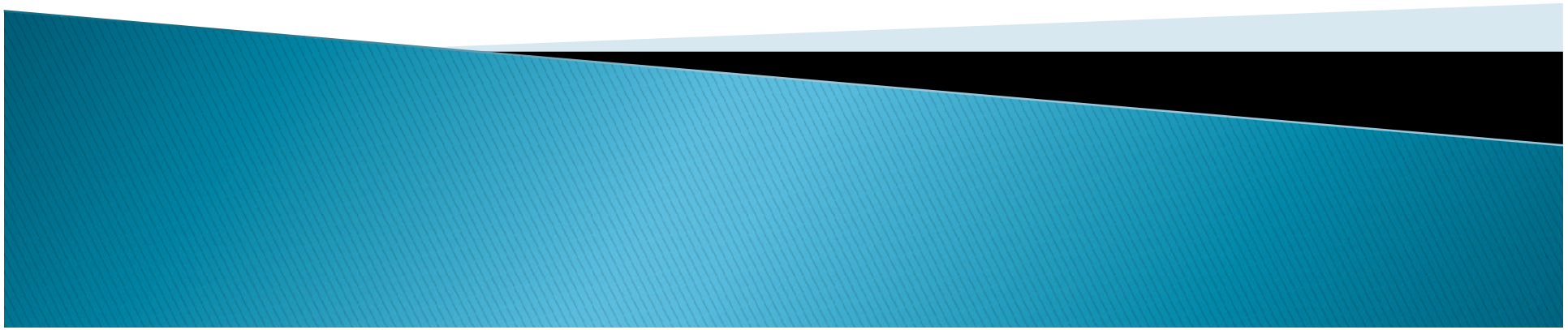
EKG
The normal and abnormal

D.HAMMOUDI .MD

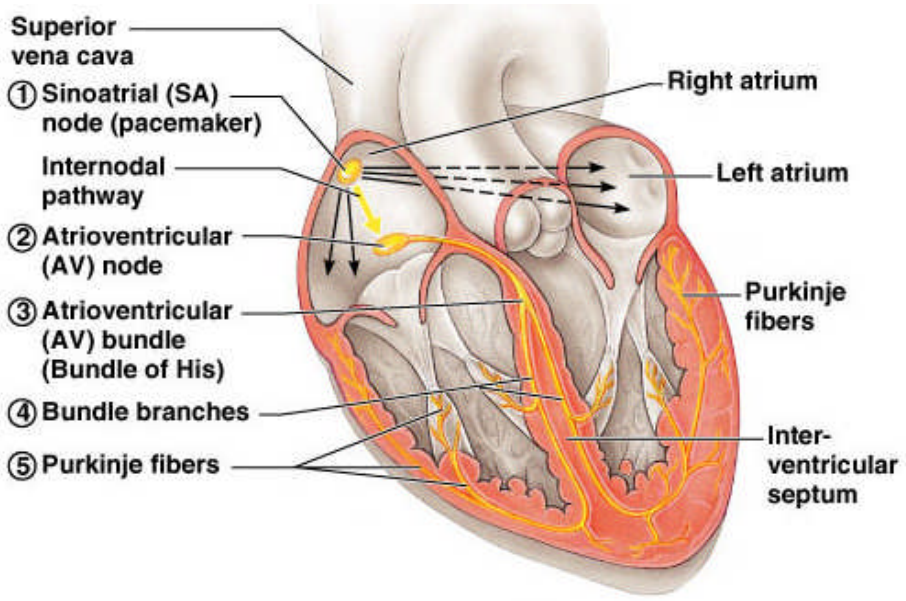


The Cardiac Cycle

- 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

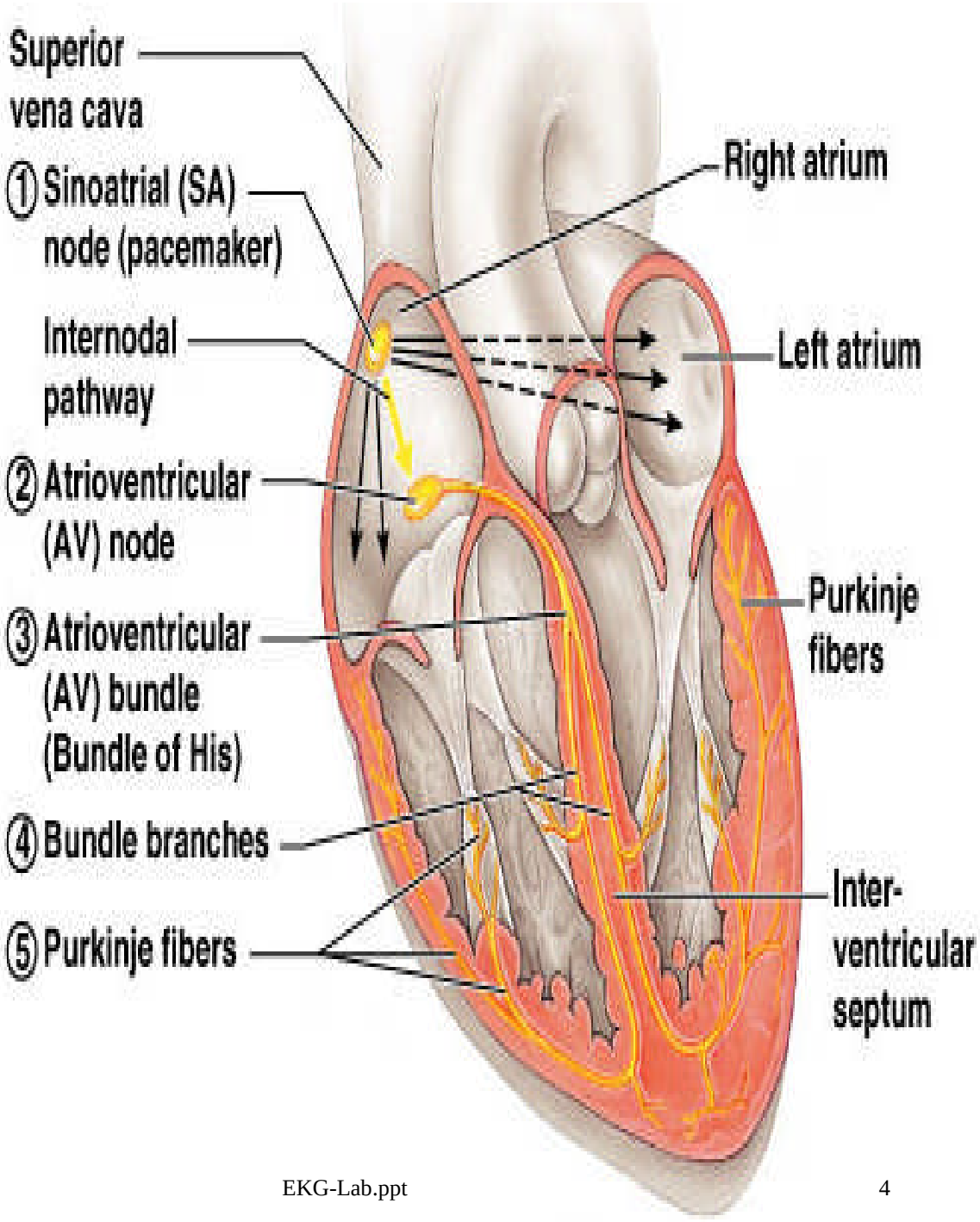
Depolarization and Impulse Conduction

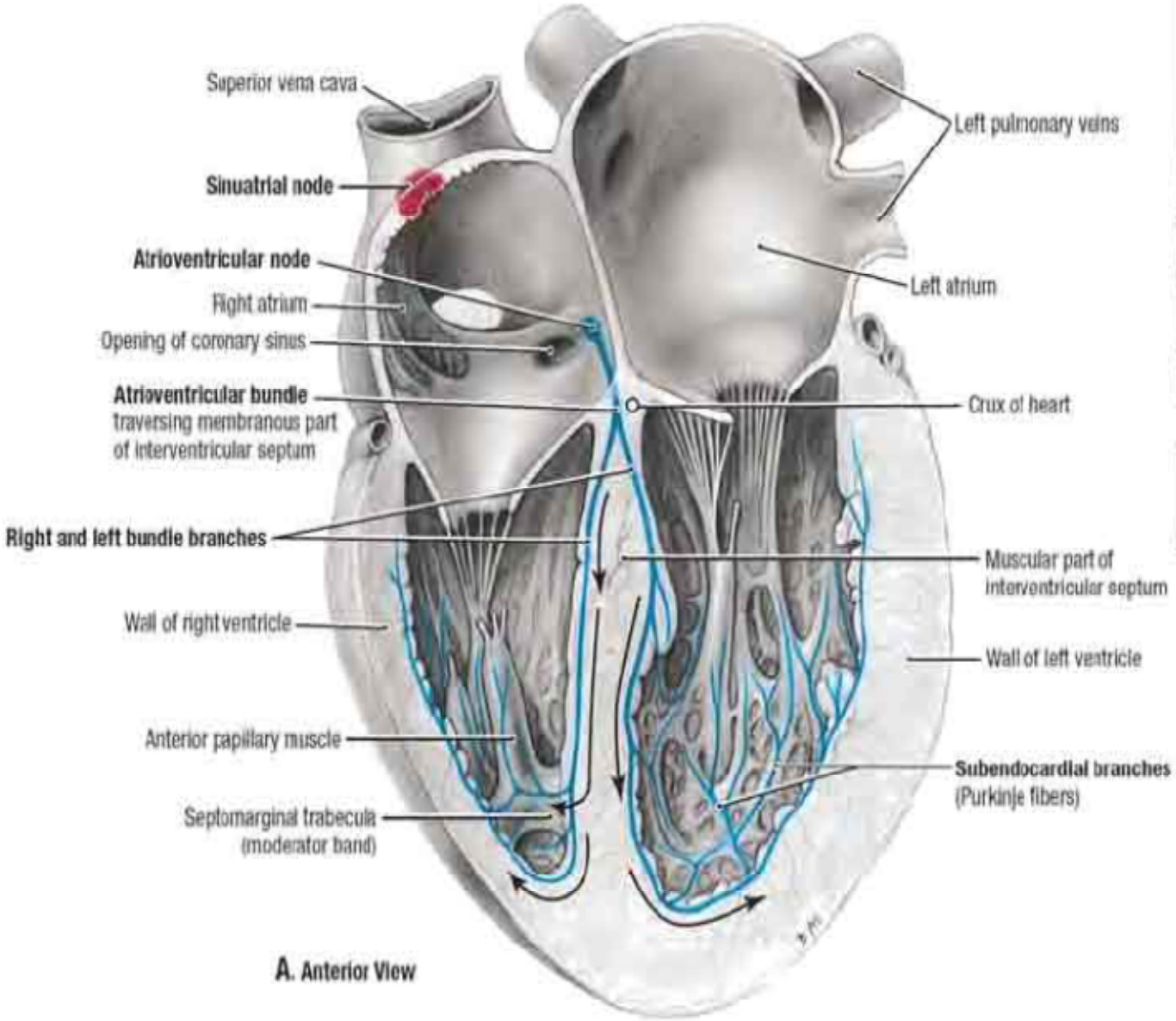
- Heart is autorhythmic
- Depolarization begins in sinoatrial (SA) node
- Spread through atrial myocardium
- Delay in atrioventricular (AV) node



Depolarization and Impulse Conduction

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

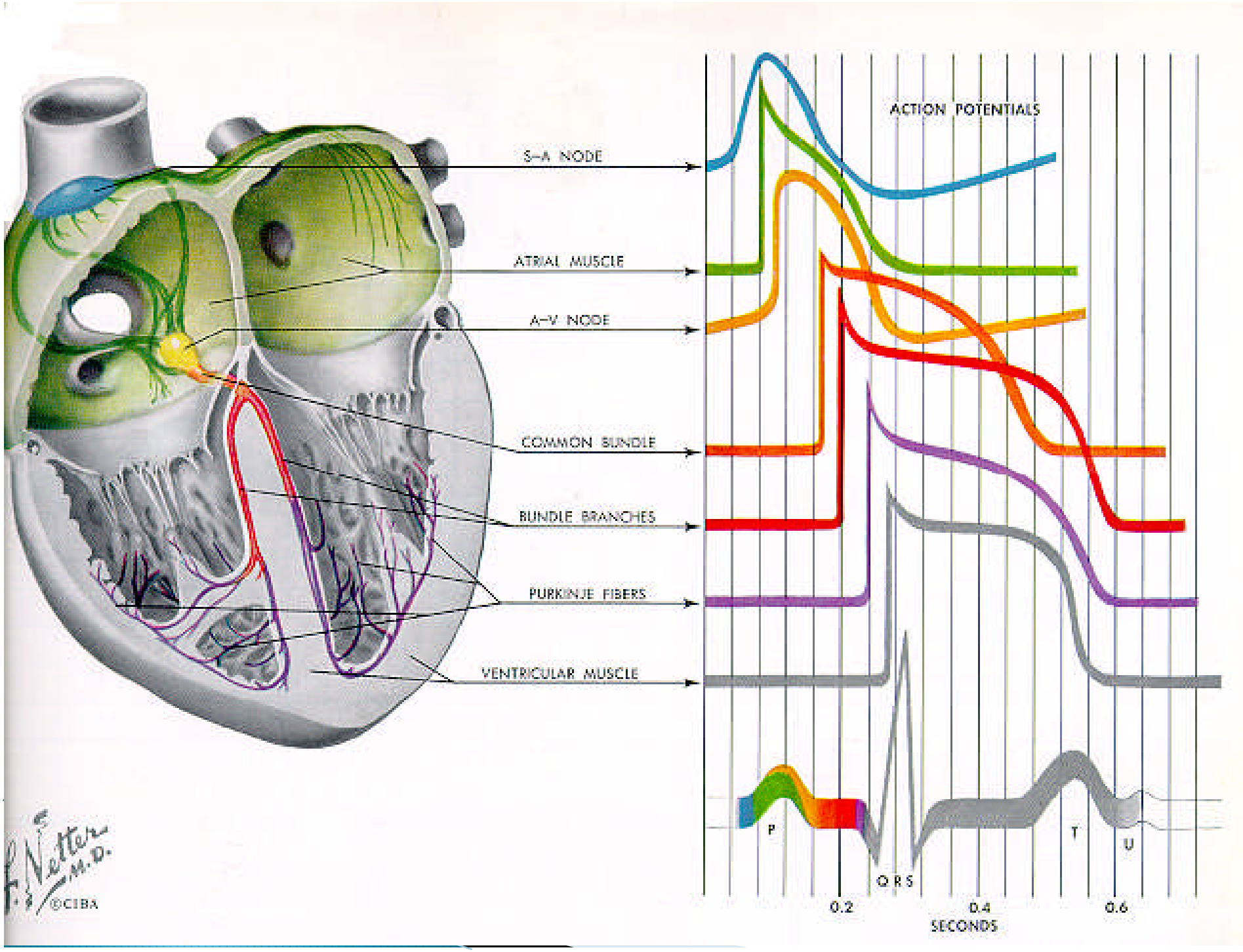




A. Anterior View

B. Echocardiogram, Apical Four-chamber View

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


S–A NODE
ATRIAL MUSCLE
A–V NODE
COMMON BUNDLE
BUNDLE BRANCHES
PURKINJE FIBERS
VENTRICULAR MUSCLE
ACTION POTENTIALS
P
Q R S
T
U
0.2
0.4
0.6
SECONDS
F. Netter M.D.
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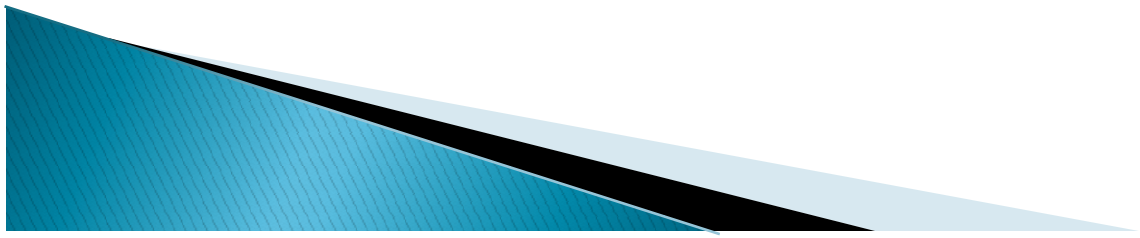
Arrhythmia Formation

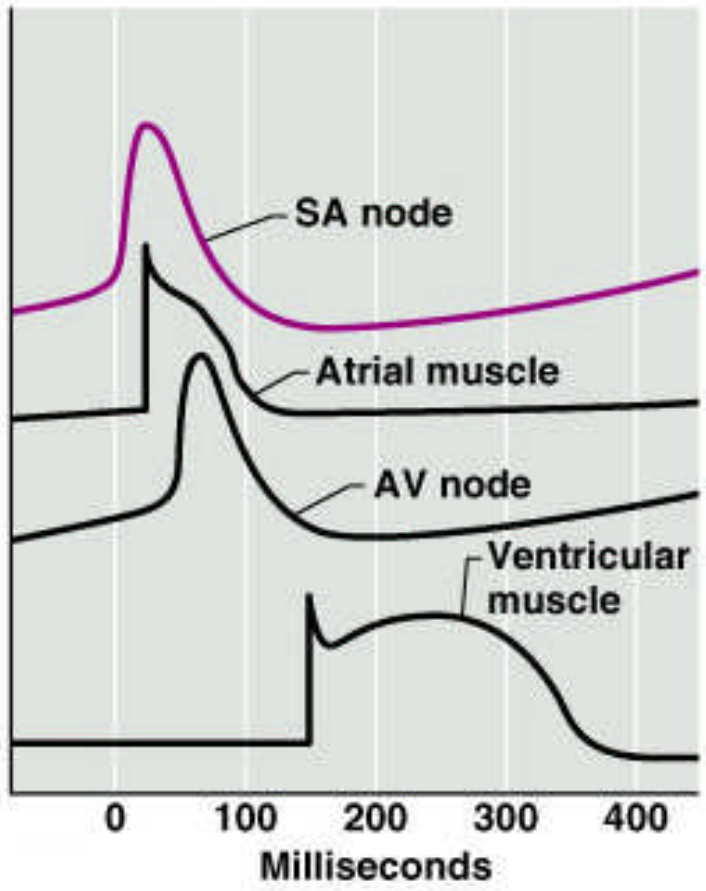
Arrhythmias can arise from problems in the:

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



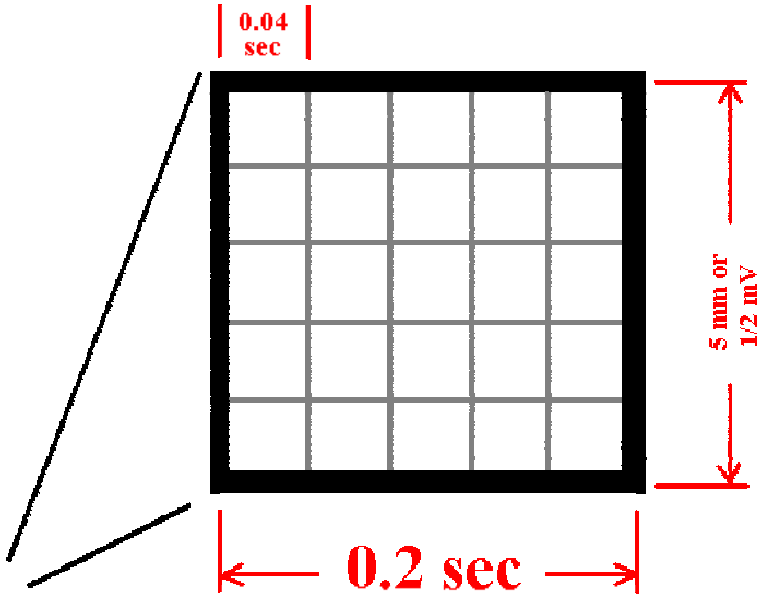
Depolarization and Impulse Conduction

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

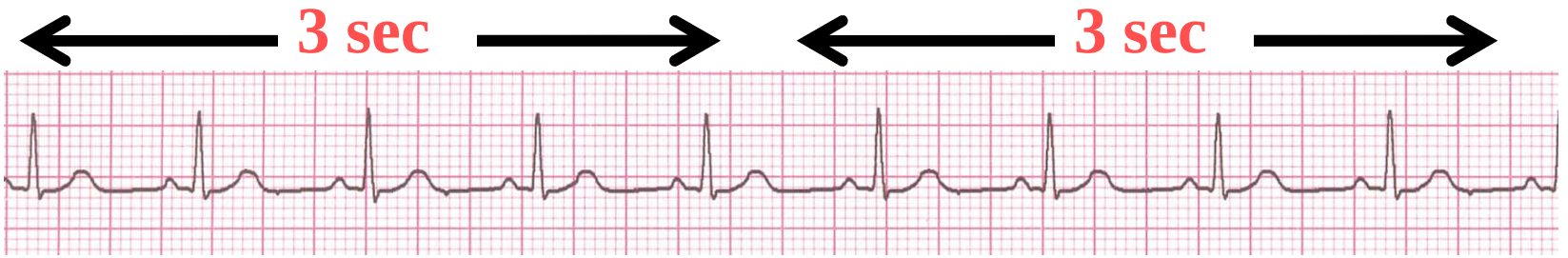


The ECG Paper

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



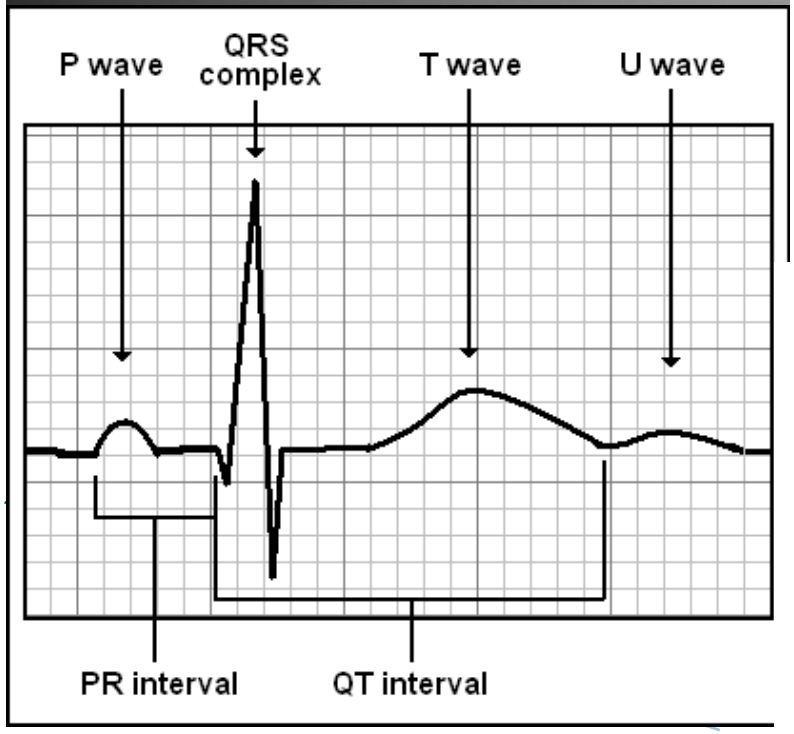
The ECG Paper (cont)



- 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



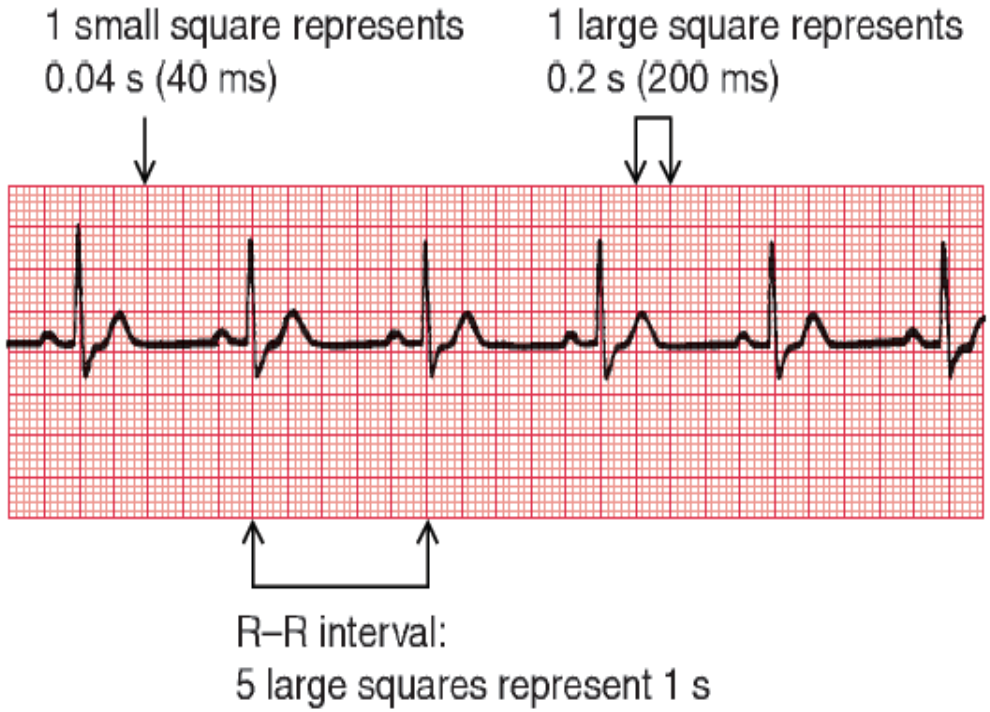
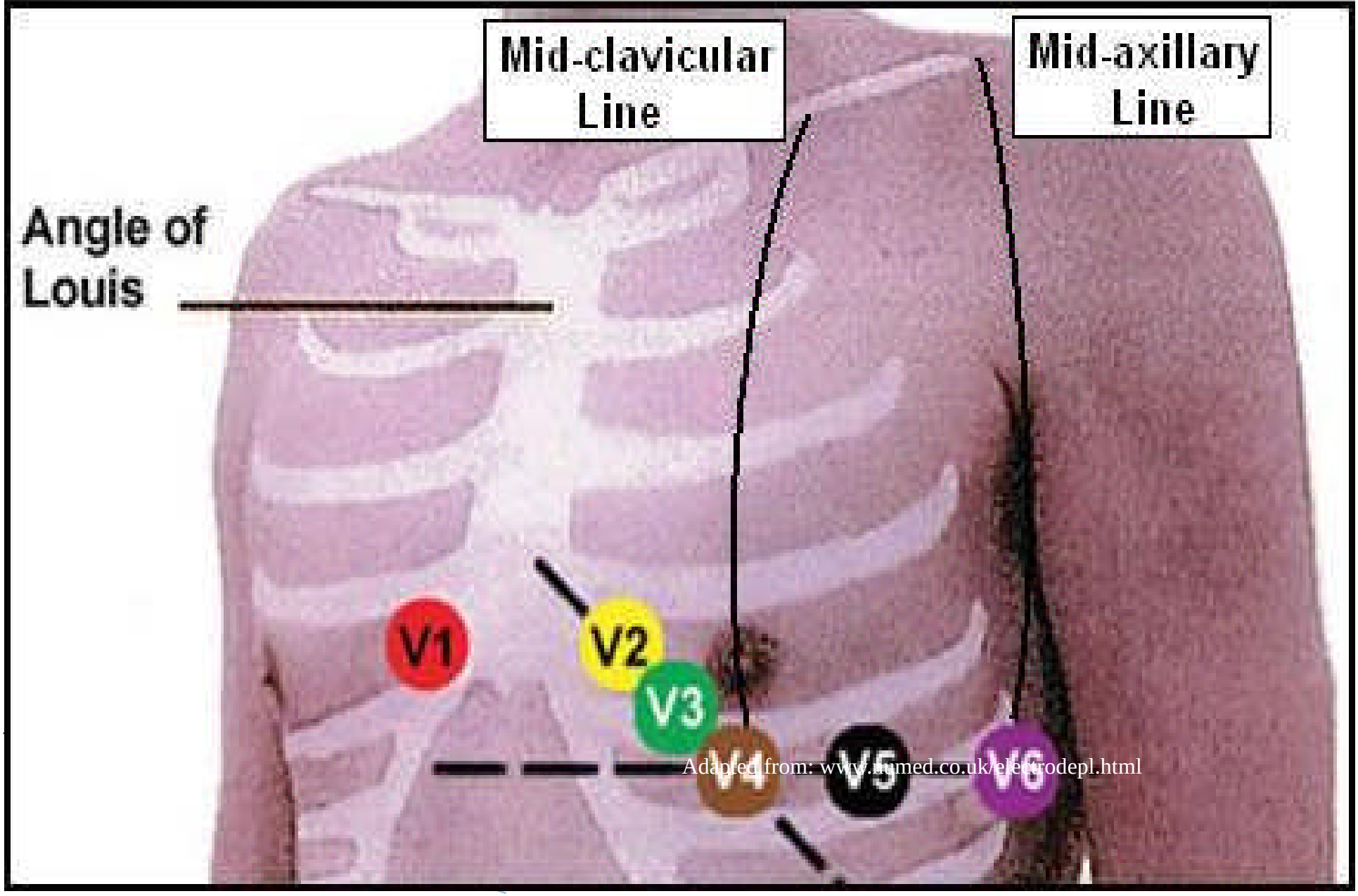
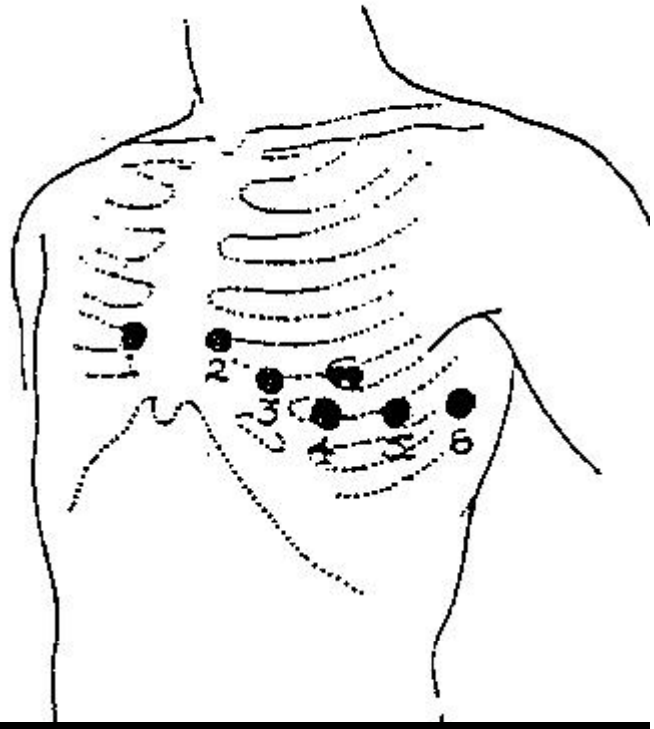


Fig. 1.4 Relationship between the squares on ECG paper and time. Here, there is one QRS complex per second, so the heart rate is 60 beats/min

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

Precordial Leads





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

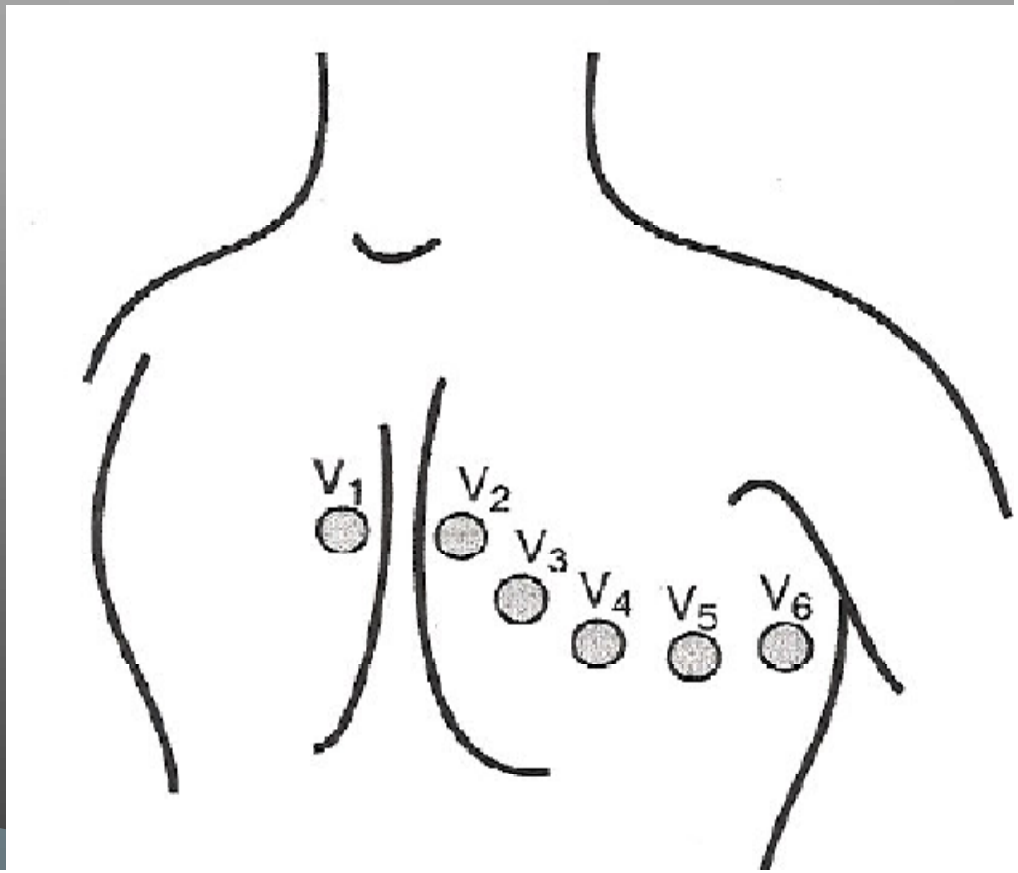
V5 = anteroaxillary line at level of V4

V6 = midaxillary line at level of V4 and V5

Electrocardiography

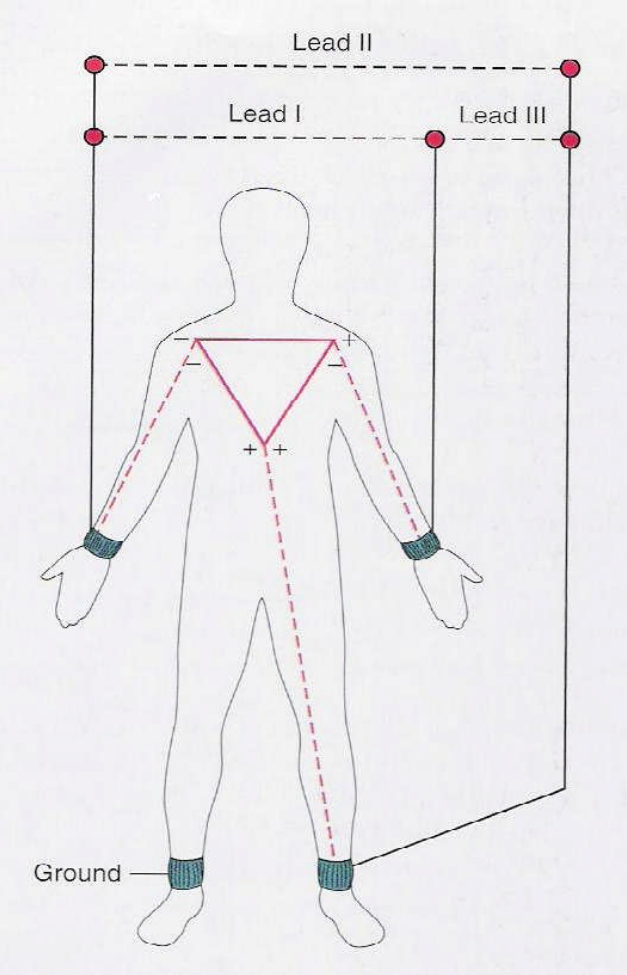
Lead Placement

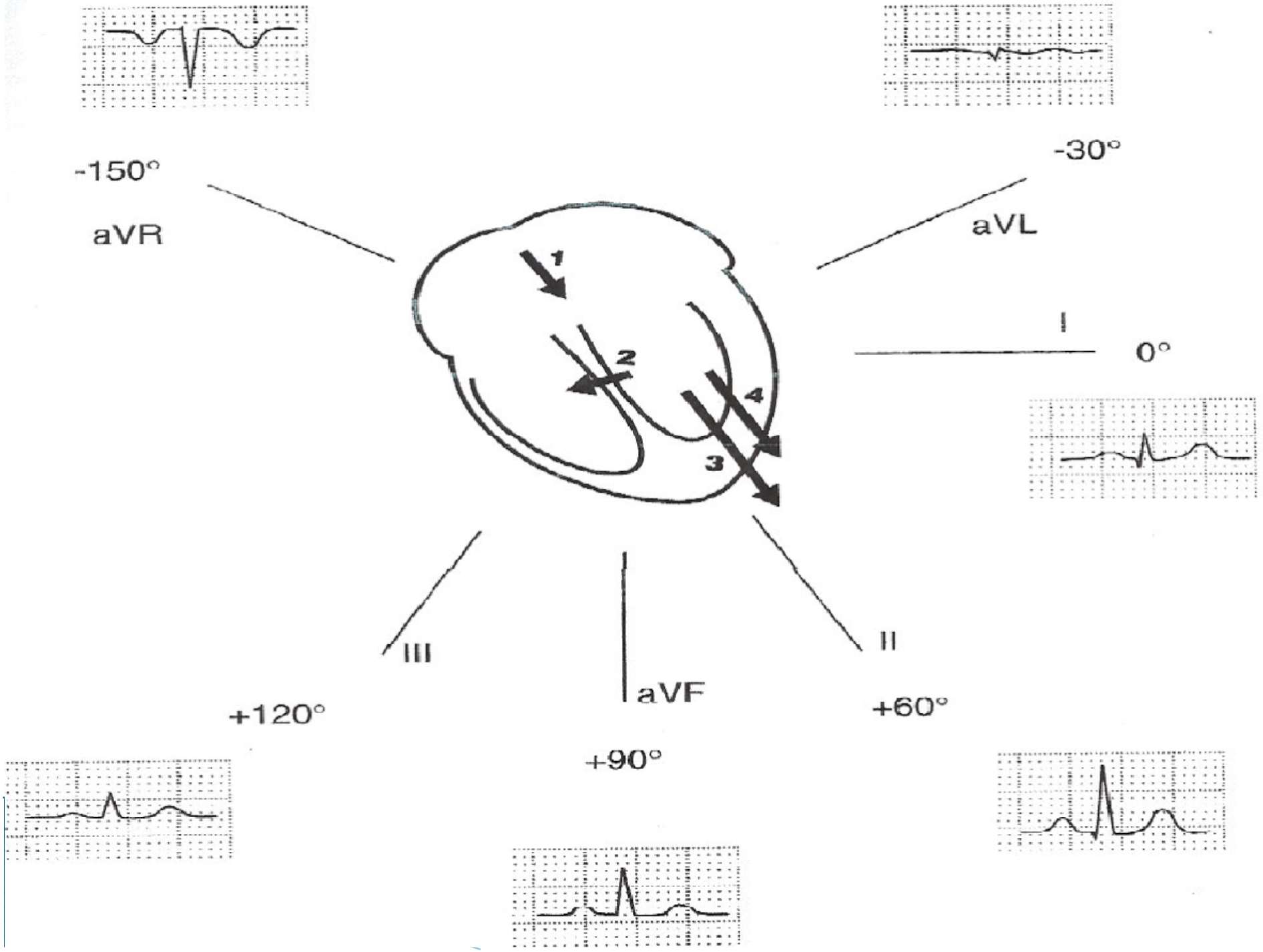
- V1 – Right Sternal Border – 4th ICS
- V2 – Left Sternal Border – 4th ICS
- V3 Midway Between V2 and V4
- V4 Midclavicular line – 5th ICS
- V5 Anterior Axillary line – 5th ICS
- V6 Mid axillary line – 5th ICS



Electrocardiogram

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




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

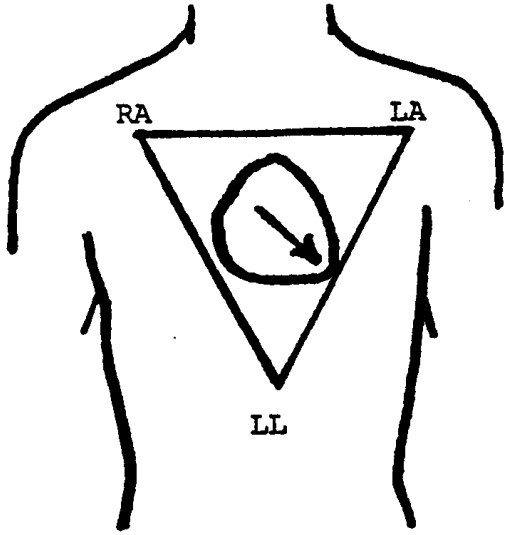
ECG Recordings: (QRS vector---leftward, inferiorly and posteriorly

3 Bipolar Limb Leads

I = RA vs. LA(+)

II = RA vs. LL(+)

III = LA vs. LL(+)

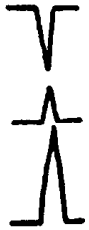


3 Augmented Limb Leads

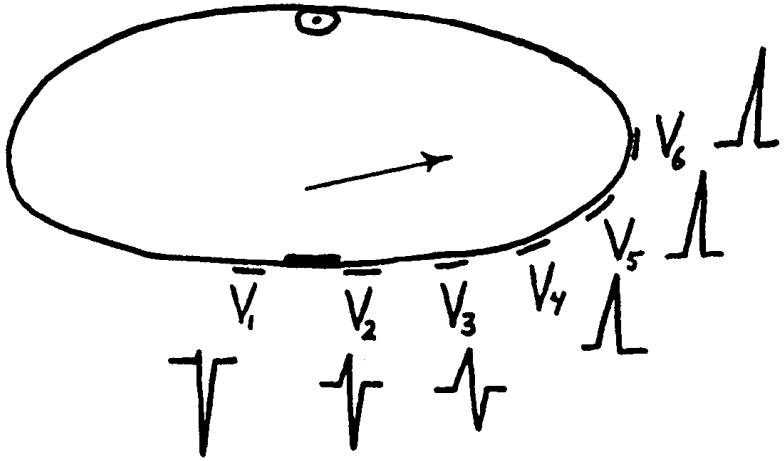
aVR = (LA-LL) vs. RA(+)

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

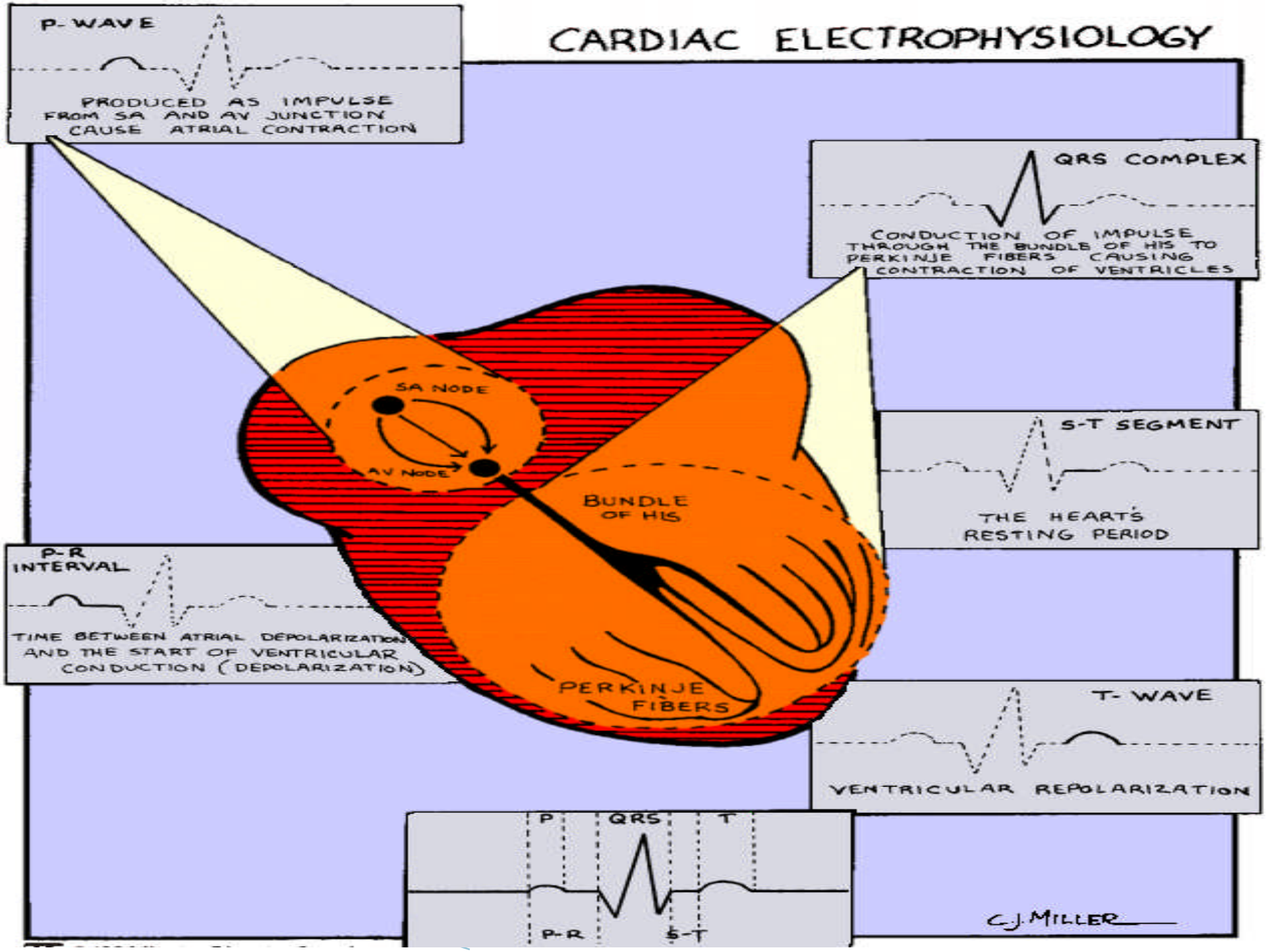
aVF = (RA-LA) vs. LL(+)



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



CARDIAC ELECTROPHYSIOLOGY



EKG Leads

The standard EKG has 12 leads:

3 Standard Limb Leads

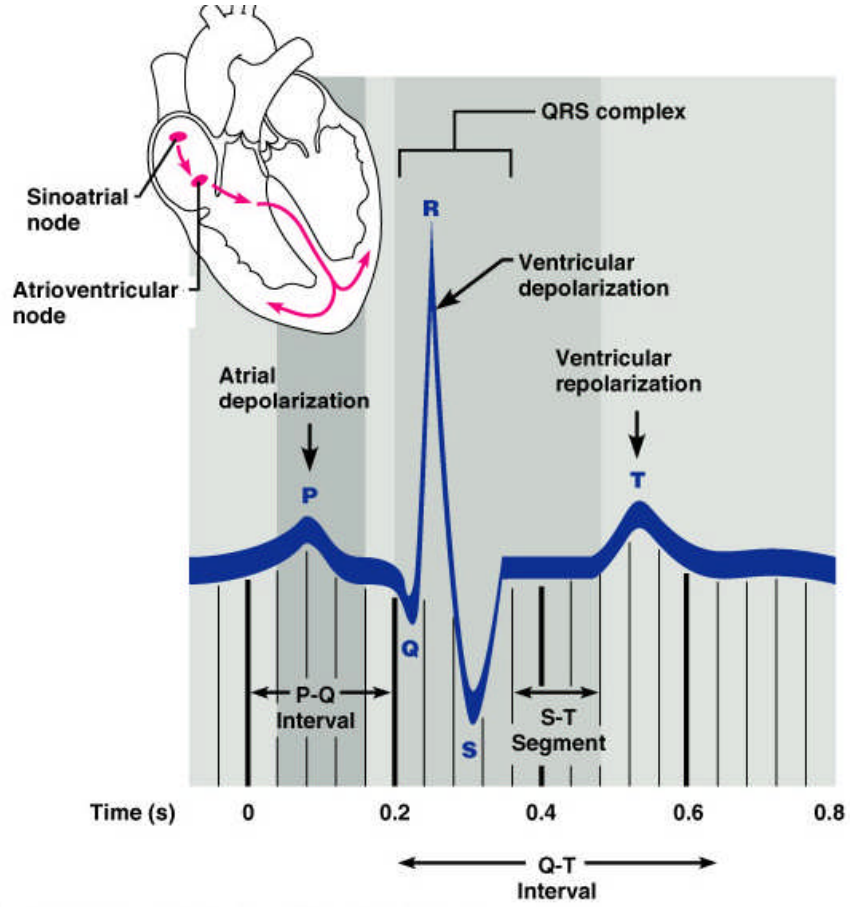
3 Augmented Limb Leads

6 Precordial Leads

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

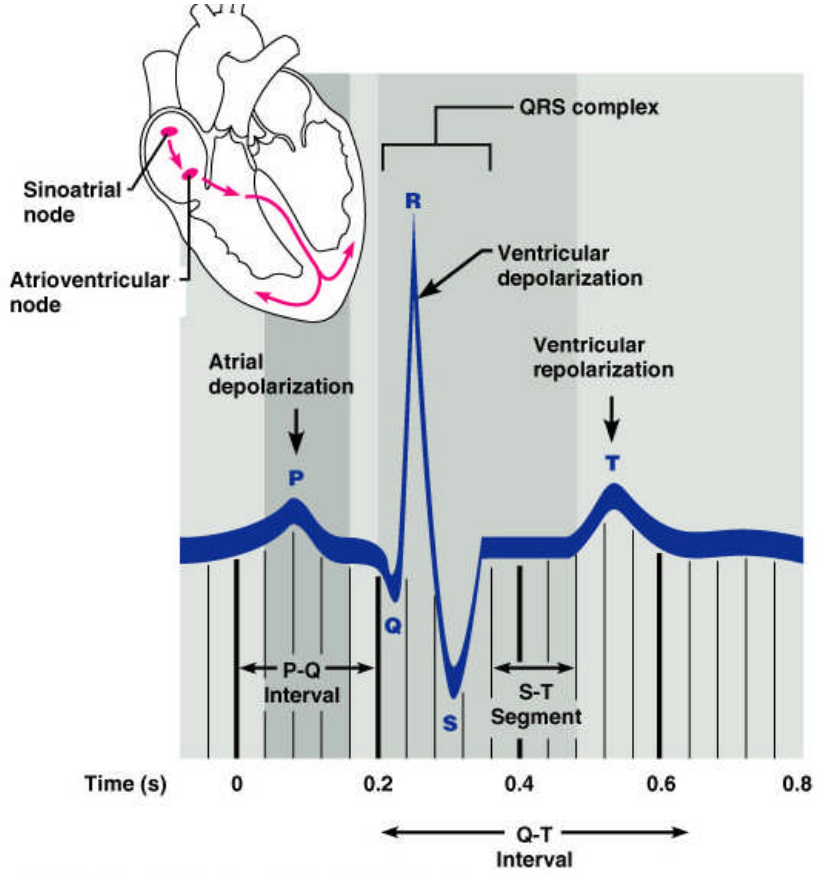
Electrocardiogram

- 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



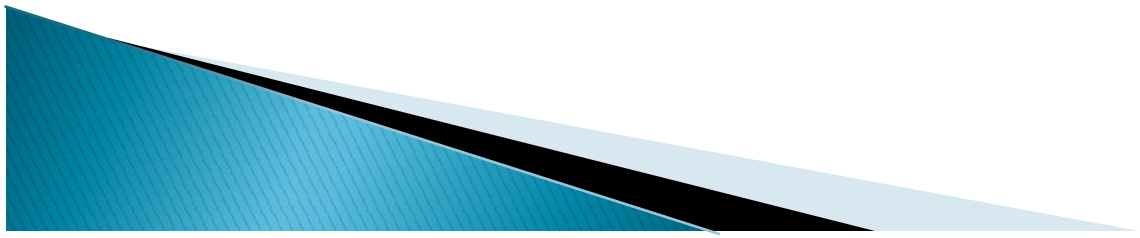
Electrocardiogram

- 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

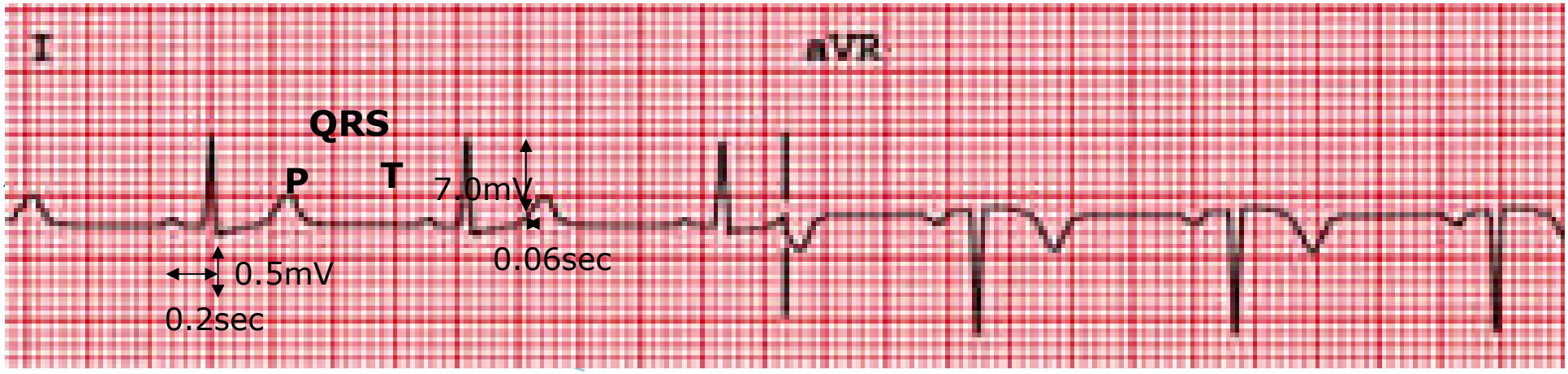


Normal EKG

- 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.



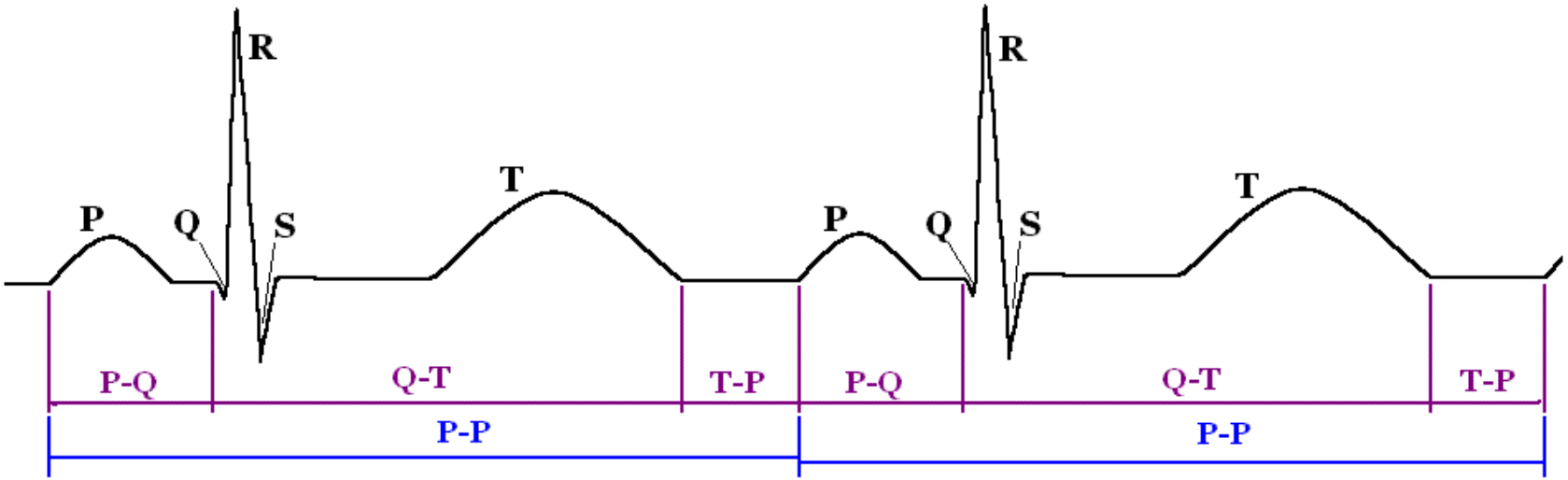
Rhythm Summary

- Rate 90–95 bpm
- Regularity regular
- P waves normal
- PR interval 0.12 s
- QRS duration 0.08 s

Interpretation? *Normal Sinus Rhythm*

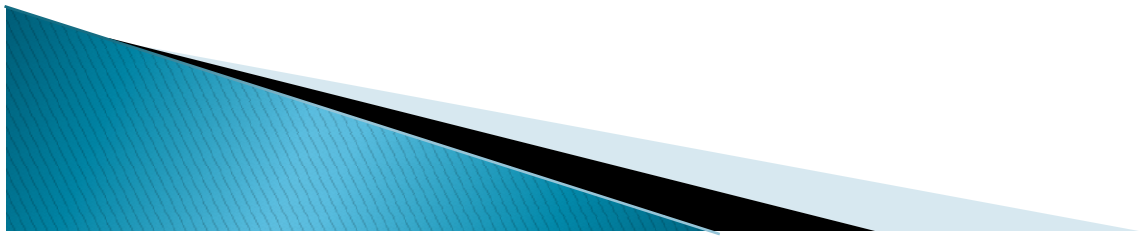
Electrocardiogram

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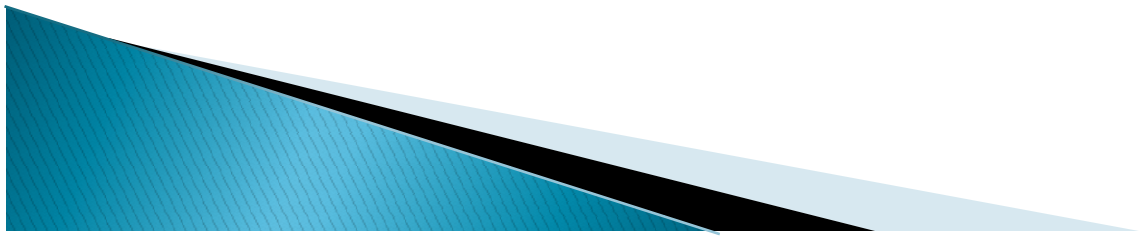
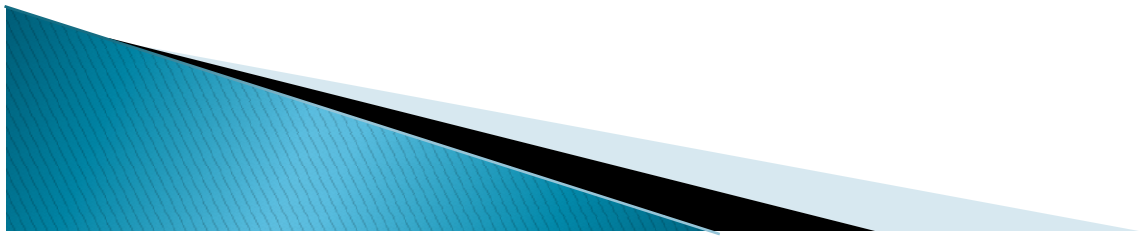
- • **PR interval – time from sinoatrial** node (S–A) to atrioventricular node (A–Vnode)
- • **QRS Complex – ventricular** depolarization
- • **ST Segment – beginning of** ventricular repolarization
- • **T Wave – later stages of** ventricular repolarization
- • **U Wave – final component of** ventricular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



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



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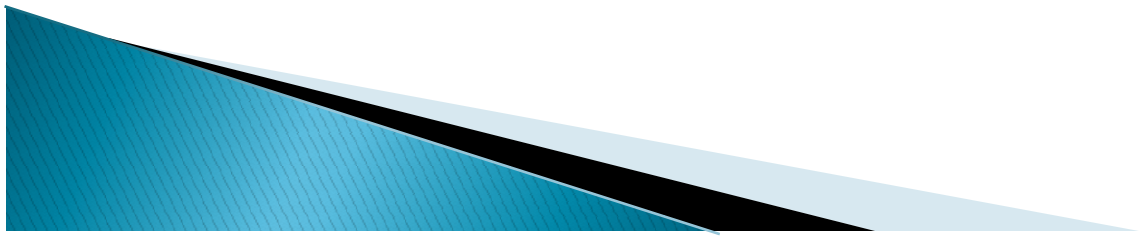
- V2 = 4th intercostal space, left border of sternum
- V3 = midway between V2 and V4
- V4 = 5th intercostal space, midclavicular line
- V5 = anteroaxillary line at level of V4
- V6 = midaxillary line at level of V4 and V5



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

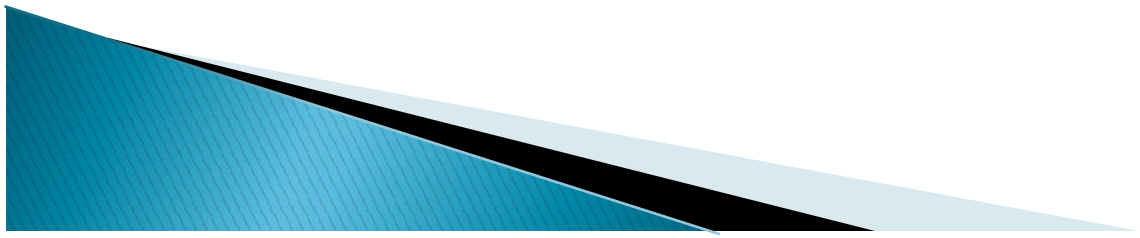
Anatomic Groups (Summary)

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

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.



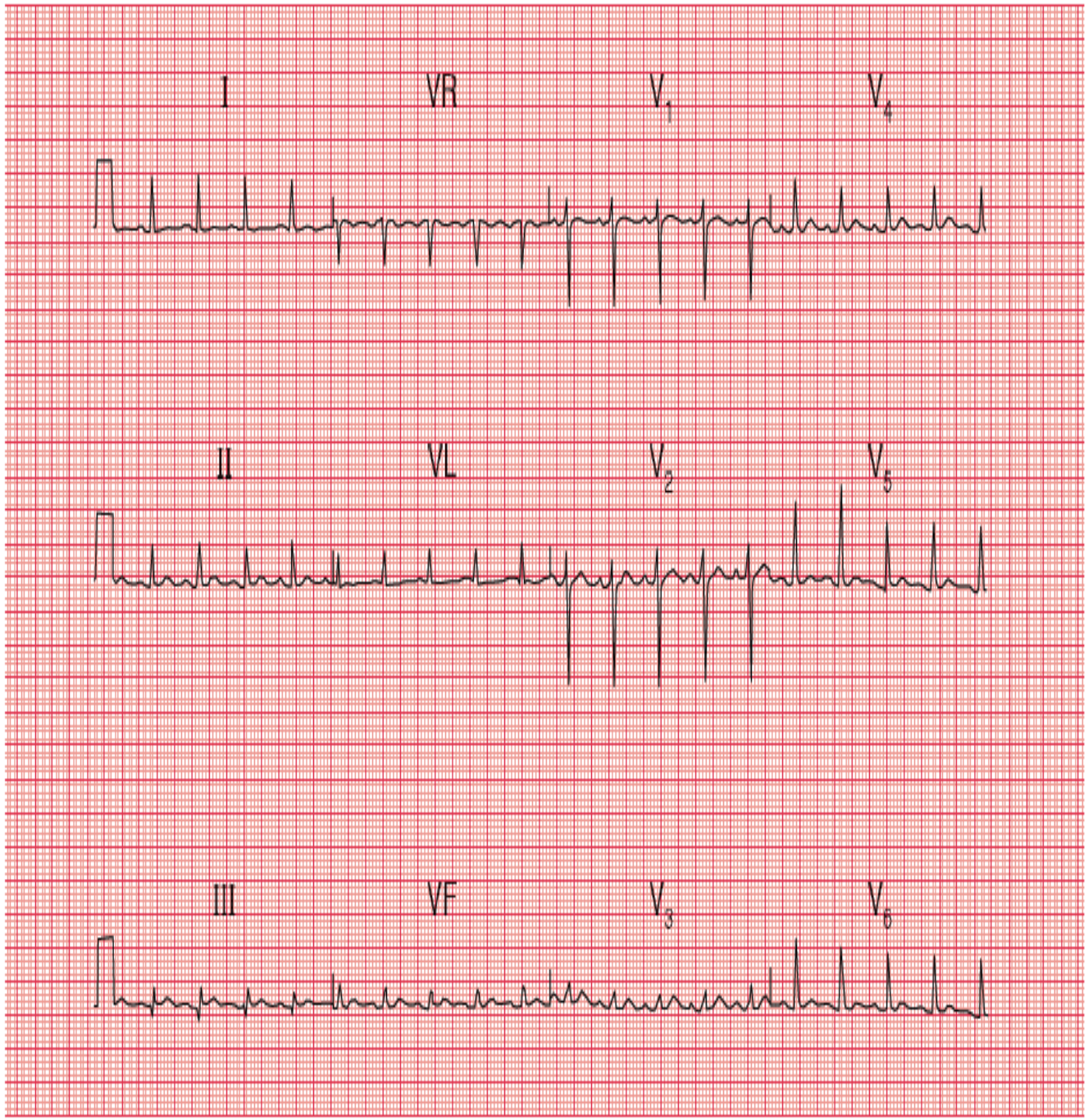


Fig. 1.23 12-lead ECG: example 1

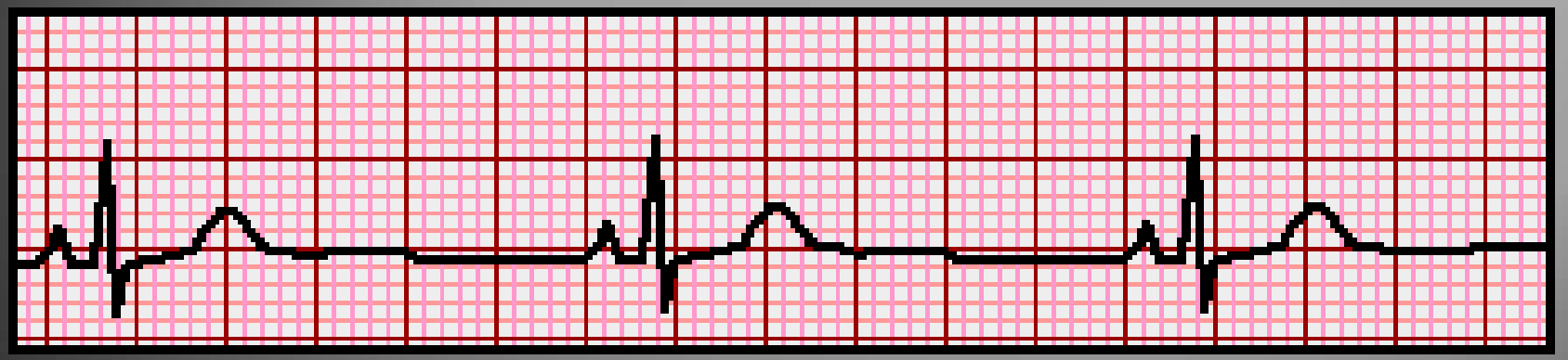
Description

- 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

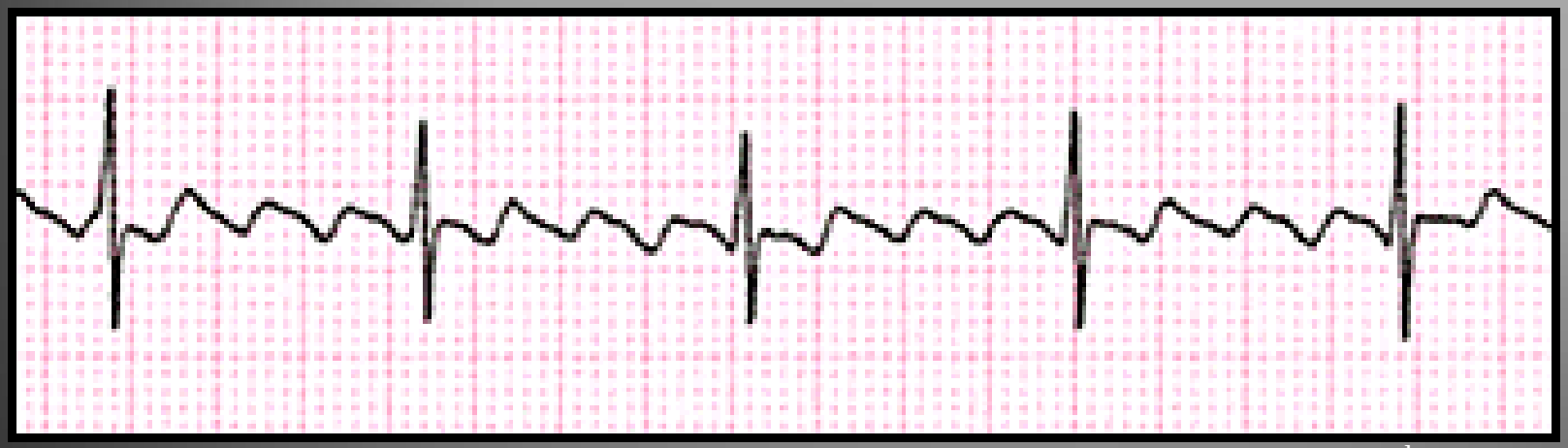
What is the heart rate?



www.uptodate.com

(300 / 6) = 50 bpm

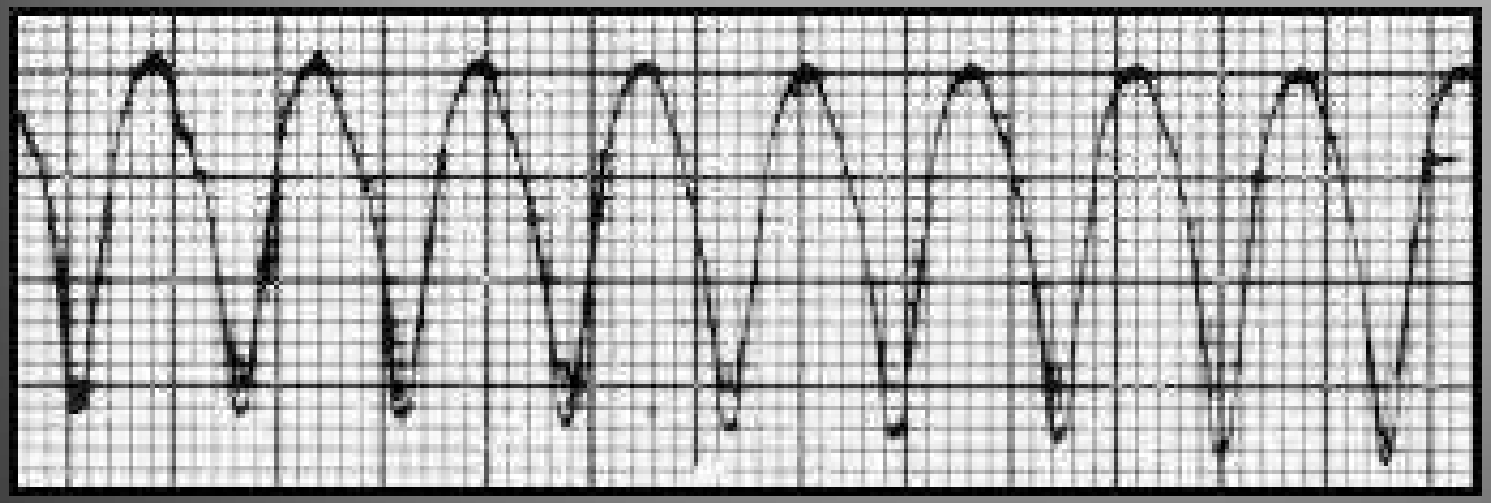
What is the heart rate?



www.uptodate.com

(300 / ~ 4) = ~ 75 bpm

What is the heart rate?



(300 / 1.5) = 200 bpm

The Rule of 300

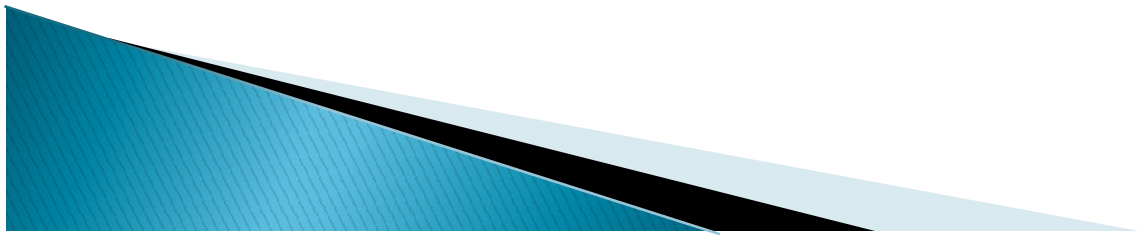
It may be easiest to memorize the following table:

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

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.

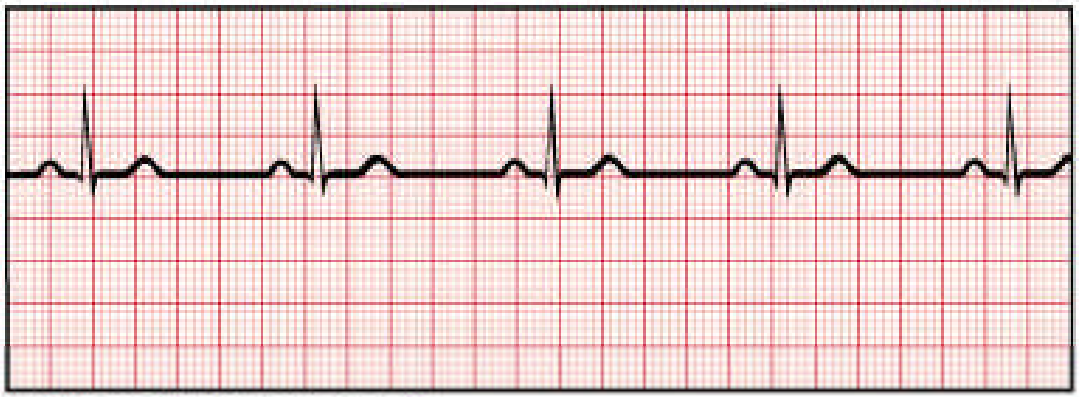


What is the heart rate?

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

33 x 6 = 198 bpm

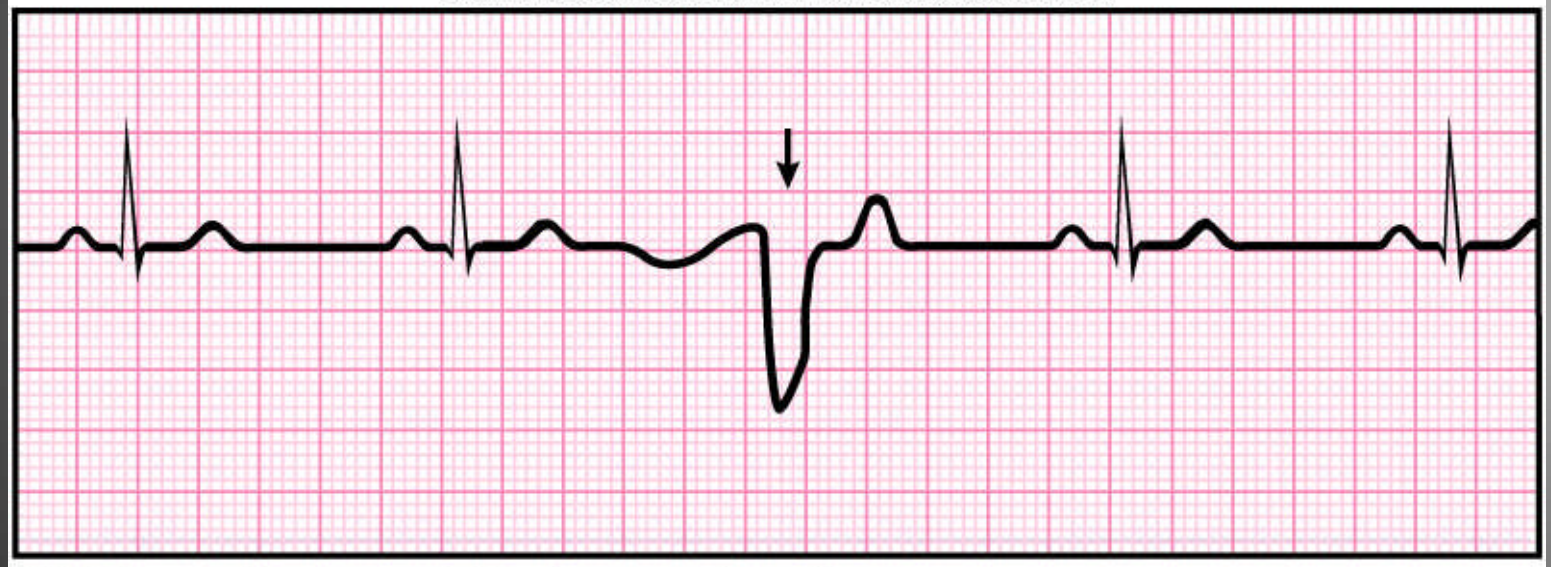
ECGs, Normal and Abnormal



(a) Sinus rhythm (normal)

(b) Nodal rhythm – no SA node activity

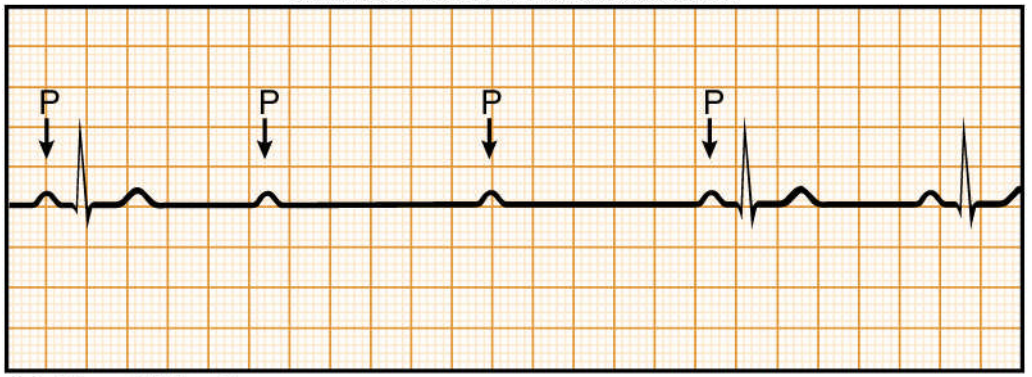
ECGs, Abnormal



(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

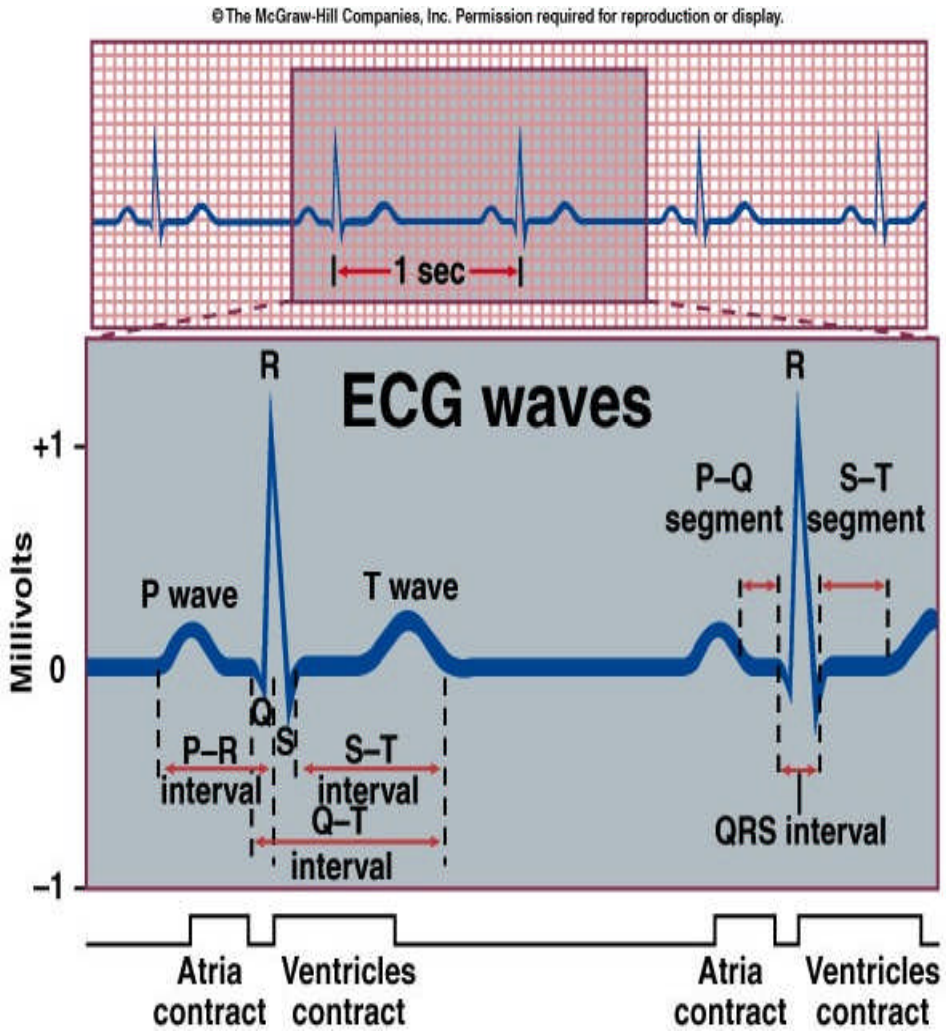
(e) Ventricular fibrillation

No pumping action occurs

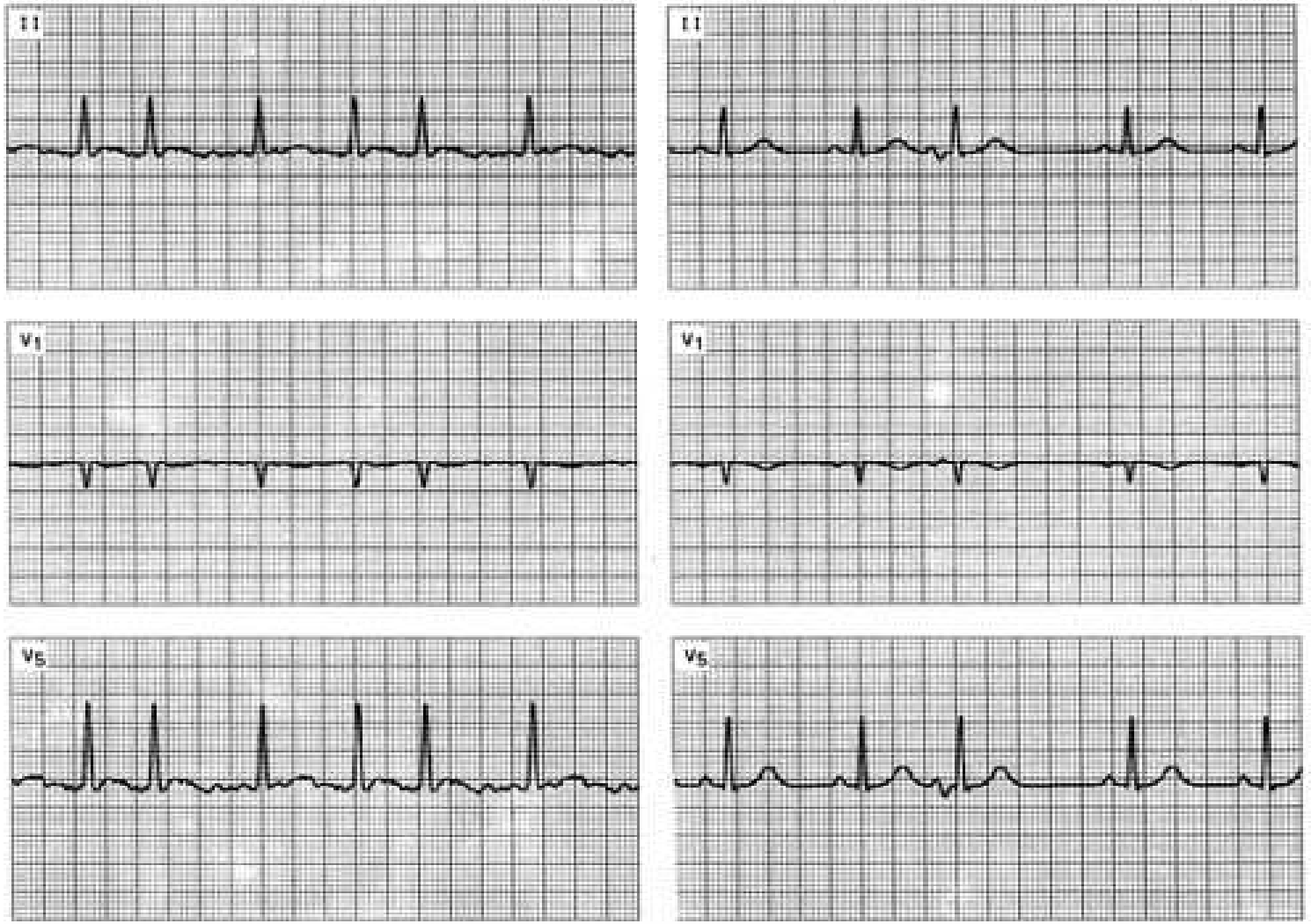
Interpretation of ECG

Normal Sinus Rhythm

- Rate: 60–100 b/min
- Rhythm: regular
- P waves: upright in leads I, II, aV_F
- PR interval: < .20 s
- QRS: < .10 s

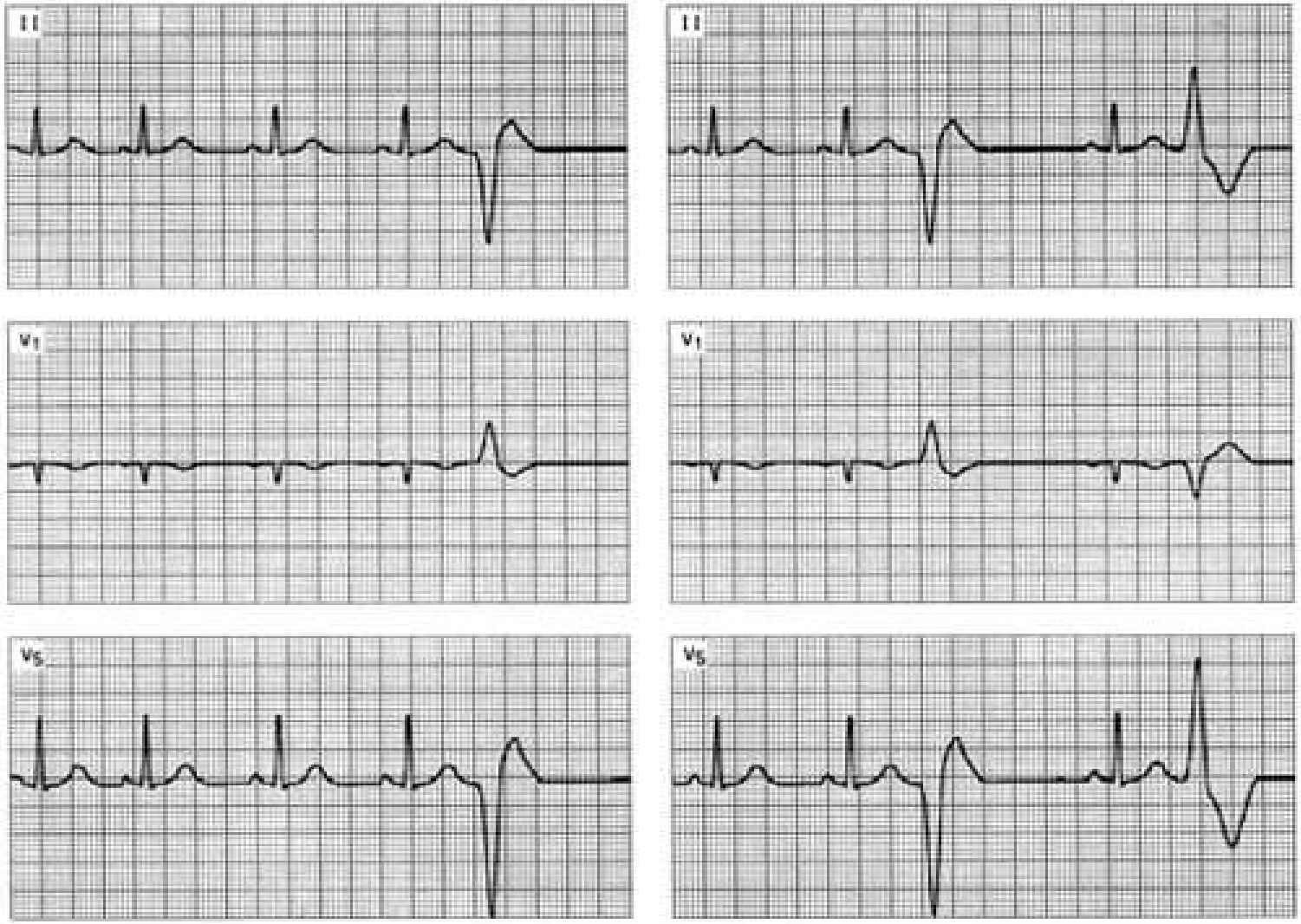


Irregular ECGs



A B

Irregular ECGs

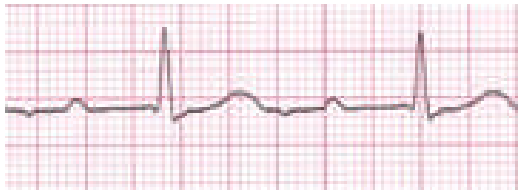


C D

Rate Rhythm Axis **Intervals** Hypertrophy Infarct

PR interval

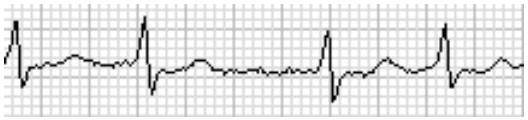
< 0.12 s	0.12-0.20 s	> 0.20 s
High catecholamine states Wolff-Parkinson-White	Normal	AV nodal blocks



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

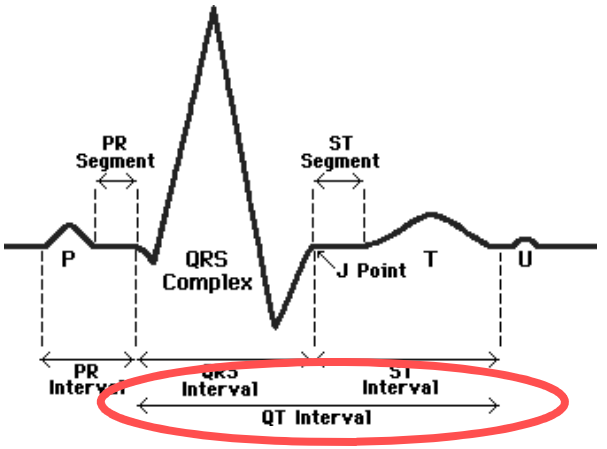


Rate Rhythm Axis Intervals Hypertrophy Infarct

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):

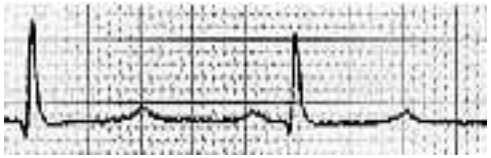


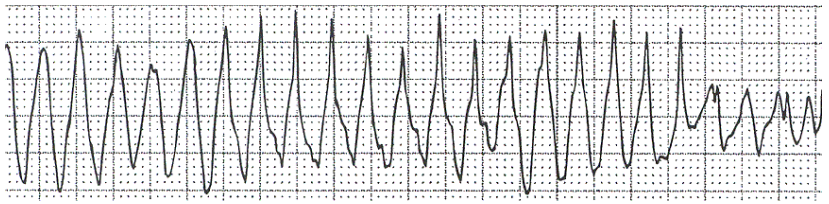
QTc = QT / square root of RR interval

Rate Rhythm Axis **Intervals** Hypertrophy Infarct

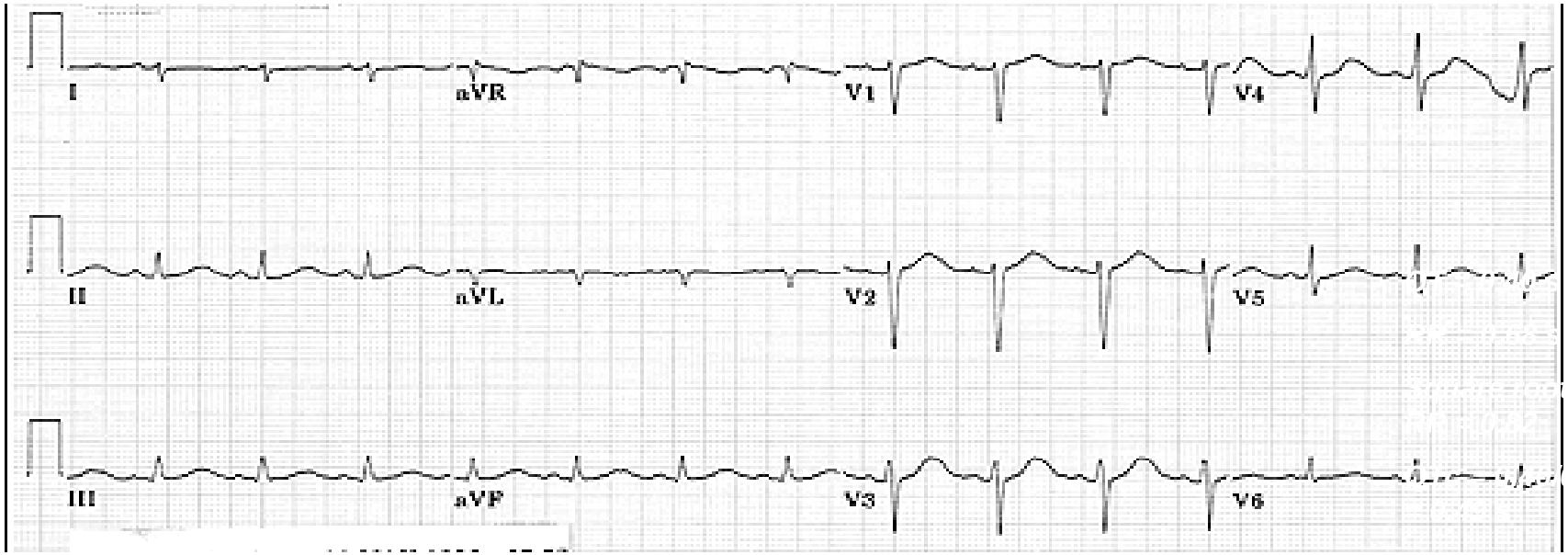
QTc interval

< 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*

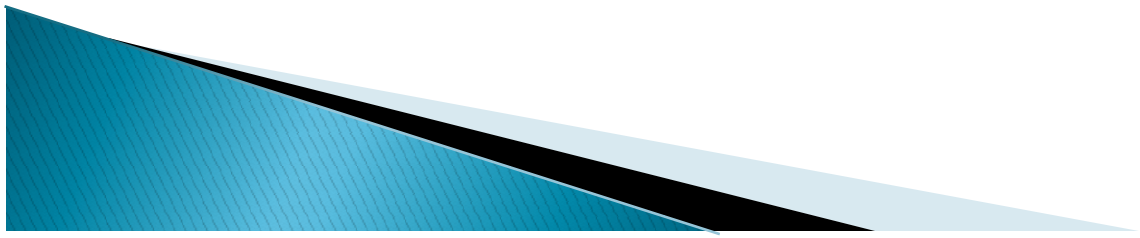
QTc interval? *0.49 seconds*

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

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:

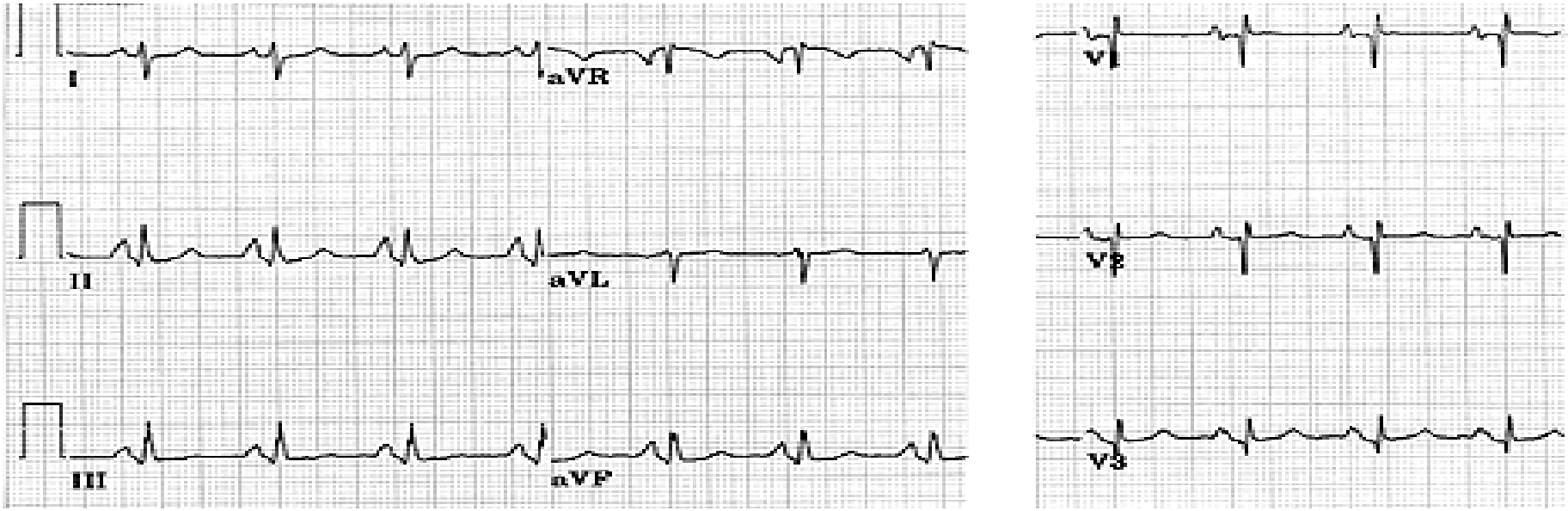
- Right atrial enlargement (RAE)
- Left atrial enlargement (LAE)
- Right ventricular hypertrophy (RVH)
- Left ventricular hypertrophy (LVH)



Rate Rhythm Axis Intervals **Hypertrophy**
Infarct

Right atrial enlargement

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

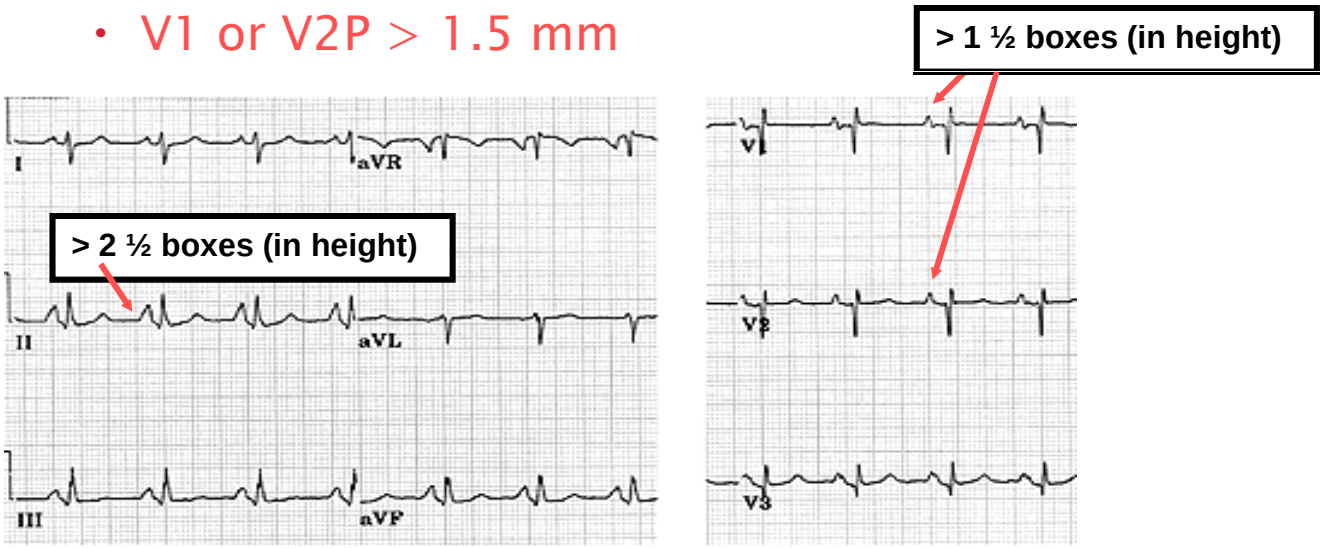


The P waves are tall, especially in leads II, III and avF. Ouch! They would hurt to sit on!!

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

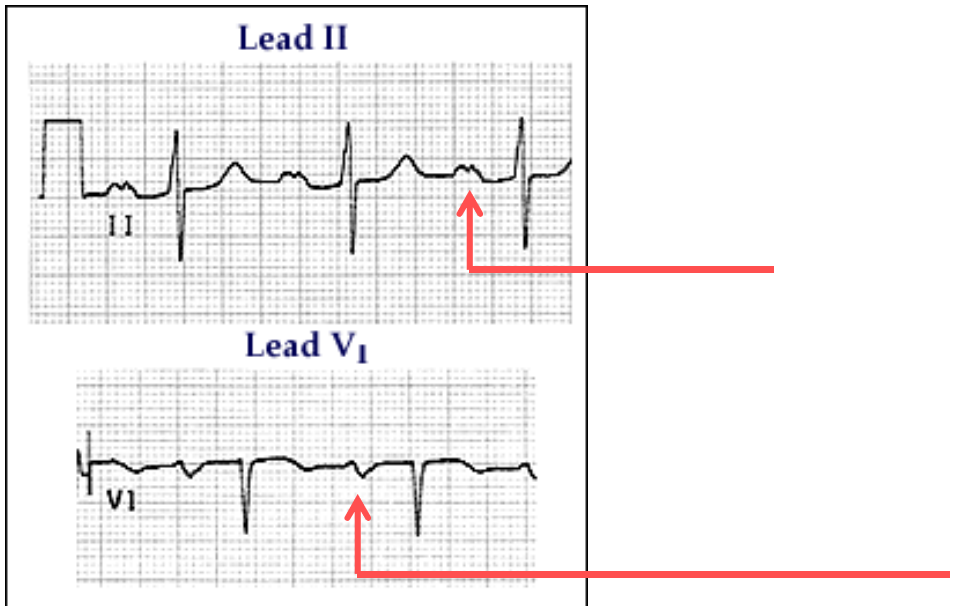


A cause of RAE is RVH from pulmonary hypertension.

Rate Rhythm Axis Intervals **Hypertrophy** Infarct

Left atrial enlargement

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

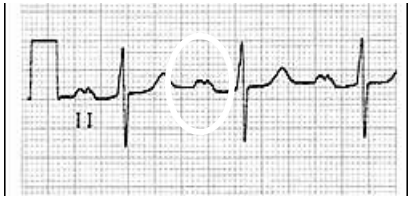


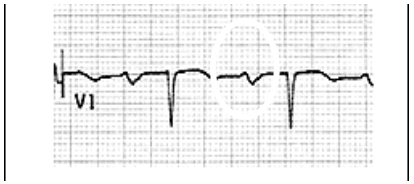
The P waves in lead II are notched and in lead V1 they have a deep and wide negative component.

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



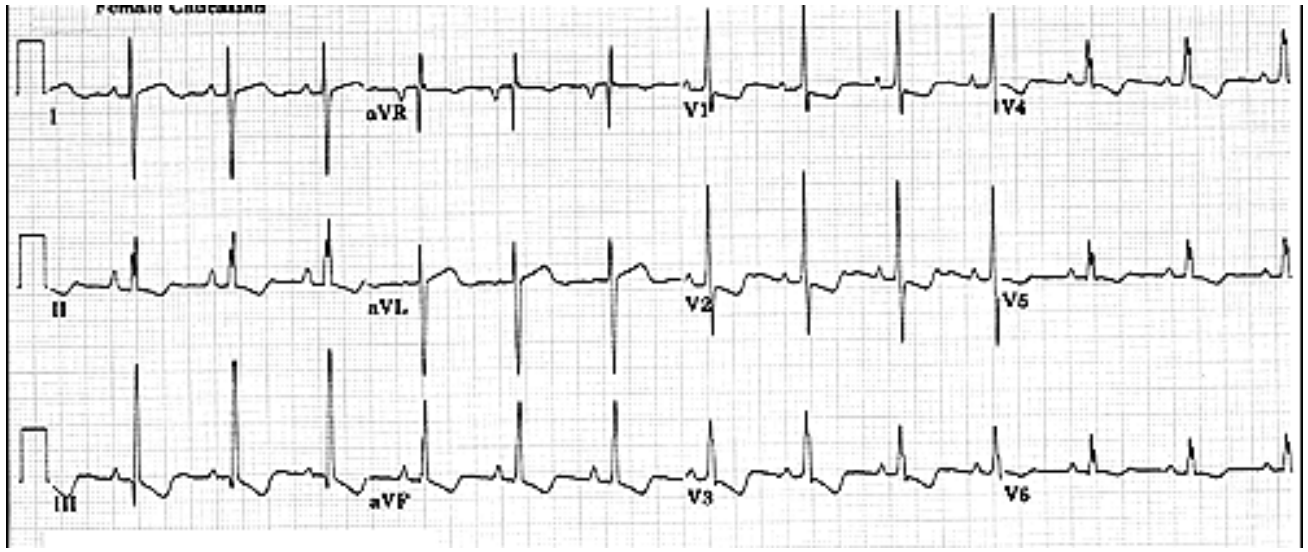


A common cause of LAE is LVH from hypertension.

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)?

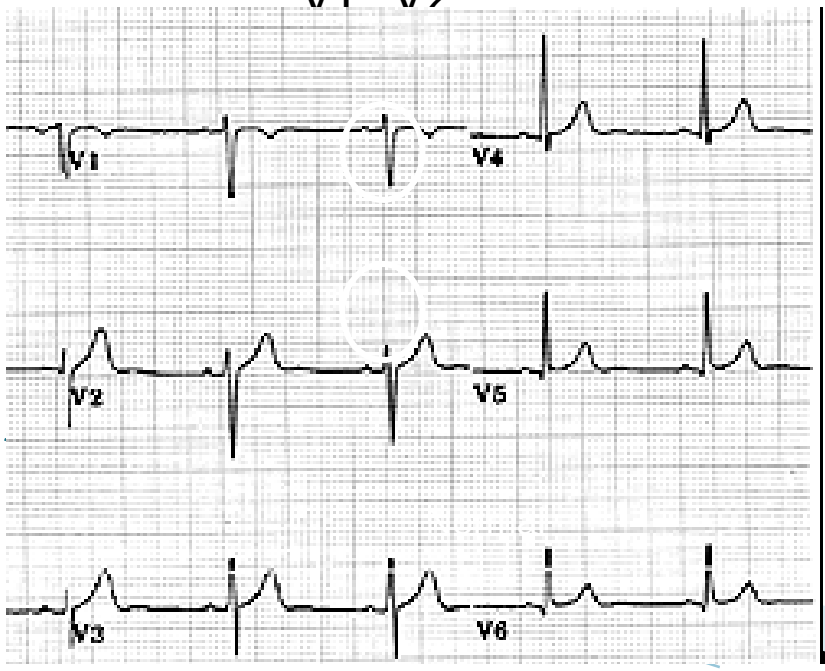


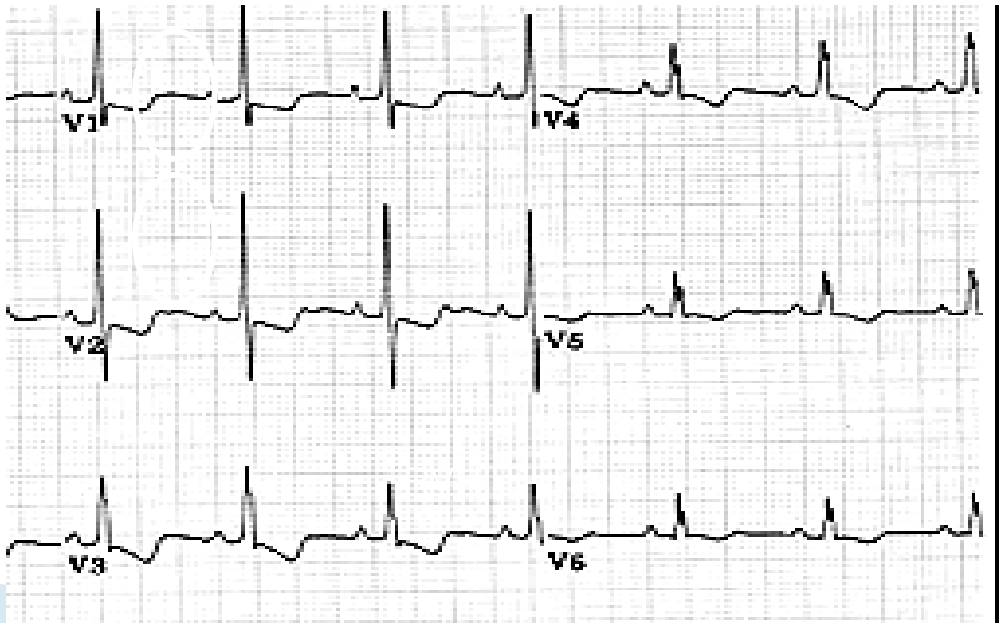
There is right axis deviation (negative in I, positive in II) and there are tall R waves in V1, V2.

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

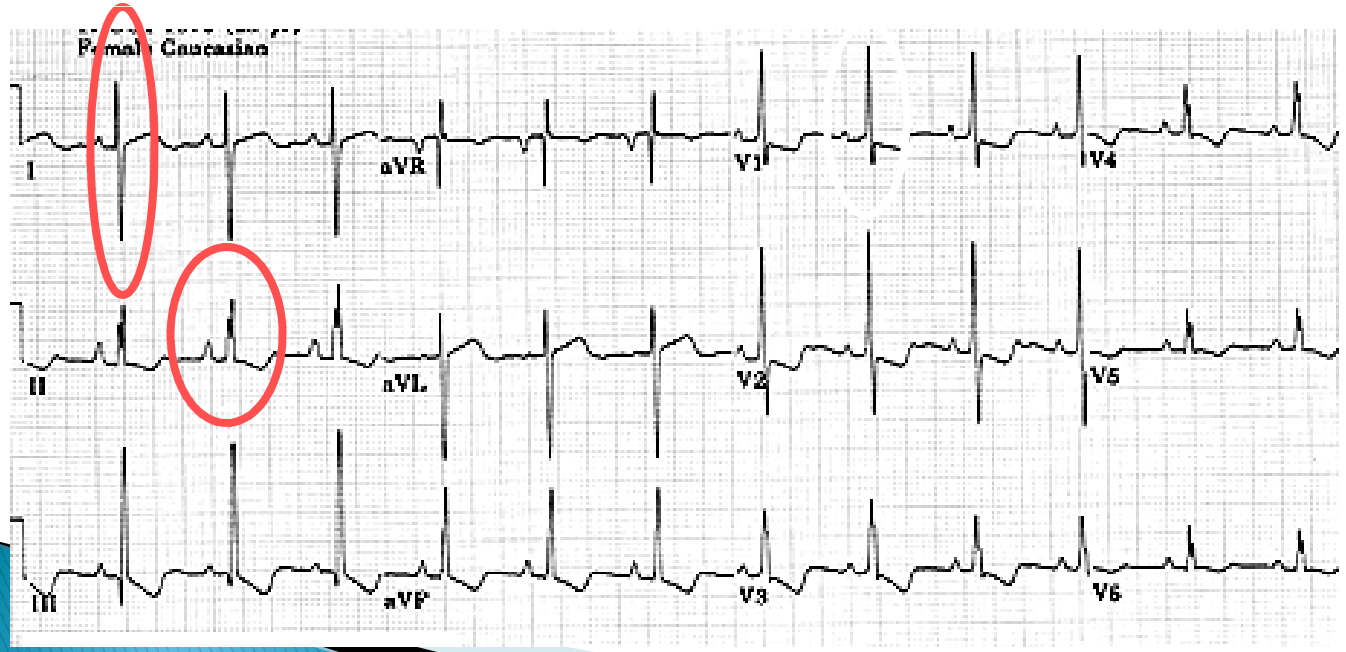




Rate Rhythm Axis Intervals **Hypertrophy**
Infarct

Right ventricular hypertrophy

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

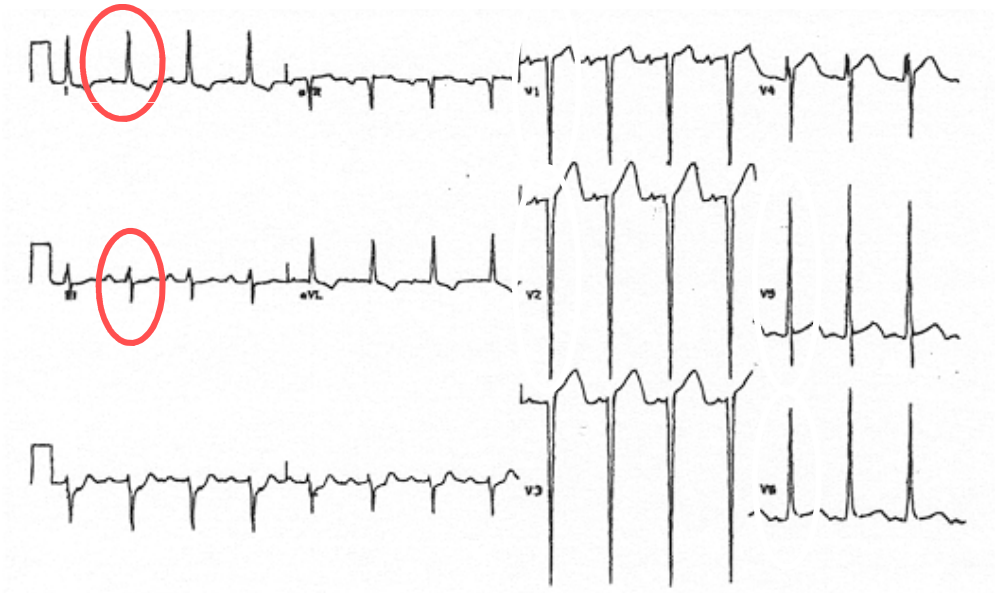


A common cause of RVH is left heart failure.

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)?

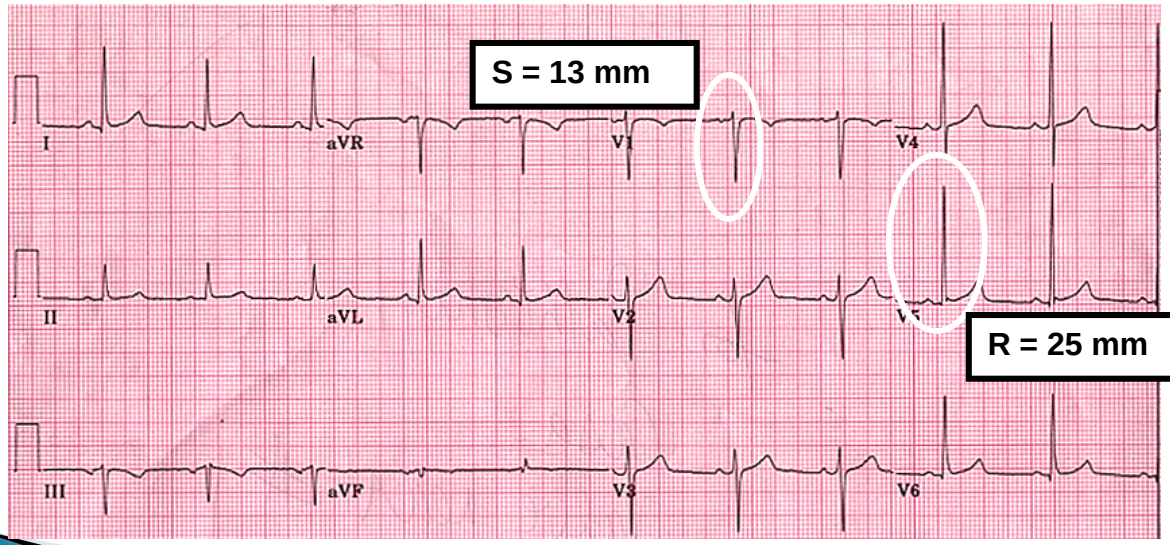


There is left axis deviation (positive in I, negative in II) and there are tall R waves in V5, V6 and deep S waves in V1, V2

Rate Rhythm Axis Intervals **Hypertrophy**
Infarct

Left ventricular hypertrophy

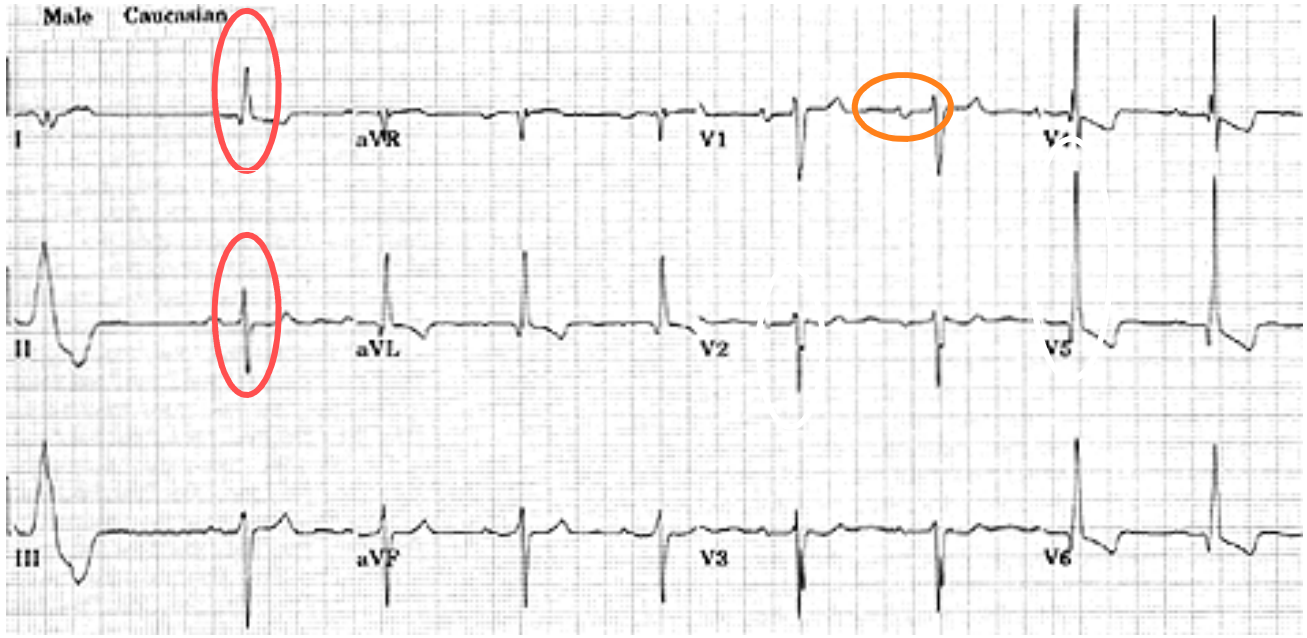
- To diagnose LVH you can use the following criteria :
  - R in V5 (or V6) + S in V1 (or V2) > 35 mm, or
  - avL R > 13 mm



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.)*

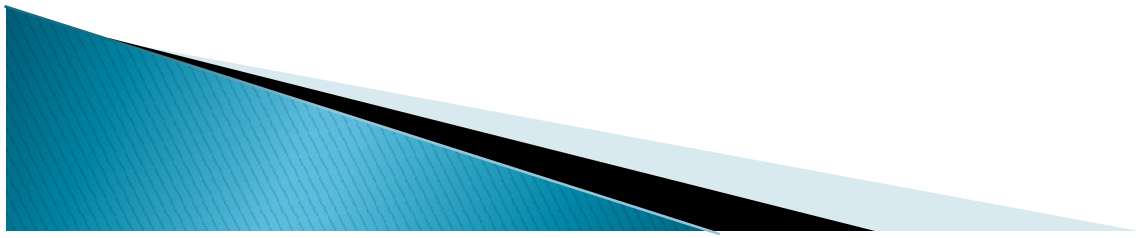


Yes, there is left axis deviation (positive in I, negative in II), left atrial enlargement (> 1 x 1 boxes in V1) and LVH (R in V5 = 27 + S in V2 = 10 → > 35 mm).

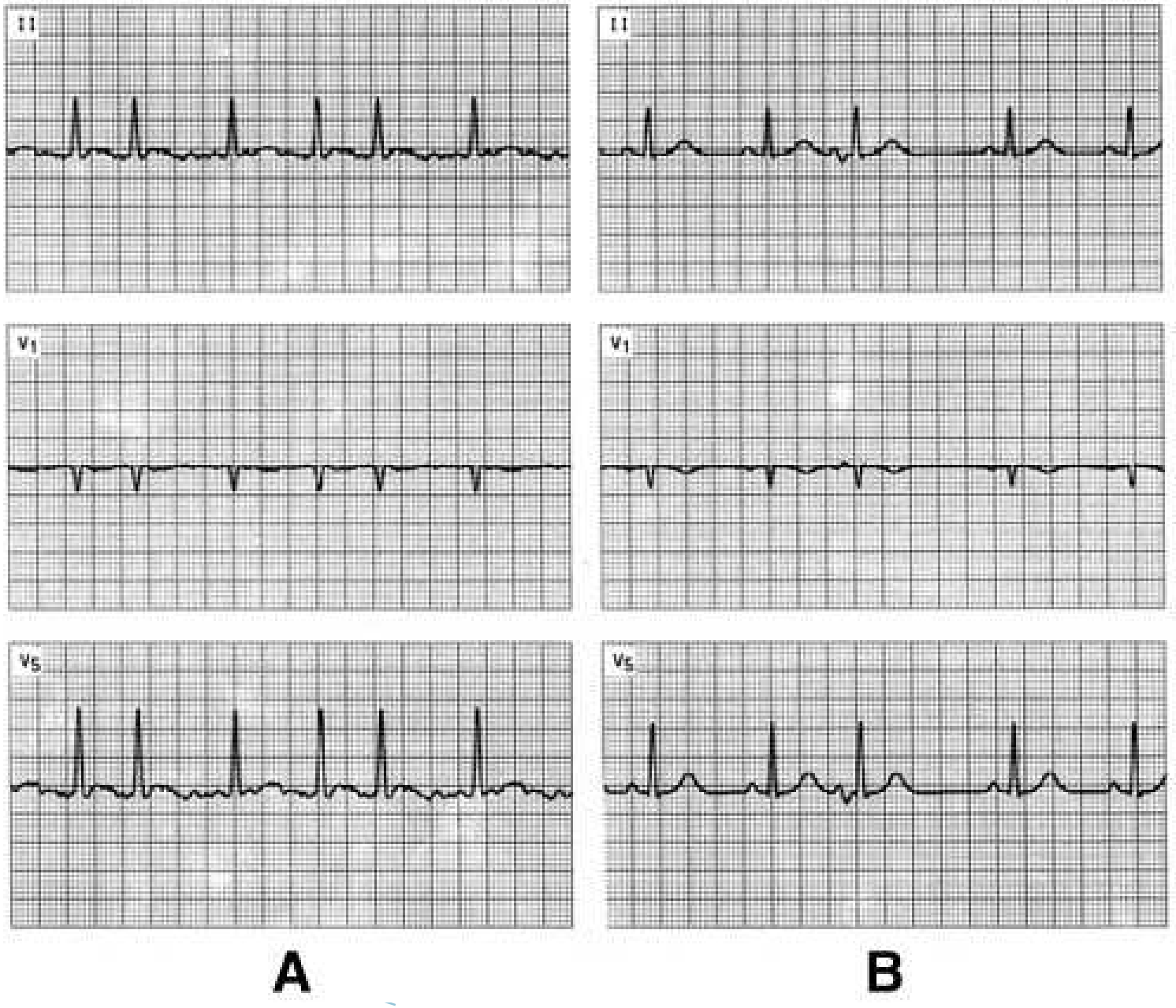
Rate Rhythm Axis Intervals Hypertrophy Infarct

- 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

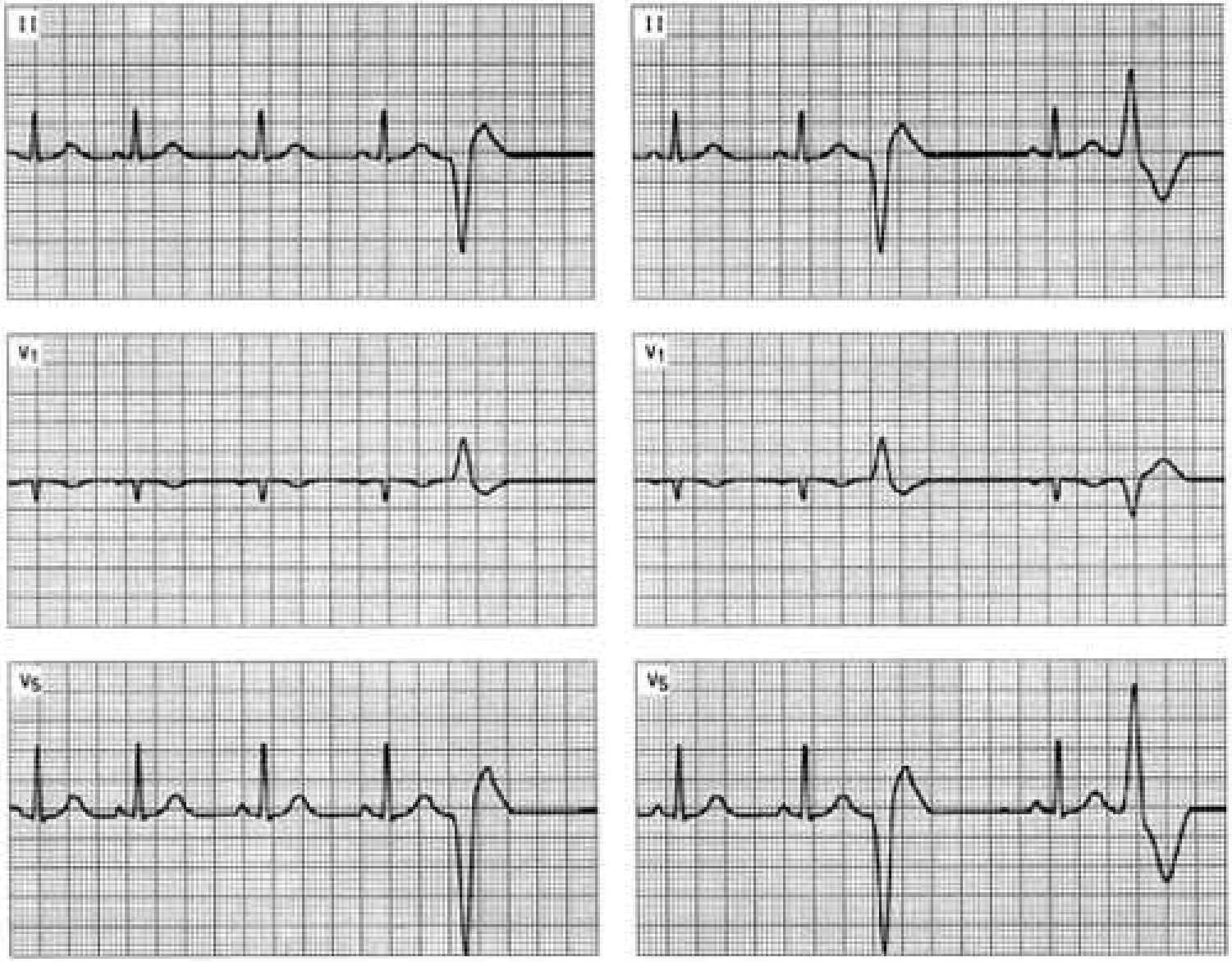
- These topics were covered in Modules V and VI where you learned:
  - ST elevation (or depression) of 1 mm in 2 or more contiguous leads is consistent with an AMI
  - There are ST elevation (Q-wave) and non-ST elevation (non-Q wave) MIs



Irregular ECGs



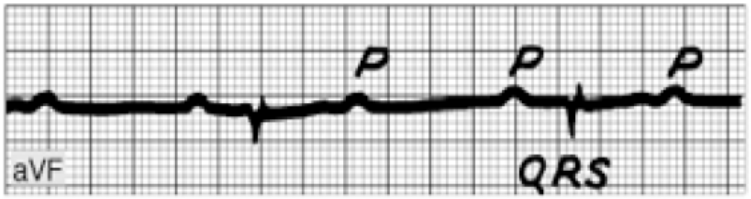
Irregular ECGs



C D

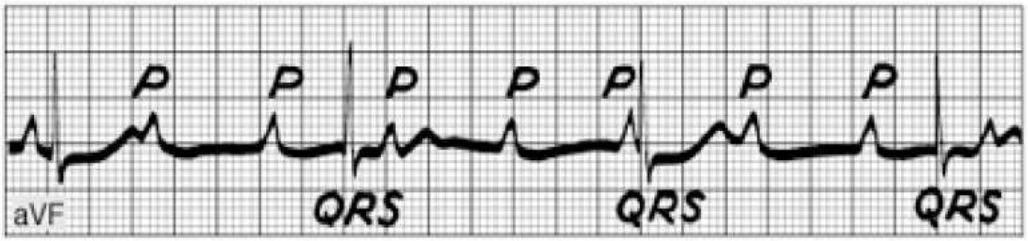
PR = 0.16 s
Normal complex

PR = 0.38 s
First-degree heart block

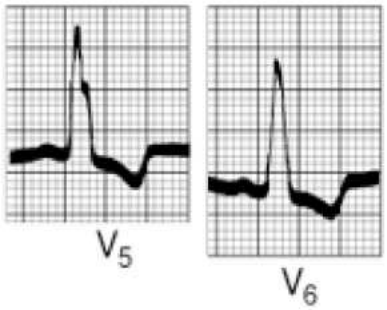


Second-degree heart block
(2:1 heart block)

Second-degree heart block
(Wenckebach phenomenon)



Complete heart block. Atrial rate, 107; ventricular rate, 43



Two V leads in left
bundle branch block

Figure 28-11. Heart block.

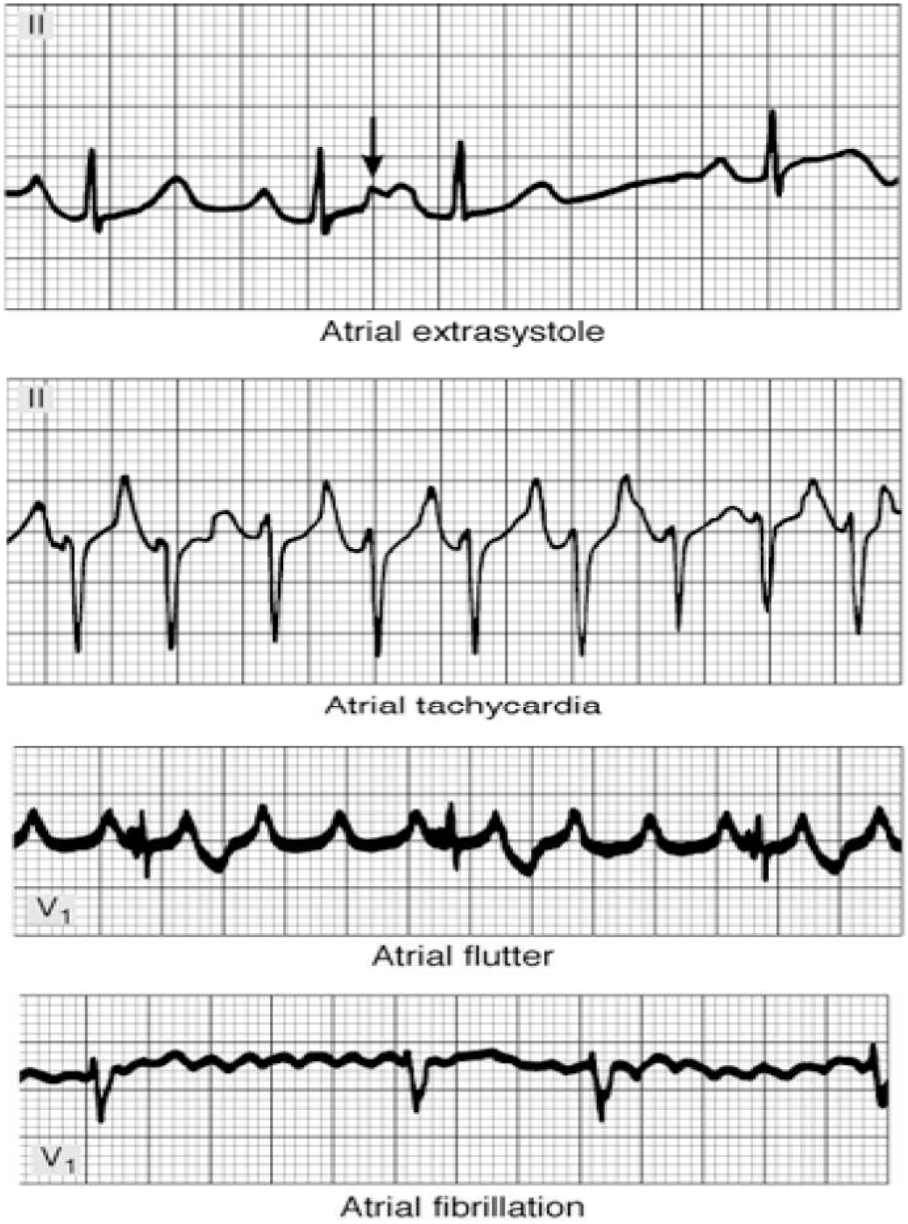


Figure 28-13. Atrial arrhythmias. The illustration shows an atrial premature beat with its P wave superimposed on the T wave of the preceding beat (arrow); atrial tachycardia; atrial flutter with 4:1 AV block; and atrial fibrillation with a totally irregular ventricular rate. (Tracings reproduced, with permission, from Goldschlager N, Goldman MJ: *Principles of Clinical Electrocardiography,* 13th ed. Originally published by Appleton & Lange. Copyright © 1989 by The McGraw-Hill Companies, Inc.)

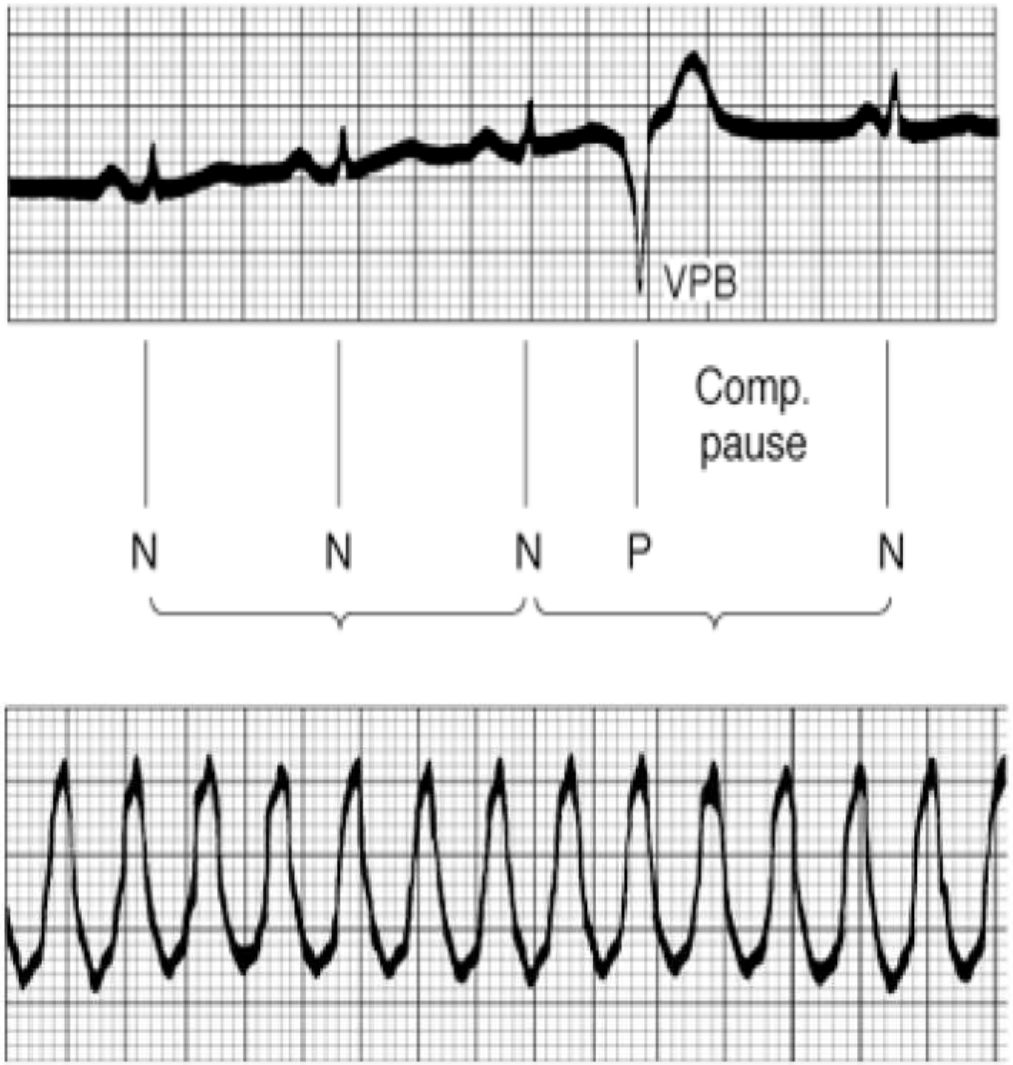


Figure 28-14. Top: Ventricular premature beats (VPB). The lines under the tracing illustrate the compensatory pause and show that the duration of the premature beat plus the preceding normal beat is equal to the duration of two normal beats. **Bottom:** Ventricular tachycardia.

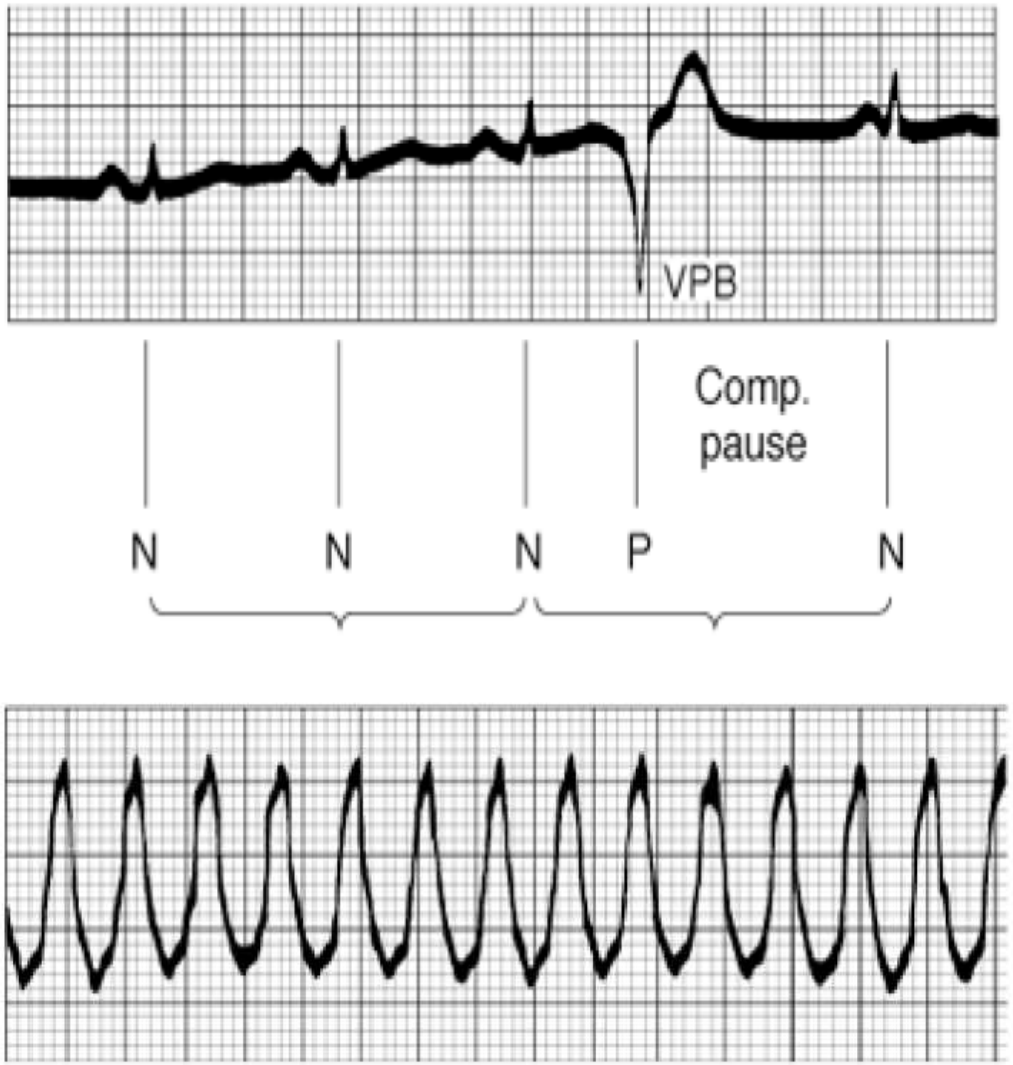
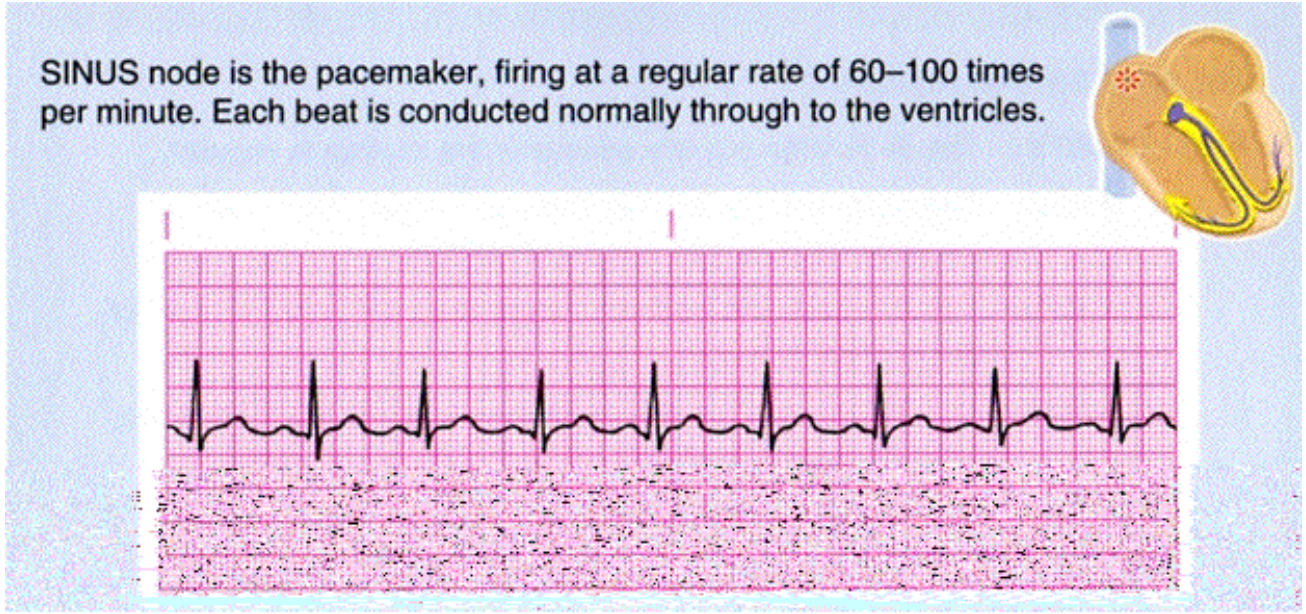
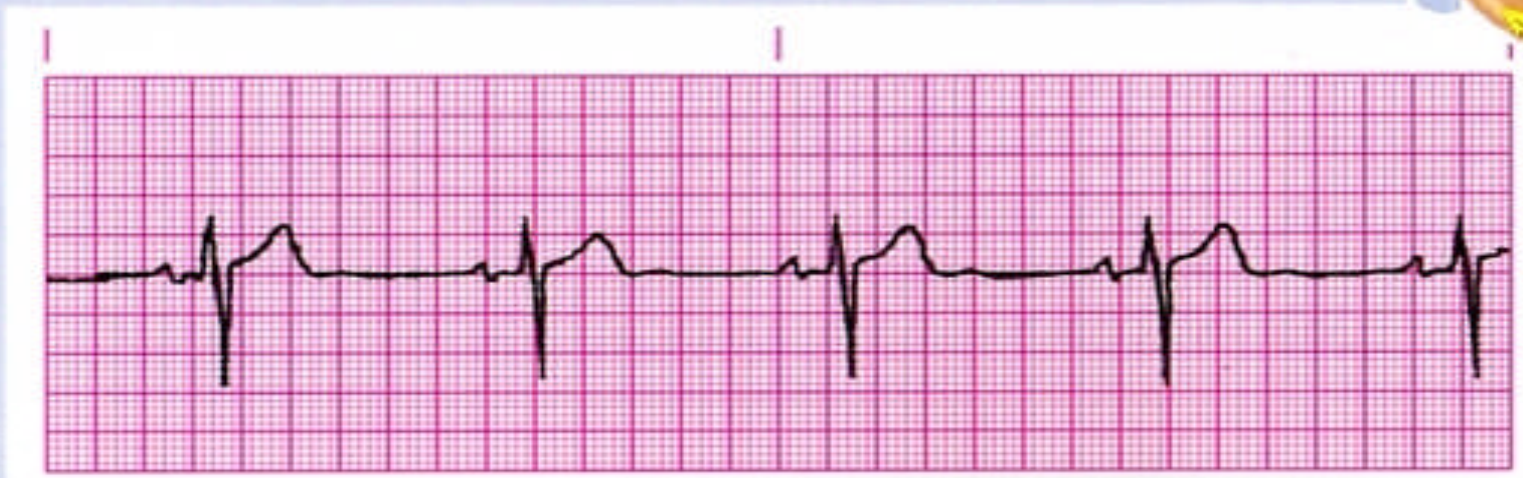


Figure 28-14. Top: Ventricular premature beats (VPB). The lines under the tracing illustrate the compensatory pause and show that the duration of the premature beat plus the preceding normal beat is equal to the duration of two normal beats. **Bottom:** Ventricular tachycardia.



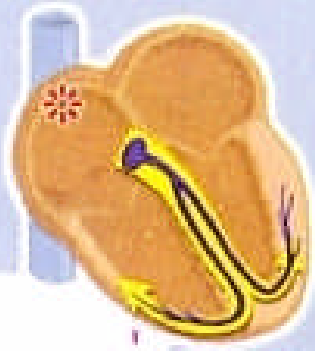
Normal Sinus Rhythm

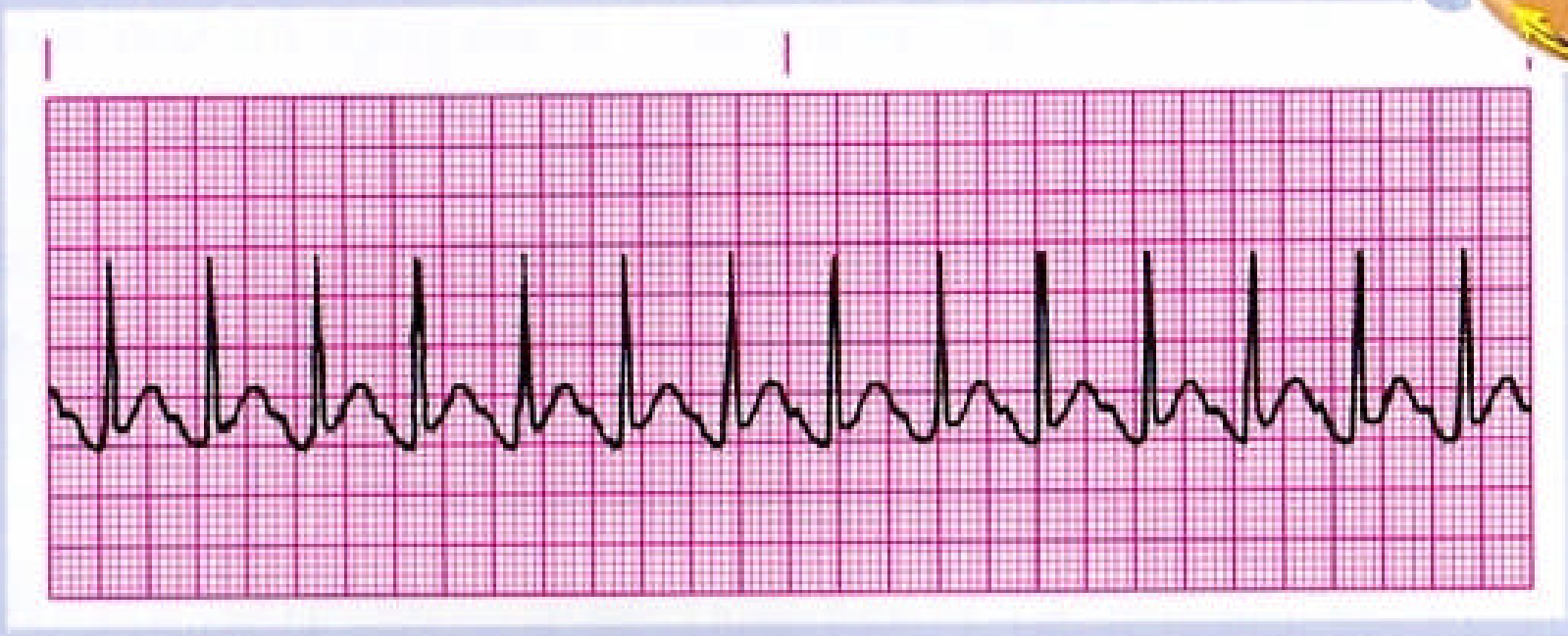
SINUS node is the pacemaker, firing regularly at a rate of less than 60 times per minute. Each impulse is conducted normally through to the ventricles.



Sinus Bradycardia

SINUS node is the pacemaker, firing regularly at a rate of greater than 100 times per minute. Each impulse is conducted normally through to the ventricles.

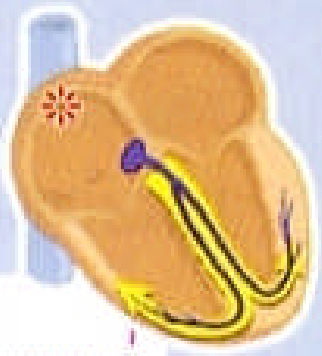




*

Sinus Tachycardia

SINUS node is the pacemaker, but impulses are initiated in an irregular pattern. The rate increases as the patient breathes in and decreases as the patient breathes out. Each beat is conducted normally through to the ventricles.

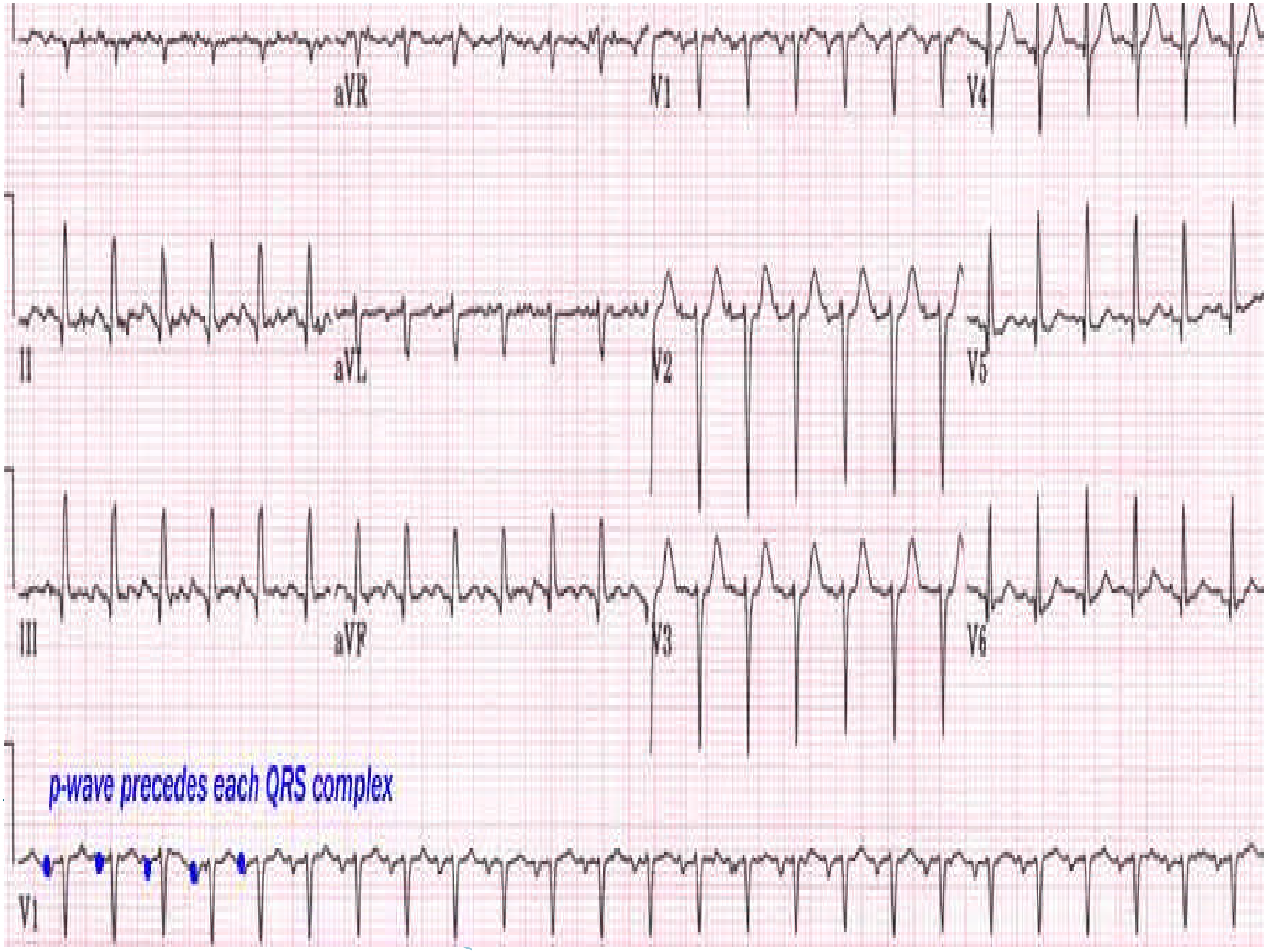


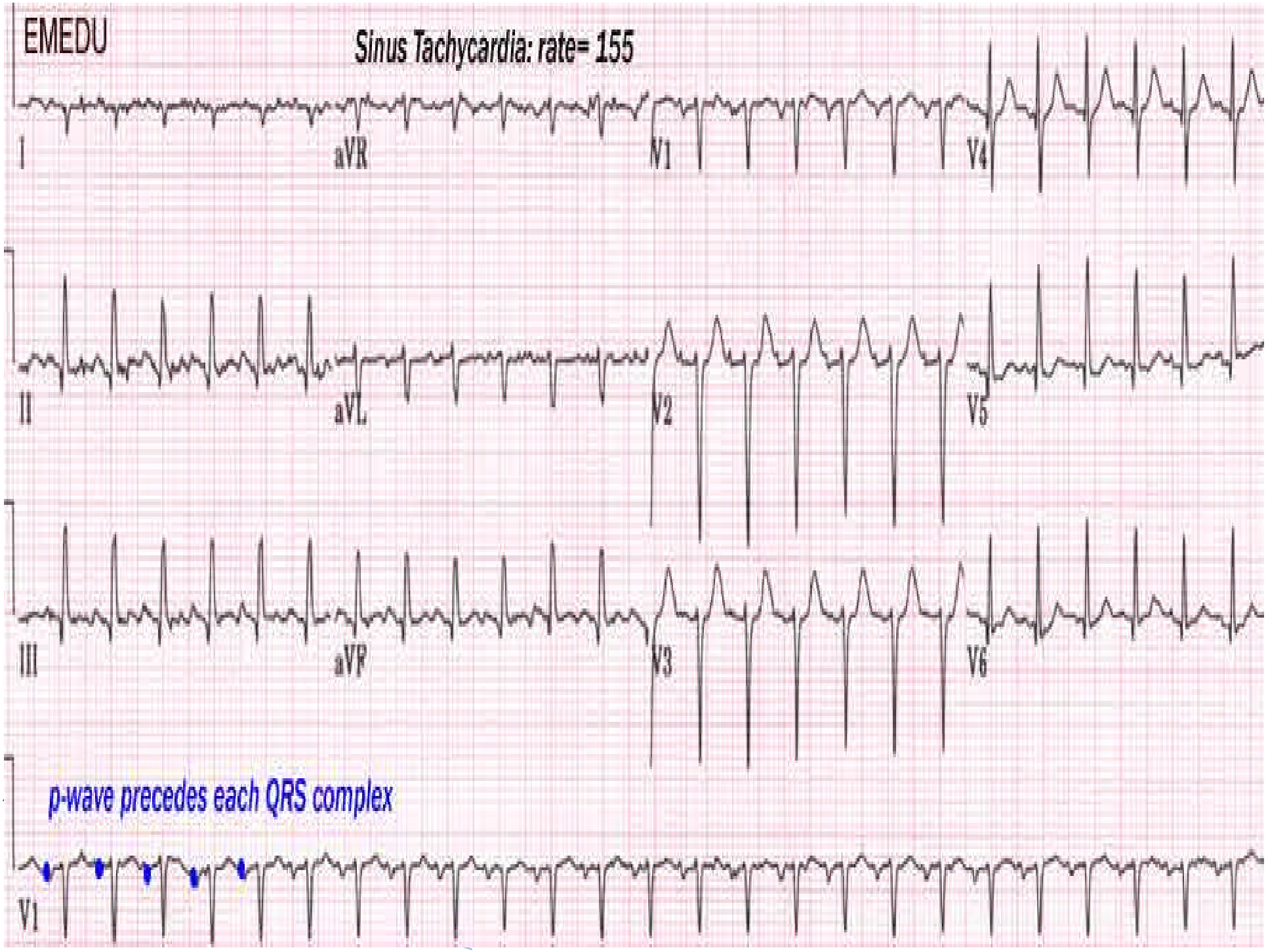
Sinus Arrhythmia

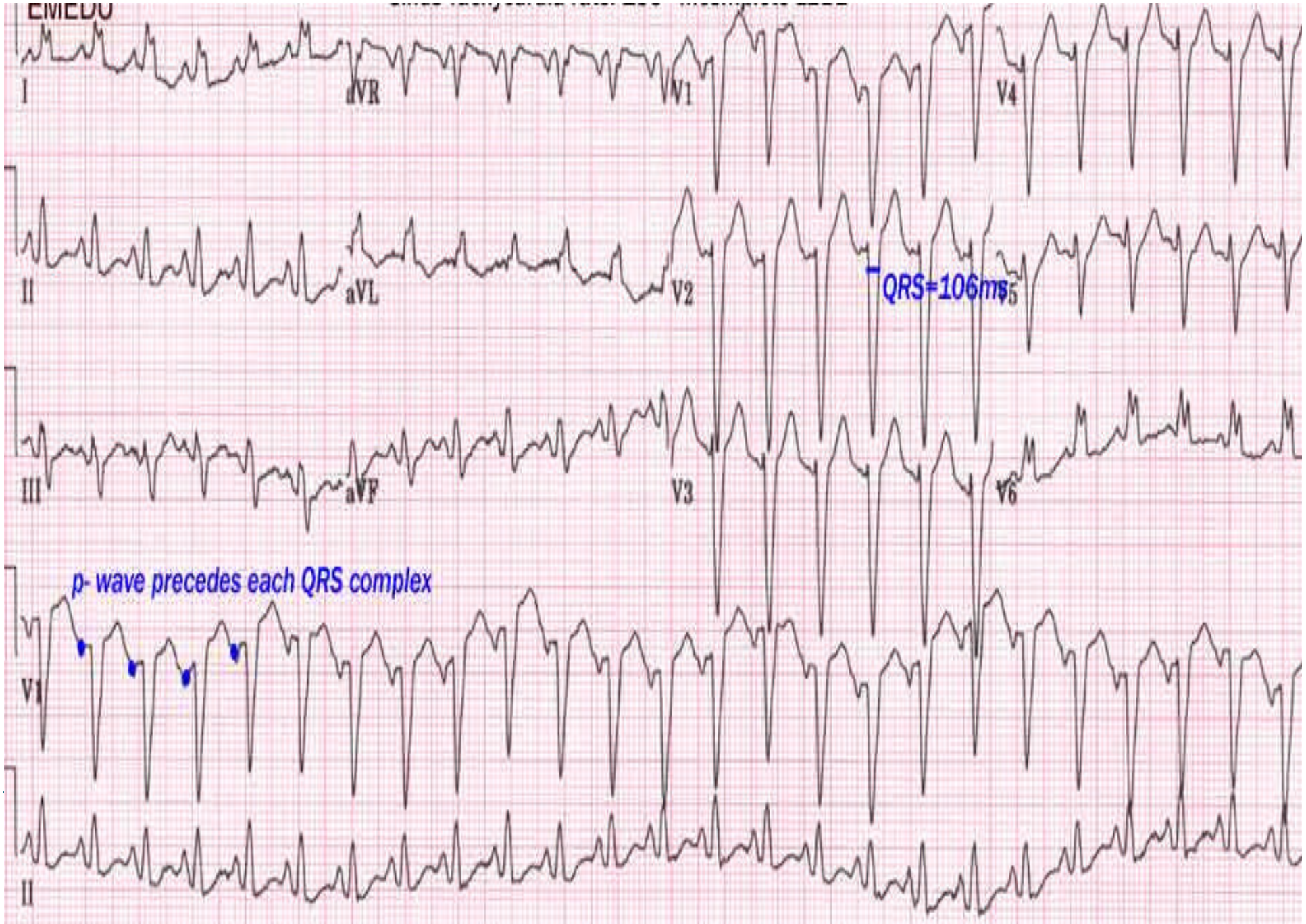
The pacemaker is an irritable focus within the ATRIUM that fires prematurely and produces a single ectopic beat. Conduction through to the ventricles is normal.

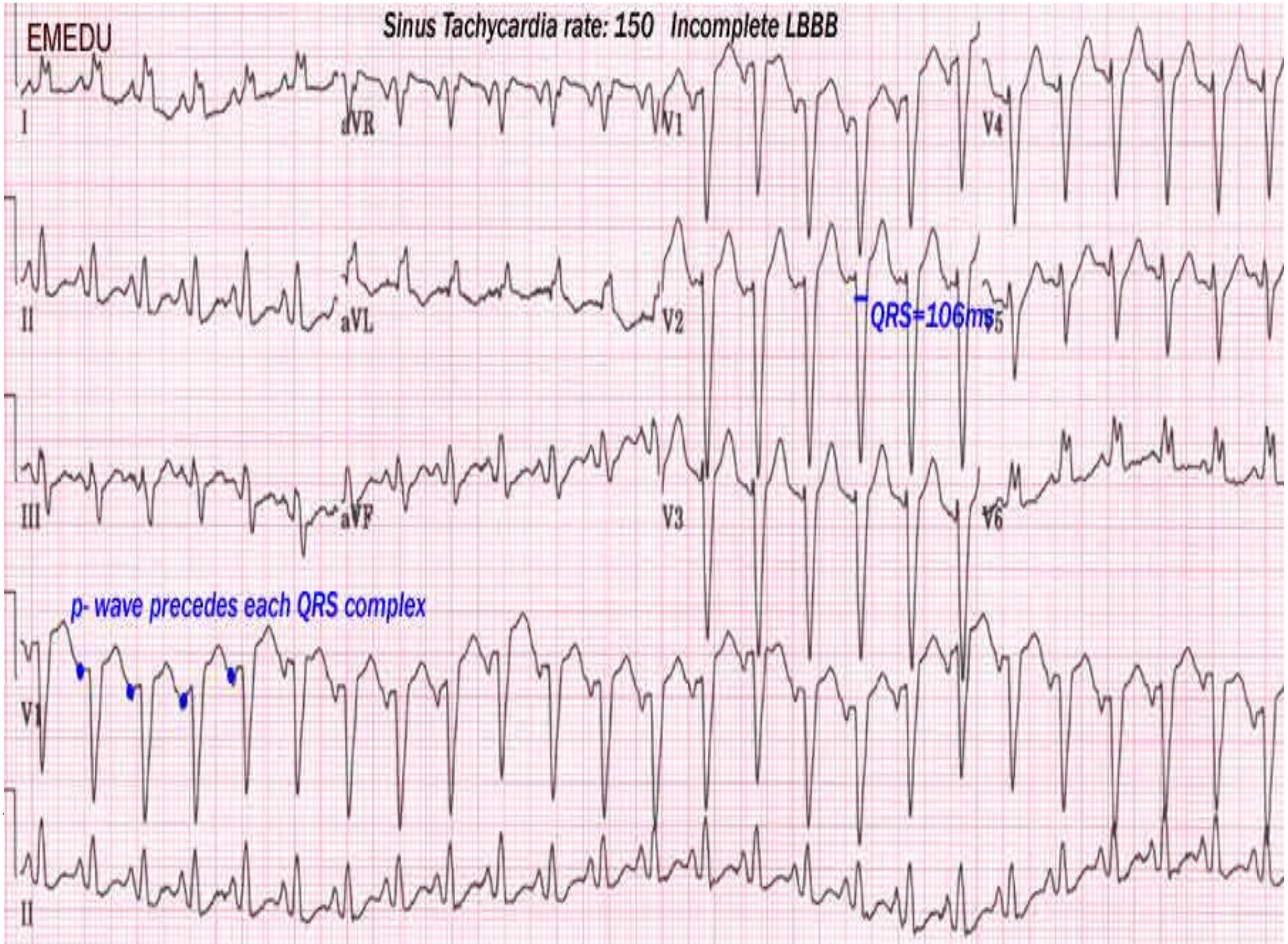
Premature atrial contraction acronym is PAC; sort of a misnomer as this is a premature atrial depolarization.
Some also call this a premature atrial beat (PAB), but again electrical depolarization does not always mean mechanical contraction.
Here there is a focus other than the SA node that is firing, 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

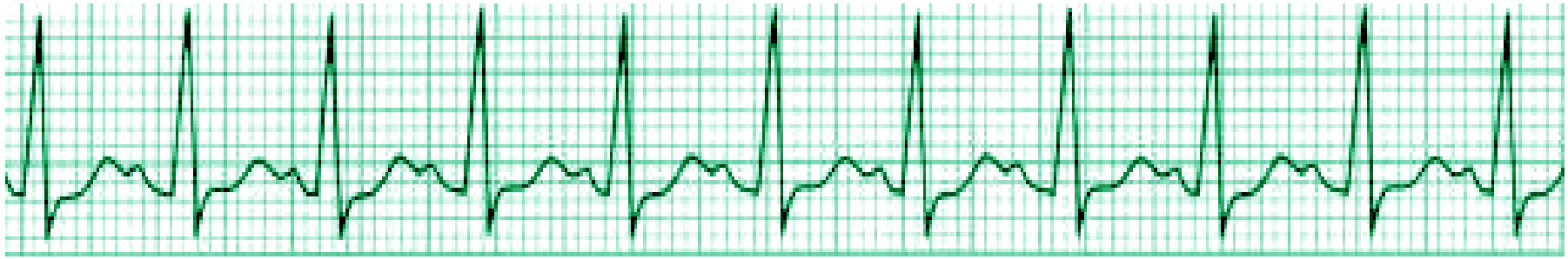

I
aVR
V1
V4
II
aVL
V2
QRS=106ms
V5
III
aVF
V3
V6
p- wave precedes each QRS complex
V1
II


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?

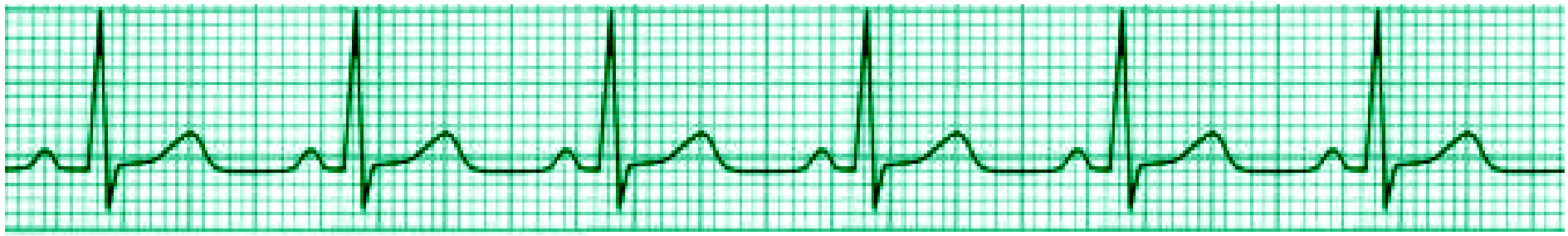
a

b

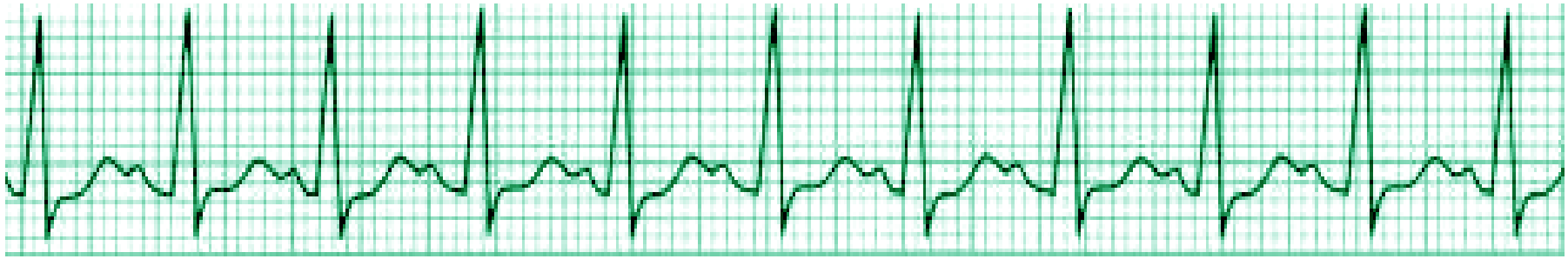


A: normal
B: sinus tachycardia

a



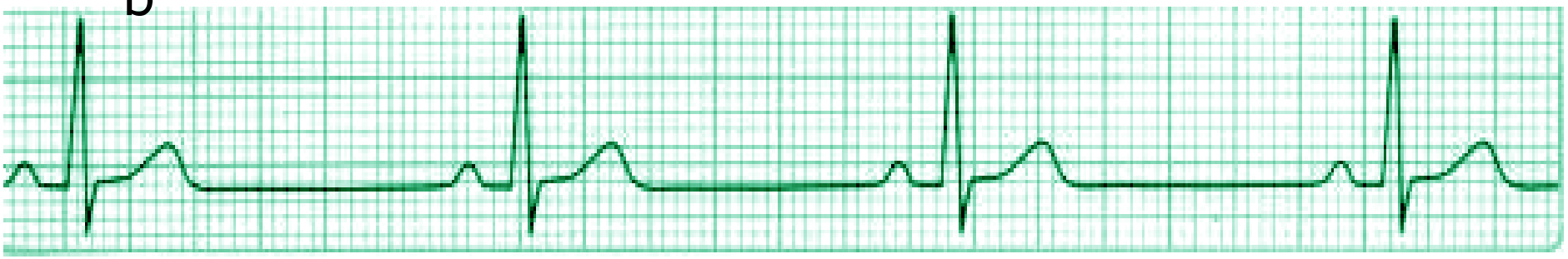
b



What do you think?

a

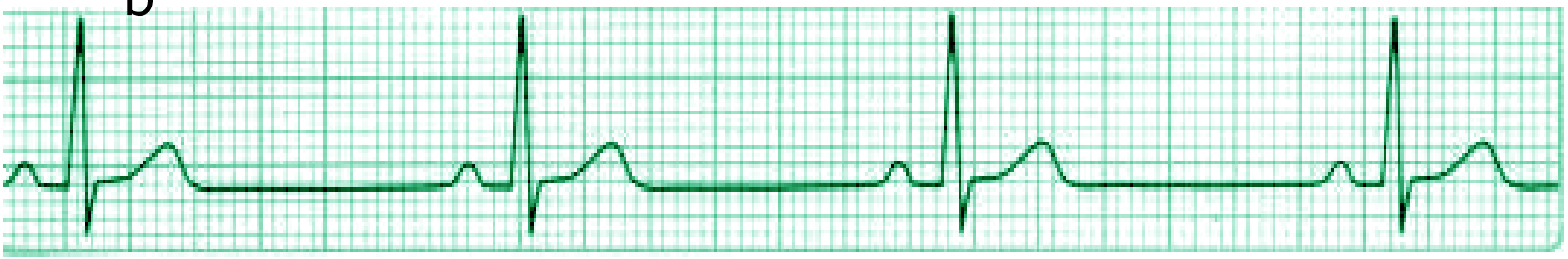
b

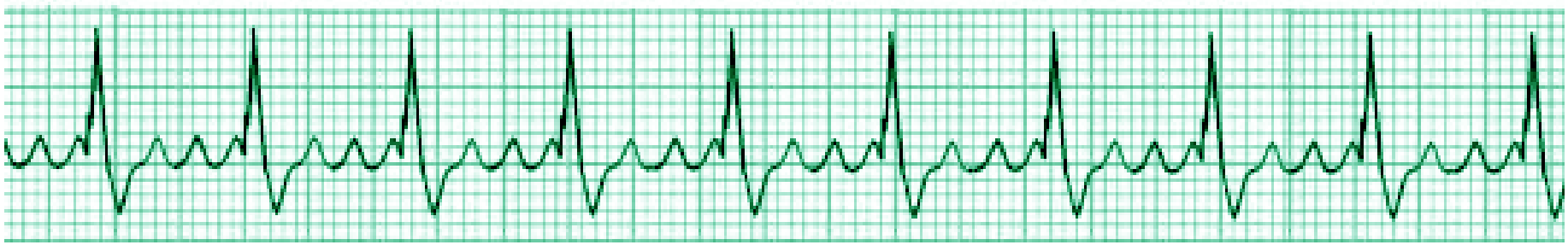


A: normal

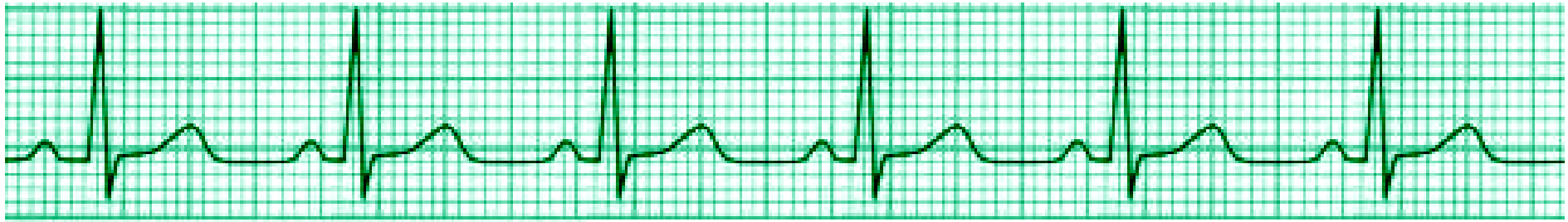
a B:sinus bradycardia

b

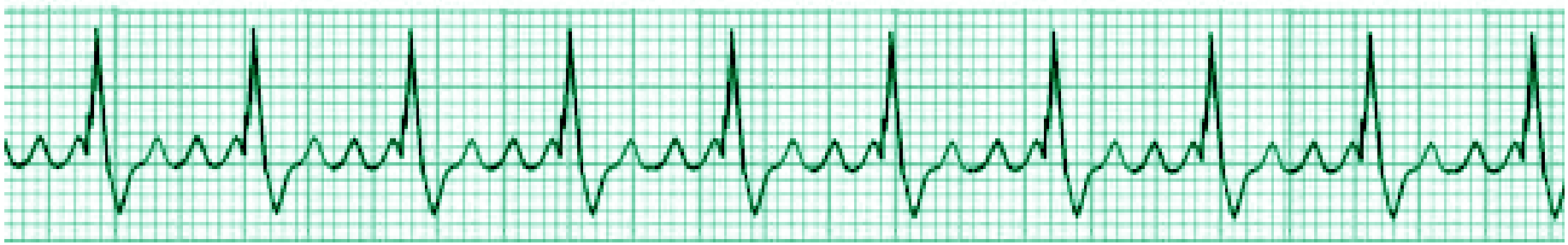


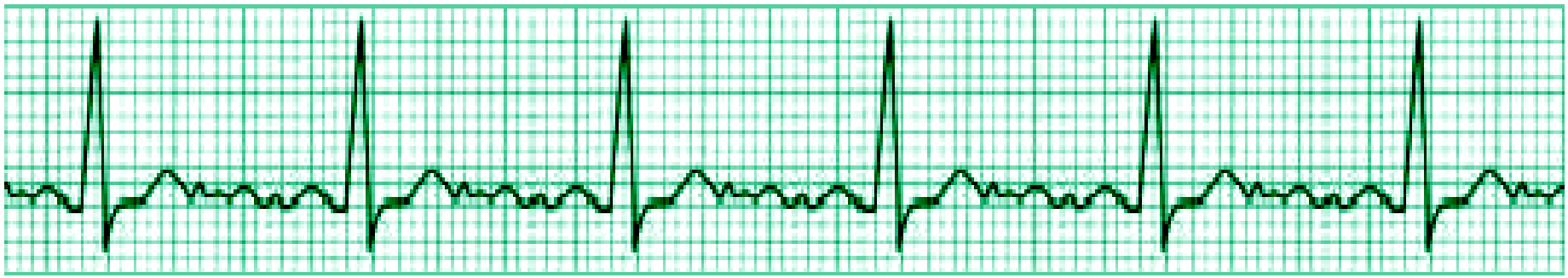


Normal

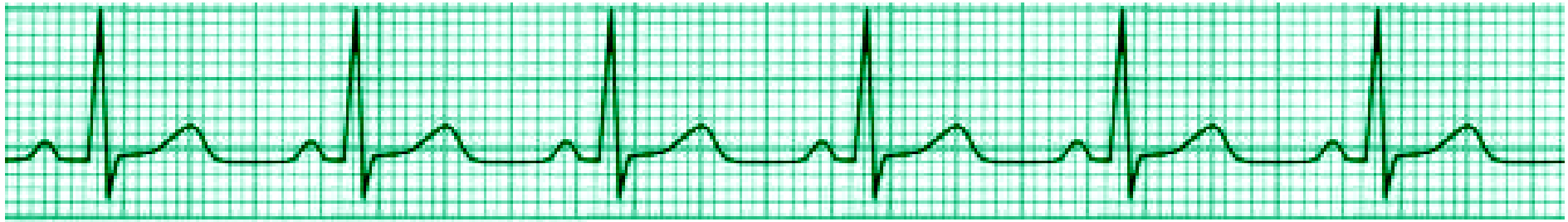


Atrial Flutter

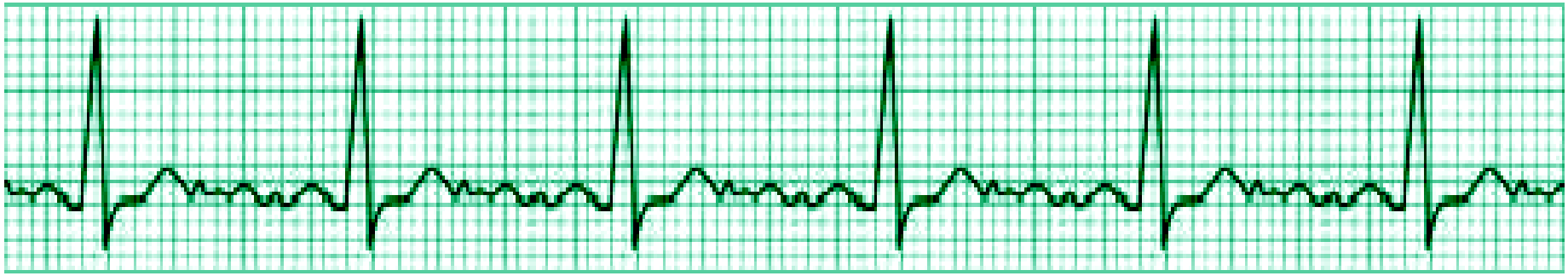


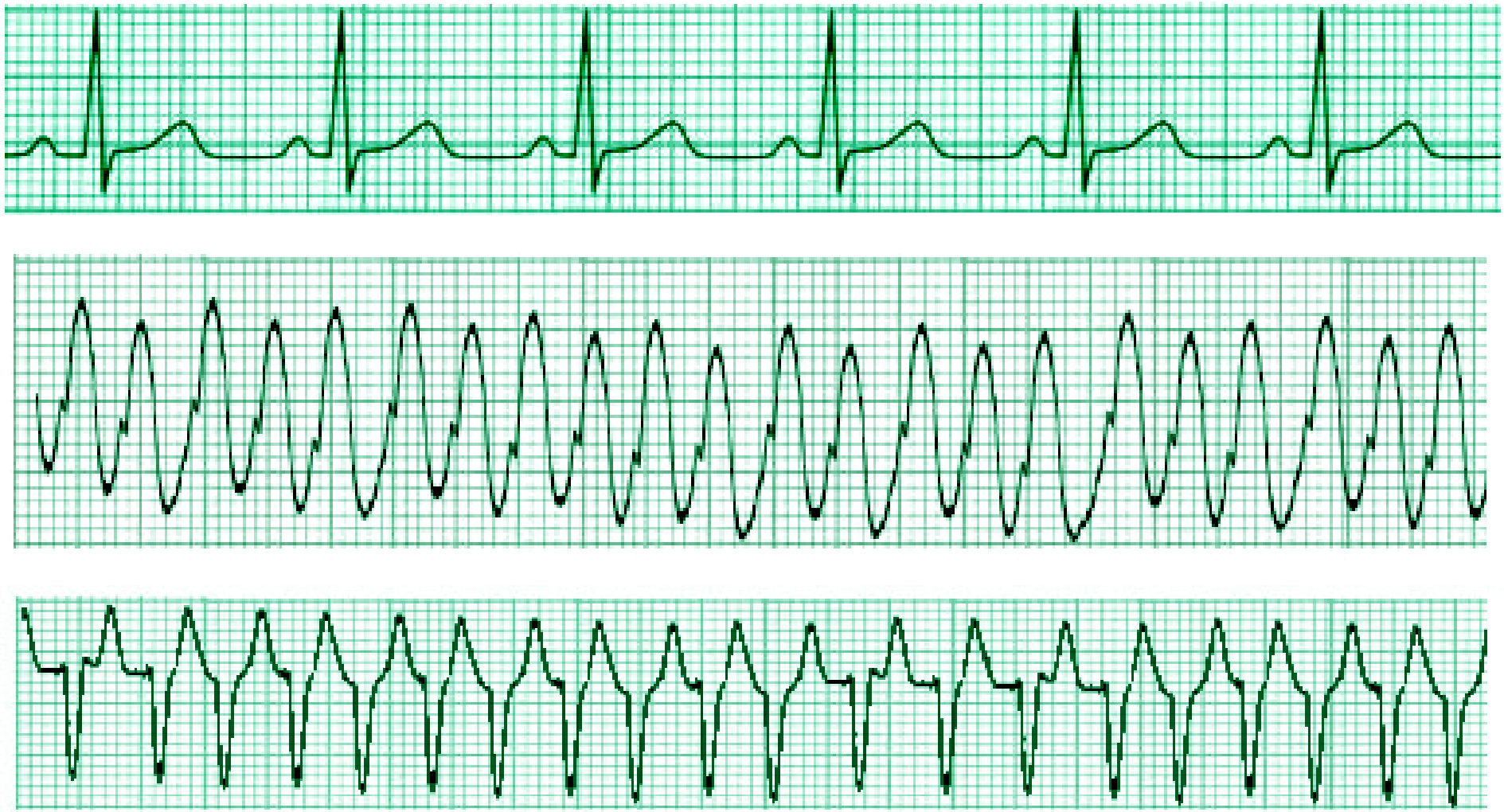


Normal

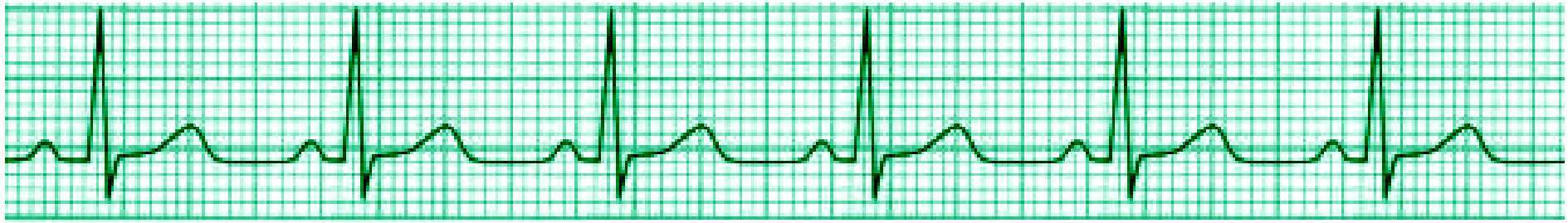


Atrial Fibrillation

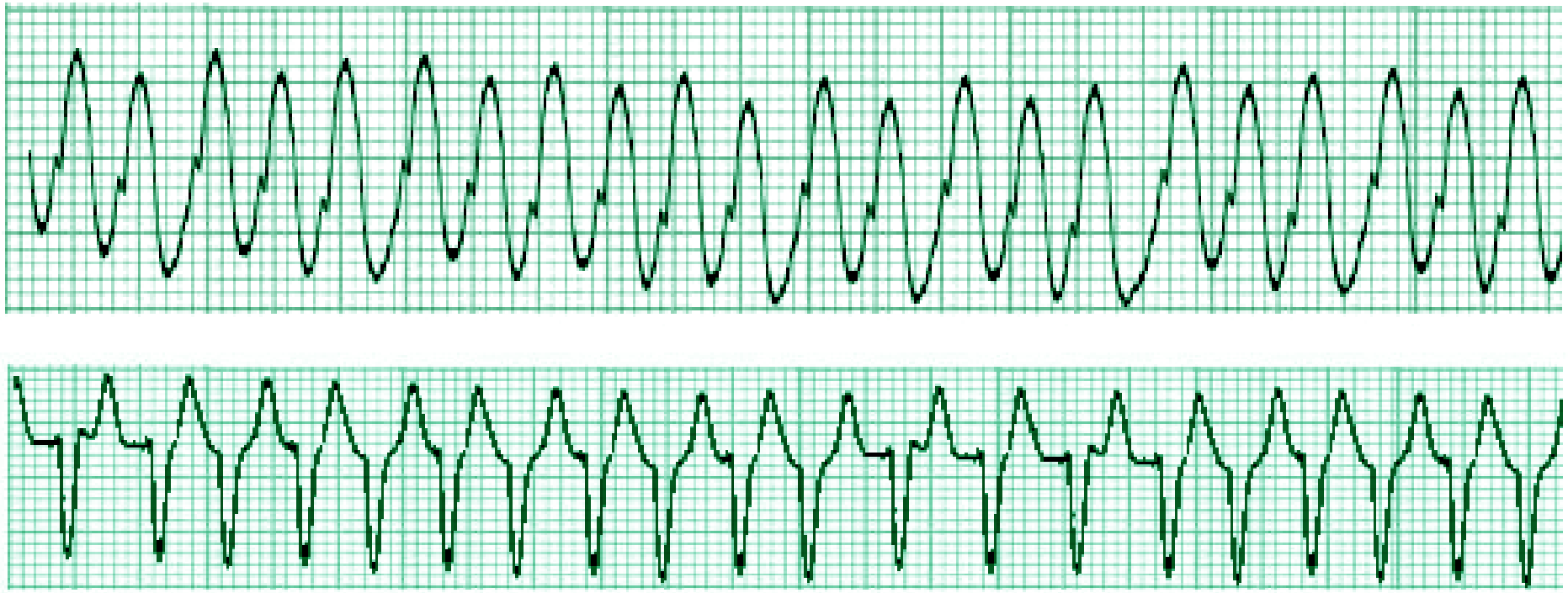


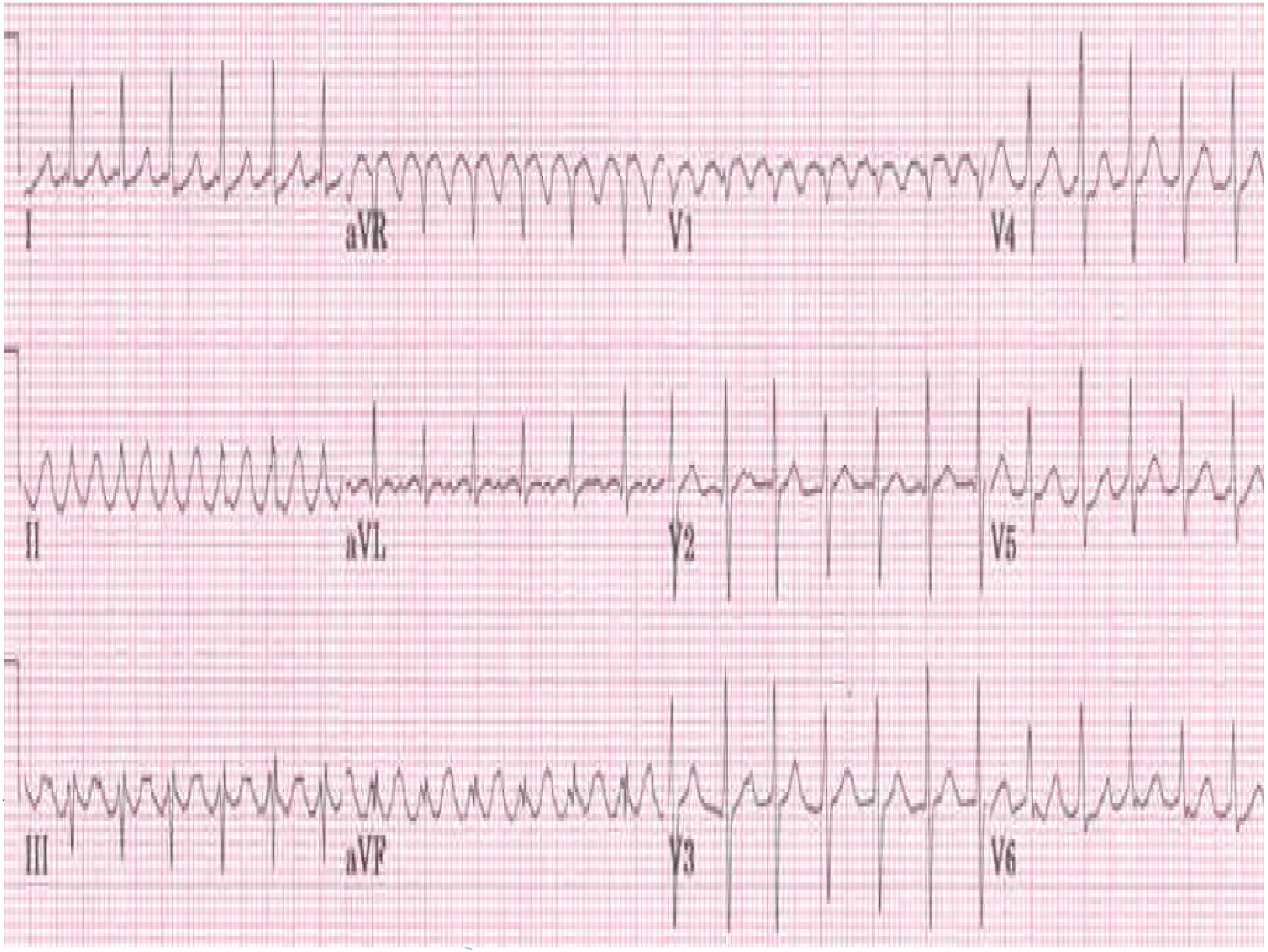


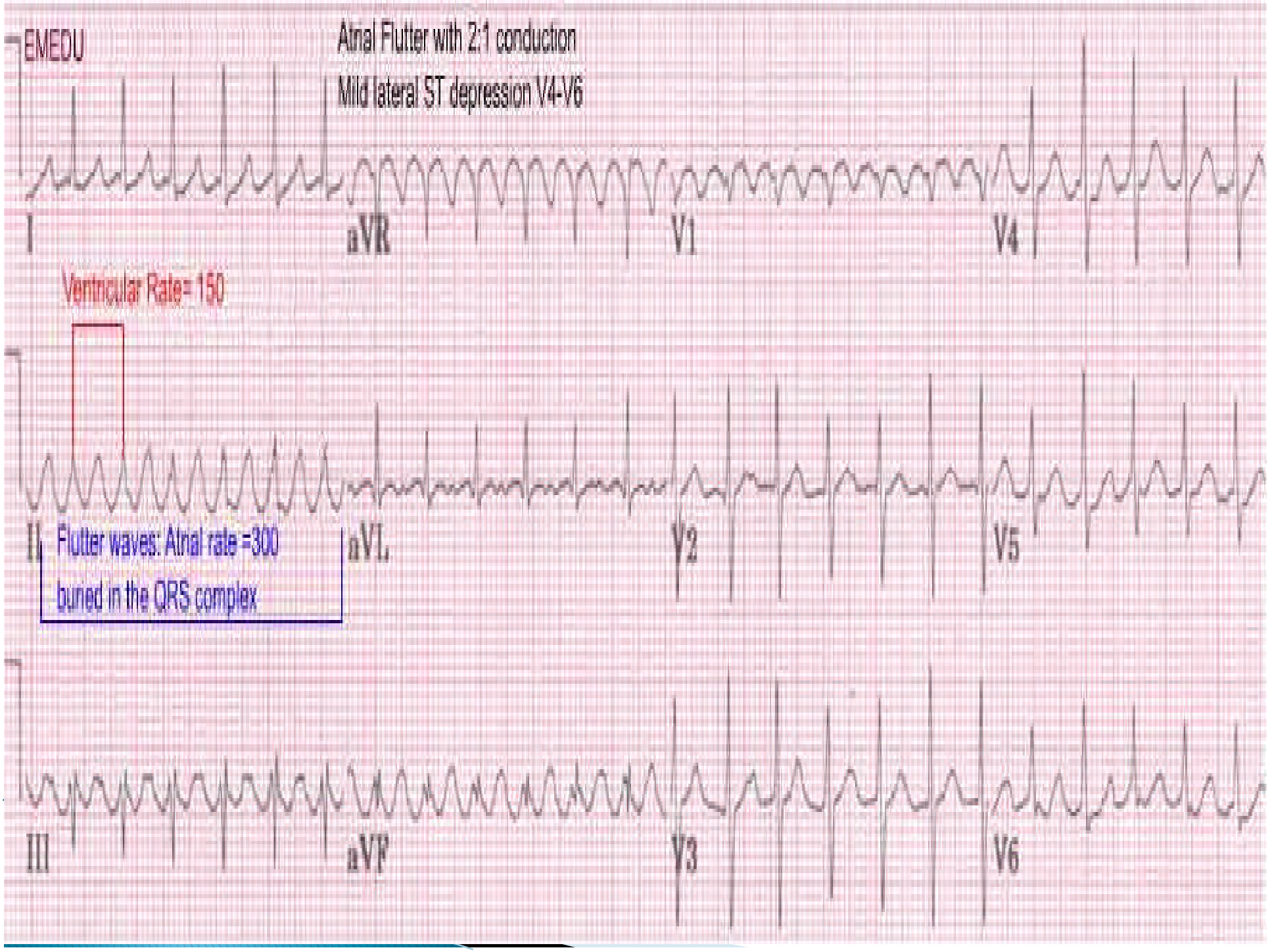
Normal

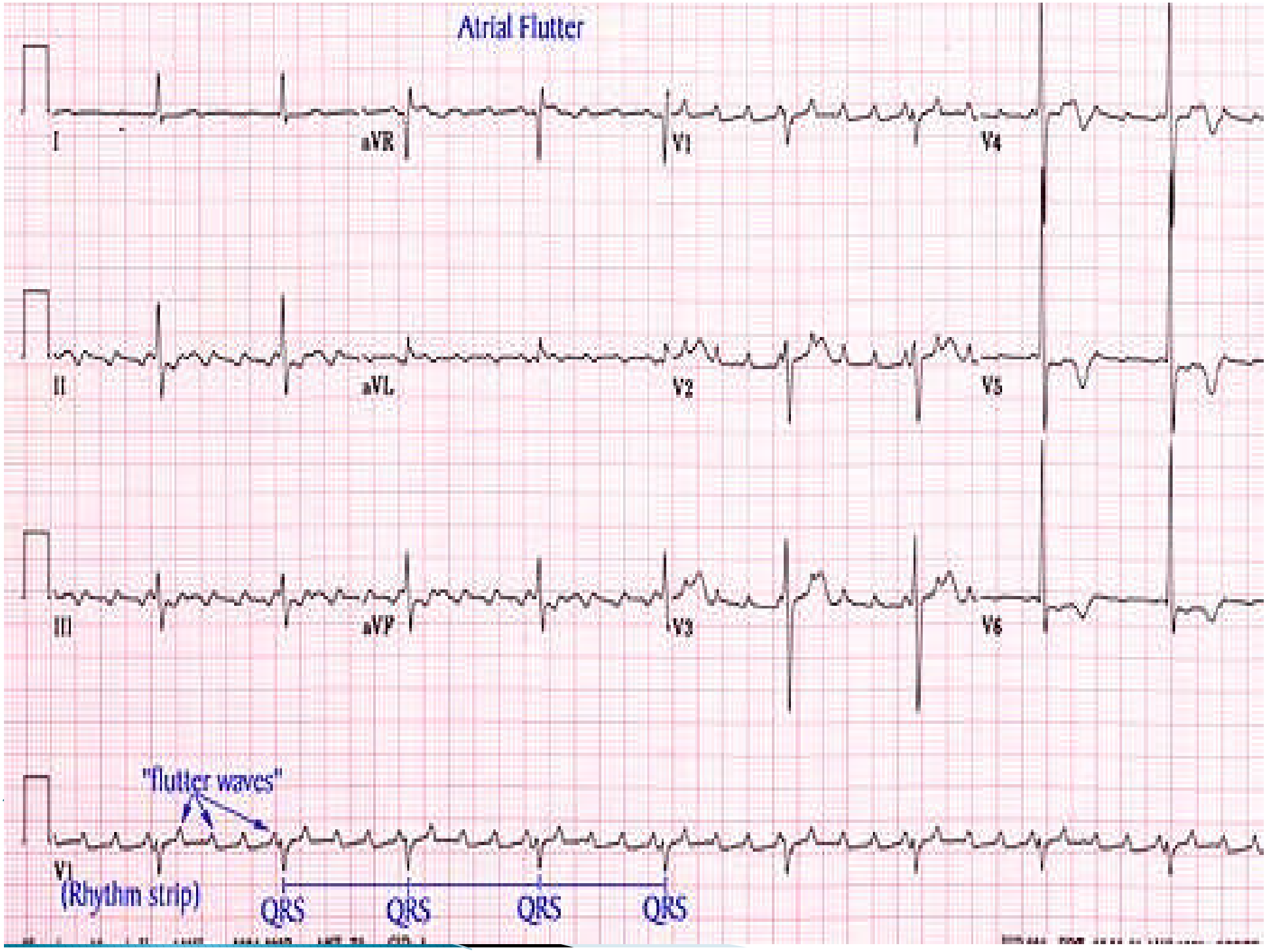


Ventricular Tachycardia (VT)




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
I
aVR
V1
V4
Ventricular Rate= 150
II
Flutter waves: Atrial rate =300
buried in the QRS complex
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

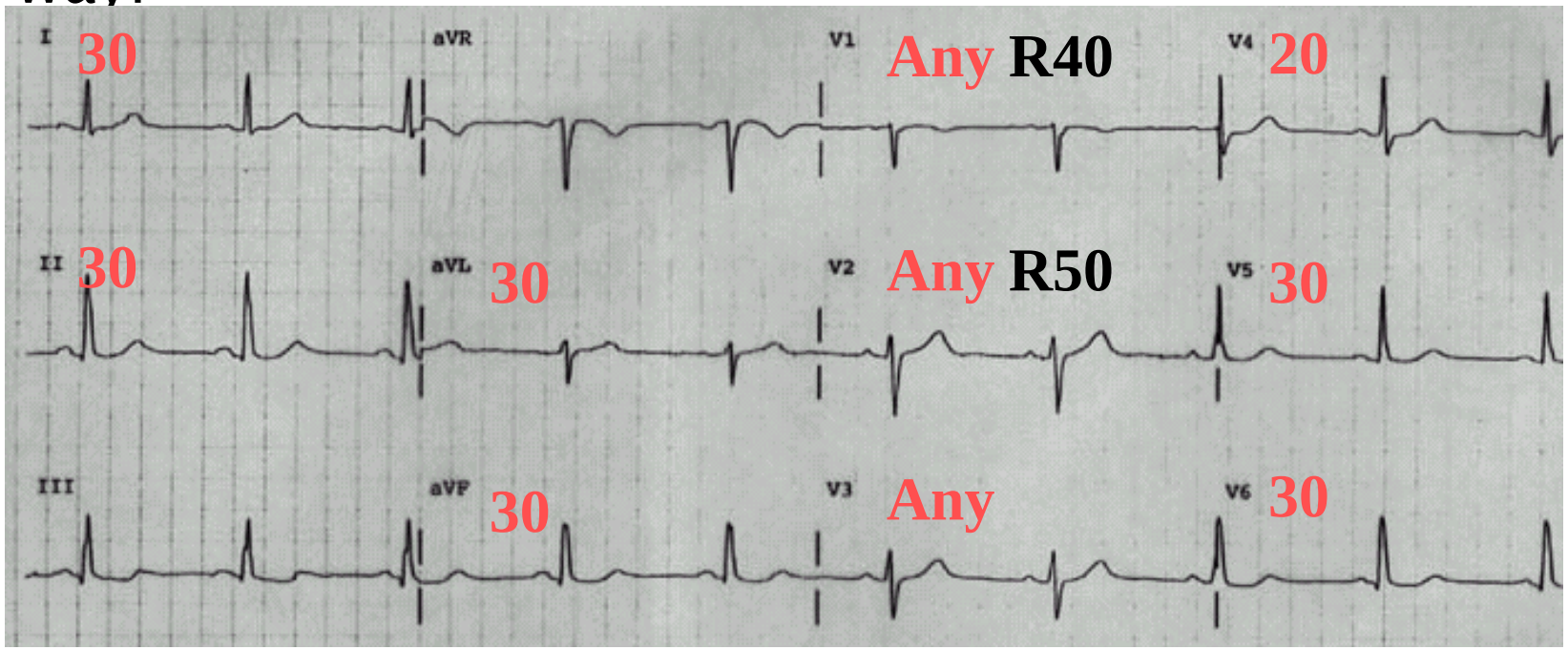
Rate Rhythm Axis Intervals Hypertrophy Infarct

Tip: One way to determine if Q waves (and R waves) are abnormal is by looking at the width and using the following mantra (read red downwards):

Any	Any Q wave in V1	
Any	Any Q wave in V2	
Any	Any Q wave in V3	
20	A Q wave $\geq$ 20 msec in V4	(i.e. 0.02 sec or ½ width of a box)
30	A Q wave $\geq$ 30 msec in V5	
30	A Q wave $\geq$ 30 msec in V6	
30	A Q wave $\geq$ 30 msec in I	
30	A Q wave $\geq$ 30 msec in avL	
30	A Q wave $\geq$ 30 msec in II	
30	A Q wave $\geq$ 30 msec in avF	
R40	A R wave $\geq$ 40 msec in V1	
R50	A R wave $\geq$ 50 msec in V2	

Rate Rhythm Axis Intervals Hypertrophy Infarct

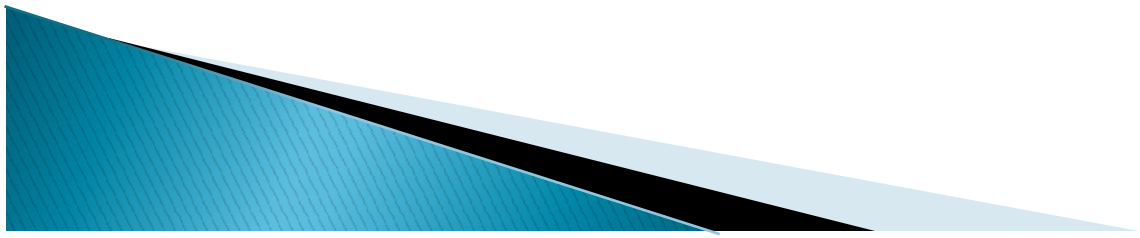
This mantra corresponds to the ECG in the following way:

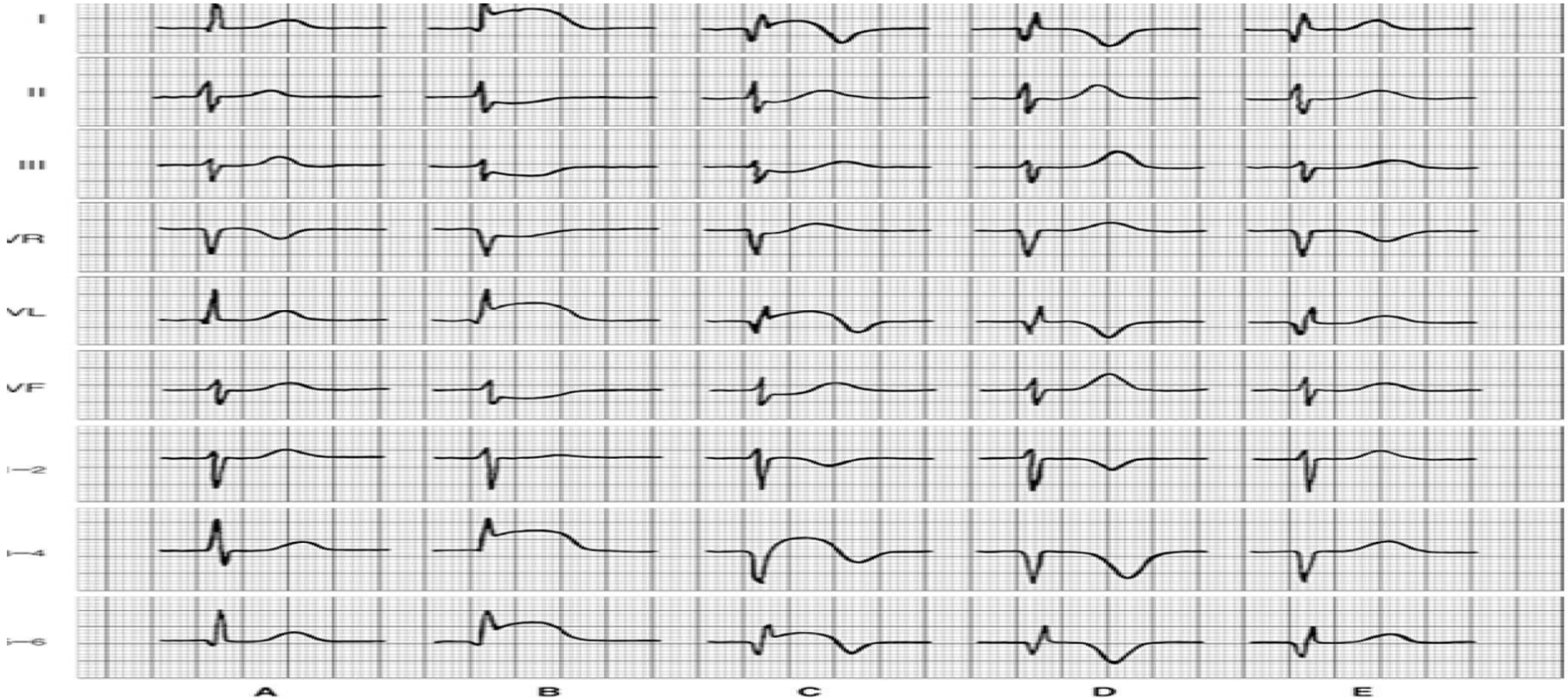


SUMMARY Rate Rhythm Axis Intervals Hypertrophy Infarct

To summarize:

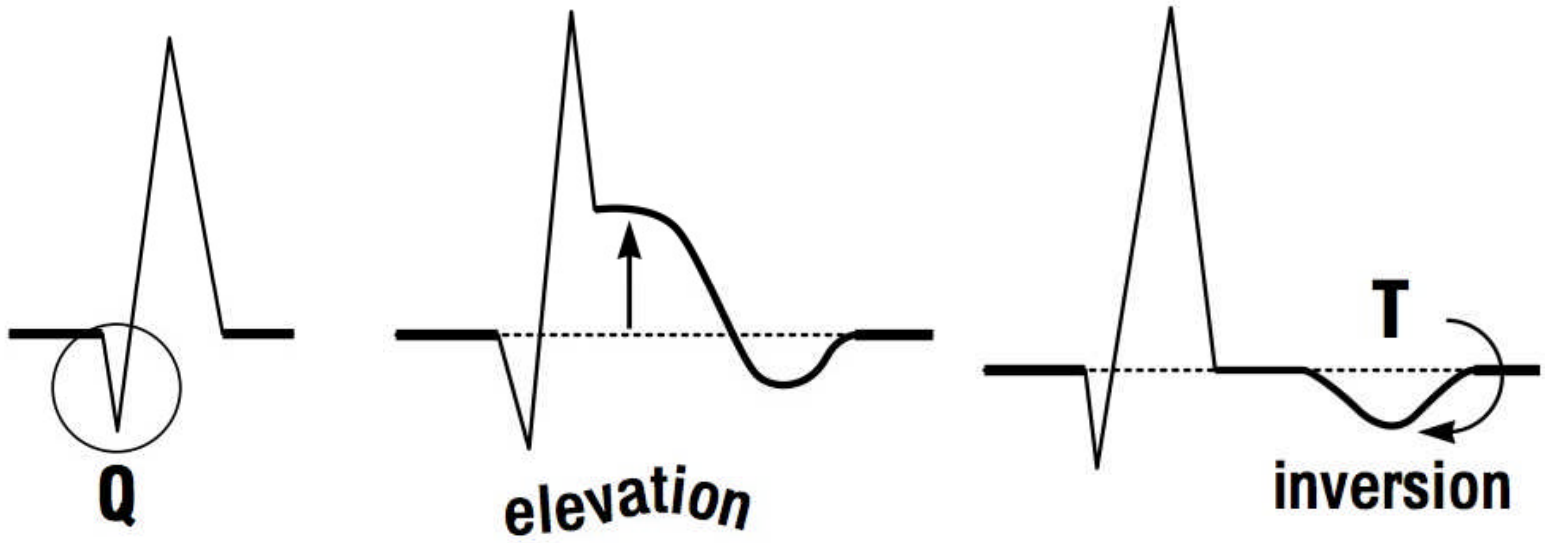
1. Calculate RATE
2. Determine RHYTHM
3. Determine QRS AXIS
   -
   -
   -
   -





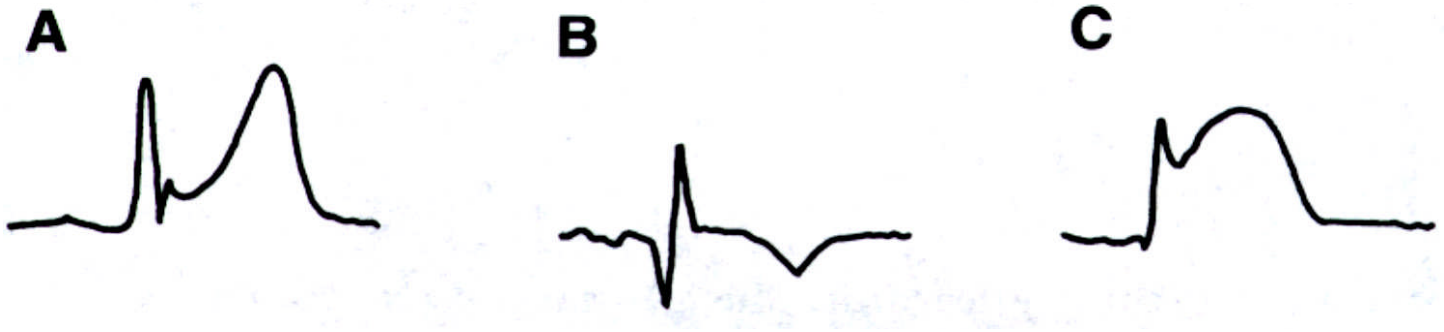
A: Normal tracing. **B:** Very early pattern (hours after infarction): ST segment elevation in I, aVL, and V_{3-6}; reciprocal ST depression in II, III, and aVF. **C:** Later pattern (many hours to a few days): Q waves have appeared in I, aVL, and V_{5-6}. QS complexes are present in V_{3-4}. This indicates that the major transmural infarction is underlying the area recorded by V_{3-4}; ST segment changes persist but are of lesser degree, and the T waves are beginning to invert in the leads in which the ST segments are elevated. **D:** Late established pattern (many days to weeks): The Q waves and QS complexes persist, the ST segments are isoelectric, and the T waves are symmetric and deeply inverted in leads that had ST elevation and tall in leads that had ST depression. This pattern may persist for the remainder of the patient's life. **E:** Very late pattern: This may occur many months to years after the infarction. The abnormal Q waves and QS complexes persist. The T waves have gradually returned to normal. (Reproduced, with permission, from Goldschlager N, Goldman MJ: *Principles of Clinical Electrocardiography,* 13th ed. Originally published by Appleton & Lange. Copyright © 1989 by The McGraw-Hill Companies, Inc.)

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

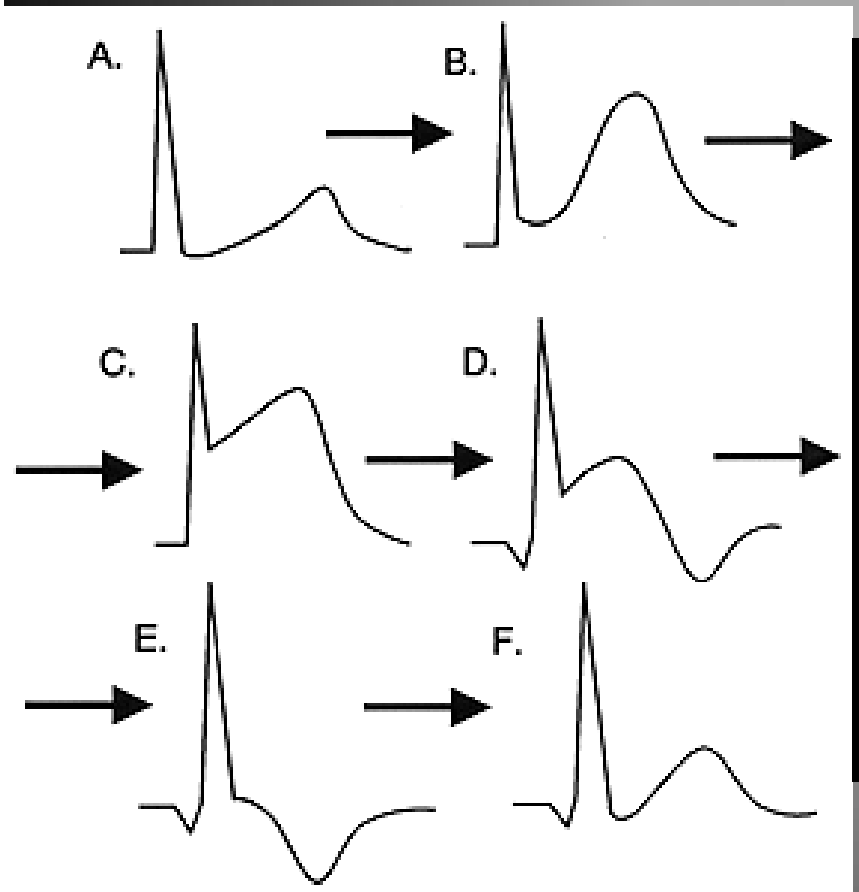


Myocardial Infarction

	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



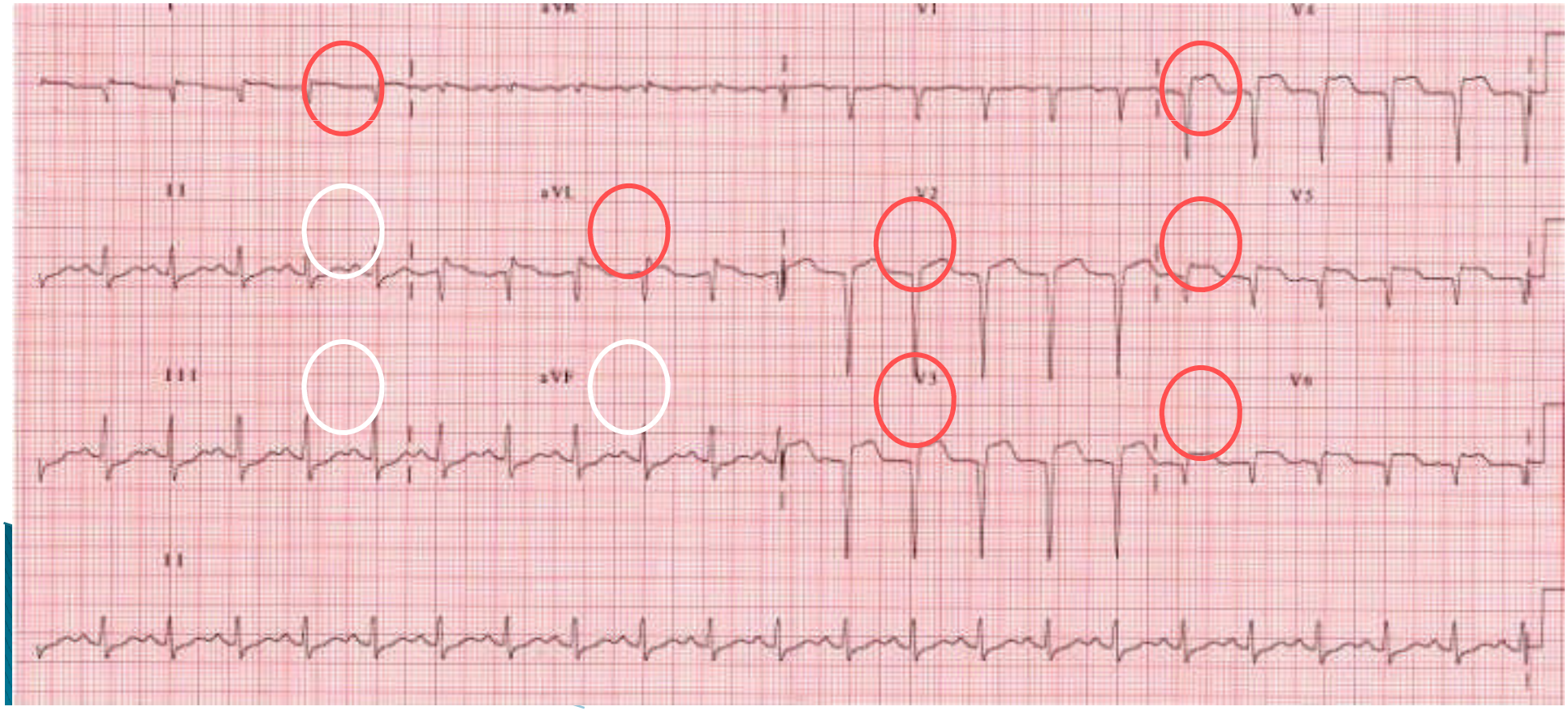
Evolution of Acute MI

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.



- ELEVATION
  - Electrolytes
  - Left bundle branch block
  - Early repolarization
  - Ventricular hypertrophy
  - Aneurysm
  - Treatment (pericardiocentesis)
  - Injury (acute MI, contusion)
  - Osborne waves (hypothermia)
  - Nonocclusive vasospasm

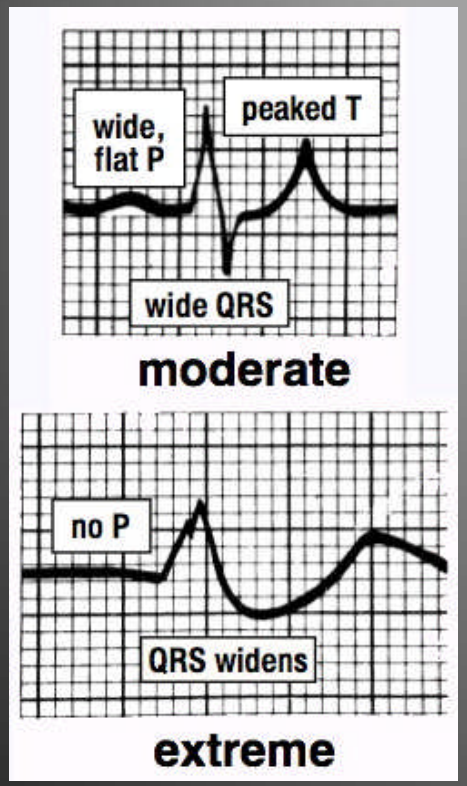
ST Segment Elevation

- 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

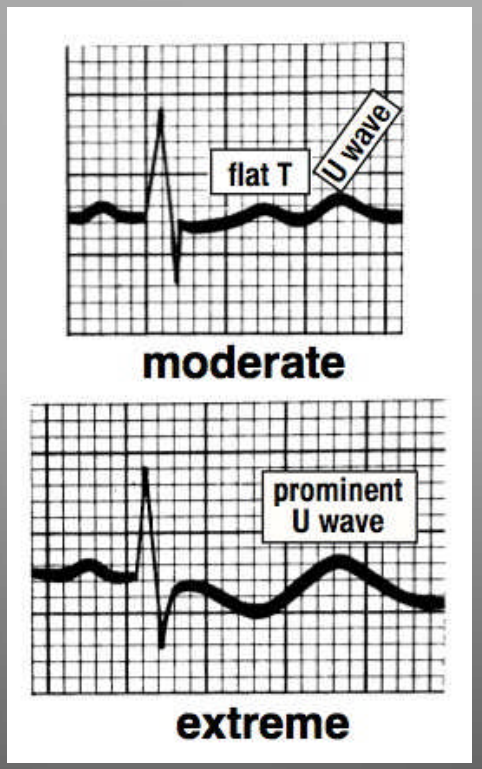
ST Segment Depression

Electrolytes & Drugs

- Hyperkalemia
  - High K+
  - Peaked T

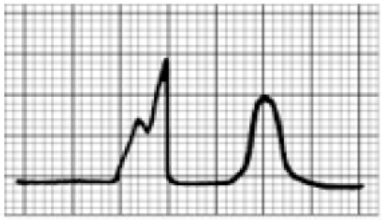


- Hypokalemia
  - Low K+
  - Flat T, U Wave

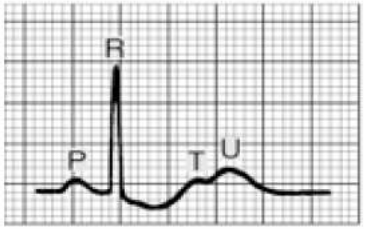


Normal tracing (plasma K^+ 4–5.5 meq/L). PR interval = 0.16 s; QRS interval = 0.06 s; QT interval = 0.4 s (normal for an assumed heart rate of 60).

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.

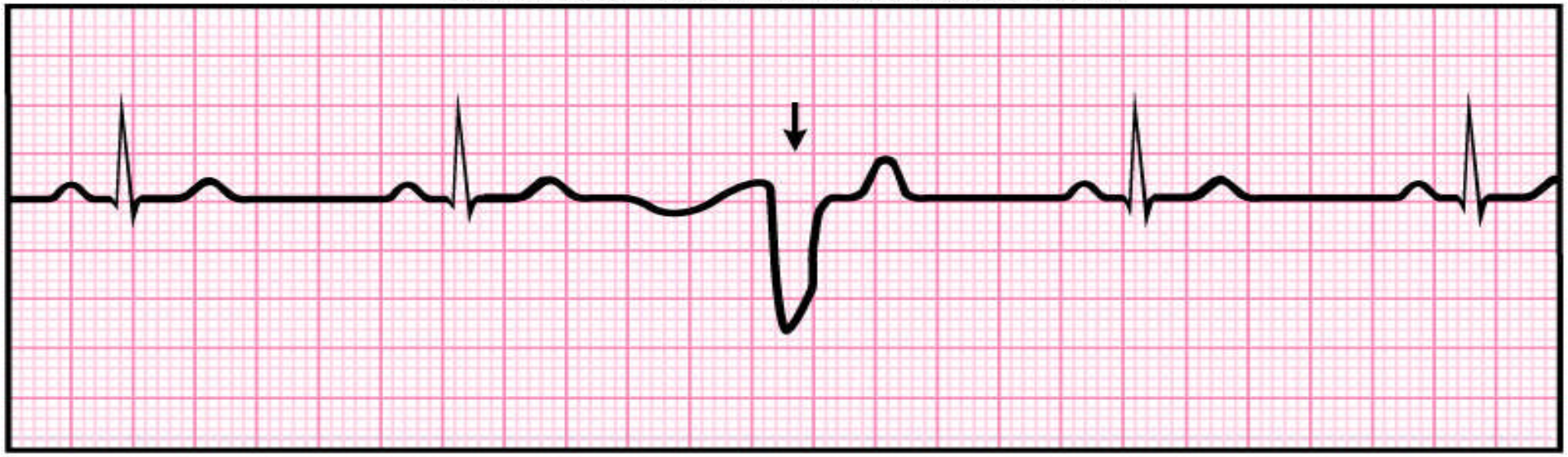
Figure 28-20. Correlation of plasma K^+ level and the ECG, assuming that the plasma Ca^{2+} level is normal. The diagrammed complexes are left ventricular epicardial leads. (Reproduced, with permission, from Goldman MJ: *Principles of Clinical Electrocardiography,* 12th ed. Originally published by Appleton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

ECGs, Normal and Abnormal

(a) Sinus rhythm (normal)

(b) Nodal rhythm — no SA node activity

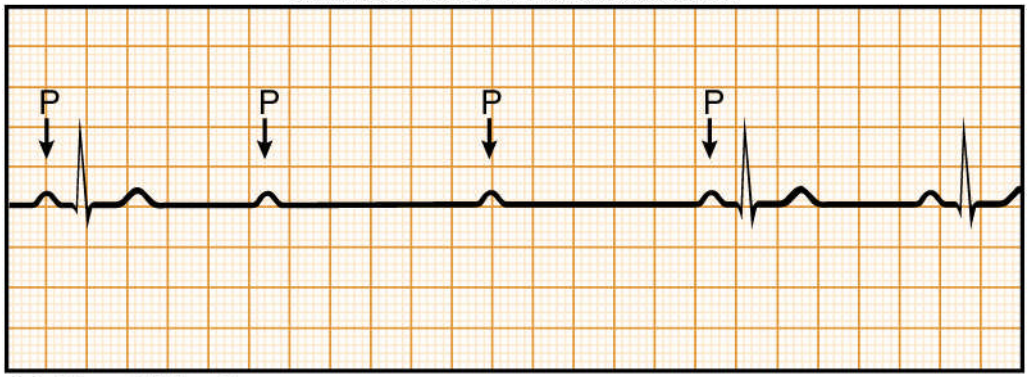
ECGs, Abnormal



(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