MEDICAL EDUCATION SYSTEMS

Primer on Basic Concepts of ECG

Medical Education Systems Inc.

TOLL FREE 1-877-295-4719
FAX (619) 295-5267
EMAIL: Info@mededsys.com
www.mededsys.com
P.O Box 81831 San Diego, CA 92138-3939

Primer on Basic Concepts of ECG

Table of Contents

Introduction to ECG Interpretation

Electrocardiogram interpretation is an invaluable clinical skill that is taught in many different ways at across the country. It is often informal and clinicians are expected to "pick it up" as they see patients on the wards and in clinics. There are many "courses" which can be purchased off the shelves at the bookstore -some of them too simplistic and others hopelessly detailed. In an effort to better meet the needs of ECG interpretation this course serves as a self study manual.

Differential diagnosis is emphasized to encourage thinking about the "art" of interpretation, not just a cookbook mechanistic approach. It is our sincere hope that you find this course worthwhile and a skill you will continue to use throughout your careers in medicine.

Learning Objectives

Upon successful completion of this course, you should be able to:

1. Identify and define key terms associated with ECG
2. Differentiate between “rate” and “rhythm”
3. List and discuss the criteria for “hypertrophy”
4. Explain how to identify an “infarct” on and ECG tracing

Electrocardiograms

The following is a brief introduction to electrocardiograms and their interpretation:

1. P wave = depolarization of the atria.
   QRS = depolarization of the ventricle.
   T wave = repolarization of the ventricle.

Figure 1: Description of the waves on the ECG.

2. Cardiac muscle cells depolarize with a positive wave of depolarization, then repolarize to a negative charge intracellularly.
3. Skin "leads" or electrodes have a positive and negative end.
4. A positive wave form (QRS mainly above the baseline) results from the wave of depolarization moving towards the positive end of the lead. 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).
5. ECG paper has 1 millimeter small squares - so height and depth of wave is measured in millimeters.

   10 mm = 1.0 m Volt
6. Horizontal axis is time.
   .04 seconds for 1 mm (1 small box).
   .2 seconds for 1 large box = 5 small boxes = 5 x .04 seconds.

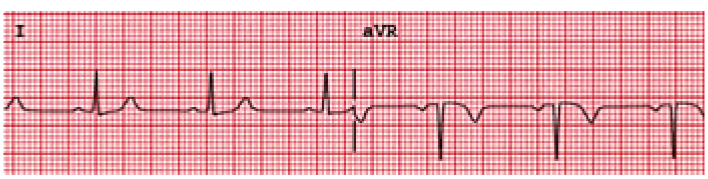
   

   Figure 2:
   Positive QRS in Lead I.
   Negative QRS in Lead aVR.
   R wave = 7-8 mm high in Lead I.
   QRS wave = .06 seconds long in Lead I.

7. Lead nomenclature.

Limb Leads	*Chest Leads*	*Rhythm Strip*
I, II, III	V1 - V6	Located on the bottom of the ECG printout. Selected

aVR, aVF, aVL		to give the best relationship of the P wave to the QRS.

8.

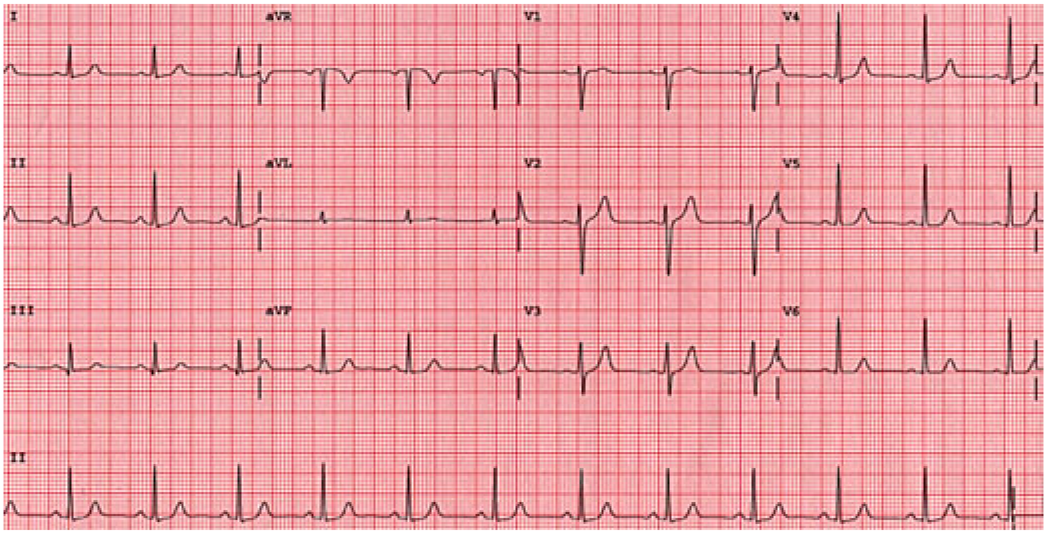
9. 

Figure 3: A normal ECG and rhythm strip.

10. ECG interpretation: look at five areas, in order, on each ECG.

Rate
Rhythm (Intervals)
Axis
Hypertrophy
Infarct

Rate

Rate is cycles or beats per minute.

Normal rate for the SA node 60-100.

<60 bradycardia	>100 tachycardia

SA node is the usual pacemaker, other potential pacemakers (if SA node fails) are atrial pacemakers with inherent rates of 60-80, AV node (rate 40-60), or ventricular pacer (rate 20-40). In certain pathologic conditions ectopic (out of place) pacemakers can go much faster at rates 150-250 cycles/minute. There are three methods of calculating rate:

1. *Most Common Method:*
   (Most rates can be calculated this way). Find an R wave on a heavy line (large box) count off "300, 150, 100, 75, 60, 50" for each large box you land on until you reach the next R wave. Estimate the rate if the second R wave doesn't fall on a heavy black line.

Rate calculation
Memorize the number sequence:
300, 150, 100, 75, 60, 50

2. 

   Figure 4: Common Method.
3. *Mathematical method:*
   Use this method if there is a regular bradycardia, i.e. - rate < 50. If the distance between the two R waves is too long to use the common method, use the approach: 300/[# large boxes between two R waves].

Figure 5: Count number of large boxes between first and second R waves=7.5. 300/7.5 large boxes = rate 40.

4. Six-second method:
   Count off 30 large boxes = 6 seconds (remember 1 large box = 0.2 seconds, so 30 large boxes = 6 seconds). Then, count the number of R-R intervals in six seconds and multiply by 10. This is the number of beats per minute. This is most useful if you have an irregular rhythm (like atrial fibrillation) when you want to know an average rate.

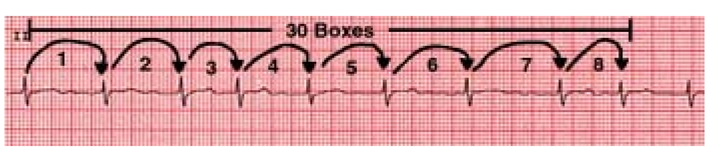


Figure 6: Count 30 large boxes, starting from the first R wave. There are 8 R-R intervals within 30 boxes. Multiply 8 x 10 = Rate 80.

Rhythm (to include intervals)

The basic "core" of rhythms and measured "intervals" (PR, QRS, QT). Rhythms are often the most challenging aspect of ECG's.

Now for some basics - "arrhythmia" means abnormal rhythm.

The normal conduction pathway is: SA node --> AV node --> Bundle of HIS --> Bundle Branches.

Arrhythmia can be understood by realizing the existence of ectopic (out of place) foci (pacemakers) and understanding the normal conduction pathway of the heart. Very simply put, if the beat originates in the *atria or AV node* (supraventricular) the *QRS is usually narrow* (normal), because it comes from above along the normal pathway.

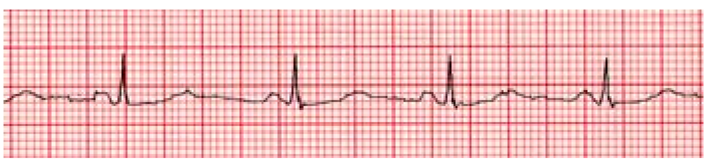


Figure 6a: QRS is narrow (normal).

If the beat is *ventricular in origin*, the *QRS is wide and bizarre* because it doesn't come down the normal pathway.

Figure 6b: QRS is wide.

Aberrancy is an exception to this rule - here it does actually follow the normal pathway (atria - AV node - ventricle) but for some reason the pathway is refractory to the beat and you get a wide QRS.

A reasonable way to group arrhythmias is in four general groups. Let us briefly review these four groups, then we will develop some common sense principles for evaluating rhythm (to include intervals).

Axis

Direction of depolarization (vector) of the QRS complex.

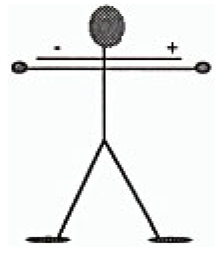
1. The left ventricle is thicker so the mean QRS vector is down and to the left. (The origin of the vector is the AV node with the left ventricle being down and to the left of this).
2. The vector will point toward hypertrophy (thickened wall) and away from the infarct (electrically dead area).

Figure 28: Axis nomenclature.

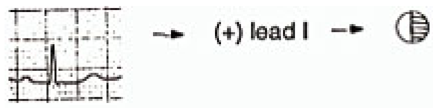
Normal axis	-30 to +90 degrees
Left axis deviation	-30 to -90 degrees
Right axis deviation	+90 to +/-180 degrees
Indeterminate (extreme) axis deviation	-90 to +/-180 degrees

Since lead I and aVF are perpendicular to each other, you can use those two leads to quickly determine axis.

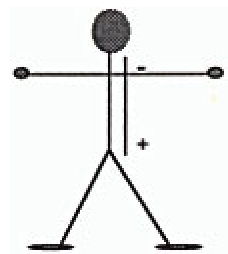
Lead I runs from right to left across a patient's body, positive at the left hand: (See figure 28).



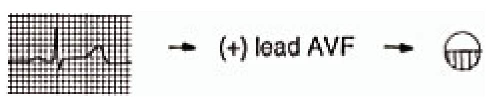
If the QRS in lead I is positive (mainly above the baseline), the direction of depolarization will be in the positive half (right half) of the circle above. You can make a diagram and shade in the positive half of the circle.



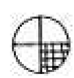
Lead aVF runs from top to bottom across a patient's body, positive at the feet:



If the QRS in lead aVF is positive (mainly above the baseline), the direction of depolarization will be in the positive half (lower half) of the circle above. You can make a diagram and shade in the positive half of the circle:



To find the axis overlap the two circles. The common shaded area is the quadrant in which the axis lies. In this example, the axis lies in the normal quadrant, which on a patient, points down and to the left.



You can repeat this process for any two leads, but I and aVF are the classic places to look. If you realize that there are two leads to consider and a positive (+) or (-) orientation for each lead, there would be four possible combinations. Memorize the following axis guidelines.

	Lead I	Lead aVF
1. Normal axis (0 to +90 degrees)	Positive	Positive
2. Left axis deviation (-30 to -90) Also check lead II. To be true left axis deviation, it should also be down in lead II. If the QRS is upright in II, the axis is still normal (0 to -30).	Positive	Negative
3. Right axis deviation (+90 to +180)	Negative	Positive
4. Indeterminate axis (-90 to -180)	Negative	Negative

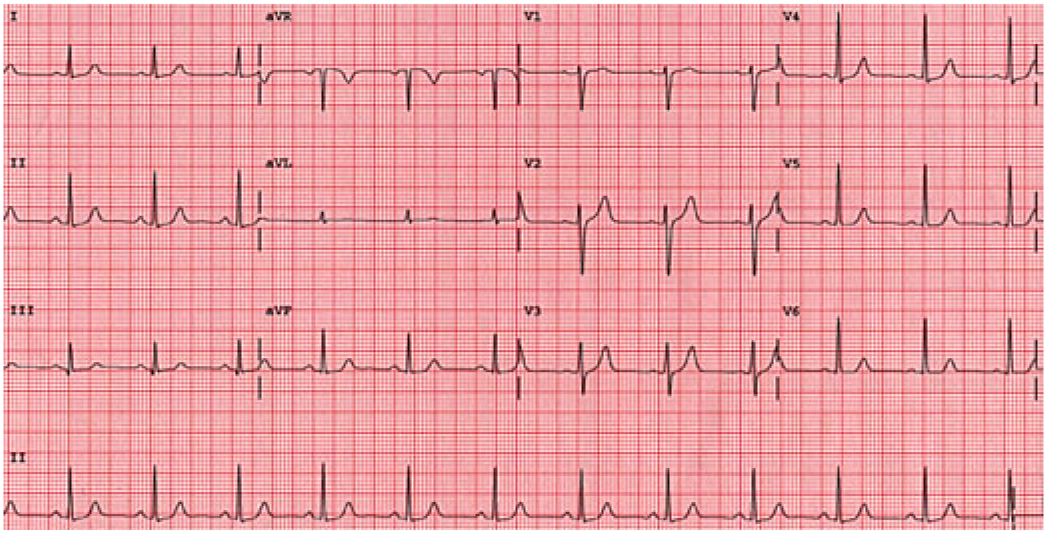


Figure 29: Normal axis.

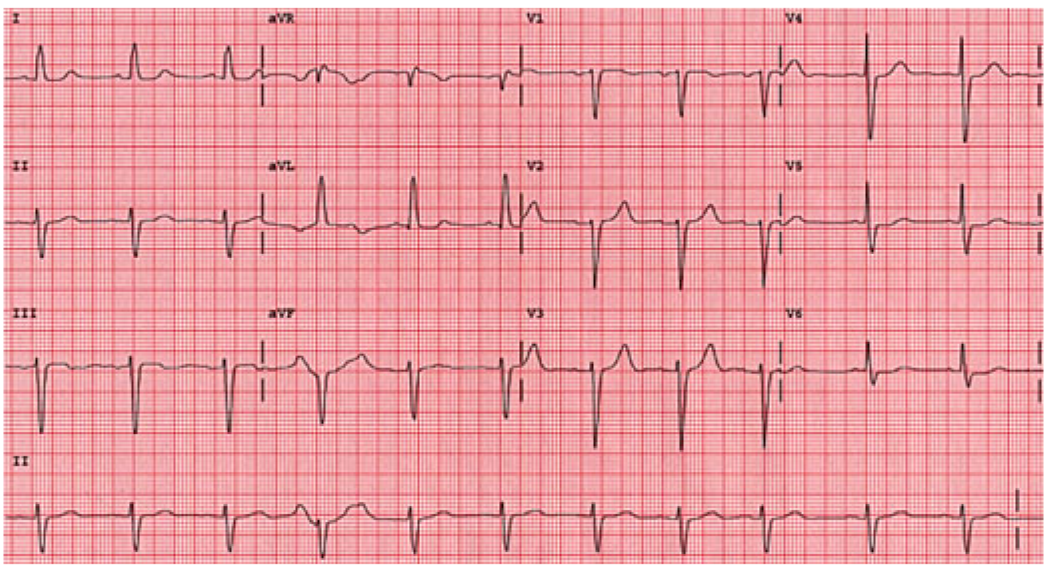


Figure 30: Left axis deviation.

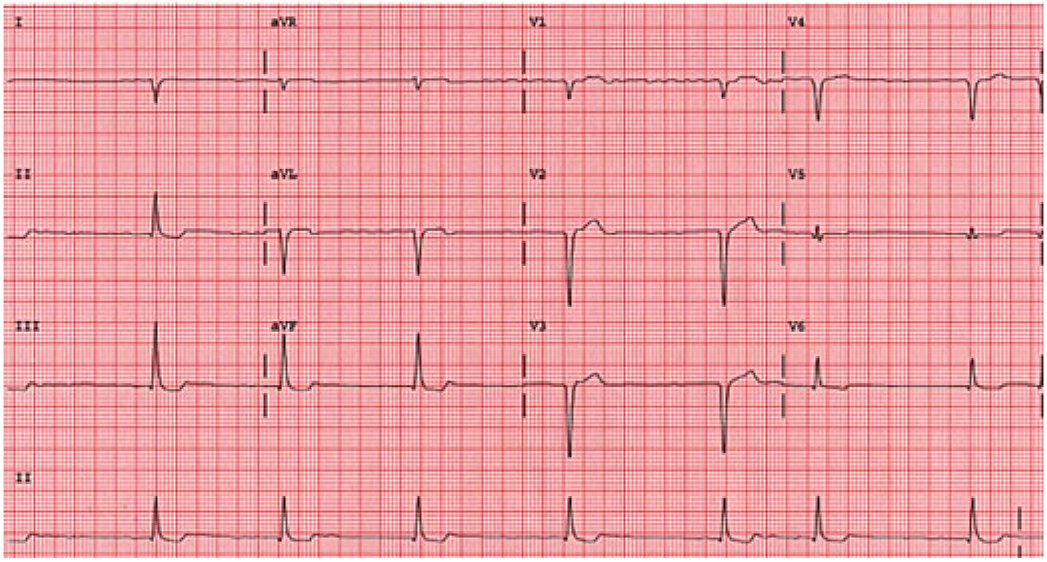


Figure 31: Right axis deviation.

The bottom line is, *if the axis is shifted out of the normal quadrant*, evaluate the reasons for this.

	Differential Diagnosis
Left axis deviation	LVH, left anterior fascicular block, inferior wall MI
Right axis deviation	RVH, left posterior fascicular block, lateral wall MI

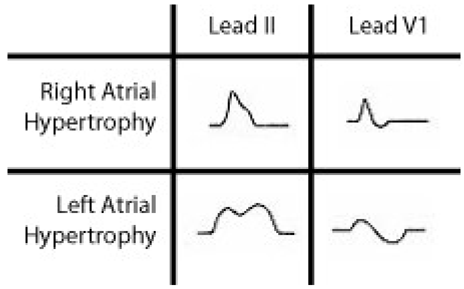
Hypertrophy

Hypertrophy criteria are fairly straightforward; we will be looking for enlargement of any of the four chambers.

1. LVH: (Left ventricular hypertrophy). Add the larger S wave of V1 or V2 (not both), measure in mm, to the larger R wave of V5 or V6. If the sum is > 35mm, it meets "voltage criteria" for LVH. Also consider if R wave is > 12mm in aVL. LVH is more likely with a "strain pattern" which is asymmetric T wave inversion in those leads showing LVH.

2. RVH: (Right ventricular hypertrophy). R wave > S wave in V1 and R wave decreases from V1 to V6.

3. Atrial hypertrophy: (leads II and V1). Right atrial hypertrophy - Peaked P wave in lead II > 2.5mm amplitude. V1 has increase in the initial positive deflection. Left atrial hypertrophy - Notched wide (> 3mm) P wave in lead II. V1 has increase in the terminal negative deflection.



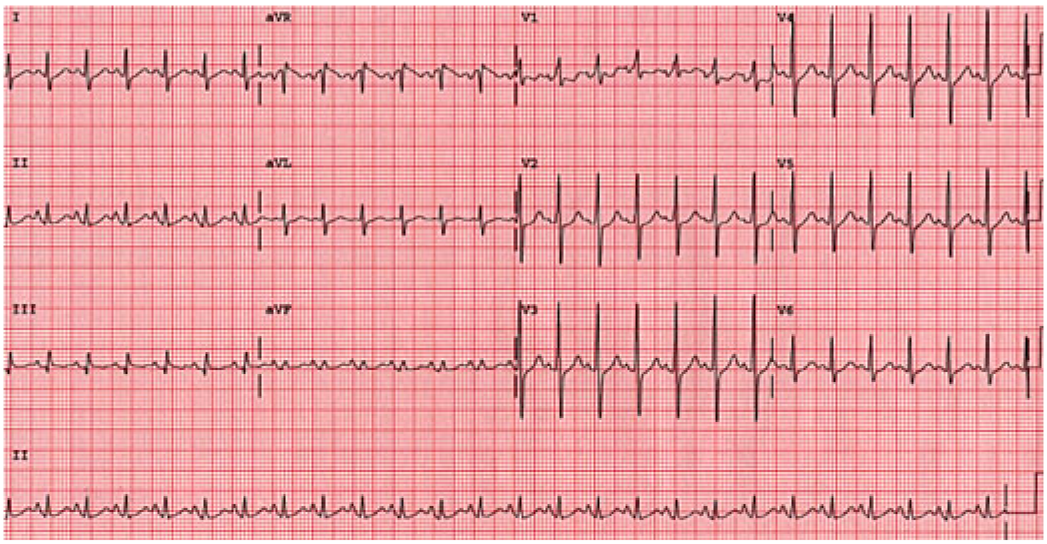


Figure 32: Right ventricular hypertrophy and right atrial enlargement.

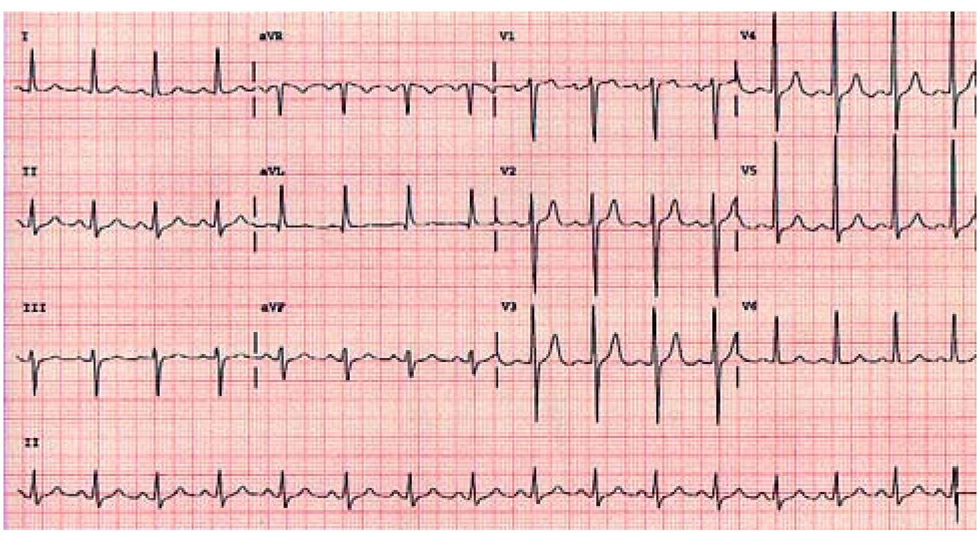


Figure 33: Left ventricular hypertrophy (S wave V2 plus R wave of V5 greater than 35mm) and left atrial enlargement (II and V1).

Infarct

Accurate ECG interpretation in a patient with chest pain is critical. Basically, there can be three types of problems - *ischemia* is a relative lack of blood supply (not yet an infarct), *injury* is acute damage occurring right now, and finally, *infarct* is an area of dead myocardium. It is important to realize that certain leads represent certain areas of the left ventricle; by noting which leads are involved, you can localize the process. The prognosis often varies depending on which area of the left ventricle is involved (i.e. anterior wall myocardial infarct generally has a worse prognosis than an inferior wall infarct).

V1-V2	anteroseptal wall
V3-V4	anterior wall
V5-V6	anterolateral wall
II, III, aVF	inferior wall
I, aVL	lateral wall
V1-V2	posterior wall (reciprocal)

Infarct	
1. Ischemia	Represented by **symmetrical T wave inversion** (upside down). The definitive leads for ischemia are: I, II, V2 - V6.
2. Injury	Acute damage - look for **elevated ST segments**. (Pericarditis and cardiac aneurysm can also cause ST elevation; remember to correlate it with the patient.
3. Infarct	Look for significant "patholgic" **Q waves**. To be significant, a Q wave must be at least one small box wide or one-third the entire QRS height. Remember, to be a Q wave, the initial deflection must be down; even a tiny initial upward deflection makes the apparent Q wave an R wave.

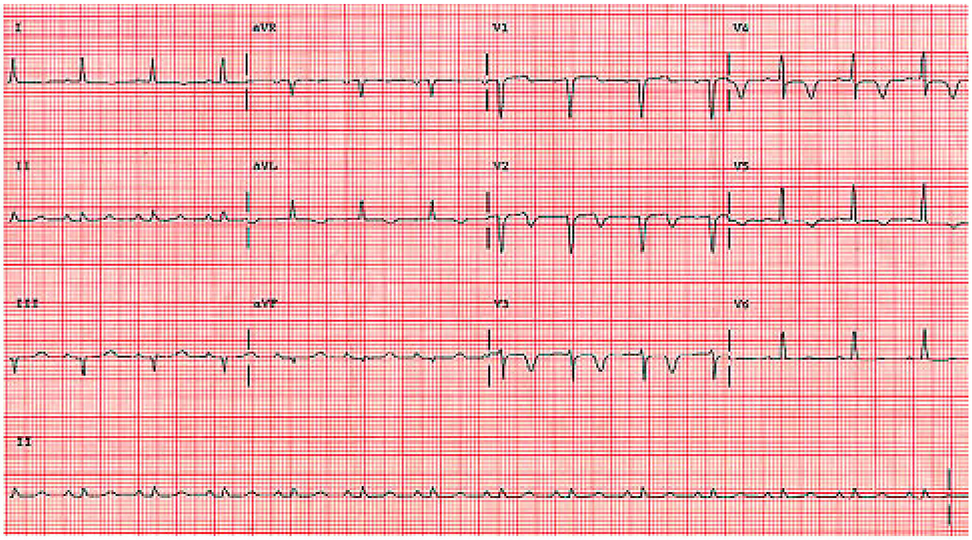


Figure 34: Ischemia: Note symmetric T wave inversions in leads I, V2-V5.

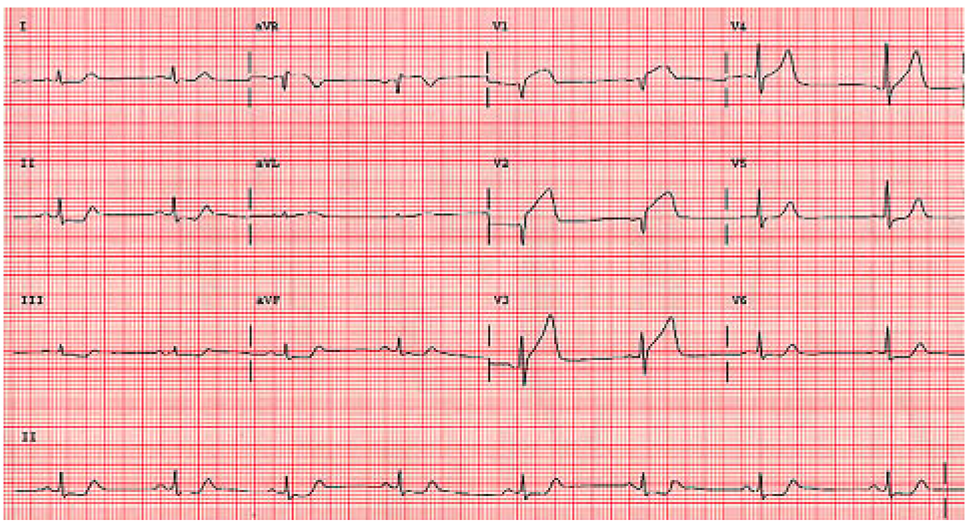


Figure 35: Injury: Note ST segment elevation in leads V2-V3 (anteroseptal/anterior wall).

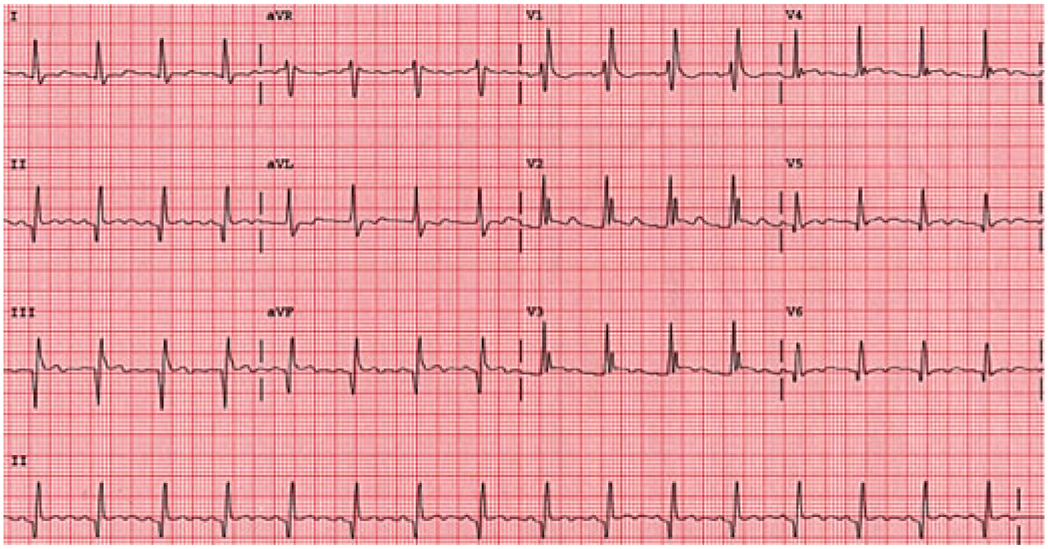


Figure 36: Infarct: Note Q waves in leads II, III, and aVF (inferior wall).

For the posterior wall, remember that vectors representing depolarization of the anterior and posterior portion of the left ventricle are in opposite directions. So, a posterior process shows up as *opposite* of an anterior process in V1. Instead of a Q wave and ST elevation, you get an R wave and ST depression in V1.

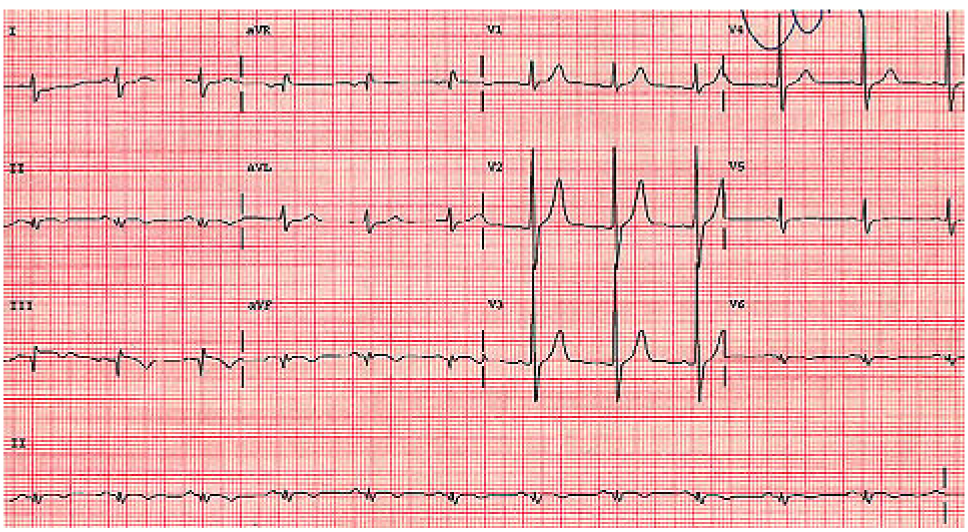


Figure 37: Posterior wall infarct. Notice tall R wave in V1. Posterior wall infarcts are often associated with inferior wall infarcts (Q waves in II, III and aVF).

Two other caveats: One is that normally the R wave gets larger as you go to V1 to V6. If there is no R wave "progression" from V1 to V6 this can also mean infarct. The second caveat is that, with a left bundle branch block, you cannot evaluate "infarct" on that ECG. In a patient with chest pain and left bundle branch block, you must rely on cardiac enzymes (blood tests) and the history.

Fascicular Blocks

Fascicular blocks are blocks of part of the left bundle, either the posterior or anterior division:

Figure 38: Divisions of the bundles.

Anterior fascicular block - the most common.

You will see left axis deviation (-30 to -90) and a small Q wave in lead I and an S in lead III (Q1S3). The QRS will be slightly prolonged (0.1 - 0.12 sec).

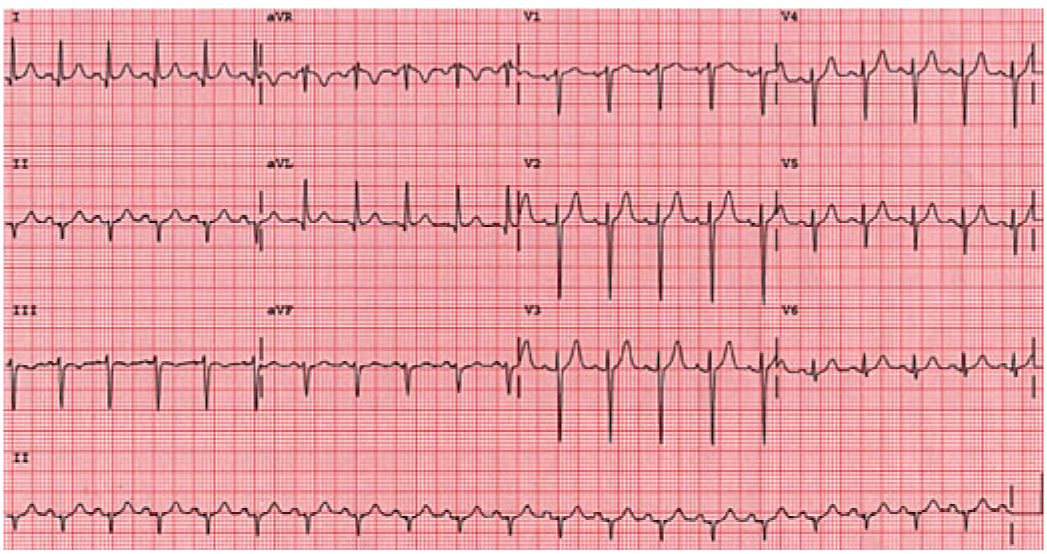


Figure 39: Anterior fascicular block.

Posterior fascicular block - less common.

You will see right axis deviation, an S in lead I and an Q in lead III (S1Q3). The QRS will be slightly prolonged (0.1 - 0.12 sec).

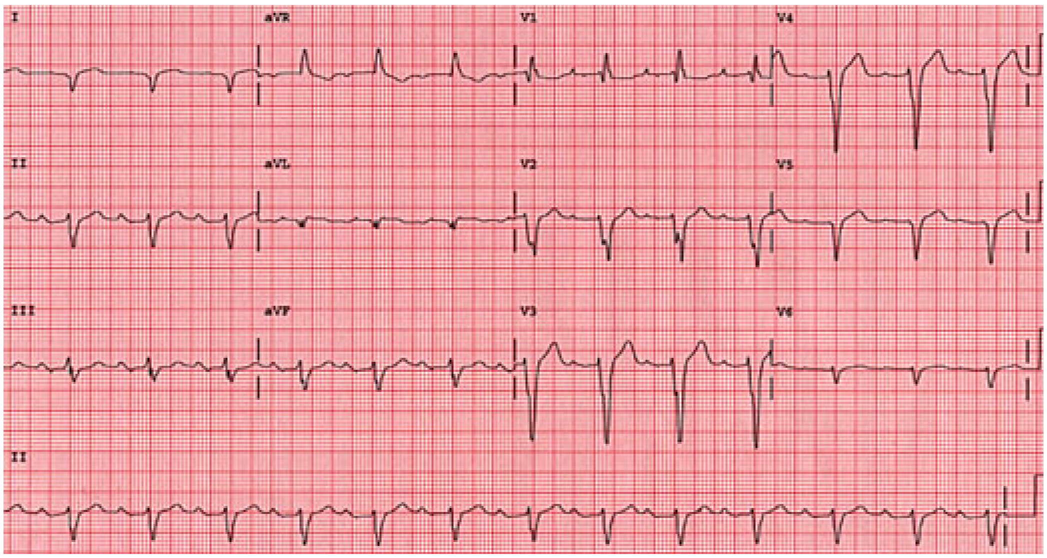


Figure 40: Posterior fascicular block.

Bifascicular block.

This means two (2) of the three (3) fascicles (in diagram) are blocked. The most important example is a right bundle branch block and a left anterior fascicular block. Watch out for this. Only one fascicle is left for conduction, and if that fascicle is intermittently blocked, the dangerous Mobitz 2 is set up!

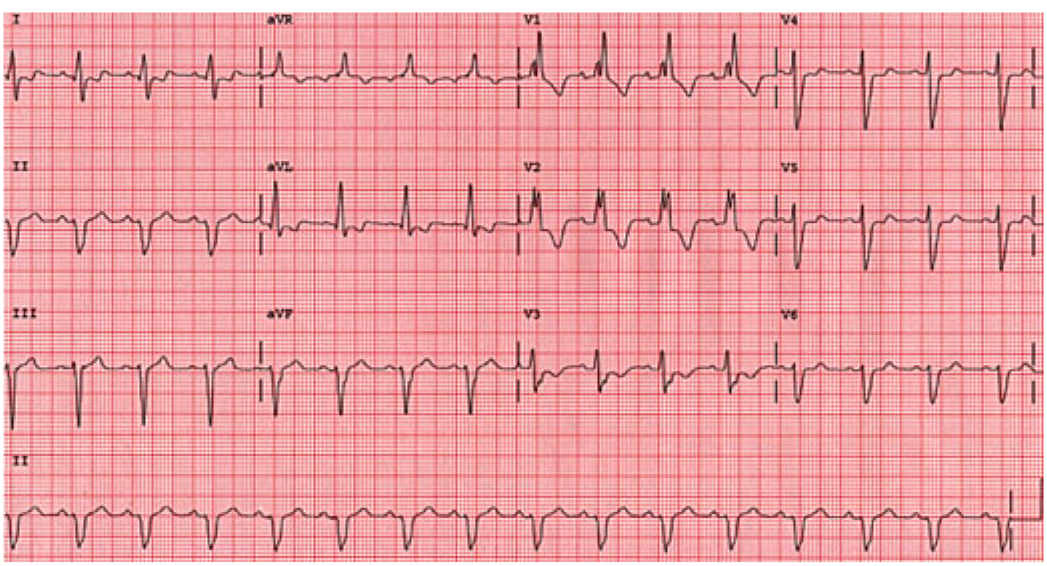


Figure 41: Right bundle branch block and left anterior fascicular block.

"Fascicular Blocks" may seem a bit complicated - simply remember that axis deviation is the clue. In your differential, consider posterior fascicular blocks with right axis deviation and consider anterior fascicular blocks with left axis deviation. Fascicular blocks cause axis deviations, like infarcts and hypertrophy. If you see a left or right axis deviation, first look for infarct or hypertrophy. If neither are present, the remaining diagnosis of fascicular block is usually correct. Review differential diagnosis of right and left axis deviation.

One Last Differential Diagnosis

Four cases of an R wave taller than an S wave in V1 (normally R wave always < S wave in V1.

1. Right bundle branch block.
2. Right ventricular hypertrophy.
3. Posterior wall myocardial infarction.
4. Wolff-Parkinson-White.

Suggestions/Summary

1. Look at each ECG for rate, rhythm, axis, hypertrophy, and infarct. The systematic interpretation guidelines below will serve as a quick reference

INTERPRETATION GUIDELINES ***for Electrocardiograms***
RATE
Rate calculation
Common method: 300-150-100-75-60-50
Mathematical method: 300/# large boxes between R waves
Six-second method: # R-R intervals x10
RHYTHM
Rhythm Guidelines:
1. Check the bottom rhythm strip for regularity, i.e. - regular, regularly irregular, and irregularly irregular.
2. Check for a P wave before each QRS, QRS after each P.
3. Check PR interval (for AV blocks) and QRS (for bundle branch blocks). Check for prolonged QT.
4. Recognize "patterns" such as atrial fibrillation, PVC's, PAC's, escape beats, ventricular tachycardia, paroxysmal atrial tachycardia, AV blocks and bundle branch blocks.

AXIS

	Lead I	Lead aVF
1. Normal axis (0 to +90 degrees)	Positive	Positive
2. Left axis deviation (-30 to -90) Also check lead II. To be true left axis deviation, it should also be down in lead II.	Positive	Negative
3. Right axis deviation (+90 to +180)	Negative	Positive
4. Indeterminate axis (-90 to -180)	Negative	Negative

Left axis deviation differential: LVH, left anterior fascicular block, inferior wall MI.
Right axis deviation differential: RVH, left posterior fascicular block, lateral wall MI.

HYPERTROPHY

1. LVH -- left ventricular hypertrophy = S wave in V1 or V2 + R wave in V5 or V6 > 35mm or aVL R wave > 12mm.
2. RVH -- right ventricular hypertrophy = R wave > S wave in V1 and gets progressively smaller to left V1-V6 (normally, R wave increases from V1-V6).
3. Atrial hypertrophy (leads II and V1)

Right atrial hypertrophy -- Peaked P wave in lead II > 2.5 mm in amplitude. V1 has increase in the initial positive direction.
Left atrial hypertrophy -- Notched wide (> 3mm) P wave in II. V1 has increase in the terminal negative direction.

INFARCT

Ischemia	Represented by symmetrical T wave inversion (upside down). Look in leads I, II, V2-V6.
Injury	Acute damage -- look for elevated ST segments.
Infarct	"Pathologic" Q waves. To be significant, a Q wave must be at least one small square wide or one-third the entire QRS height.

Certain leads represent certain areas of the left ventricle:

V1-V2	anteroseptal wall	II, III, aVF	inferior wall
V3-V4	anterior wall	I, aVL	lateral wall
V5-V6	anterolateral wall	V1-V2	posterior wall (reciprocal)

ECG Exam

Select the ***best*** answer to each of the following items. Mark your responses on the Answer form.

1. In the illustration above, the "T" wave section represents which of the following:

a. repolarization of the ventricle
b. depolarization of the ventricle
c. depolarization of the atria
d. none of the above

2. In the illustration above, the "P" wave section represents which of the following

a. repolarization of the ventricle
b. depolarization of the ventricle
c. depolarization of the atria
d. none of the above

3. ECG paper has 1-millimeter small squares - so height and depth of wave is measured in millimeters.

a. inches
b. micrometers
c. millimeters
d. none of the above

4.In ECG terms, _______ is cycles or beats per minute.

a. Rhythm
b. Rate
c. Axis deviation
d. Pulse

5. Accurate ECG interpretation in a patient with _______ is critical.

a. chest pain
b. lung cancer
c. breathing difficulties
d. none of the above

6. In the case of an _______, ECG interpreters should look for significant "pathologic" **Q waves**. To be significant, a Q wave must be at least one small box wide or one-third the entire QRS height.

a. injury
b. ischemia
c. infarct
d. none of the above

7. "Fascicular Blocks" may seem a bit complicated - simply remember that _______ is the clue.

a. rhythm variances
b. axis deviation
c. wave deviation
d. none of the above

8. "Arrhythmia" means abnormal _______.

a. hypertrophy
b. pulse rate
c. wave length
d. rhythm

9. In ECG, direction of depolarization (vector) of the _____ complex.

a. QRS
b. AV
c. VF
d. LVH

10. In calculating "rate" by the _______ method, you count off 30 large boxes, then count the number of R-R intervals in six seconds and multiply by 10. This is the number of beats per minute.

a. mathematical
b. six-second
c. most common
d. none of the above

MEDEDSYS

PO BOX 81831, San Diego, CA, 92138-3939

TOLL FREE 1-877-295-4719

FAX: 619-295-0252

info@mededsys.com

www.mededsys.com

How to Complete Your Test and Print Your Certificate Online

If you chose to receive your order by postal mail, you have been mailed the printed course material(s) and the printed test(s). To take a test, simply complete the mailed test and send it back. Upon successful completion of a test, a certificate will be mailed or faxed to you. If you don't wish to mail the test back, customers who chose to have the course material(s) mailed may also follow the steps below to complete a test and print a certificate online.

INSTRUCTIONS

1. Go to www.mededsys.com
2. Login and go to "My Account".
3. On the page that opens, select an option from the "My Courses" menu.
4. Select the test you wish to complete.
5. After completion of test, print your certificate online by clicking on the "Continue" button. Alternatively, you may return to the "My Courses" section and select the option to print a certificate.