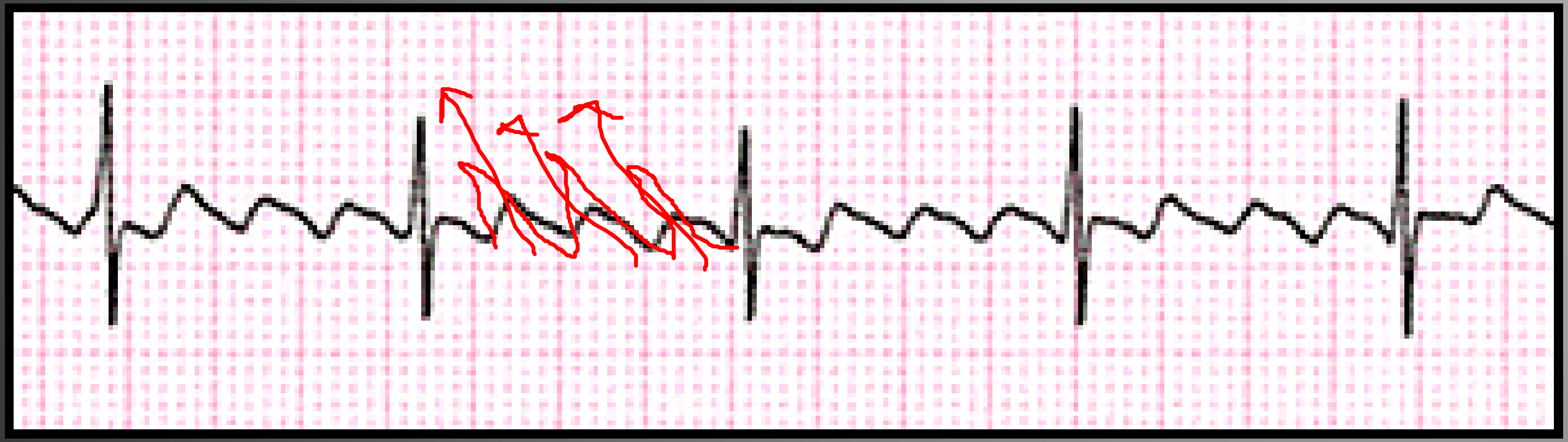
What is the heart rate?



www.uptodate.com

(300 / 6) = 50 bpm

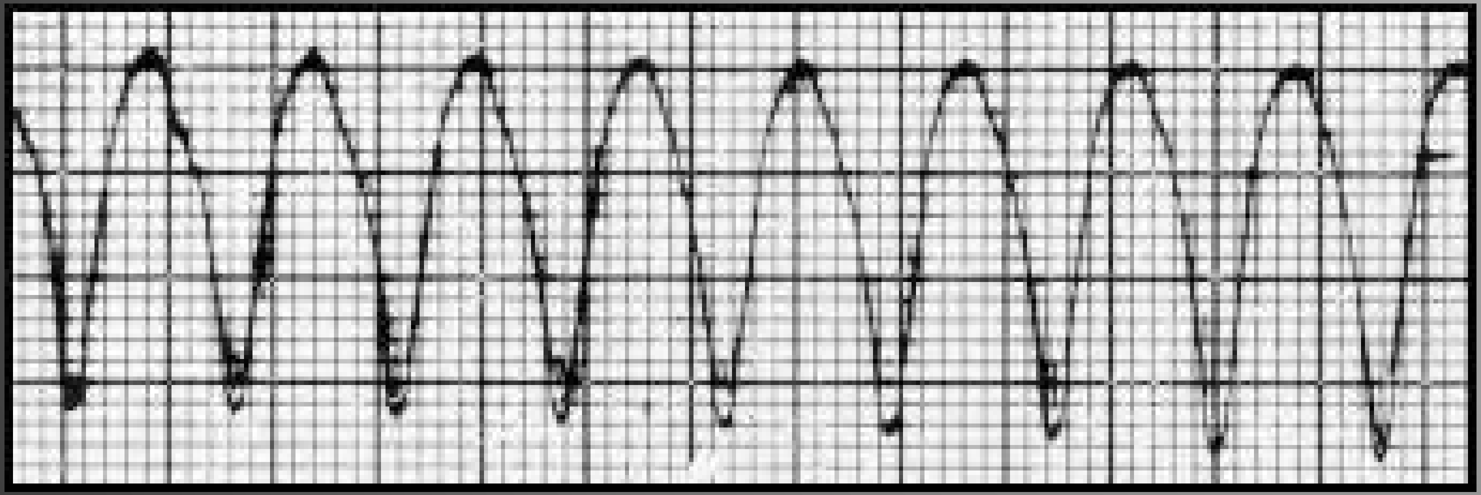
What is the heart rate?



www.uptodate.com

(300 / ~ 4) = ~ 75 bpm

What is the heart rate?



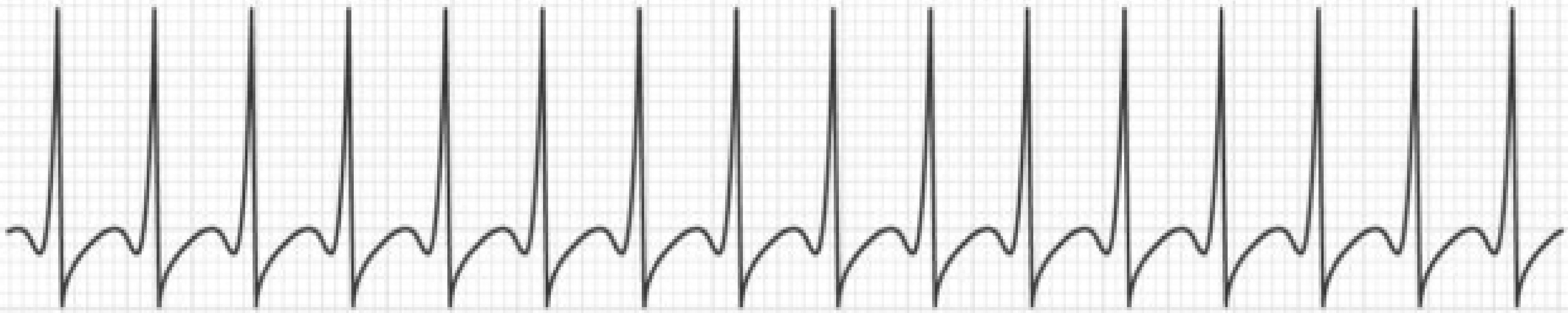
(300 / 1.5) = 200 bpm

The Rule of 300

It may be easiest to memorize the following table:

# of big boxes	Rate
1	300
2	150
3	100
4	75
5	60
6	50

Superventricular tachycardia (SVT)



Standard calibrations: 25 mm/sec 10 mm/mV

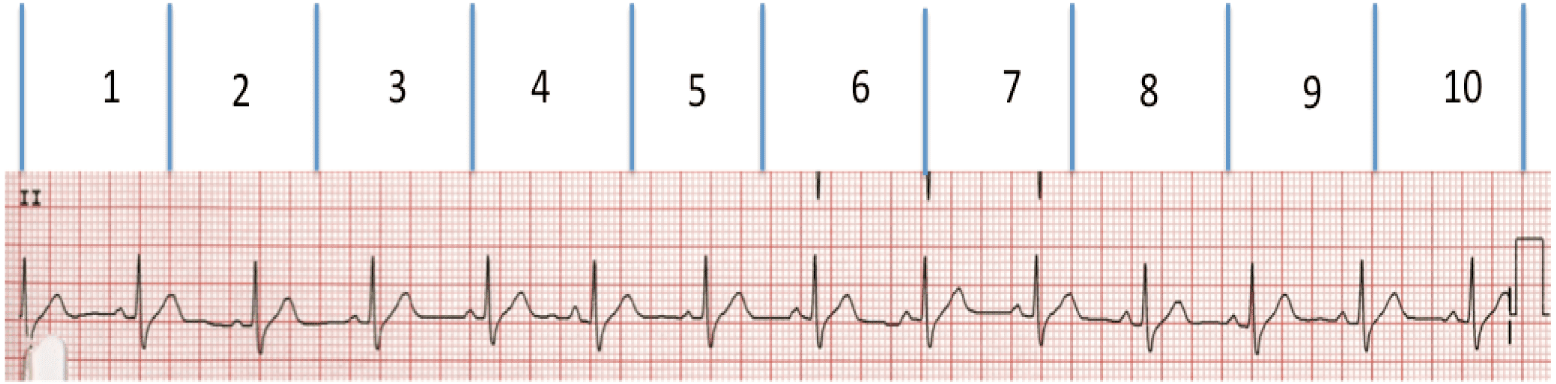
Like in the example identify two consecutive R waves and count the number of small squares (0.04s) between them. By dividing this number into 1500 (remember, this number also represents one minute) we are able to calculate a person’s heart rate.

What is the 10 Second Rule?

As most EKGs record 10 seconds of rhythm per page, one can simply count the number of beats present on the EKG and multiply by 6 to get the number of beats per 60 seconds.
This method works well for irregular rhythms.

What is the 6 second rule on ECG?

Count the number of R waves in a 6 second strip and multiply by 10. For example, if there are 7 R waves in a 6 second strip, the heart rate is 70 (7x10=70).



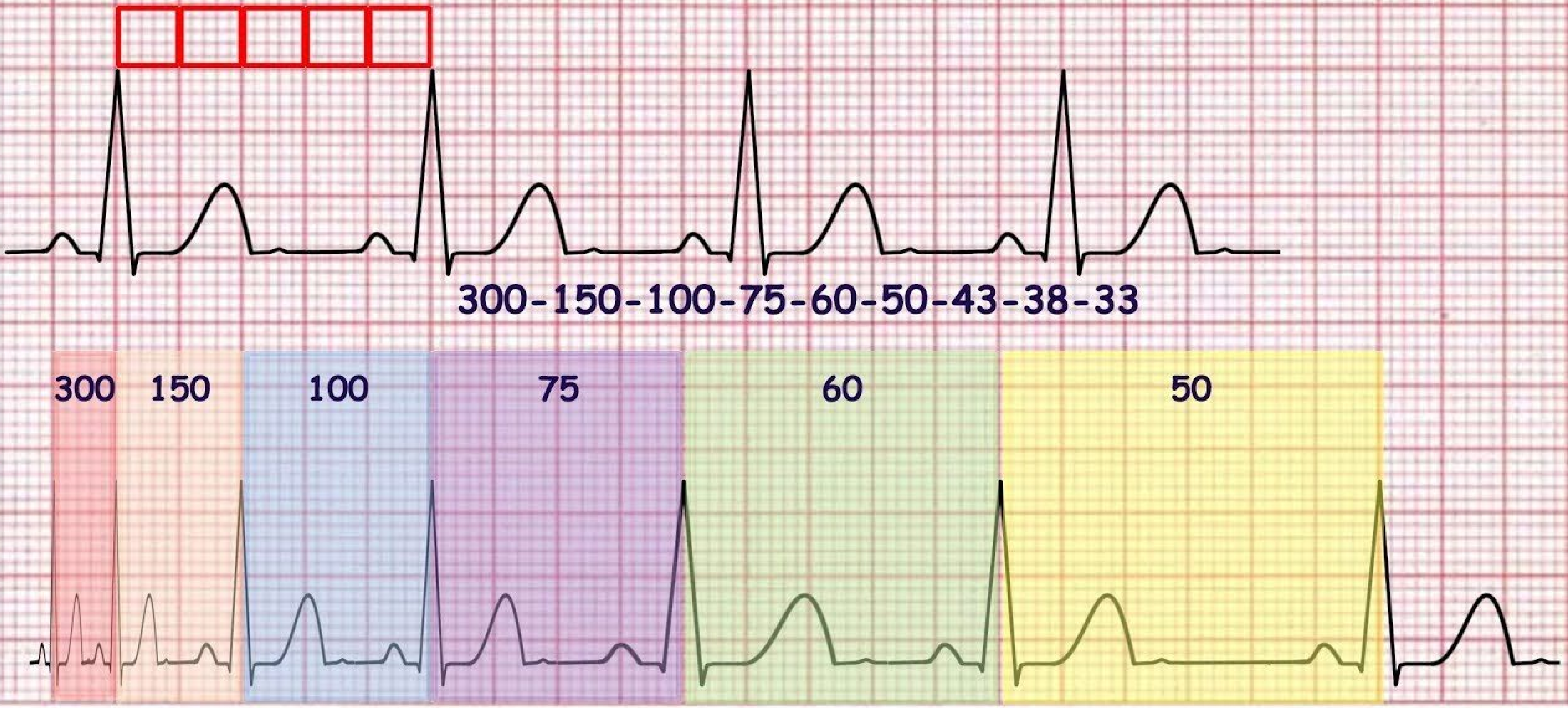
14 R waves in 10 secs

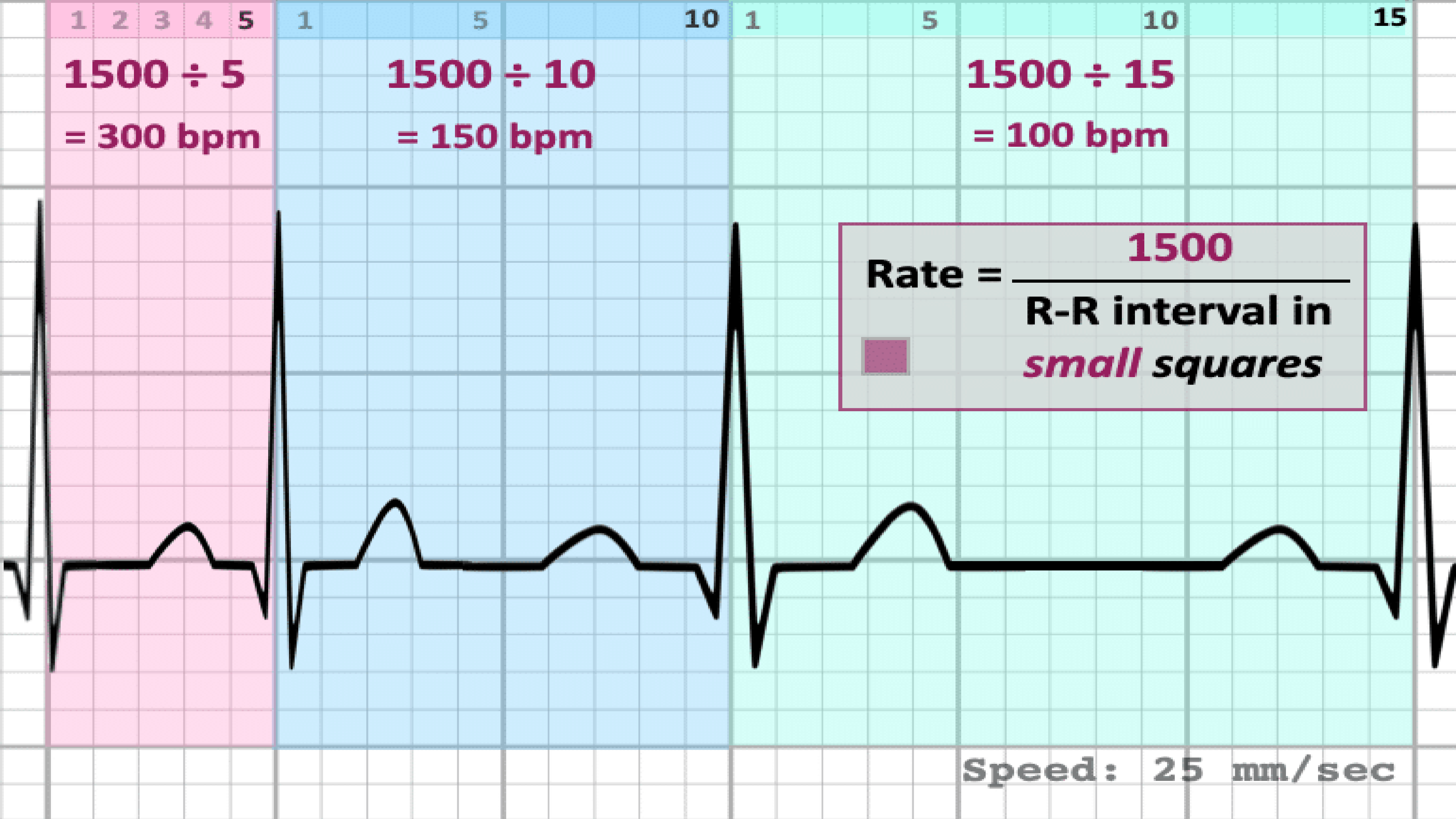
14 x 6 = 84 BPM

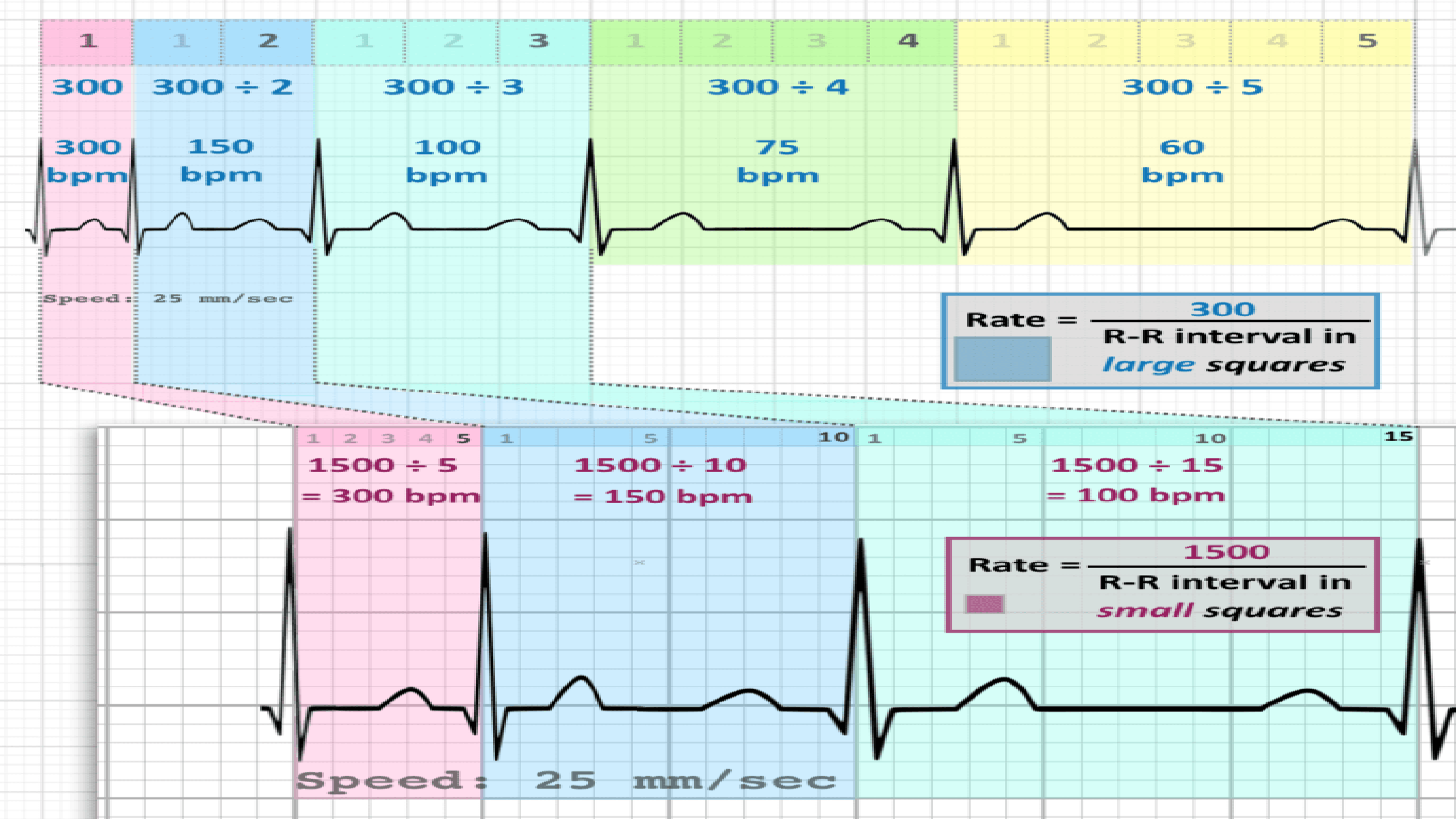
What is the 1500 rule for ECG?

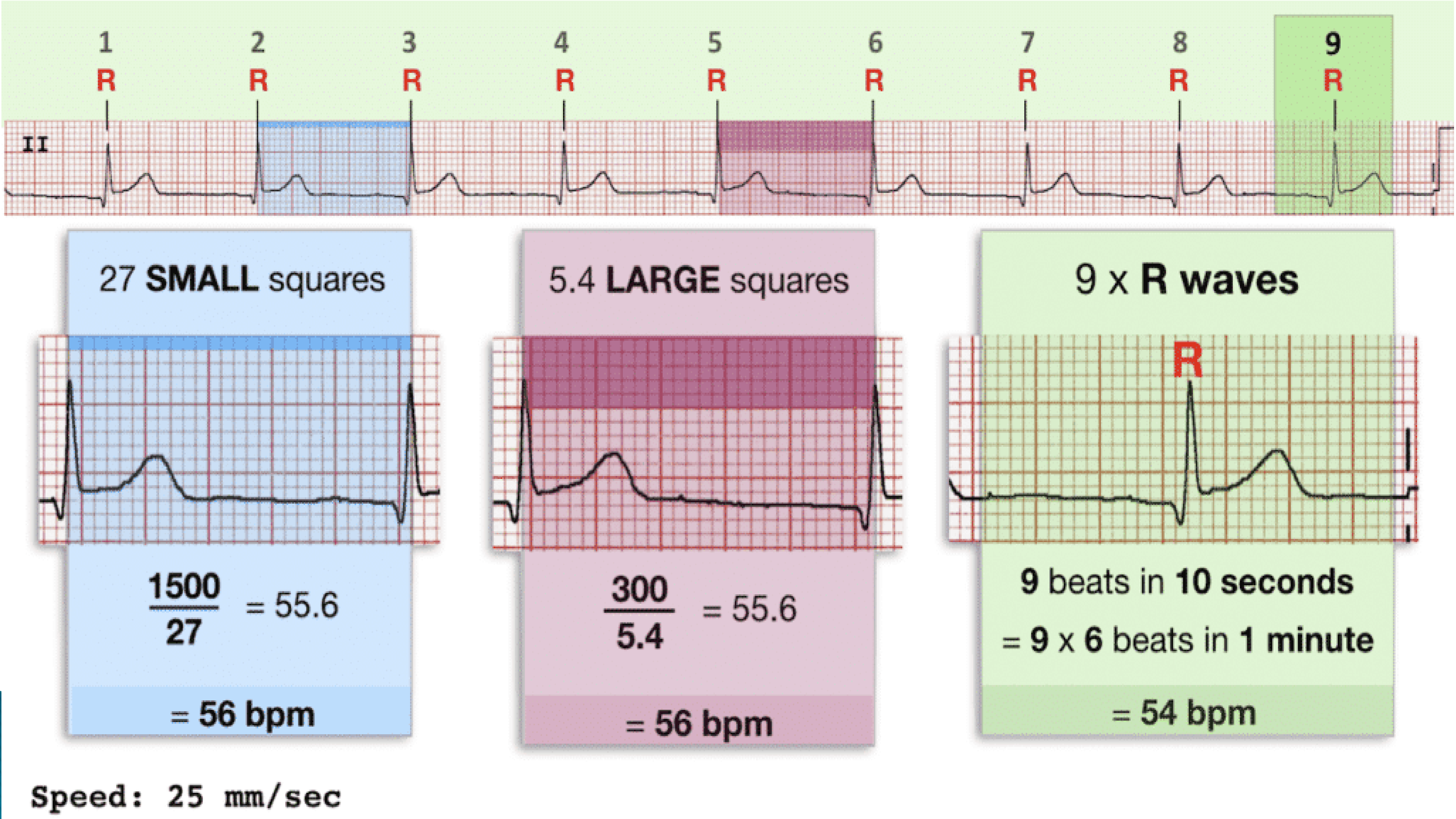
Count the number of small boxes between two successive R waves and divide this number into 1500 to obtain heart rate. This works well for faster heart rates.

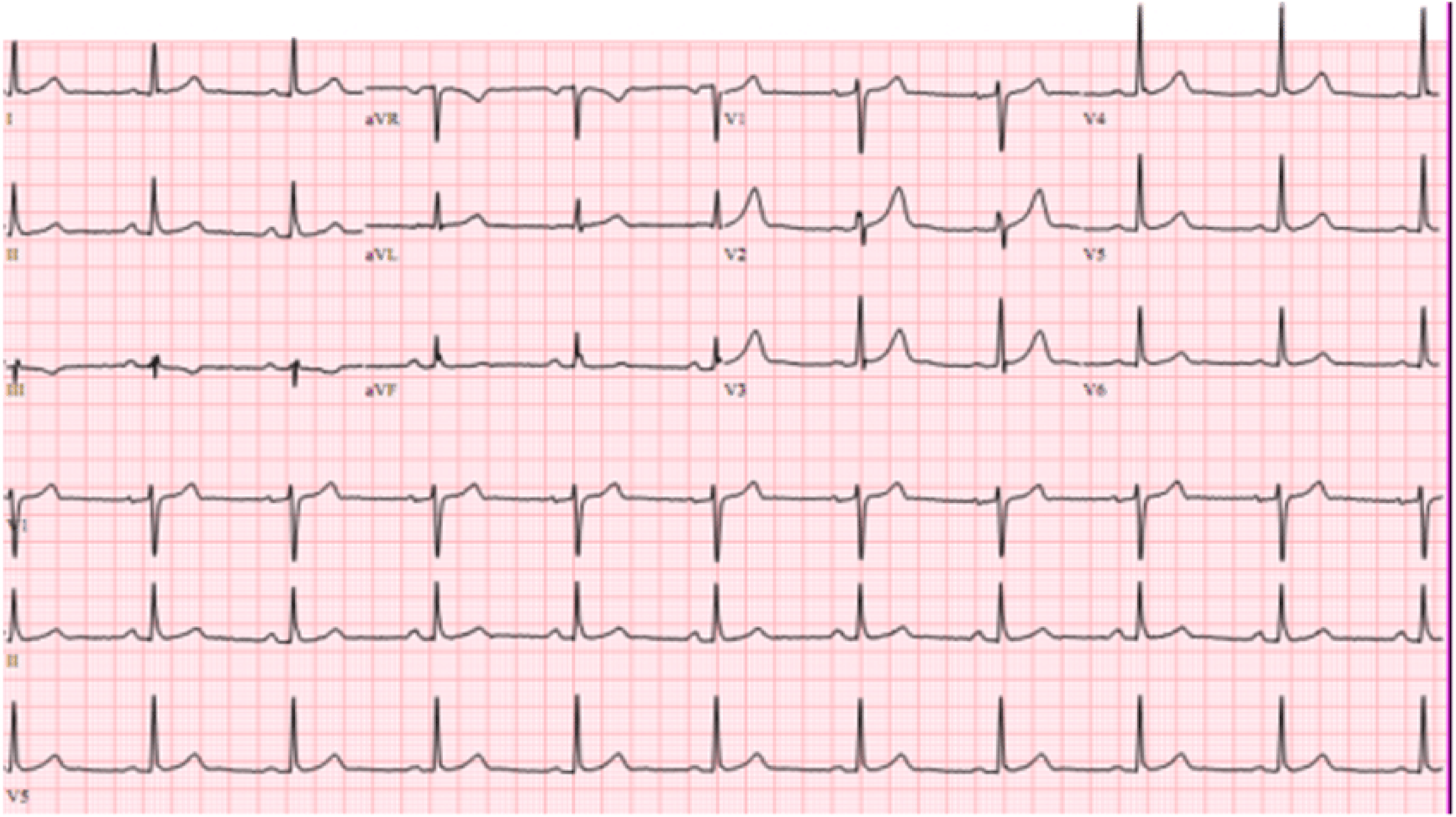
Heart rate




1 2 3 4 5
1500 ÷ 5
= 300 bpm
1 5 10
1500 ÷ 10
= 150 bpm
1 5 10 15
1500 ÷ 15
= 100 bpm
Rate = 1500 / R-R interval in small squares
Speed: 25 mm/sec

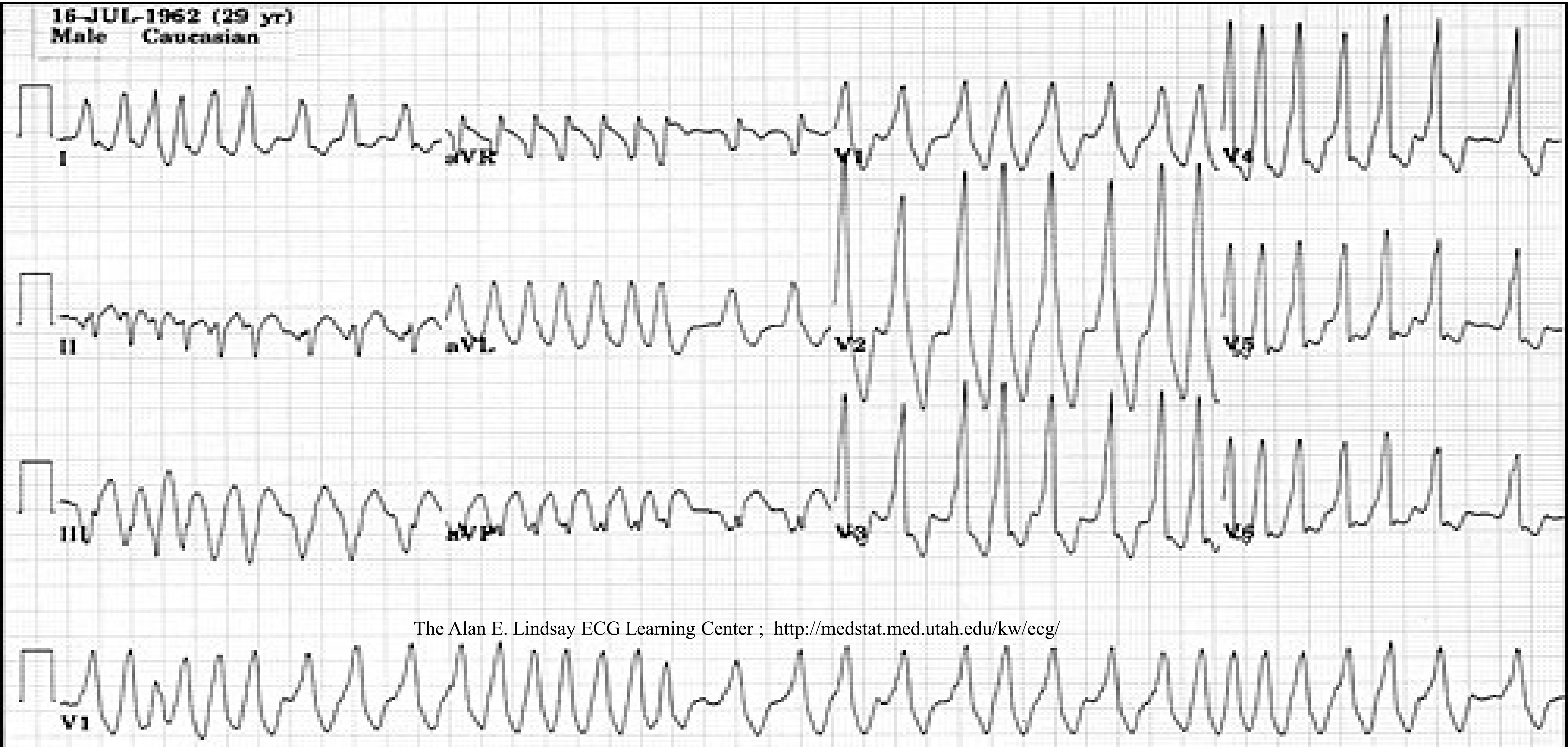

1
1 2
1 2 3
1 2 3 4
1 2 3 4 5
300
300 ÷ 2
300 ÷ 3
300 ÷ 4
300 ÷ 5
300 bpm
150 bpm
100 bpm
75 bpm
60 bpm
Speed: 25 mm/sec
Rate = 300 / R-R interval in large squares
1 2 3 4 5
1 5 10
1 5 10 15
1500 ÷ 5 = 300 bpm
1500 ÷ 10 = 150 bpm
1500 ÷ 15 = 100 bpm
Rate = 1500 / R-R interval in small squares
Speed: 25 mm/sec


1 2 3 4 5 6 7 8 9
R R R R R R R R R
II
27 **SMALL** squares
$\frac{1500}{27} = 55.6$
= 56 bpm
5.4 **LARGE** squares
$\frac{300}{5.4} = 55.6$
= 56 bpm
9 x **R waves**
R
9 beats in 10 seconds
= 9 x 6 beats in 1 minute
= 54 bpm
Speed: 25 mm/sec


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

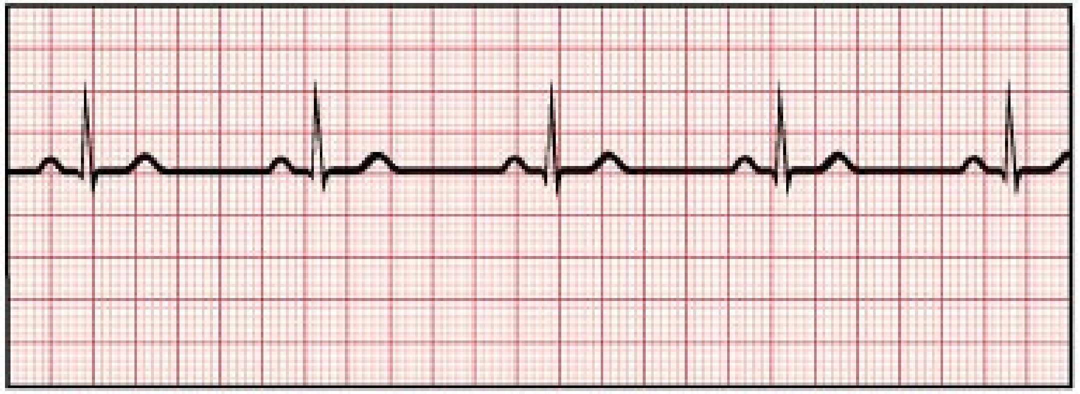
What is the heart rate?

33 x 6 = 198 bpm

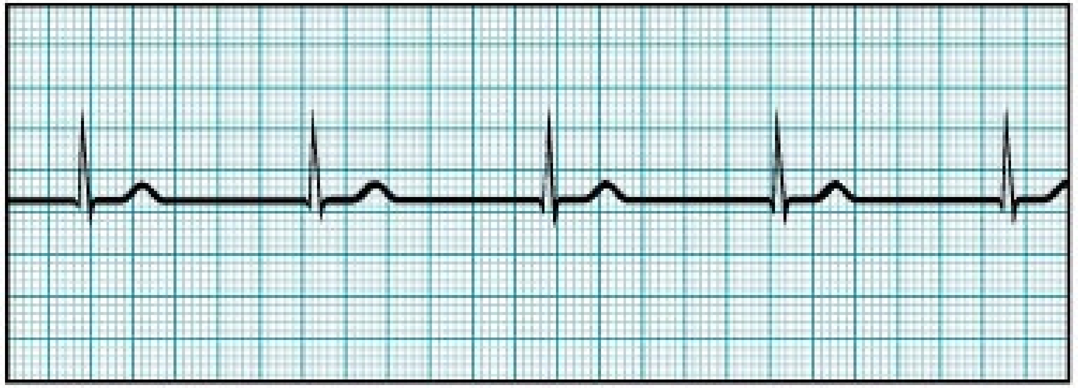


The Alan E. Lindsay ECG Learning Center ; http://medstat.med.utah.edu/kw/ecg/

ECGs, Normal and Abnormal

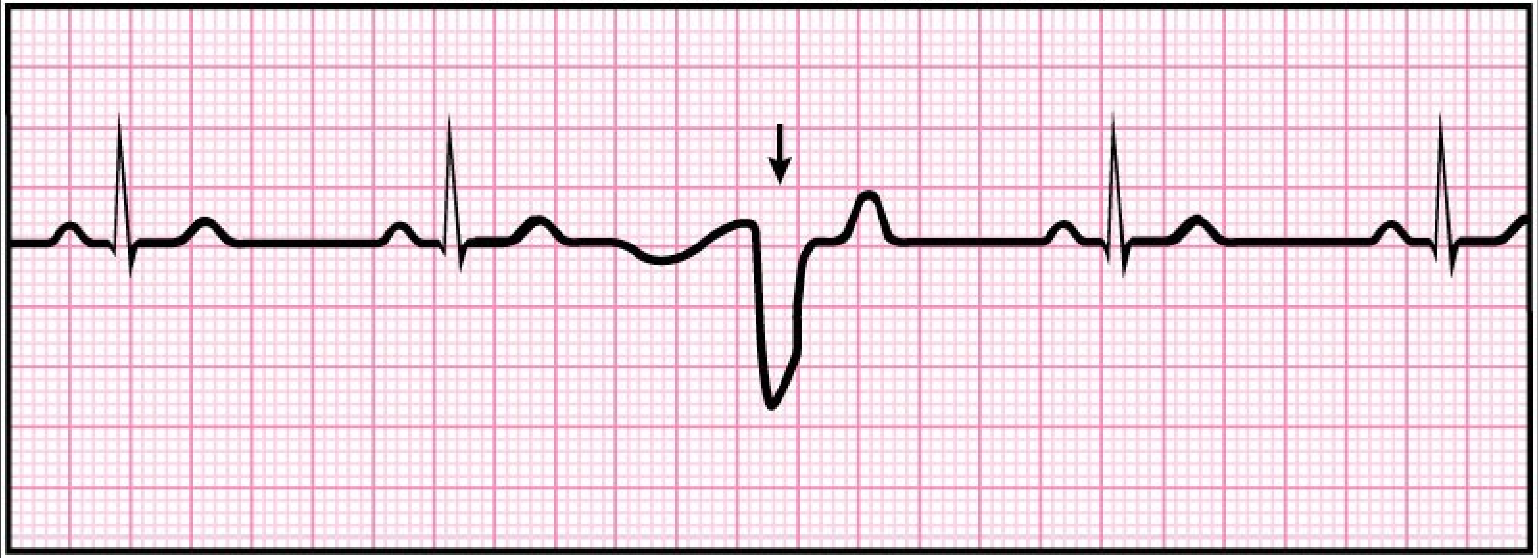


(a) Sinus rhythm (normal)



(b) Nodal rhythm – no SA node activity

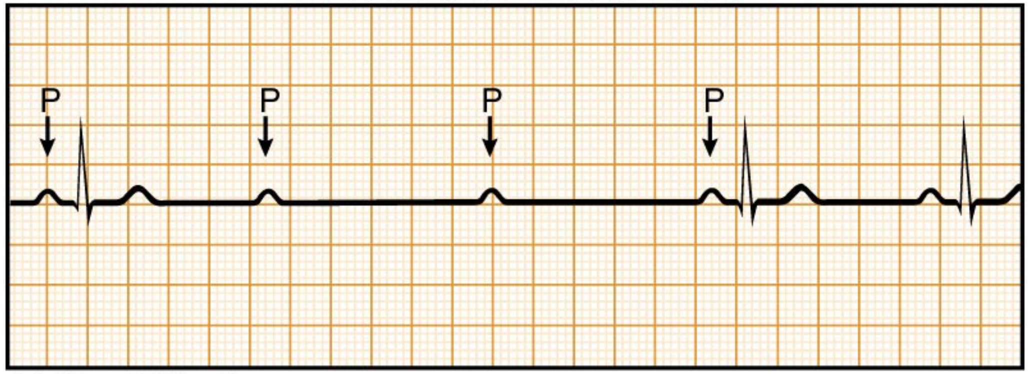
ECGs, Abnormal



(d) Premature ventricular contraction

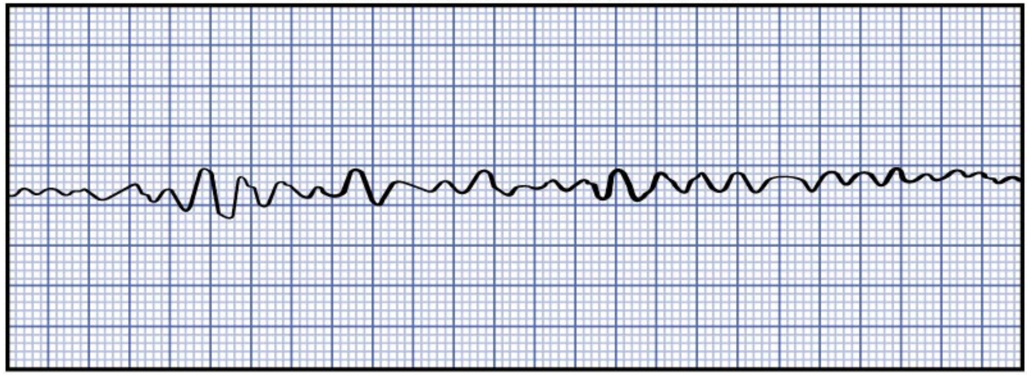
Extrasystole : note inverted QRS complex, misshapen QRS and T and absence of a P wave preceding this contraction.

ECGs, Abnormal



(c) Heart block

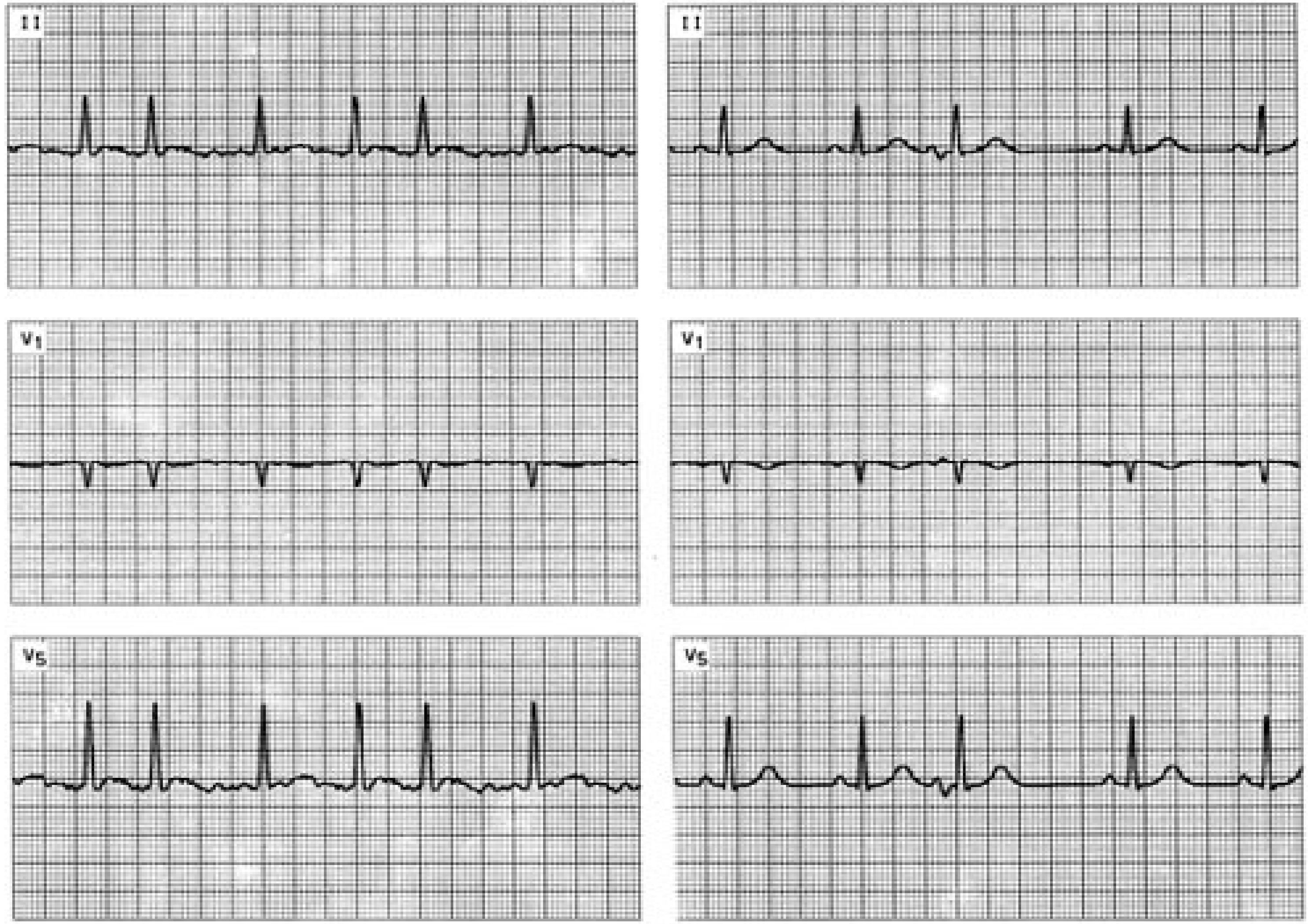
Arrhythmia: conduction failure at AV node



(e) Ventricular fibrillation

No pumping action occurs

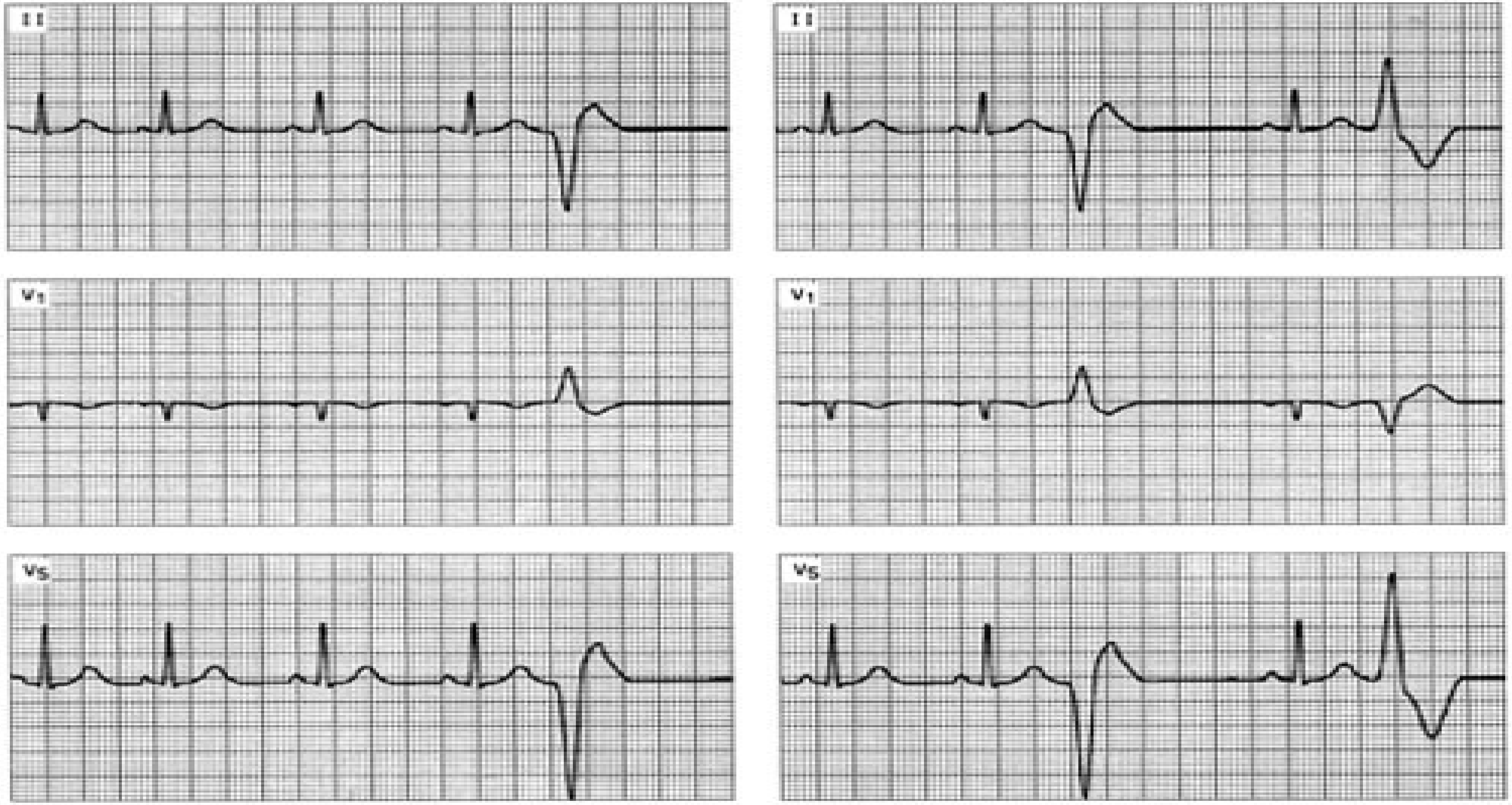
Irregular ECGs



A

B

Irregular ECGs

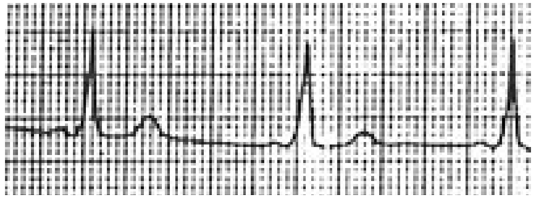


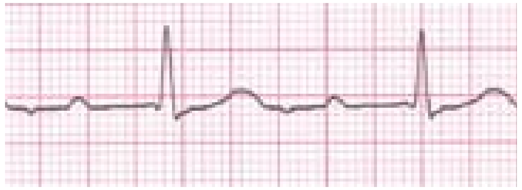
C D

Rate Rhythm Axis **Intervals** Hypertrophy Infarct

PR interval

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

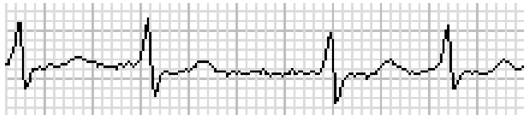


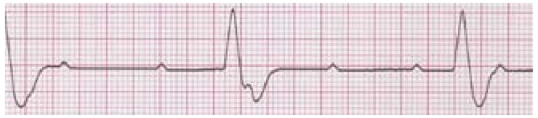


Rate Rhythm Axis **Intervals** Hypertrophy Infarct

QRS complex

< 0.10 s	0.10-0.12 s	> 0.12 s
Normal	Incomplete bundle branch block	Bundle branch block PVC Ventricular rhythm





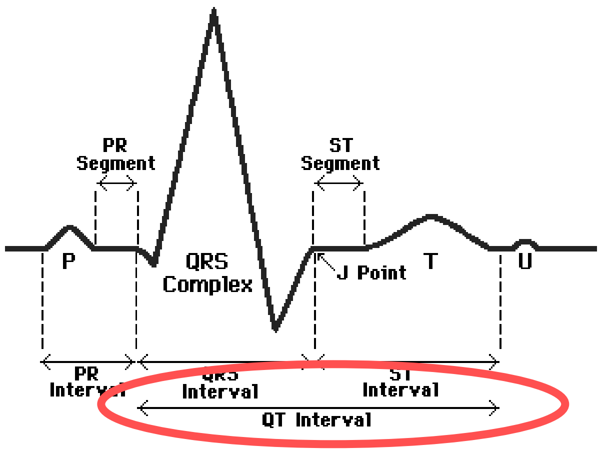
Rate Rhythm Axis Intervals Hypertrophy Infarct

QT interval

The duration of the QT interval is proportionate to the heart rate.

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

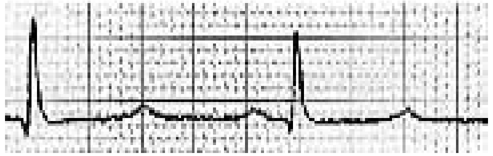
QTc = QT / square root of RR interval

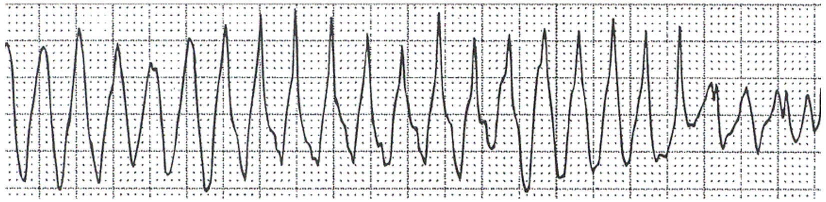


Rate Rhythm Axis **Intervals** Hypertrophy Infarct

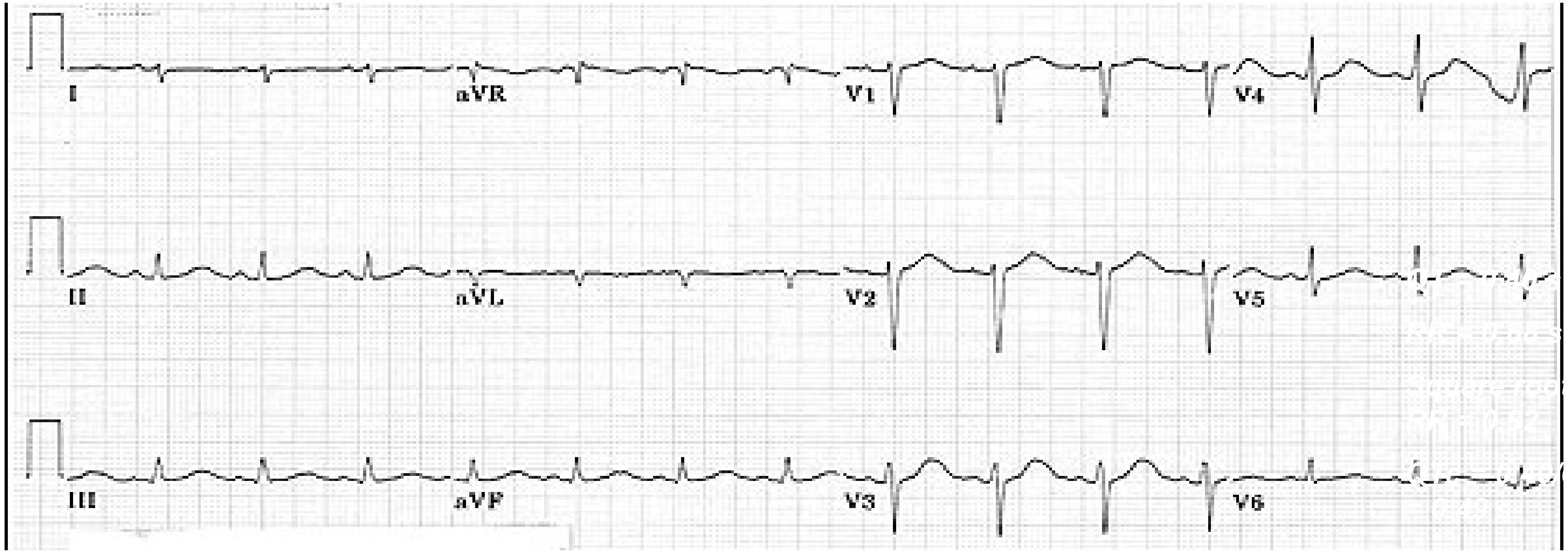
QTc interval

< 0.44 s	> 0.44 s
Normal	Long QT





Rate Rhythm Axis **Intervals** Hypertrophy Infarct



PR interval? *0.16 seconds*

QRS width? *0.08 seconds*

QTc interval? *0.49 seconds*

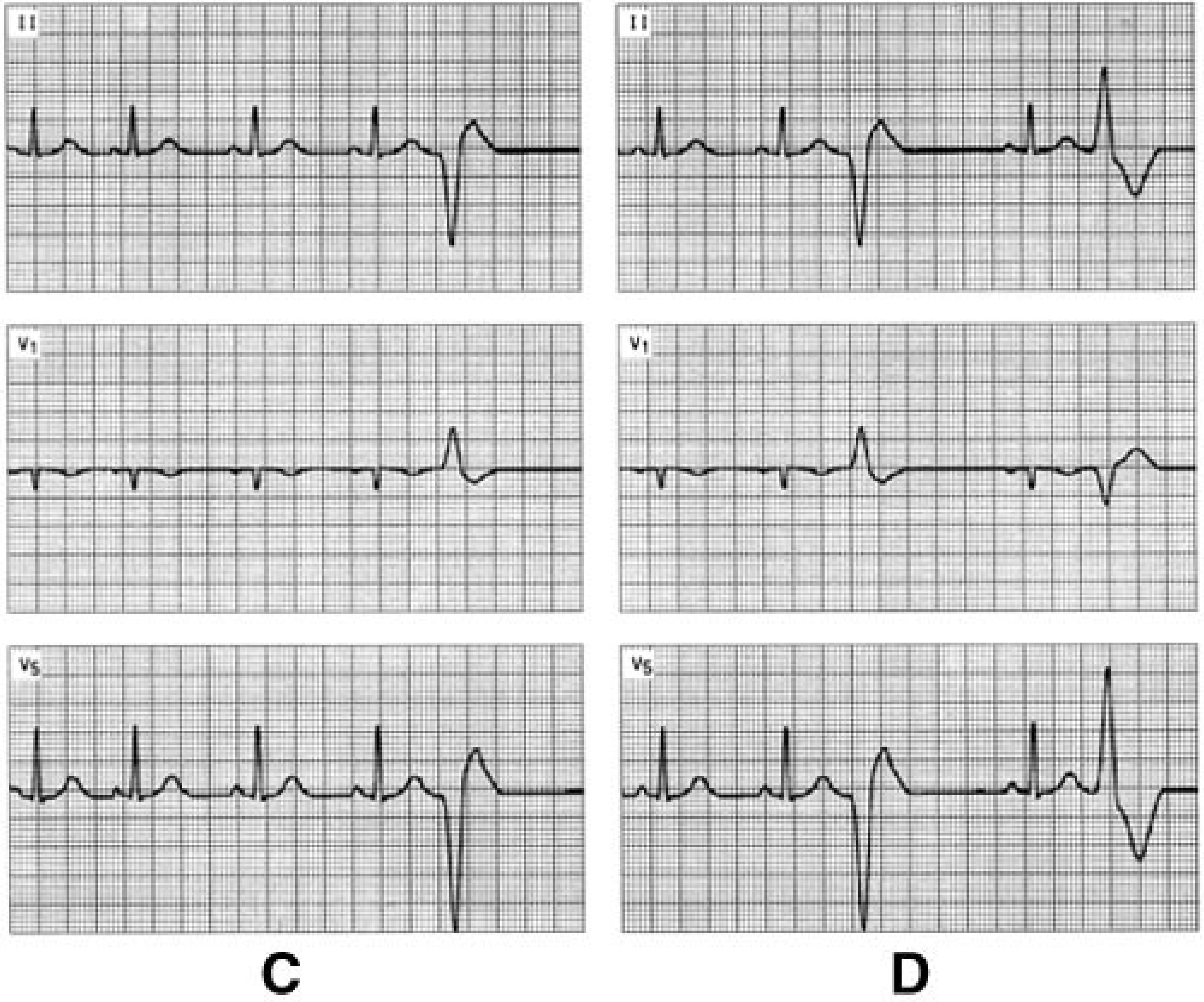
Interpretation of intervals? *Normal PR and QRS, long QT*

Irregular ECGs

A

B

Irregular ECGs



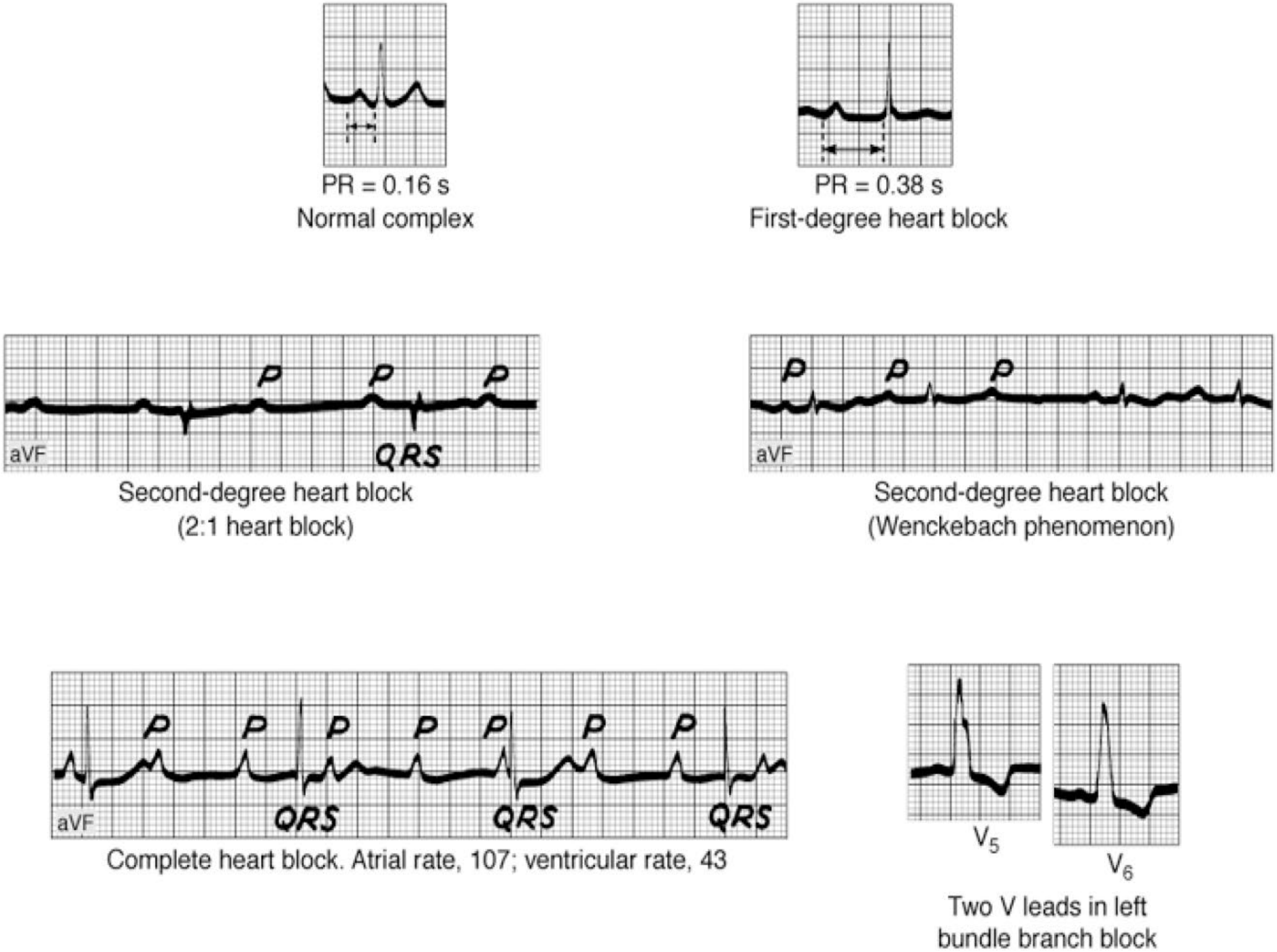
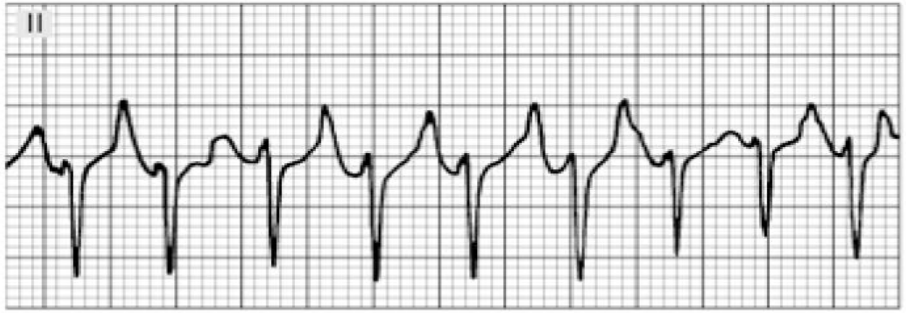
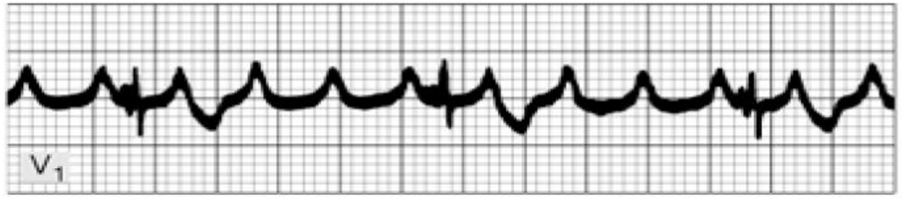


Figure 28-11. Heart block.

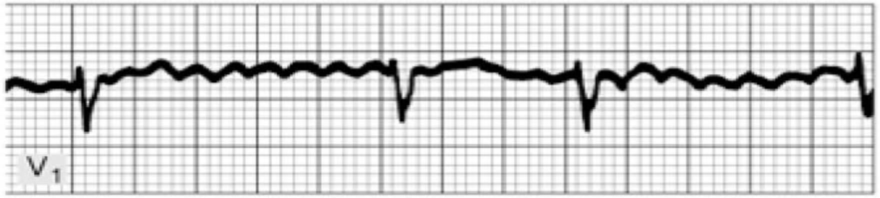
Atrial extrasystole



Atrial tachycardia



Atrial flutter



Atrial fibrillation

Figure 28-13. Atrial arrhythmias. The illustration shows an atrial premature beat with its P wave superimposed on the T wave of the preceding beat (arrow); atrial tachycardia; atrial flutter with 4:1 AV block; and atrial fibrillation with a totally irregular ventricular rate. (Tracings reproduced, with permission, from Goldschlager N, Goldman MJ: *Principles of Clinical Electrocardiography,* 13th ed. Originally published by Appleton & Lange.

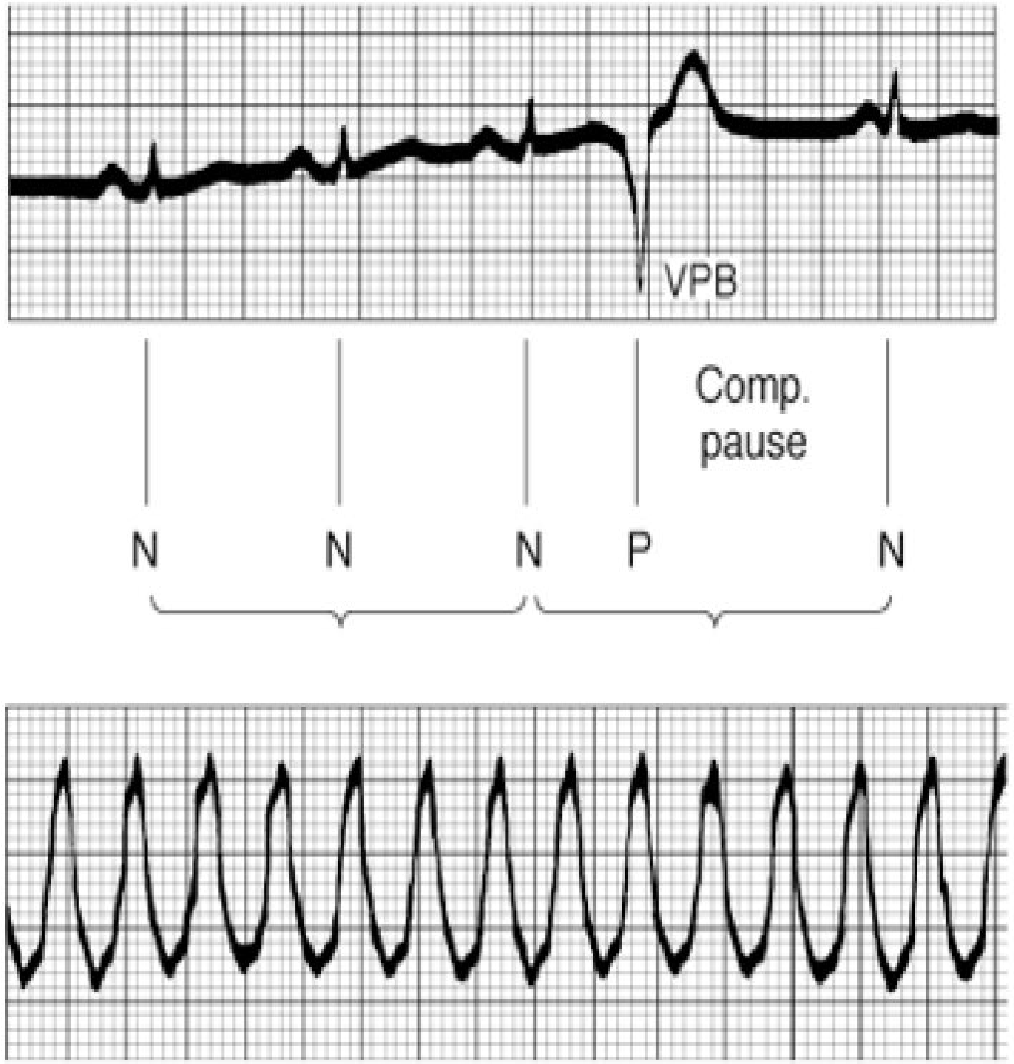
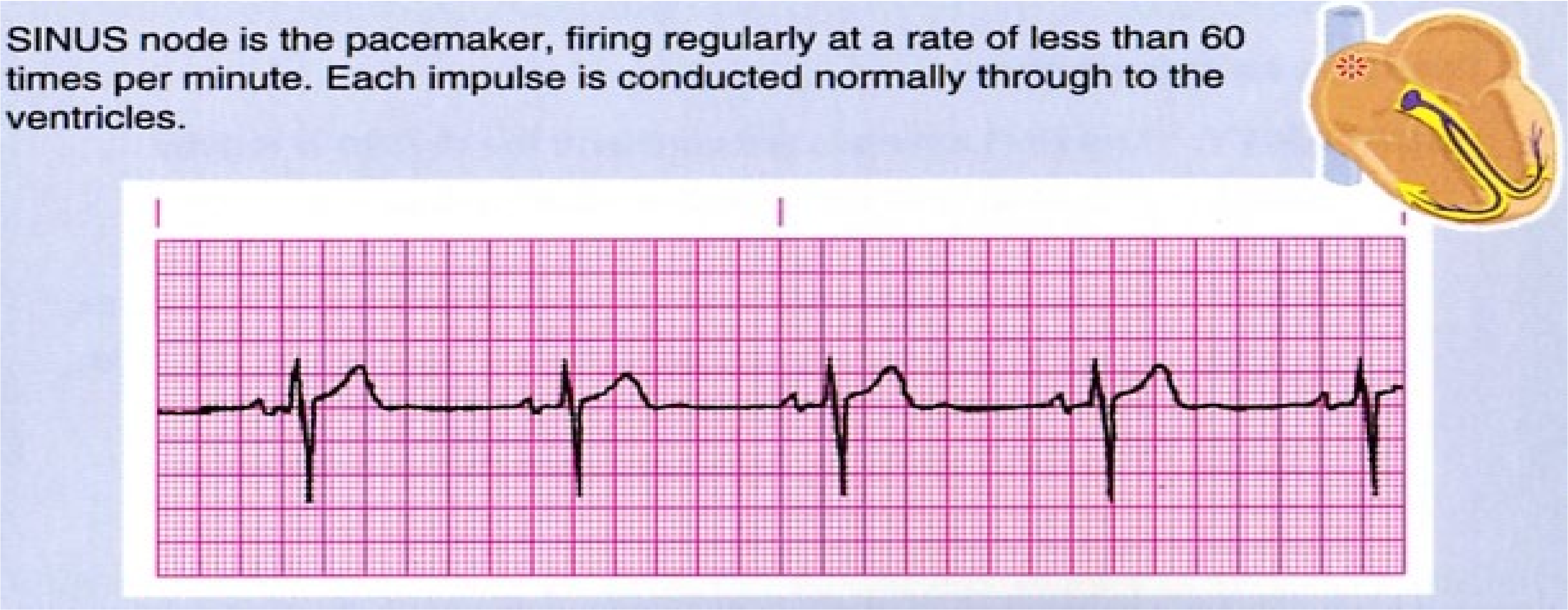
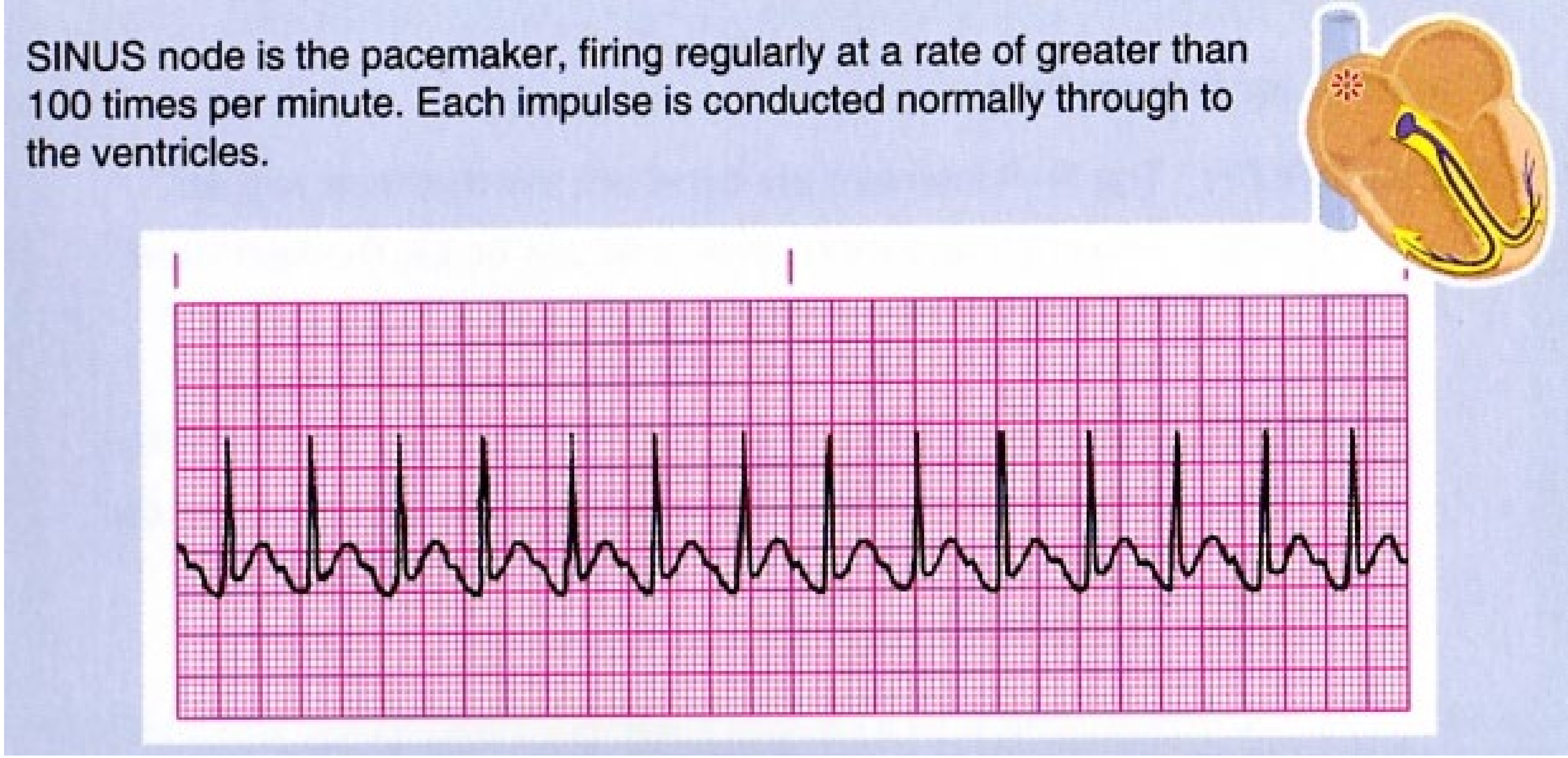


Figure 28-14. **Top:** Ventricular premature beats (VPB). The lines under the tracing illustrate the compensatory pause and show that the duration of the premature beat plus the preceding normal beat is equal to the duration of two normal beats. **Bottom:** Ventricular tachycardia.

Normal Sinus Rhythm

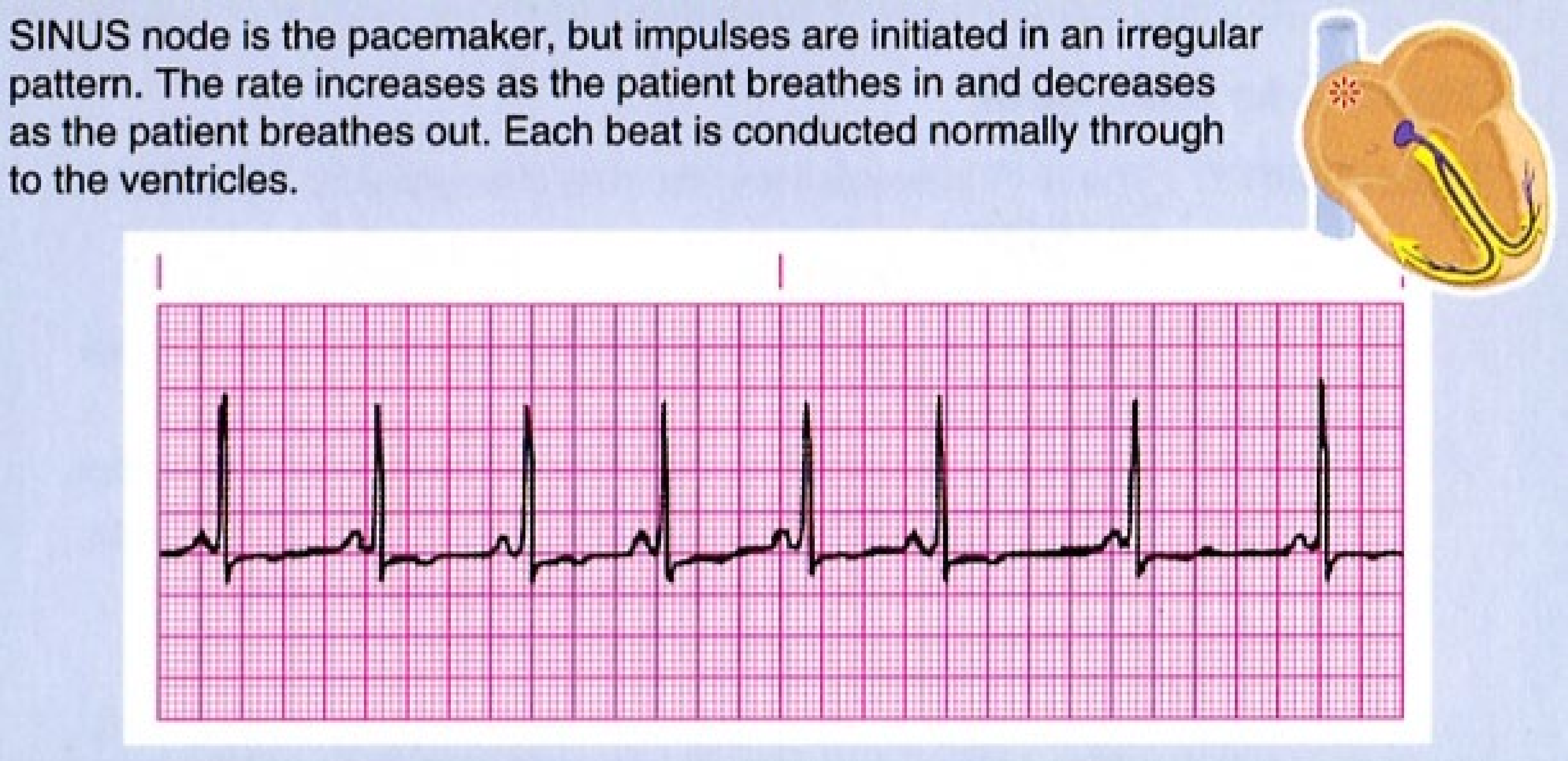


Sinus Bradycardia

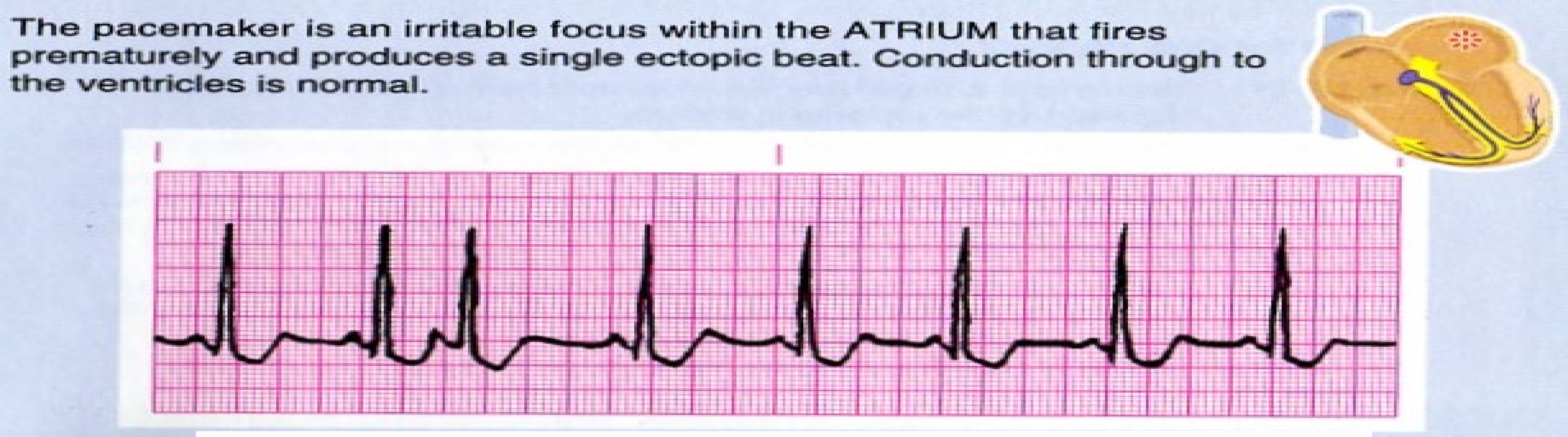


*

Sinus Tachycardia

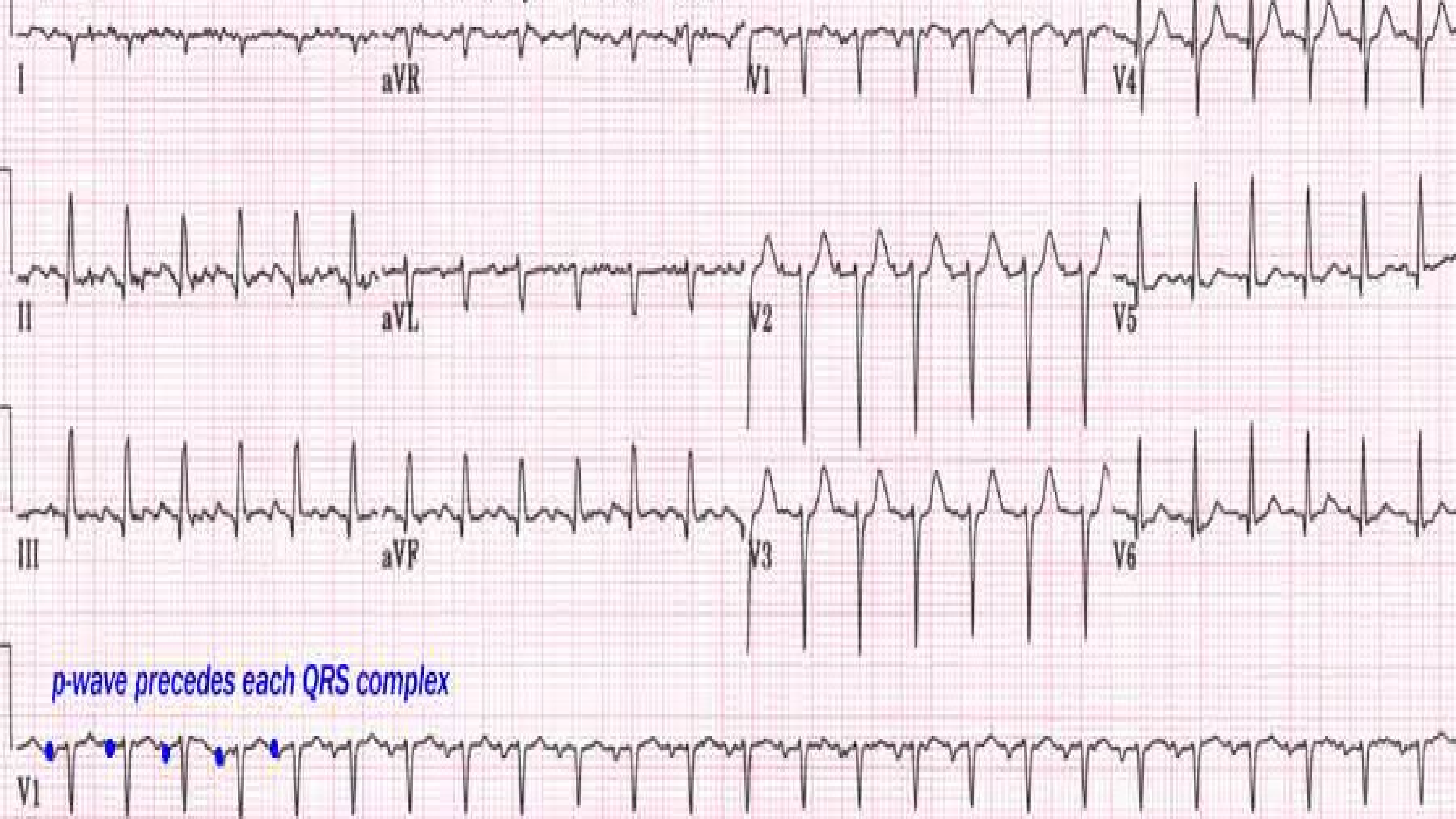


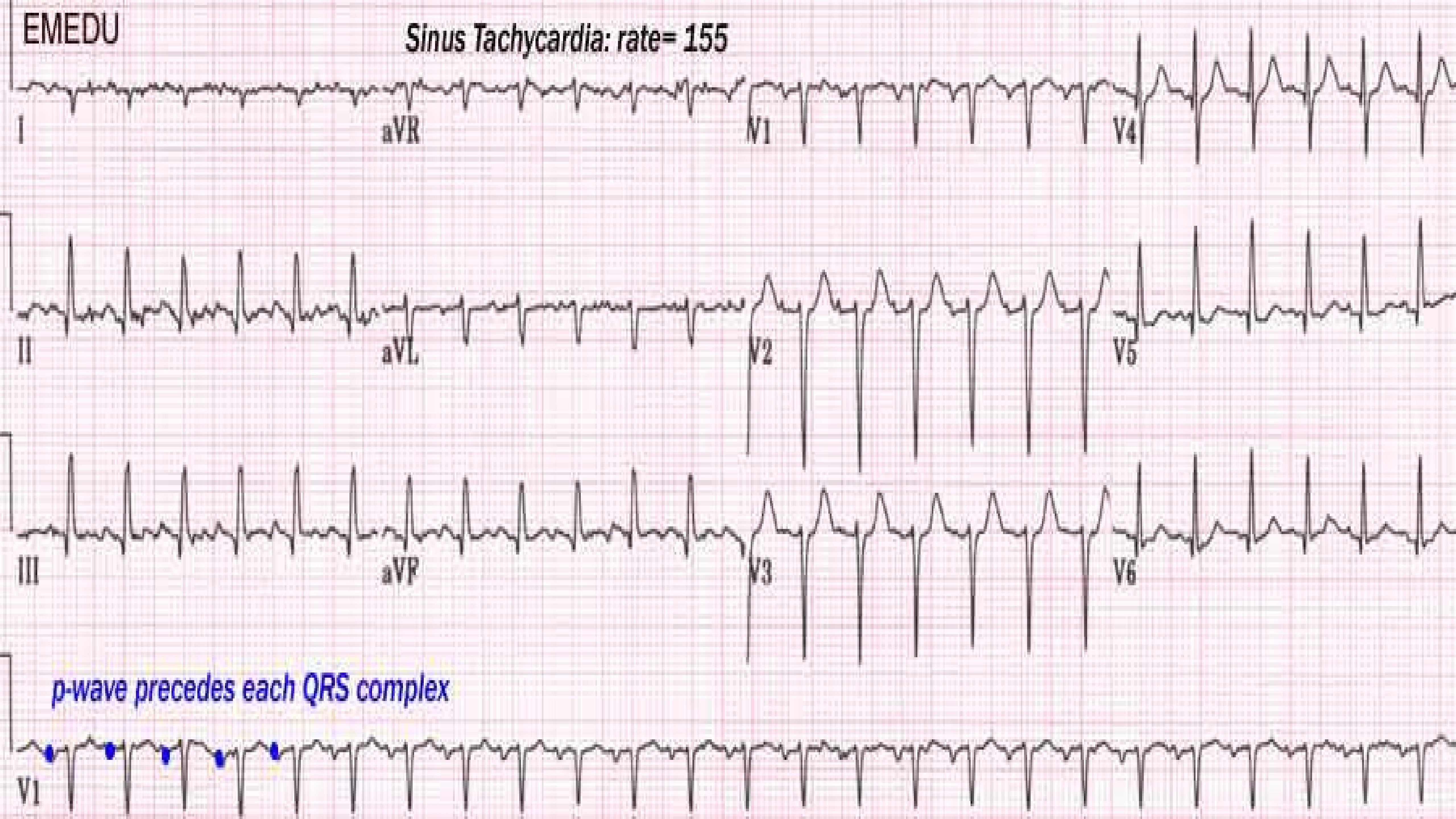
Sinus Arrhythmia

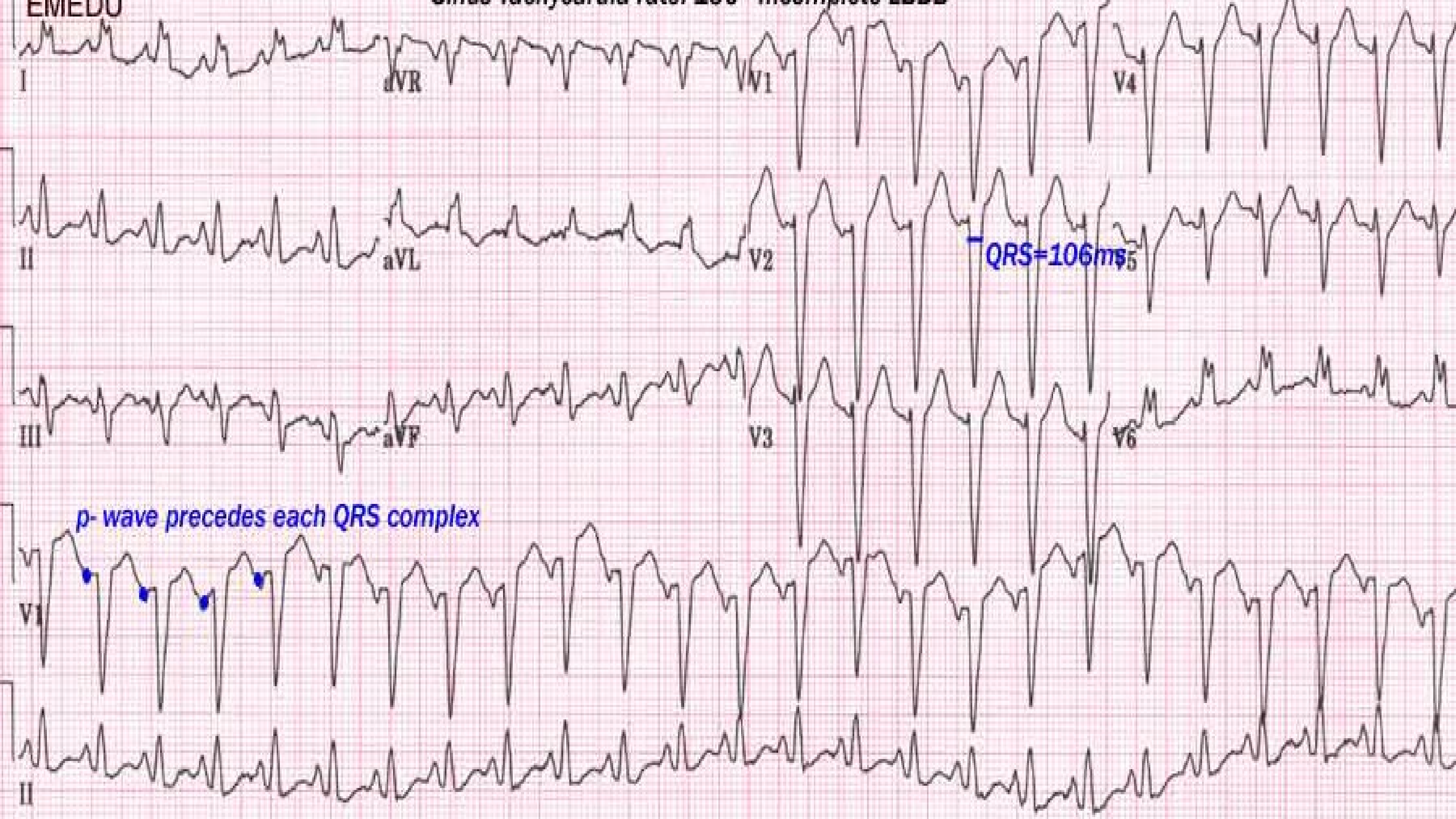


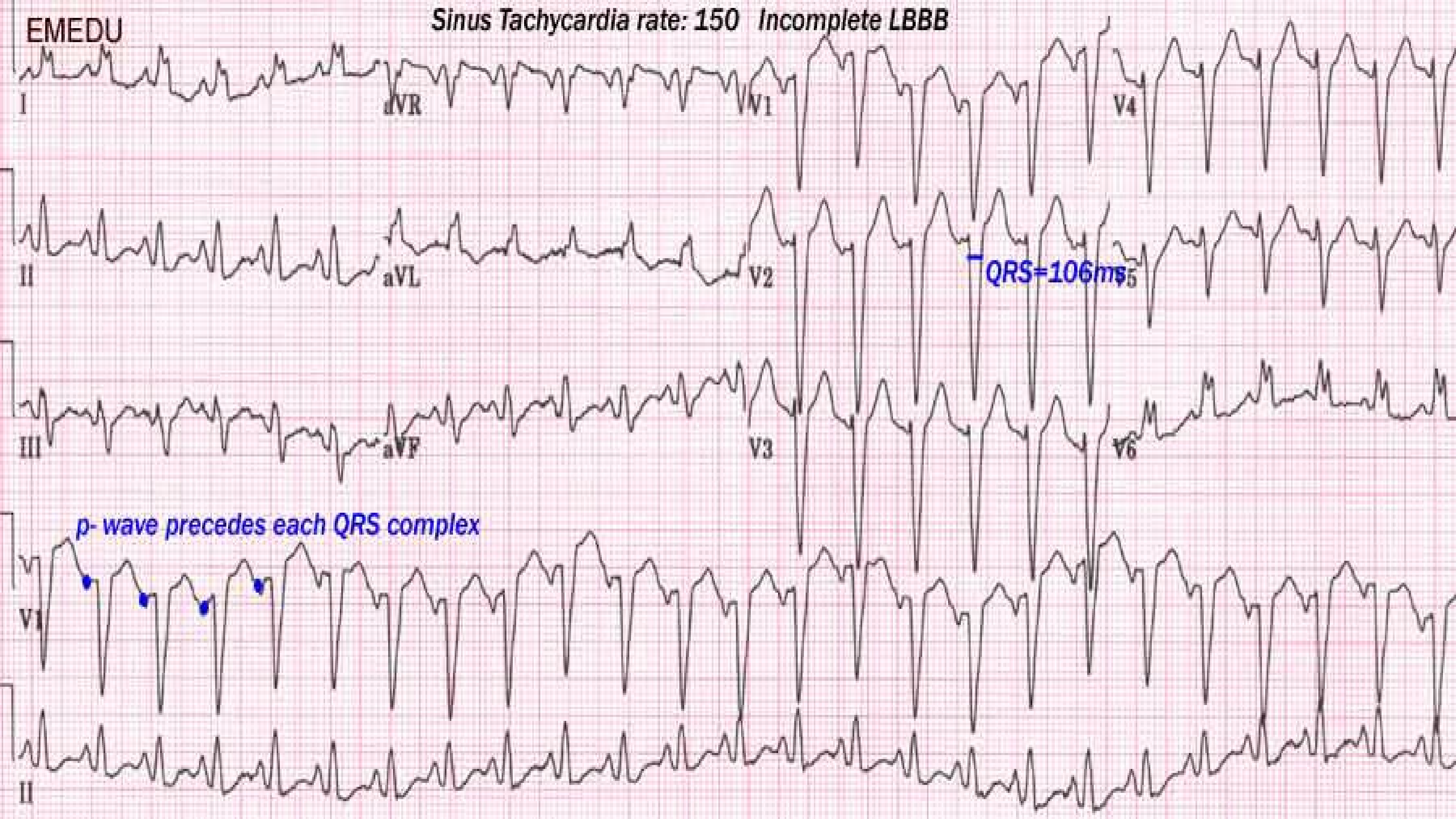
Premature atrial contraction acronym is PAC; sort of a misnomer as this is a premature atrial depolarization.
Some also call this a premature atrial beat (PAB), but again electrical depolarization does not always mean mechanical contraction.
Here there is a focus other than the SA node that is firing, which causes a QRS.
What is they underlying rate? 7*10 using 6-second. Or, 75 using 4 big boxes per QRS.
The PAC is the third QRS; you can see there is only about 1 big box between the 2nd and 3rd QRS.
Usually the abnormal focus will cause a p-wave the looks different from the other p-waves (the SA node p-waves).
Here the aberrant atrial depolarization appears as a peaked p-wave in comparison.

Premature Atrial Contraction


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
p-wave precedes each QRS complex
V1


EMEDU
Sinus Tachycardia: rate= 155
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
p-wave precedes each QRS complex
V1


EMEDU
I
aVR
V1
V4
II
aVL
V2
QRS=106ms
V5
III
aVF
V3
V6
p- wave precedes each QRS complex
V1
II


EMEDU
Sinus Tachycardia rate: 150 Incomplete LBBB
I
aVR
V1
V4
II
aVL
V2
QRS=106ms
V5
III
aVF
V3
V6
p- wave precedes each QRS complex
V1
II

What do you think?

a

b

A: normal
B: sinus tachycardia

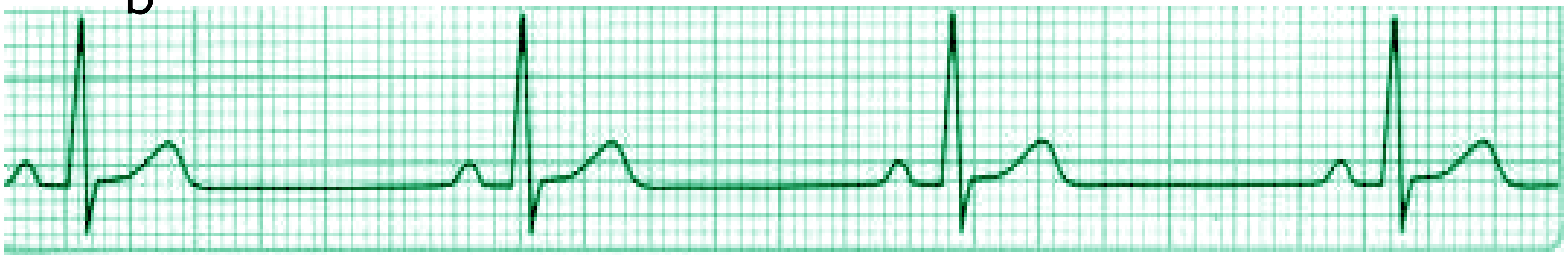
a

b

What do you think?

a

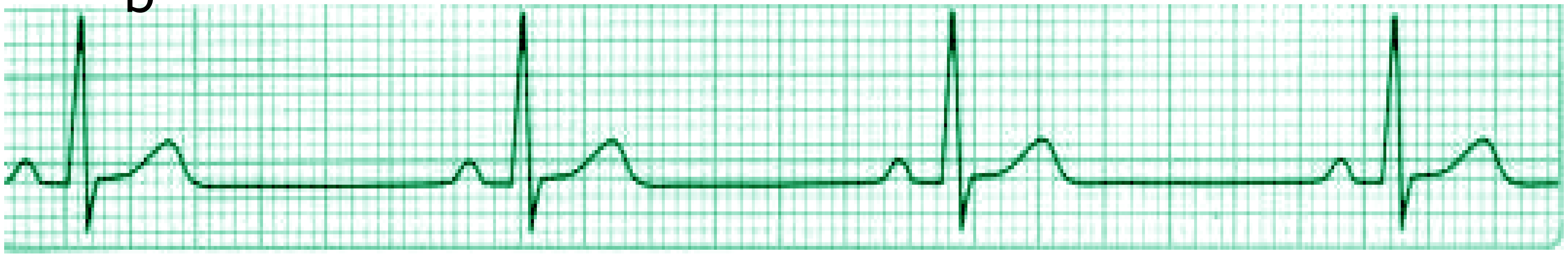
b

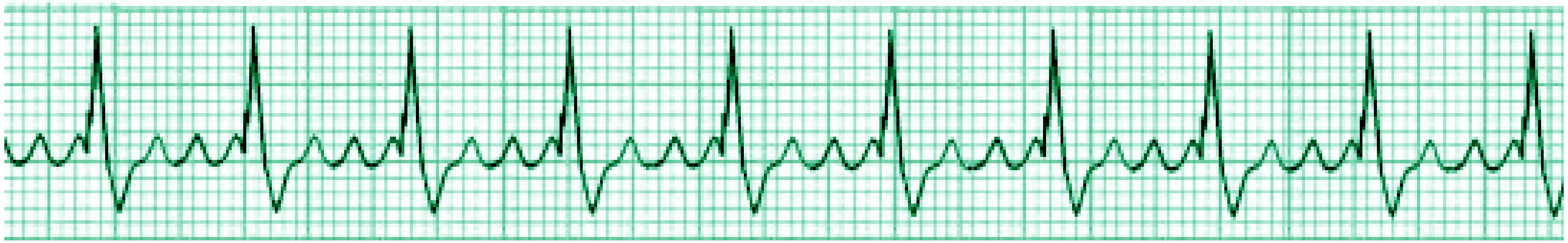


A: normal
B:sinus bradycardia

a

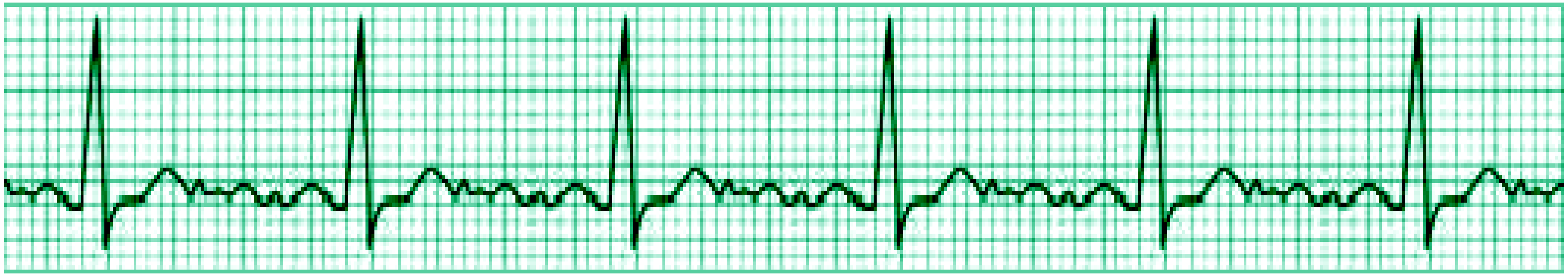
b





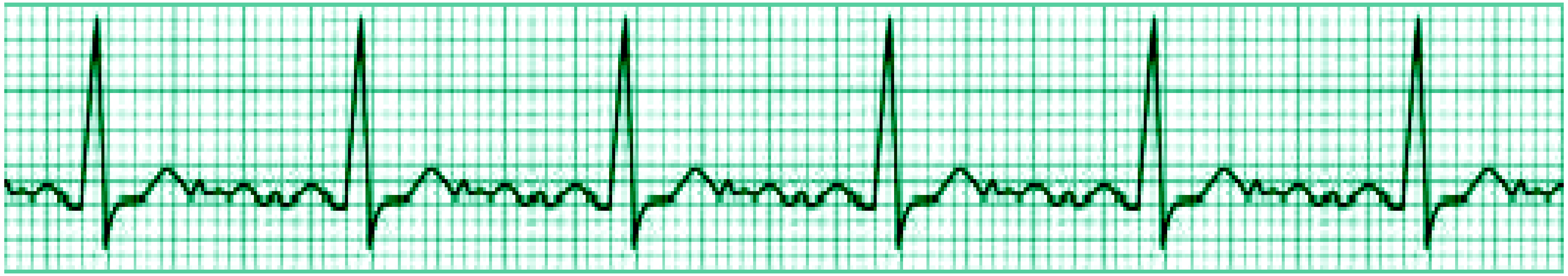
Normal

Atrial Flutter



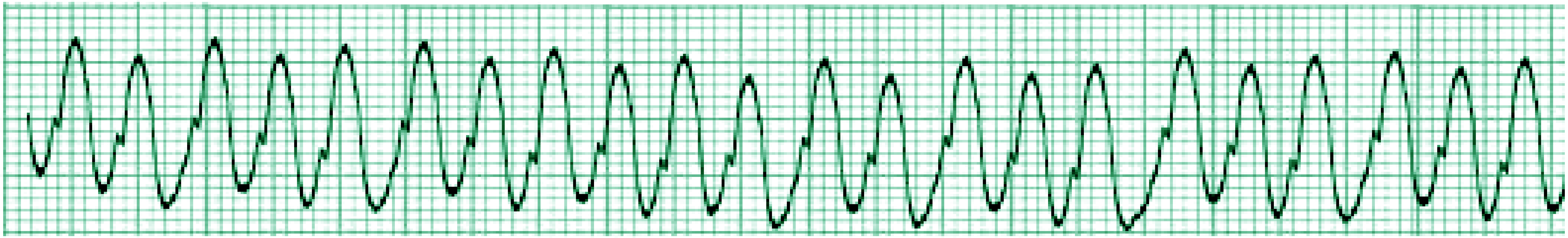
Normal

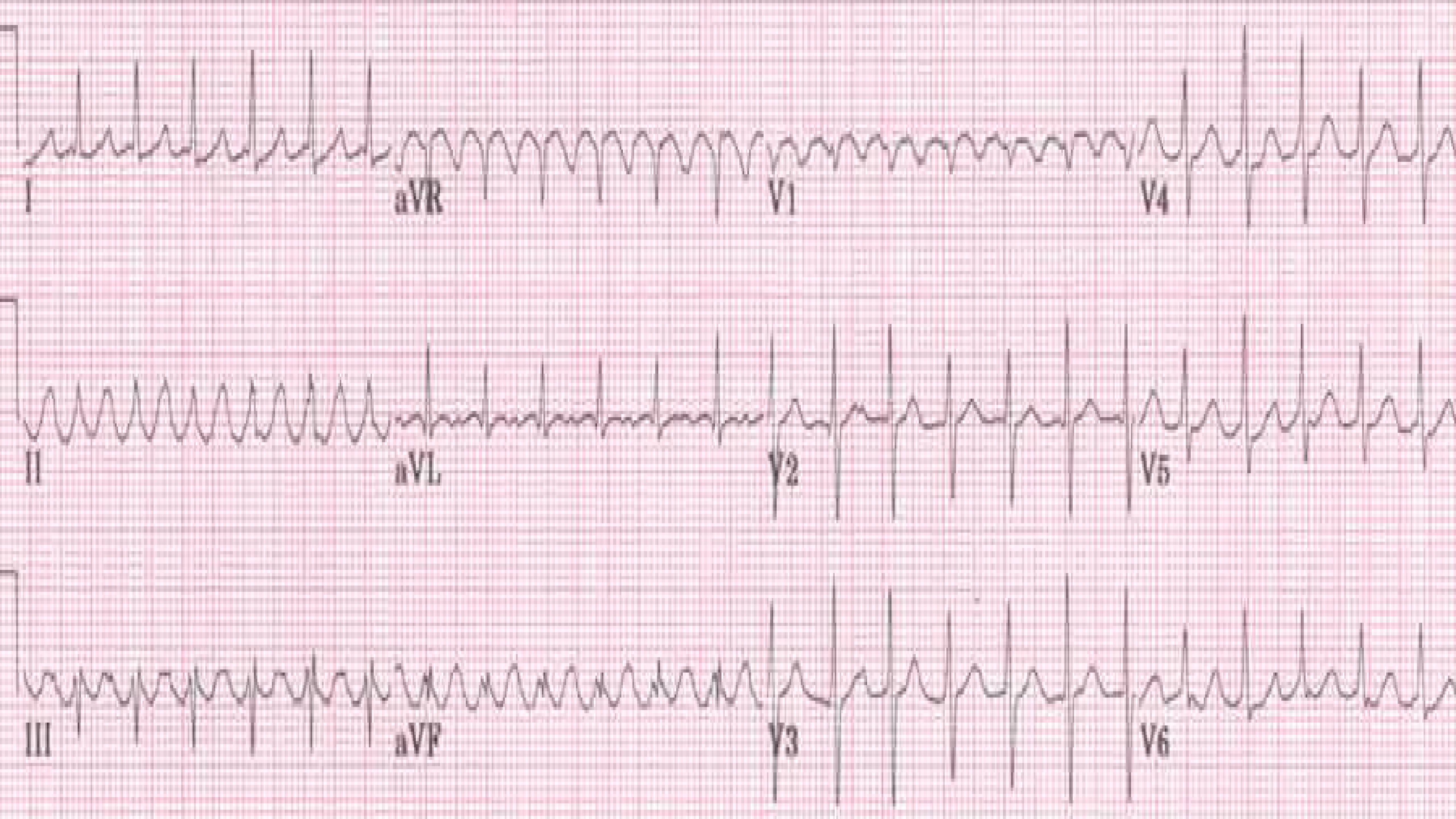
Atrial Fibrillation

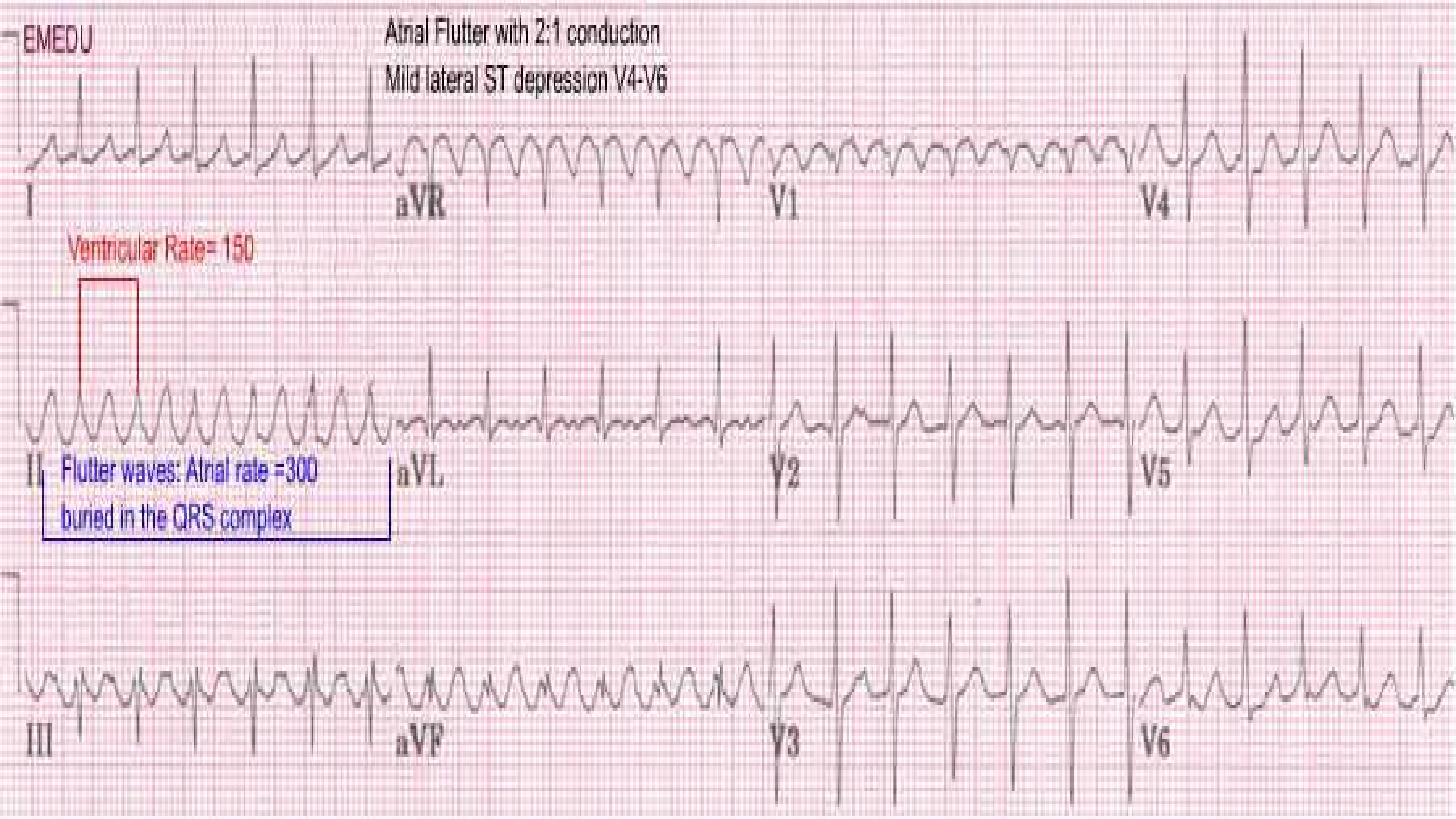


Normal

Ventricular Tachycardia (VT)




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


EMEDU
Atrial Flutter with 2:1 conduction
Mild lateral ST depression V4-V6
Ventricular Rate= 150
Flutter waves: Atrial rate =300
buried in the QRS complex
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6


Atrial Flutter
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
"flutter waves"
V1
(Rhythm strip)
QRS
QRS
QRS
QRS

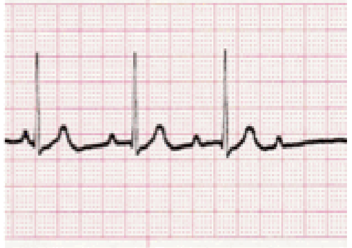
Heart Blocks

Constant P-R interval

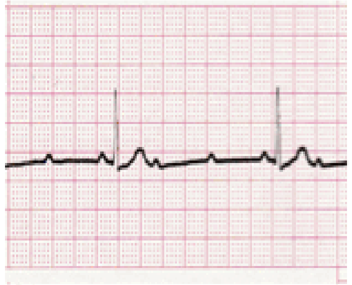
Variable P-R Interval

First Degree Heart Block

Second Degree Heart Block Type I



Second Degree Heart Block Type II



Third Degree Heart Block

First degree AV block

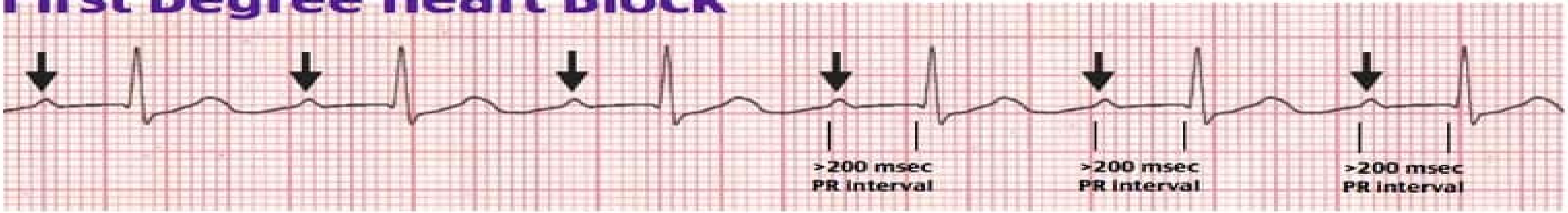
Second degree AV block (Mobitz I or Wenckebach)

Second degree AV block (Mobitz II)

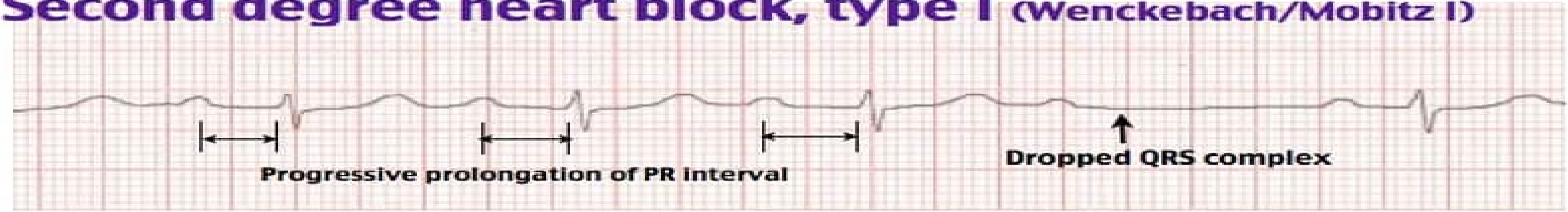
Second degree AV block (2:1 block)

Third degree AV block with junctional escape

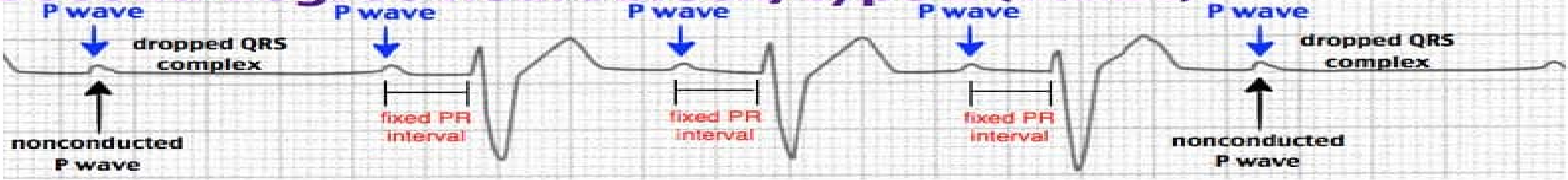
First Degree Heart Block



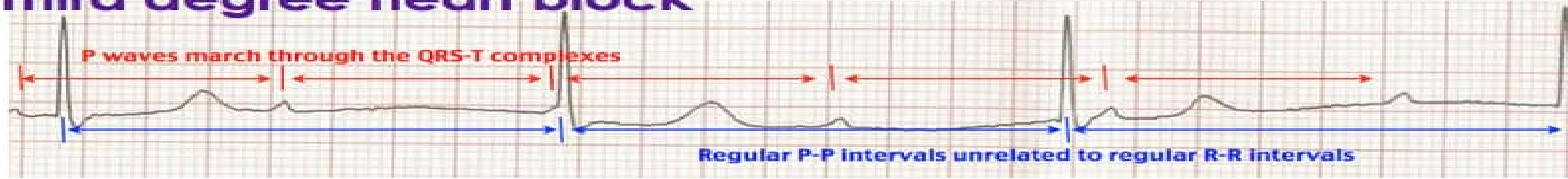
Second degree heart block, type I (Wenckebach/Mobitz I)



Second degree heart block, type 2 (Mobitz 2)



Third degree heart block

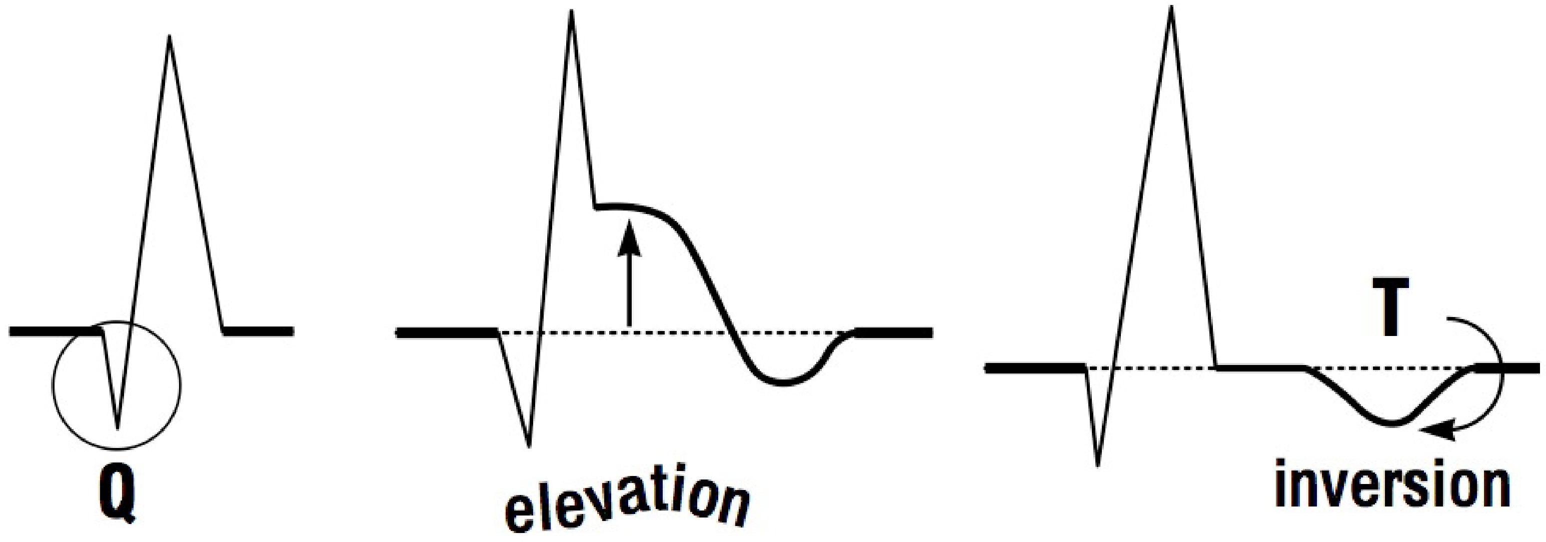


SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

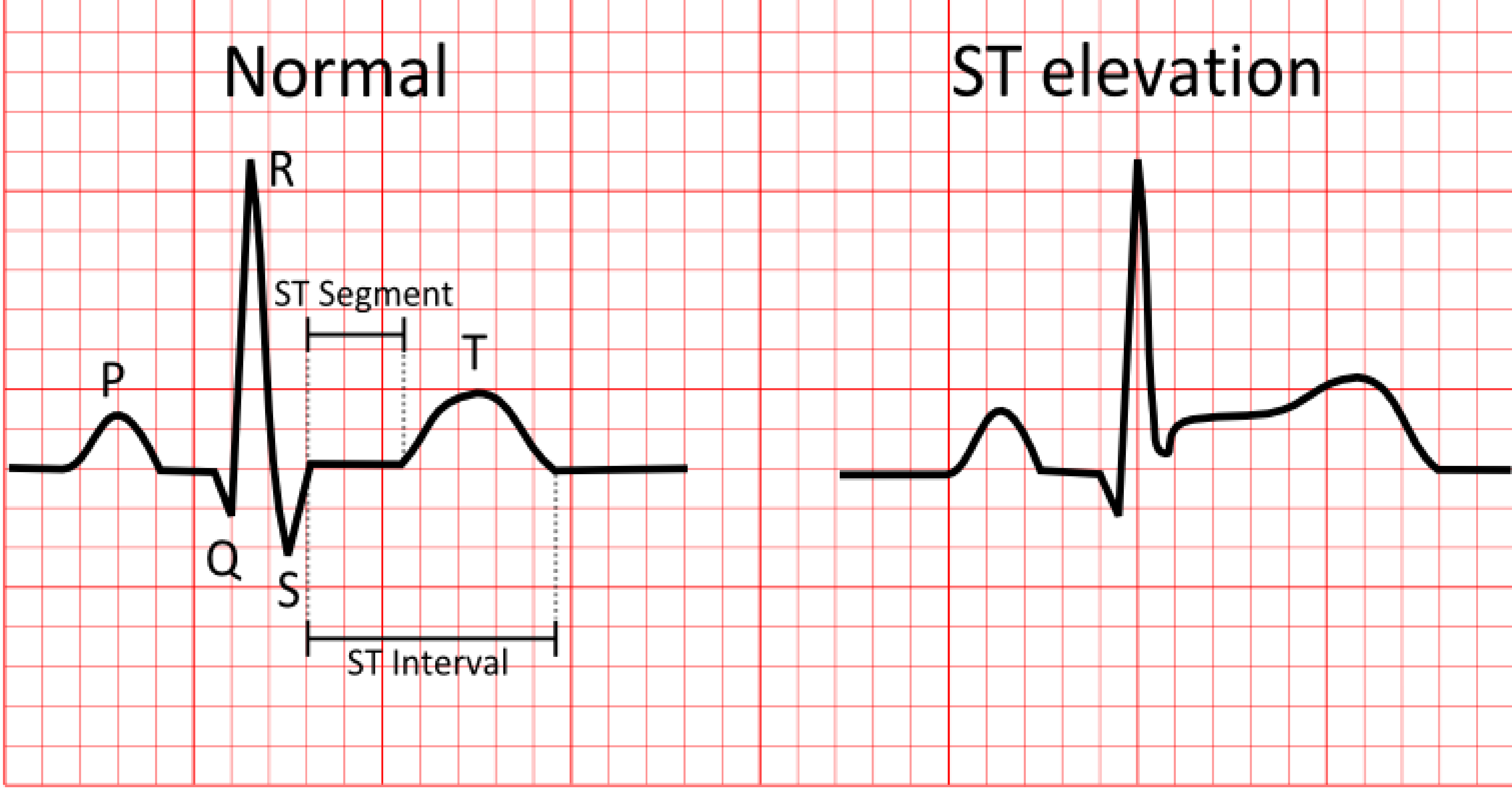
To summarize:

1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
   –
   –
   –
   –

- Significant Q wave = Necrosis
- ST elevation = Injury
- T wave inversion = Ischemia

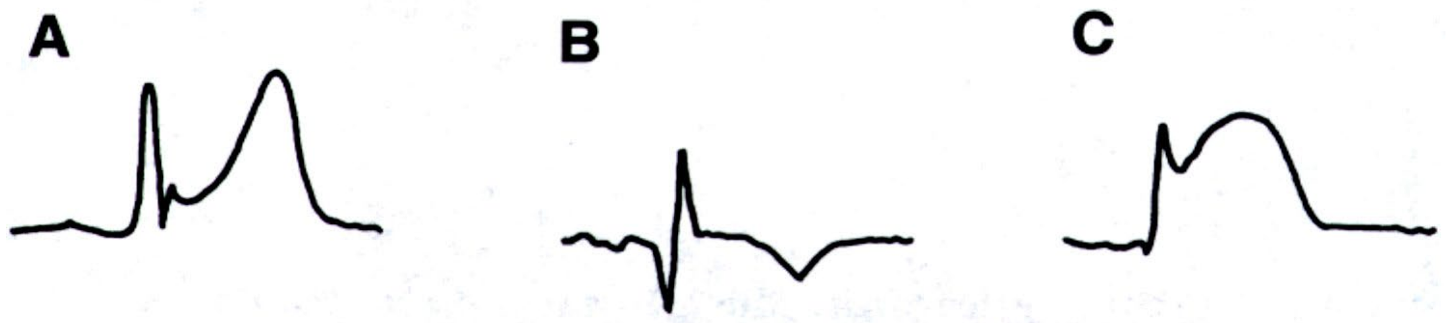


Myocardial Infarction

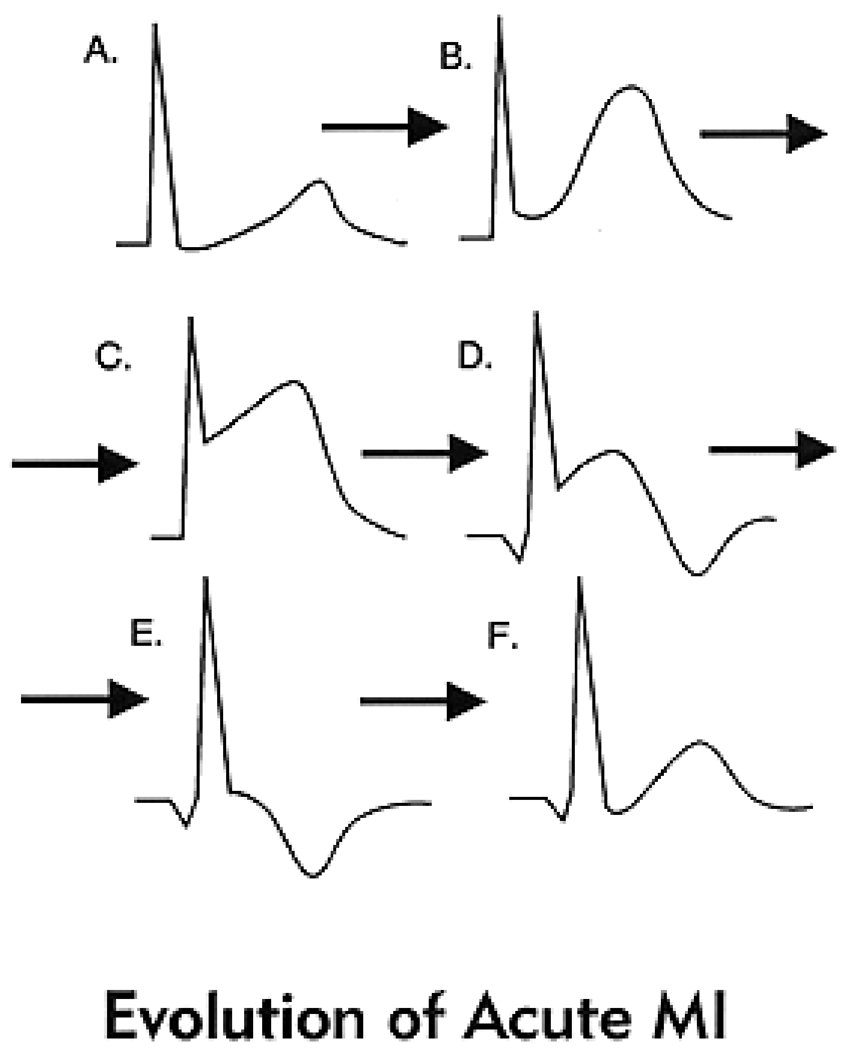

Normal
R
ST Segment
T
P
Q
S
ST Interval
ST elevation

Location of Myocardial Ischemia/ Infarction

Location	Leads
Anterior	I, V_2, V_3, and V_4
Anterolateral	I, aVL, V_5, and V_6
Lateral	V_5 and V_6
High lateral	I and aVL (often with V_5, V_6)
Inferior	II, III, and aVF
Inferolateral	II, III, aVF, and V_6
True posterior	Reciprocal changes in V_1 and V_2



MI Location

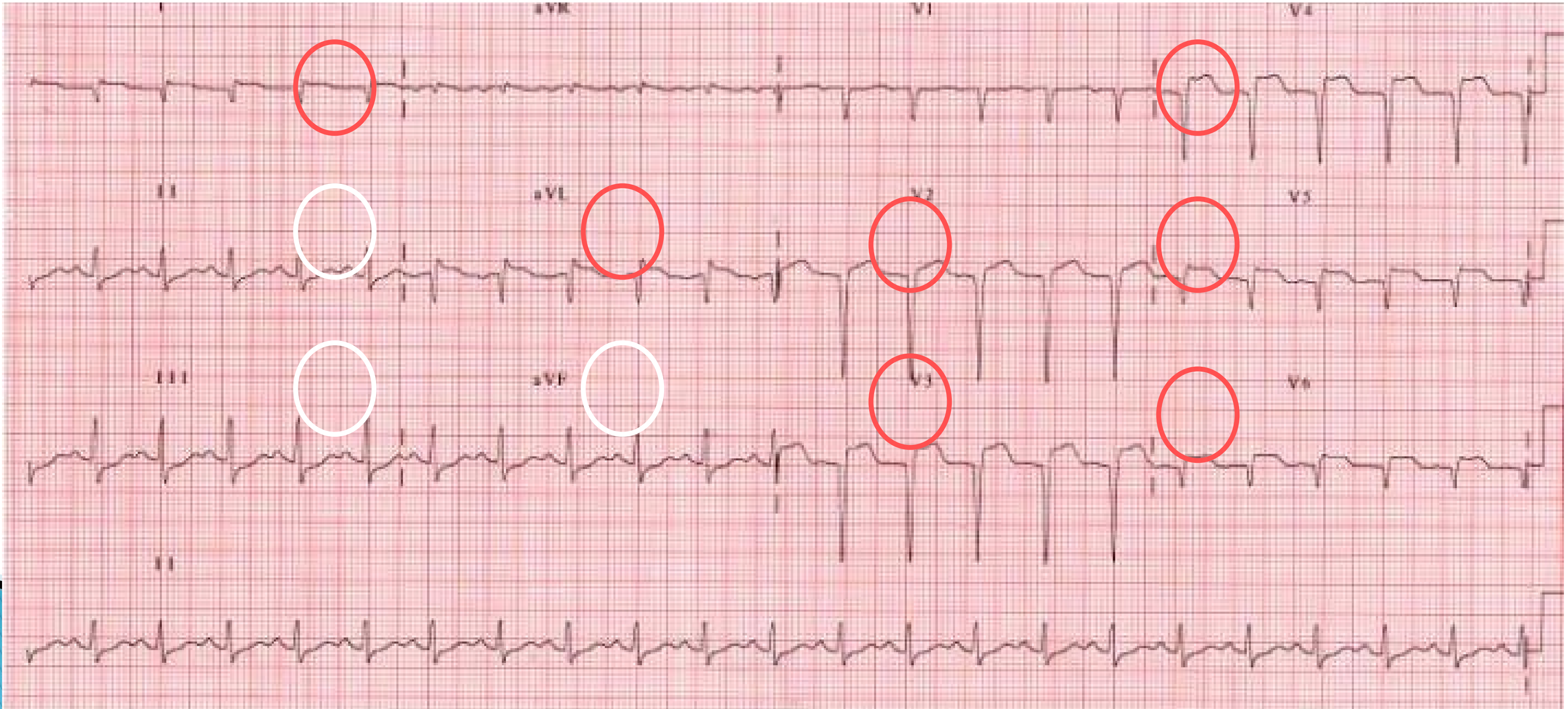


Myocardial involvement	EKG leads
Anterior	V2, V3, V4 (at least 2)
Anteroseptal	V1, V2, V3 (+V4)
Anterolateral	V4, V5, V6 (+V3, +V2)
Extensive Anterior	V1 through V6 (all)
Lateral	V5, V6 (+I, +aVL)
High lateral	I, aVL
Inferior	II, III, aVF (at least 2)
Inferolateral	as above, +V6 (+V5)
Posterior	V1, V2 (*recip. changes)
Inferoposterolateral	Combine above 3 items
Right Ventricular	V4R, +V3R and/or V5R

SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

Infarct: Is the ST elevation or depression?

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



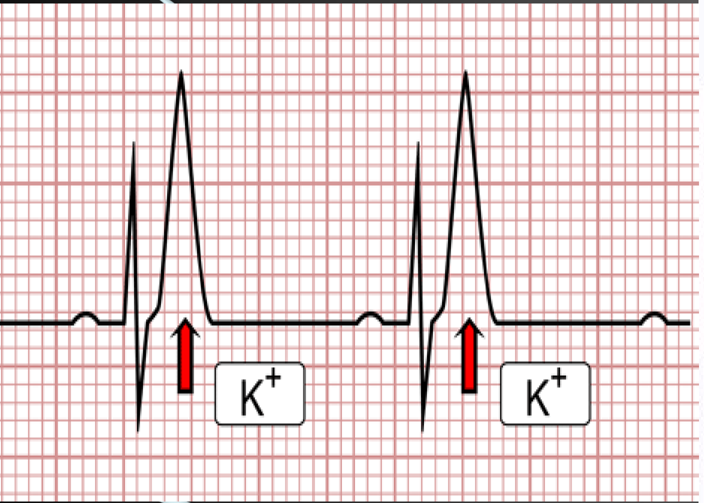
ST Segment Elevation

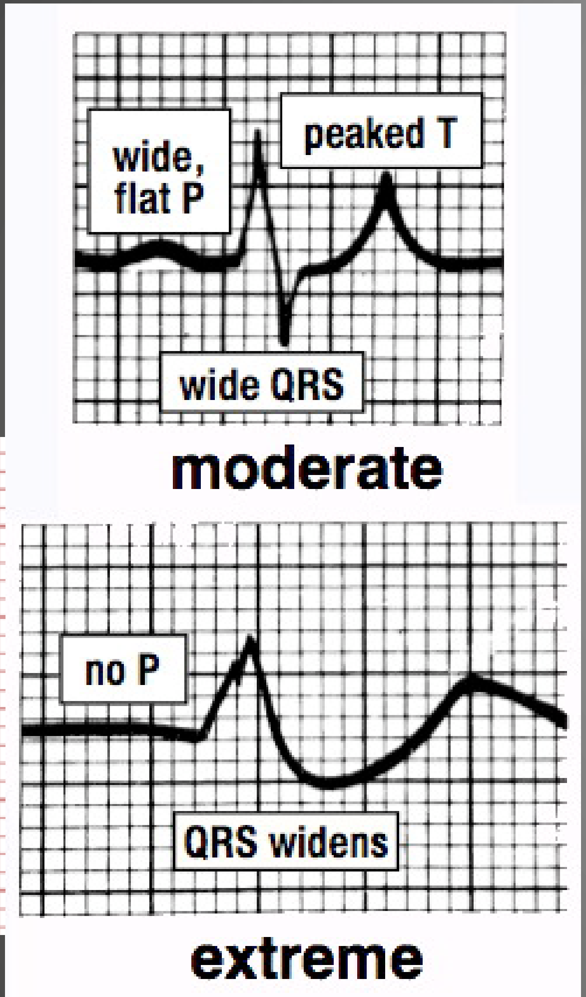
- ELEVATION
  - **E**lectrolytes
  - **L**eft bundle branch block
  - **E**arly repolarization
  - **V**entricular hypertrophy
  - **A**neurysm
  - **T**reatment (pericardiocentesis)
  - **I**njury (acute MI, contusion)
  - **O**sborne waves (hypothermia)
  - **N**onocclusive vasospasm

ST Segment Depression

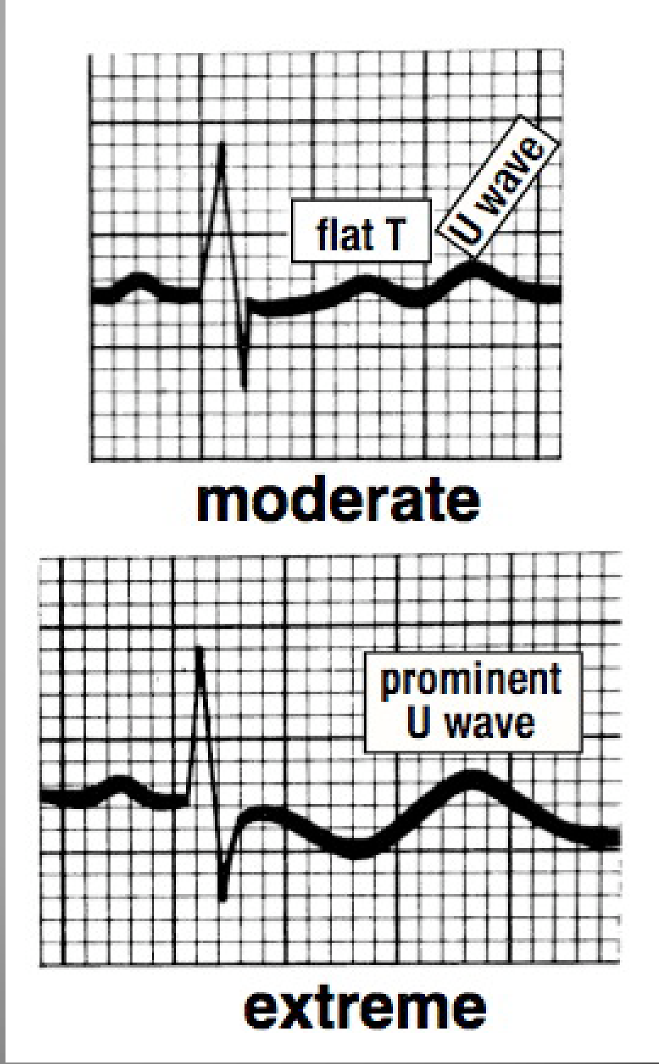
- DEPRESSED ST
  - Drooping valve (mitral valve prolapse)
  - Enlargement or LV with strain
  - Potassium loss (hypokalemia)
  - Reciprocal ST depression (inferior MI)
  - Embolism (PE)
  - Subendocardial ischemia
  - Subendocardial infarct
  - Encephalon hemorrhage
  - Dilated cardiomyopathy
  - Shock
  - Toxicity of digitalis, quinidine

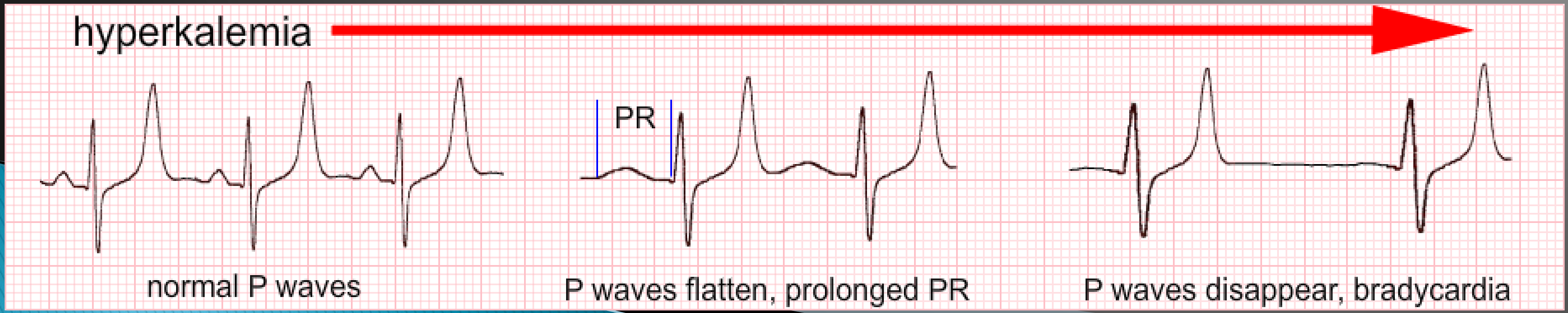
- Hyperkalemia
  - High K+
  - Peaked T





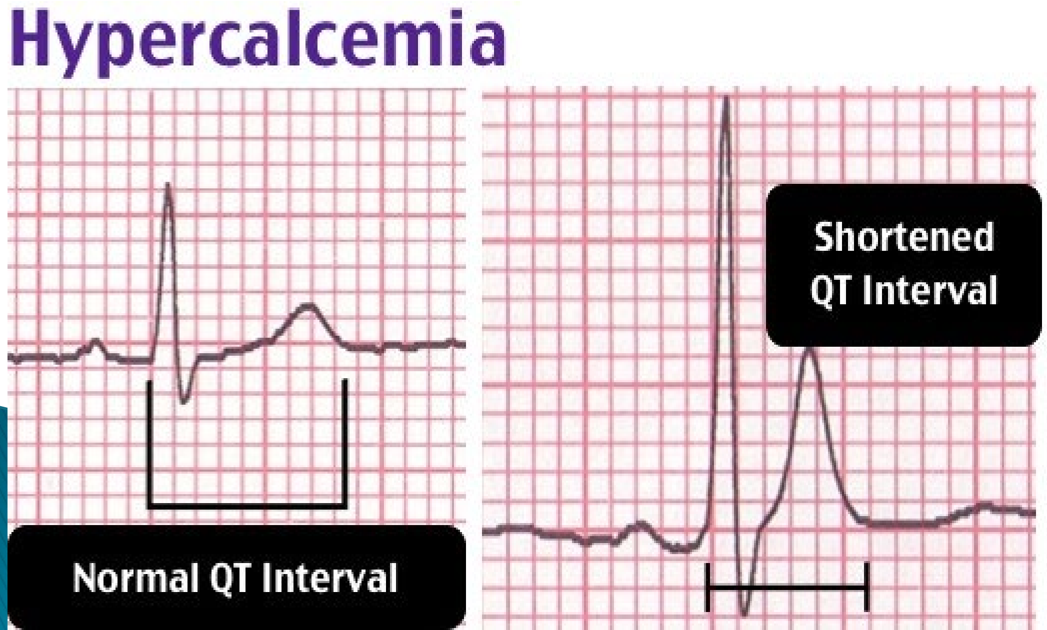
- Hypokalemia
  - Low K+
  - Flat T, U Wave





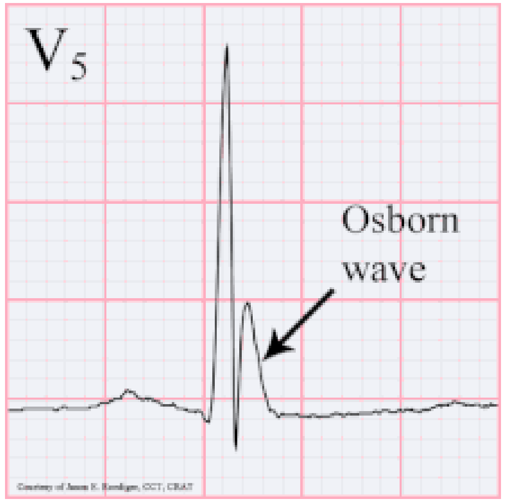
- HYPERCALCEMIA
- HYPOCALCEMIA

HYPERcalcaemia Normal HYPOcalcaemia



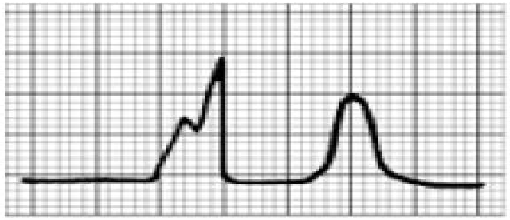
Causes of Hypercalcemia

- Malignancy
- Milk-alkali syndrome
- Vitamin D toxicity
- Paget's disease
- Hyperparathyroidism
- Immobilization
- Granulomatous disease
- Thiazide diuretics

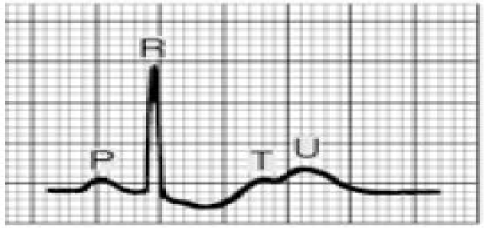


Normal tracing (plasma K^+ 4–5.5 meq/L). PR interval = 0.16 s; QRS interval = 0.06 s; QT interval = 0.4 s (normal for an assumed heart rate of 60).

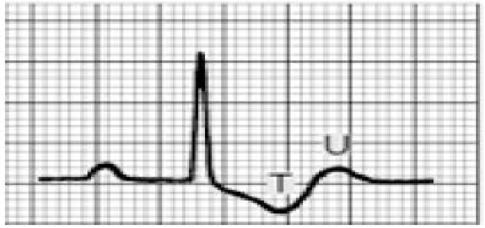
Hyperkalemia (plasma K^+ ±7.0 meq/L). The PR and QRS intervals are within normal limits. Very tall, slender peaked T waves are now present.



Hyperkalemia (plasma K^+ ±8.5 meq/L). There is no evidence of atrial activity; the QRS complex is broad and slurred and the QRS interval has widened to 0.2 s. The T waves remain tall and slender. Further elevation of the plasma K^+ level may result in ventricular tachycardia and ventricular fibrillation.



Hypokalemia (plasma K^+ ±3.5 meq/L). PR interval = 0.2 s; QRS interval = 0.06 s; ST segment depression. A prominent U wave is now present immediately following the T. The actual QT interval remains 0.4 s. If the U wave is erroneously considered a part of the T, a falsely prolonged QT interval of 0.6 s will be measured.

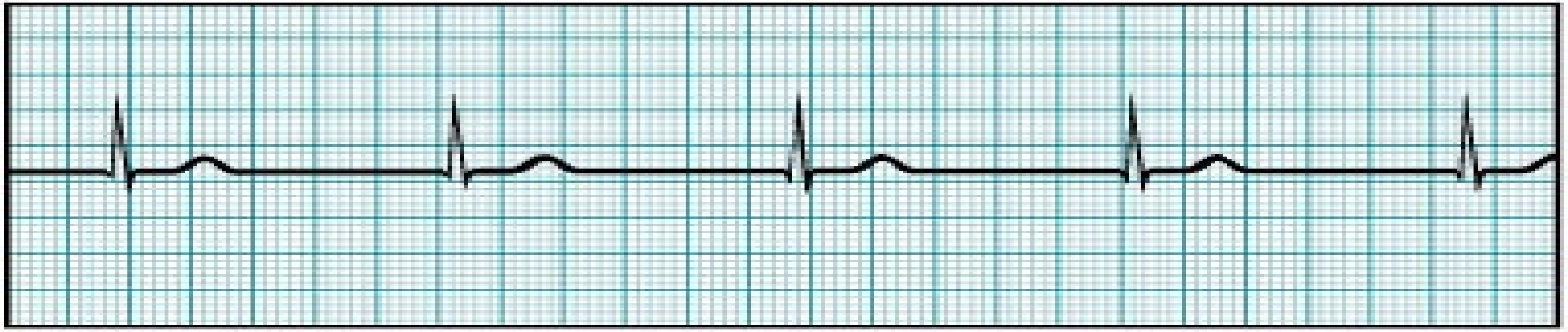


Hypokalemia (plasma K^+ ±2.5 meq/L). The PR interval is lengthened to 0.32 s; the ST segment is depressed; the T wave is inverted; a prominent U wave is seen. The true QT interval remains normal.

Figure 28-20. Correlation of plasma K^+ level and the ECG, assuming that the plasma Ca^{2+} level is normal. The diagrammed complexes are left ventricular epicardial leads. (Reproduced, with permission, from Goldman MJ: *Principles of Clinical Electrocardiography,* 12th ed. Originally published by Appleton & Lange. Copyright © 1989 by The McGraw-Hill Companies, Inc.)

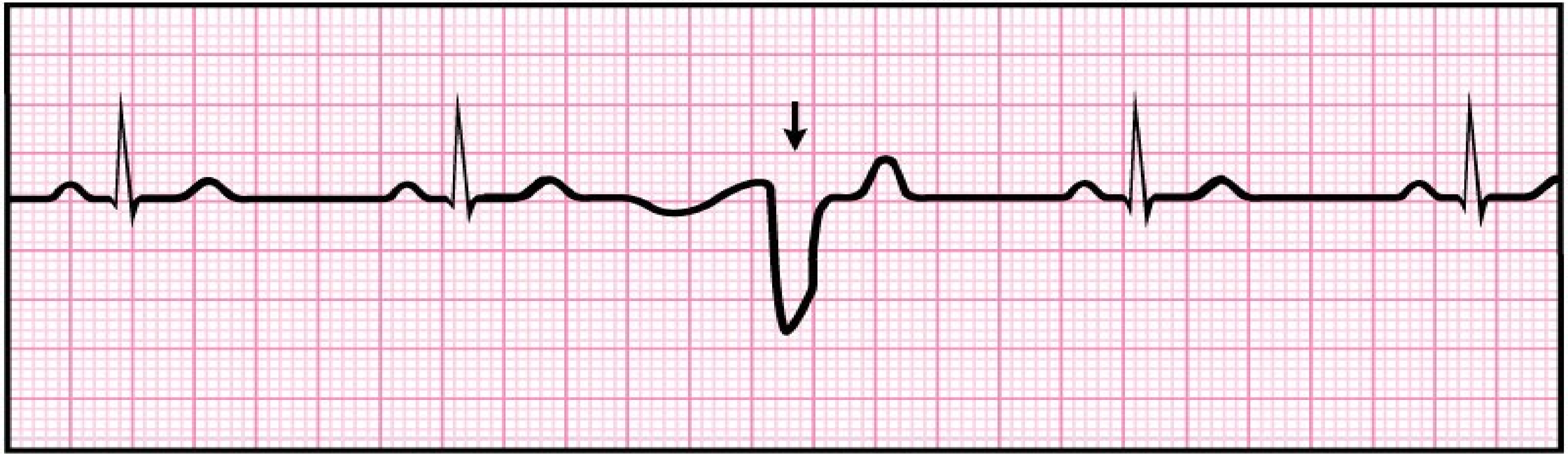
ECGs, Normal and Abnormal

(a) Sinus rhythm (normal)



(b) Nodal rhythm – no SA node activity

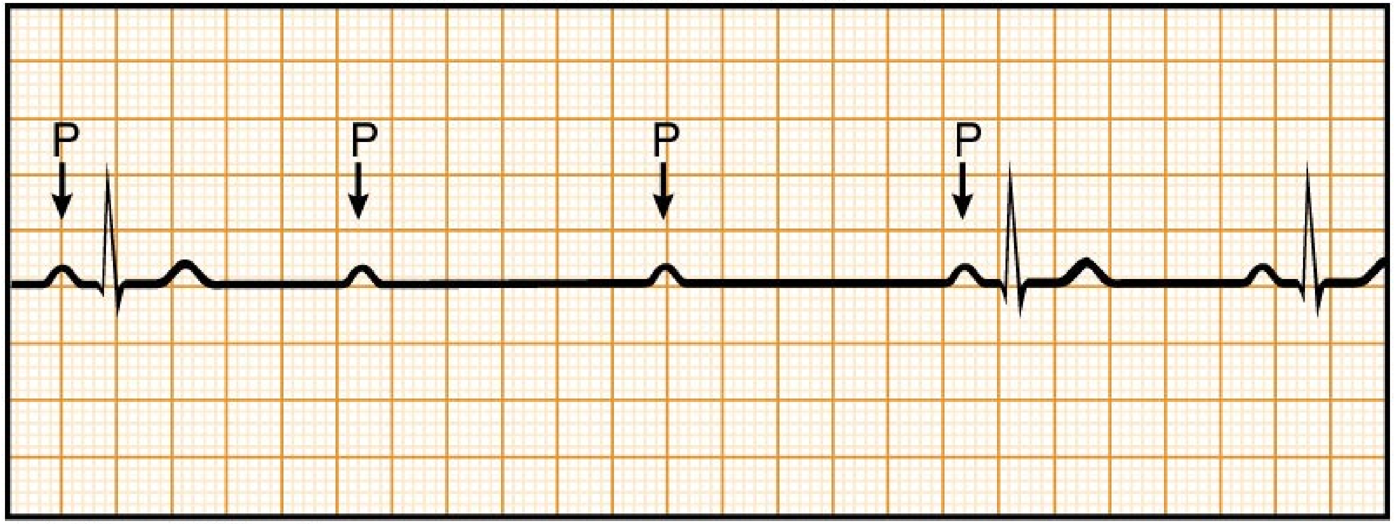
ECGs, Abnormal



(d) Premature ventricular contraction

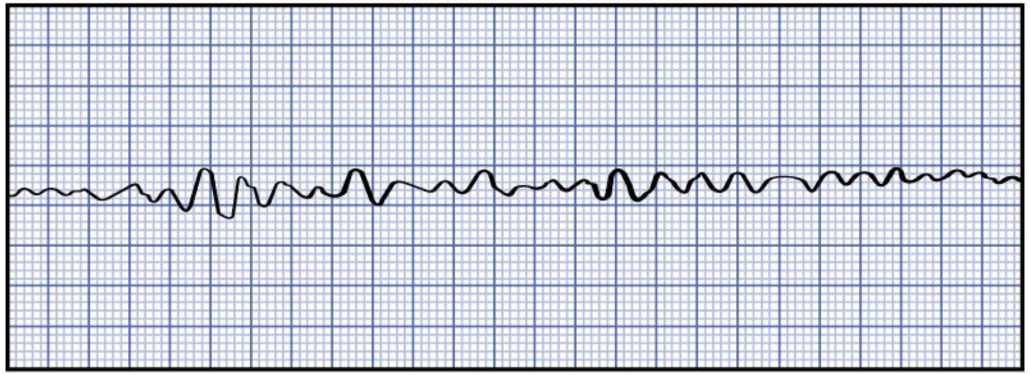
Extrasystole : note inverted QRS complex, misshapen QRS and T and absence of a P wave preceding this contraction.

ECGs, Abnormal



(c) Heart block

Arrhythmia: conduction failure at AV node



(e) Ventricular fibrillation

No pumping action occurs

THE ABNORMAL

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

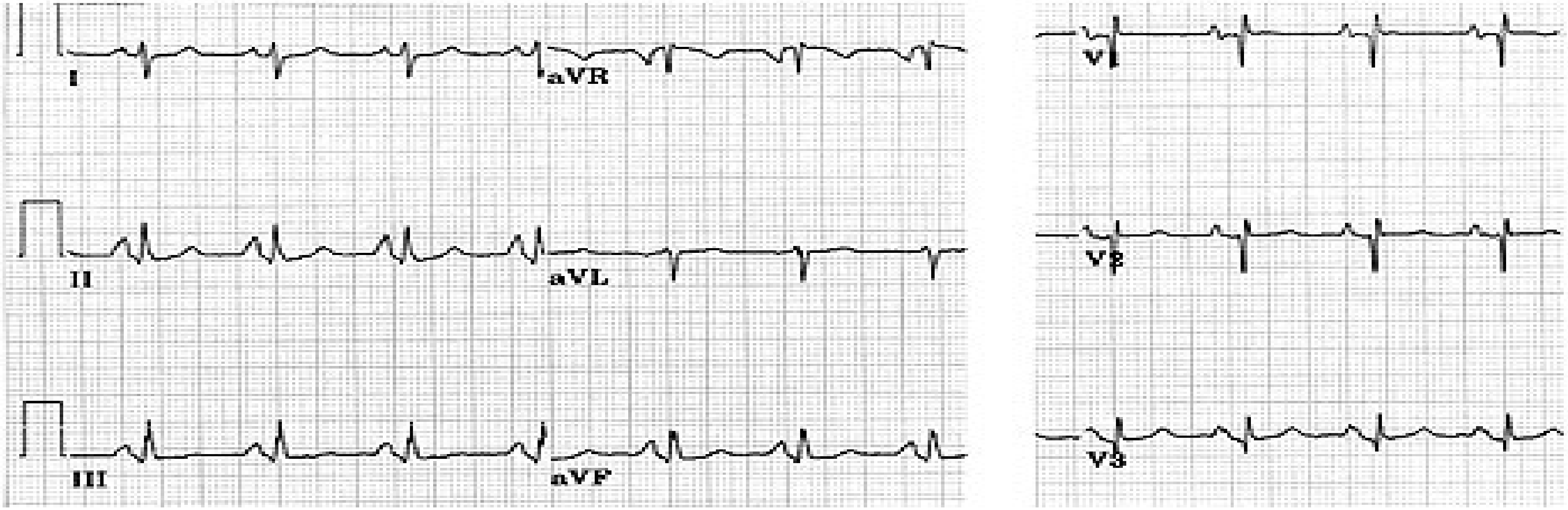
In this step of the 12-lead ECG analysis, we use the ECG to determine if any of the 4 chambers of the heart are enlarged or hypertrophied. We want to determine if there are any of the following:

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

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right atrial enlargement

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

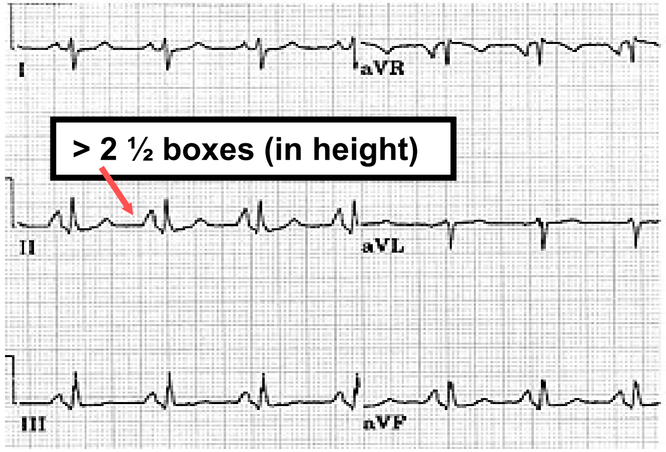


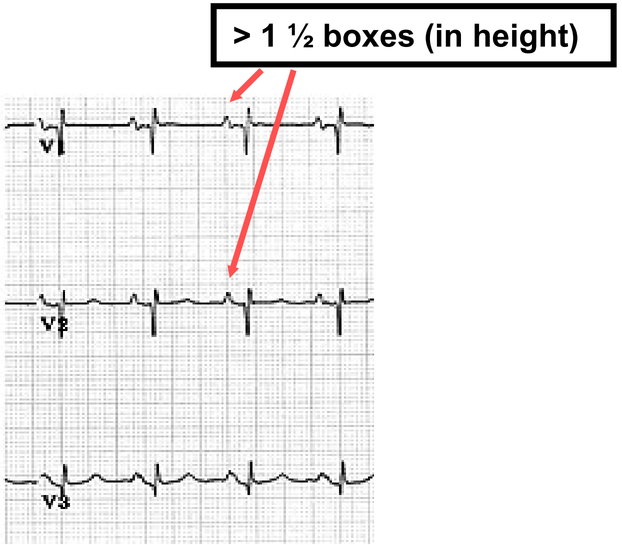
The P waves are tall, especially in leads II, III and avF. Ouch! They would hurt to sit on!!

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right atrial enlargement

- To diagnose RAE you can use the following criteria:
  - II P > 2.5 mm, or
  - V1 or V2P > 1.5 mm



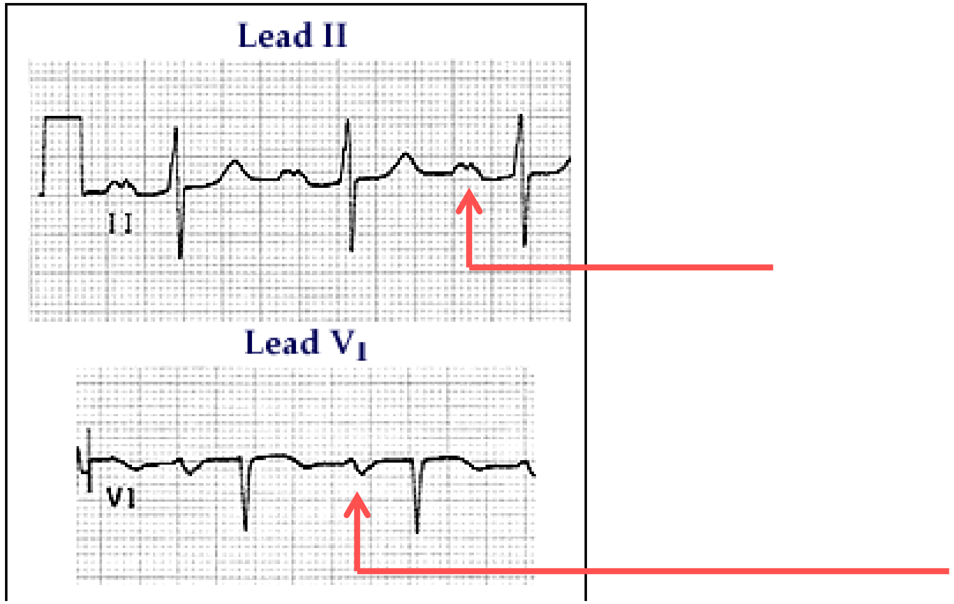


A cause of RAE is RVH from pulmonary hypertension.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Left atrial enlargement

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

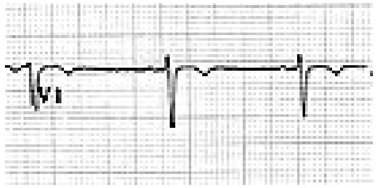


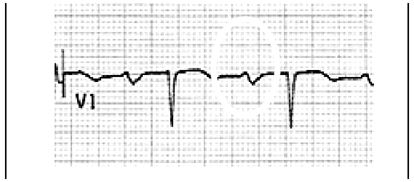
The P waves in lead II are notched and in lead V1 they have a deep and wide negative component.

Rate Rhythm Axis Intervals Hypertrophy Infarct

Left atrial enlargement

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



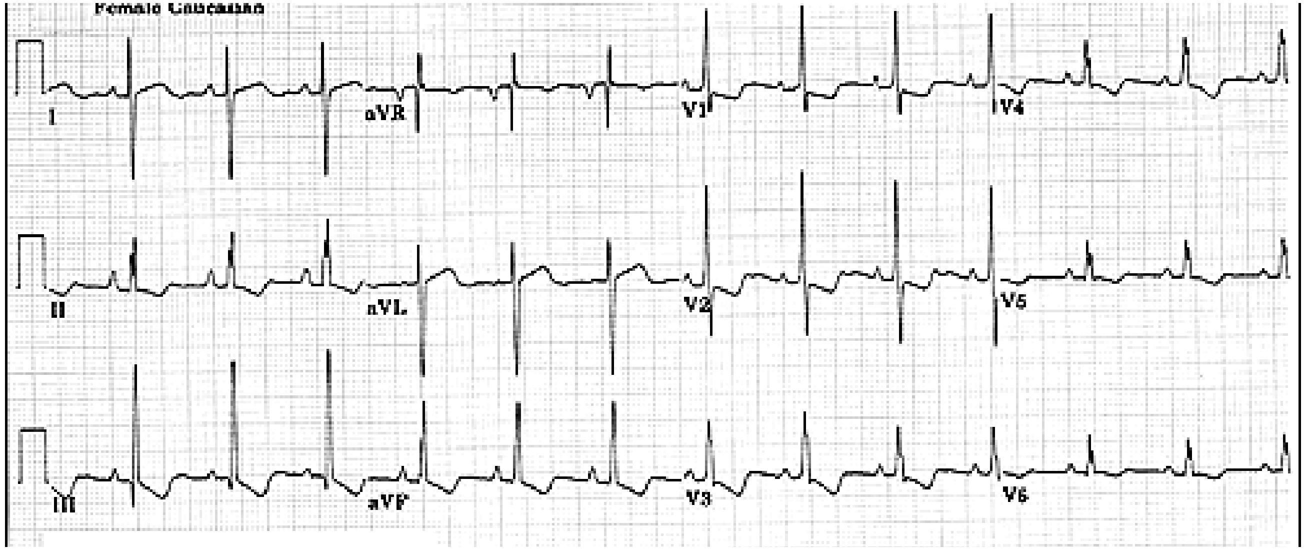


A common cause of LAE is LVH from hypertension.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right ventricular hypertrophy

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

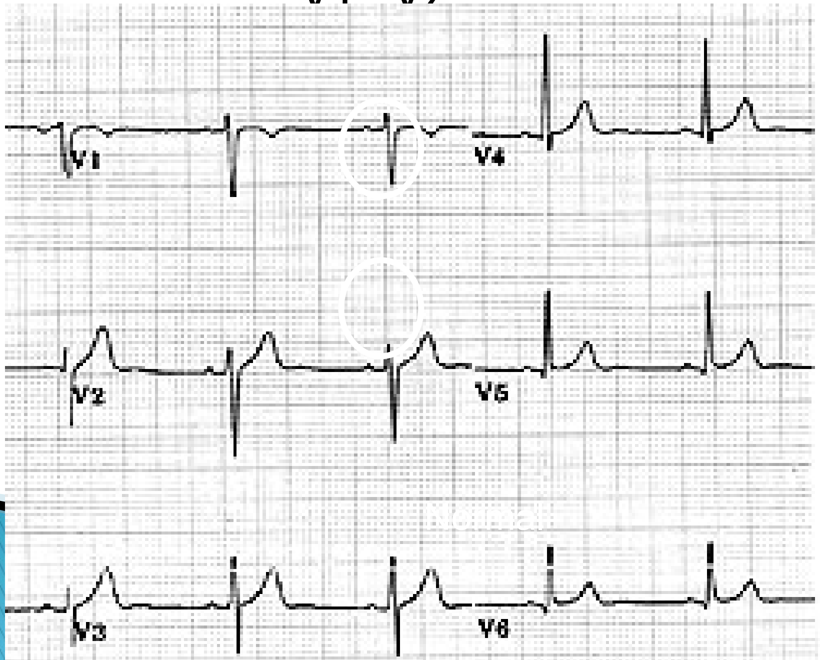


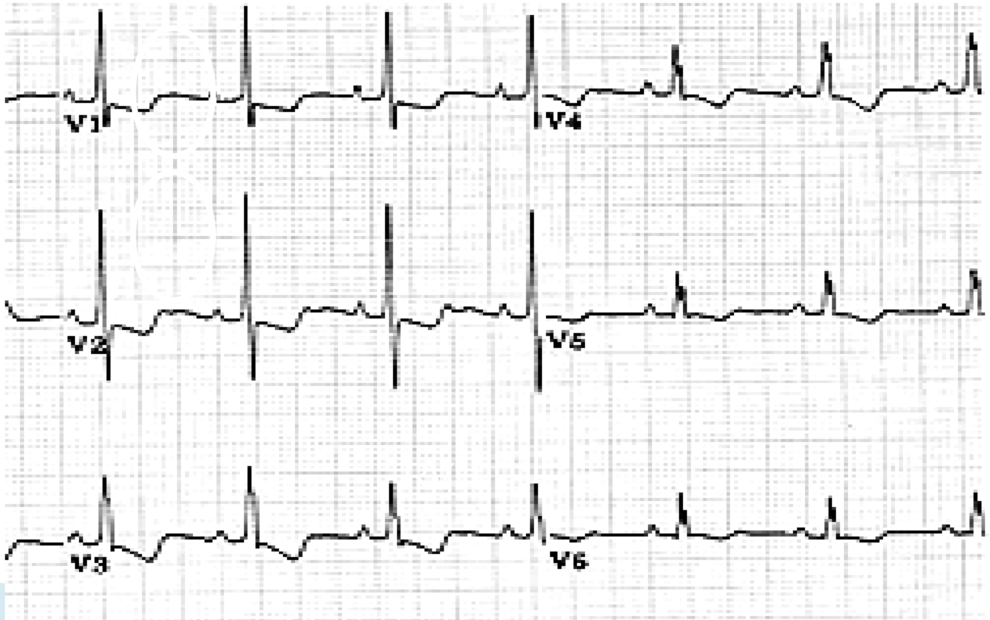
There is right axis deviation (negative in I, positive in II) and there are tall R waves in V1, V2.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Right ventricular hypertrophy

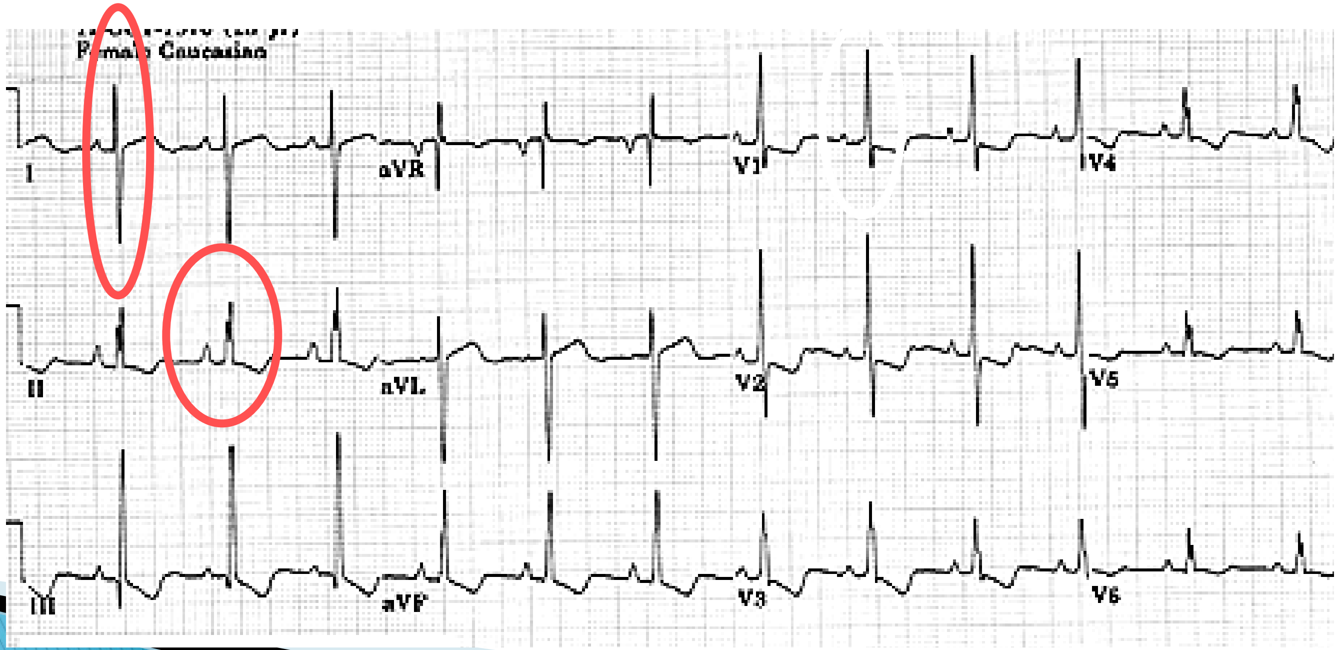
- Compare the R waves in V1, V2 from a normal ECG and one from a person with RVH.
- Notice the R wave is normally small in V1, V2 because the right ventricle does not have a lot of muscle mass.
- But in the hypertrophied right ventricle the R wave is tall in V1, V2





Right ventricular hypertrophy

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

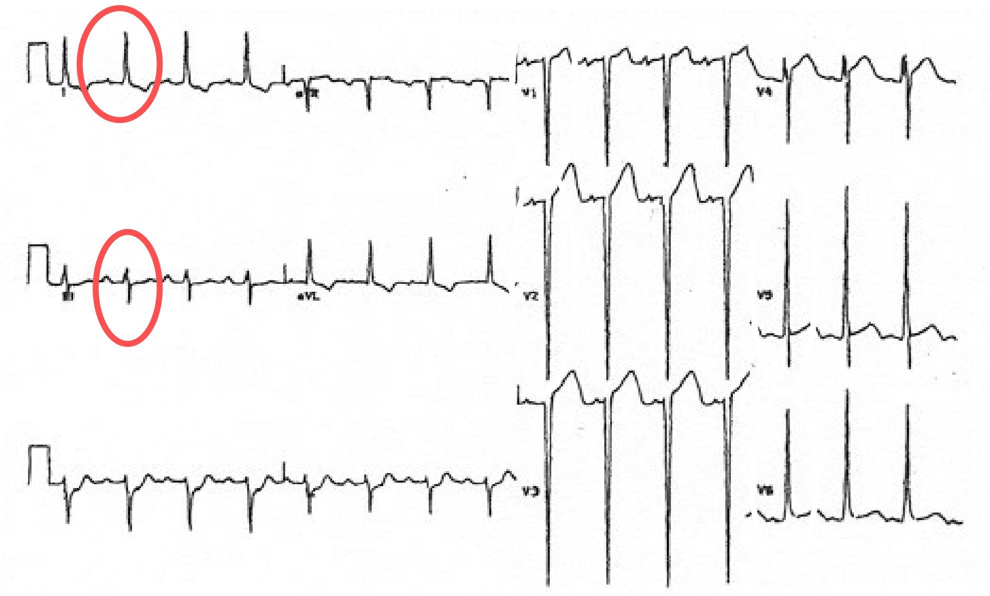


A common cause of RVH is left heart failure.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Left ventricular hypertrophy

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

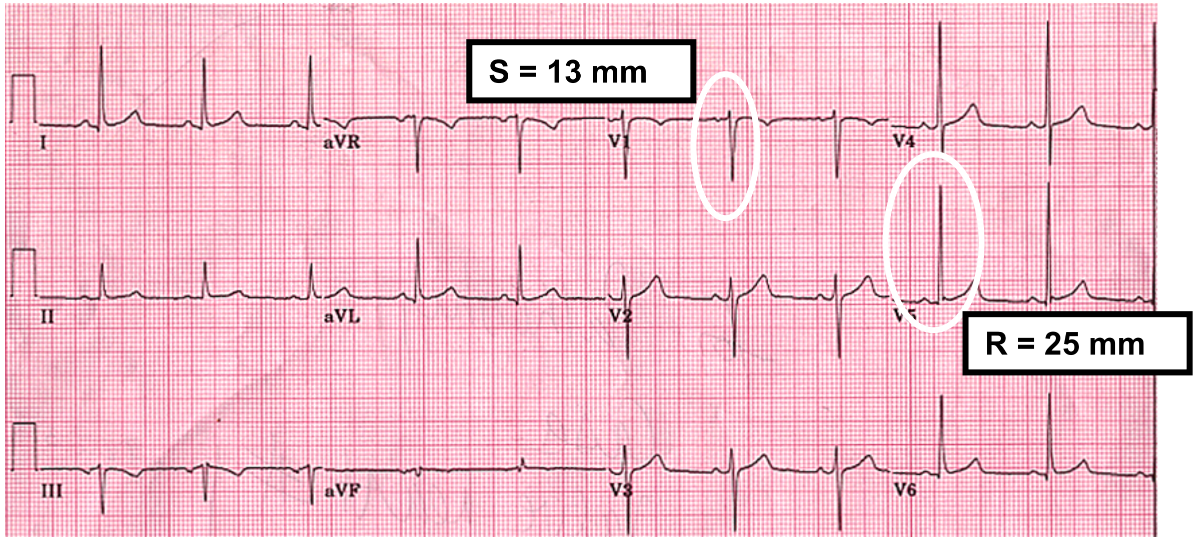


There is left axis deviation (positive in I, negative in II) and there are tall R waves in V5, V6 and deep S waves in V1, V2

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Left ventricular hypertrophy

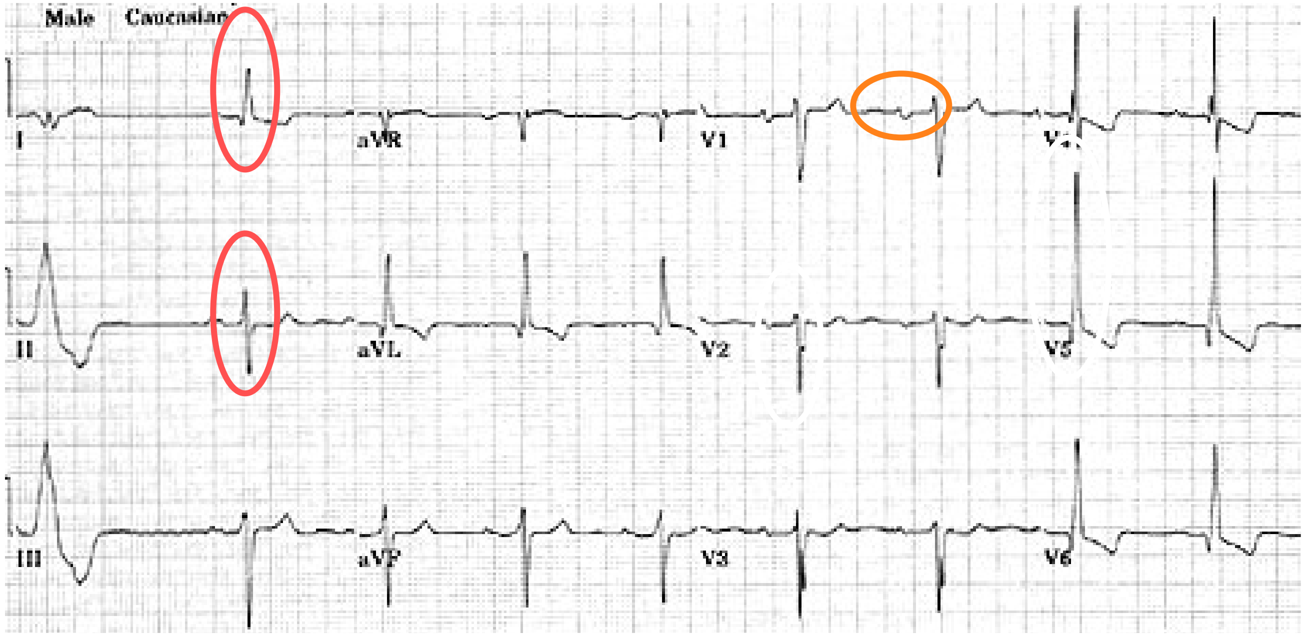
- To diagnose LVH you can use the following criteria :
  - R in V5 (or V6) + S in V1 (or V2) > 35 mm, or
  - avL R > 13 mm



A common cause of LVH is hypertension.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

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



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

Rate Rhythm Axis Intervals Hypertrophy Infarct

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

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

Cadogen, M. (2019). ECG rate interpretation. Retrieved from: https://litfl.com/ecg-rate-interpretation/
Goldberger, A. L. (2019). Basic principles of electrocardiographic interpretation. Retrieved from: https://www.uptodate.com/contents/basic-principles-of-electrocardiographic-interpretation
Prutkin, J. M. (2019). ECG tutorial: Basic principles of ECG analysis. Retrieved from: https://www.uptodate.com/contents/ecg-tutorial-basic-principles-of-ecg-analysis
Wagner, G. S., & Strauss, D. G. (2014). Marriott's practical electrocardiography (12th ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.
Wesley, K. (2016). Huszar's ECG and 12 lead interpretation (5th ed.). Missouri: Elsevier.

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