12-Lead ECG Interpretation: Mastering the Skill

Wendy L. Wright, MS, ARNP, FNP, FAANP, FAAN
Adult/Family Nurse Practitioner
Owner: Wright & Associates Family Healthcare
Amherst, New Hampshire &
Concord, New Hampshire
Partner – Partners in Healthcare Education, LLC

Wright, 2016
Objectives

Upon completion of this lecture, the participant will be able to:

- Develop a systematic approach to the interpretation of a 12-lead ECG
- Distinguish abnormalities seen on a 12-lead ECG that might be indicative of heart block, conduction defects, ischemia, injury, and infarction
- Interpret sample 12-lead ECG’s

Wright, 2016
12 Lead ECG

- Provides the clinician with valuable information regarding electrical activity of the heart, heart function, and overall structure
  - Electrical activity: Conduction defect such as BBB
  - Function: Ischemia, Injury, Infarction
  - Structure: LVH, Right atrial enlargement

Wright, 2016
Pacemaker of the Heart

- Sinoartrial Node (SA Node)
  - Sinus node
  - Heart’s dominant pacemaker
  - It produces a rhythm known as sinus rhythm
  - Located in the right atrium (upper-posterior wall)
  - Depolarization waves begin in the SA node and proceed outward and downward
  - Depolarization stimulates the atria to contract
  - It produces the p wave on the ECG

Wright, 2016
P Wave

P wave

- Represents the electrical activity or depolarization of both atria and also represents the simultaneous contraction of both atria
- Once depolarization begins in the SA node, the electrical stimulus passes through the atria to the AV node
- Produces an upward deflection

Wright, 2016
P wave

Atrial Contraction
AV Node

- AV Node
  - Located just above but continuous with a specialized conduction system that distributes depolarization to the ventricles
  - Depolarization slows at the AV node producing a brief pause
  - Pause allows the blood to enter from the atria into the ventricles
  - AV node is the only electrical conduction system between the atria and the ventricles
**PR Interval**

- Measured from the beginning of the p wave to the beginning of the QRS complex
- Represents time for electrical impulse to travel from the atria to the ventricles
- PR interval has 2 components:
  - p wave (time to depolarize atria)
  - pr segment (end of p wave to beginning of QRS complex)
    - Represents time the impulse spends in the AV node
  
**PR Interval measures: 0.12 seconds - 0.20 seconds**

Wright, 2016
Ventricular Conduction System

- Once through the AV node, depolarization speeds up very rapidly through the Bundle of His and the left and right Bundle Branches
- The depolarization is then quickly distributed to the myocardial cells of the ventricles
- This results in a ventricular contraction

Wright, 2016
Ventricular Conduction System

- Comprised of:
  - Bundle of His
  - Left and Right Bundle Branches

Wright, 2016
QRS Complex

- **Ventricular Conduction System**
  - Produces the QRS on the ECG
  - The QRS signifies the depolarization of the ventricles and simultaneous contraction of the ventricles
  - Measures: 0.06 seconds - 0.10 seconds

Wright, 2016
Components of QRS Complex

Wright, 2016
Components of the QRS Complex

- **Q Wave**
  - 1st negative or downward stroke of the QRS
  - Always downward in deflection
  - Represents depolarization of the interventricular septum

- **R Wave**
  - Follows the Q wave
  - 1st positive or upward deflection (always +)
  - Represents depolarization of the main bulk of ventricular muscle

Wright, 2016
Wright, 2016
Components of the QRS Complex

- **S Wave**
  - Downward or negative deflection following the R wave
  - Represents the late depolarization of the last little amount of ventricular muscle

Wright, 2016
Ventricular Repolarization

- Once the ventricles contract, relaxation occurs
- This is called ventricular repolarization
- Indicated by the ST segment and the T wave on the 12 Lead ECG

Wright, 2016
ST segment

- **ST segment**
  - **Horizontal segment after the QRS**
    - Measured from the end of the S wave to the beginning of the T wave
  - **Initial phase of ventricular repolarization**
    - No electrical activity is flowing through the heart
  - **Should be flat, horizontal and level with other areas of the baseline (Isoelectric)**
  - **If it isn’t, serious pathology**

*Wright, 2016*
Wright, 2016
T Wave

- T wave
  - Rapid phase of ventricular repolarization
  - Resting the pacemaker or the SA node
  - Should be upright
  - If inverted, may indicated serious pathology

Wright, 2016
QT Interval

- QT Interval
  - Represents duration of ventricular depolarization and repolarization
    - This is the contraction and relaxation of the ventricles
  - Measured beginning of the QRS to the end of the T wave
  - Measures 0.40 seconds or <
  - A prolonged QT interval may signal that the patient is vulnerable to rapid ventricular rhythms

Wright, 2016
Normal Cardiac Intervals

- PR Interval
  - 0.12 seconds - 0.20 seconds

- QRS Interval
  - 0.06 seconds - 0.10 seconds

- QT Interval
  - < 0.40 seconds
Systematic Process of Interpretation is Essential

Wright, 2016
Components Essential to Interpreting an ECG

- Rate
- Rhythm
- Cardiac Cycle Measurements
- Axis
- Hypertrophy
- Infarction

Wright, 2016
ECG Measurements

- **ECG Measurements**
  - Paper: each small box is 1mm wide and 1mm high
  - Each heavy black line = 5mm wide
  - Each small box = 0.04 seconds
  - Each large box = 0.20 seconds
Step 1: Rate
Rate

- Rate: 60 - 100 bpm is normal
- SA node: produces rates between 60 and 100 bpm (Sinus Rhythm)
  - <60 bpm: Sinus Bradycardia
  - >100 bpm: Sinus Tachycardia
Rate

Methods for determining rate

- Count black boxes between R waves and memorize the following:
  - 1 box: 300 bpm
  - 2 boxes: 150 bpm
  - 3 boxes: 100 bpm
  - 4 boxes: 75 bpm
  - 5 boxes: 60 bpm
  - 6 boxes: 50 bpm
  - 7 boxes: 43 bpm
  - 8 boxes: 38 bpm; 9 boxes: 35 bpm; 10 boxes: 30 bpm

Wright, 2016
Rate

- Second method of determining rate
  - Each strip of paper has 3 second marks on it
  - Count the number of R’s in 6 seconds and multiply by 10

Wright, 2016
Step 2: Rhythm

Wright, 2016
Rhythm

- 12 Lead ECG provides most accurate means of identifying cardiac arrhythmias (abnormal rhythms)
- Best to use Lead II or aVF for rhythm interpretation
- Remember: The SA node produces a regular rhythm called (Normal Sinus Rhythm)

Wright, 2016
Procedure for Determining Rhythm

- Inspect the ECG in Lead II
- Look closely at the R waves and then “march” them out using your calipers
- Because the SA node is producing impulses in a regular, predictable pattern, all of the R waves should occur at equal lengths or distances

Wright, 2016
Premature Beats

- Premature Atrial Beat
- Premature Junctional Beat
- Premature Ventricular Beat
Premature Atrial Beats (PAB’s)

- Irritable atrial focus
- Produces an abnormal p wave sooner than would be expected

Wright, 2016
Premature Atrial Beat
Premature Ventricular Contractions (PVC’s)

- Irritable automatic focus that originates from the ventricle
- Produces a giant ventricular complex on ECG
- Usually opposite the polarity of the normal QRS complex
- Most common reason: hypoxemia

Wright, 2016
Premature Ventricular Beat (PVC’s)

- PVC’s are followed by a compensatory pause
- Pause allows the ventricles to finish repolarizing; thus making them ready for the next sinus generated cycle

Wright, 2016
compensatory pause

P.V.C.

Wright, 2016
Step 3: Evaluate the Cardiac Cycle
Cardiac Cycle

- Cardiac cycle
  - Beginning of the p wave to the end of the t wave

Wright, 2016
Cardiac Cycle

- P wave
  - Is it present?
  - Is it upright?
  - What is it’s height?

- PR interval
  - Measurement
PR Interval

- Measures 0.12 seconds - 0.20 seconds
- Longer than 0.20 seconds
  - First degree heart block
AV Blocks

- Blocks which delay or prevent atrial impulses from reaching the ventricles

- 3 Types
  - 1st degree AV Block
  - 2nd degree AV Block
  - 3rd degree AV Block

Wright, 2016
1st Degree AV Block

- Prolonged P-R Interval
- Measures longer than 0.20 seconds

Wright, 2016
$I^0$ AV Block

$I^0$ AV Block

Wright, 2016
2nd Degree AV Block

- Some p’s without a QRS response
- Types
  - Wenckebach: pr interval gradually increases with each cycle until the last p wave in the series does not produce a QRS
  - Mobitz II: Some p’s do not produce a QRS response
    - Looks like a dropped QRS complex
    - Can be a 2:1 or 3:1 ratio

Wright, 2016
2º AV Block

"Wenckebach"

Wright, 2016
Type I

Wright, 2016
3rd Degree AV Block (Complete Heart Block)

- **Junctional Focus**
  - Normal (narrow) QRS’s
  - Ventricular rate: 40 - 60 bpm

- **Ventricular Focus**
  - PVC like QRS’s
  - Ventricular rate: 20 - 40 bpm
  - **Emergency situation**

Wright, 2016
3rd Degree AV Block (Complete Heart Block)

- None of the atrial depolarizations conduct to the ventricles
- When this happens, another focus in the AV junction or ventricles takes over to pace the heart
- Clues: AV rhythm is regular but very different from the ventricular rate (AV dissociation)
3° AV Block  
(complete AV Block)

Junctional focus:
- normal (narrow) QRS's
- ventricular rate: 40-60/min.
3rd Degree (Complete Heart Block)
QRS Complex

- QRS complex
  - Measurement
    Measures 0.06 - 0.10 seconds
  - Abnormality: 0.12 seconds or greater
    Bundle Branch Block
Bundle Branch Block

Wright, 2016
Bundle Branch Block

- Caused by block of the electrical conduction in the right or left bundle branch
- This causes a delay in depolarization and contraction of the ventricle it supplies
- Stimulus normally goes to both ventricles at the same time
- Delay causes the unblocked ventricle to depolarize and contract 1st
- QRS reflects ventricular depolarization

Wright, 2016
Bundle Branch Block

- Delay-Widened QRS (0.12 seconds or greater).
  - What you are seeing is 2 R waves on the ECG
  - 1st R wave-R
  - 2nd R wave-R prime
  - R prime is the delayed ventricular contraction

Wright, 2016
To Diagnose BBB

- Use limb leads (I, II, III, AVR, AVF, AVL)
- Look at the QRS
- If it is 0.12 seconds or >, you have a BBB
- Now to determine if it is left or right
  - 1st look at leads V1 and V2 (right chest leads) and V5 and V6 (left chest leads) for R and R prime
  - If R and R’ are in V1 or V2 - RBBB
  - If R and R’ are in V5 or V6 - LBBB
Bundle Branch Block

Wright, 2016
If an individual has a LBBB, you can not diagnose an infarction because the Q wave falls in the middle of the R and R’. It is hidden.

Also-axis and ventricular hypertrophy can not be determined accurately in the individual with a BBB.
Cardiac Cycle

- **ST segment**
  - Horizontal; elevated or depressed

- **T wave**
  - Upright or inverted

- **QT interval**
  - Measurement

Wright, 2016
QT Interval

- Measurement should be less than 0.40 seconds
- 0.40 seconds or greater = prolonged QT
  - Increased risk of ventricular dysrhythmias

Wright, 2016
Step 4: Axis
FYI

- Keep in mind that the heart’s electrical impulses never change from lead to lead.
- It is the electrode positions from lead to lead that allow us to see the electrical activity in the different aspects of the heart

Wright, 2016
Precordial or Chest Leads

- Unipolar leads
- V1-V6
- Electrodes are in different positions on the anterior chest
- Allows us to view the heart in a horizontal plane
- Complement the limb leads to provide a complete view of the heart's electrical activity
- Each electrode is considered positive and the heart is negative

Wright, 2016
Important Concept

- If depolarization moves toward a positive electrode, it will produce an upward deflection on the ECG.
- If it moves away from the positive electrode, it will produce a downward deflection.
- **Remember, depolarization begins in the SA node and moves downward and to the left as it progresses. As you get further into the V leads, you would expect upward deflection.**
  - (V1: QRS downward, V3: isoelectric, V6: upward)

Wright, 2016
Mean QRS Vector

- Mean QRS Vector
  - Also called Axis
  - This is the direction that the depolarization or electrical current is flowing
  - Position of the mean QRS vector or axis is described in degrees within a circle drawn over a patient's chest

Wright, 2016
Axis

- Very important
- Gives us significant clues regarding pathology
  - Heart position
    If a heart is displaced or rotated, the axis also rotates
  - Hypertrophy
    Enlarged tissue has more myocardial cells
    If tissue is hypertrophied such as in one ventricle (most commonly the left ventricle), the axis is displaced toward the hypertrophied side

Wright, 2016
Axis

Infarction

- If tissue is dead, there is a decreased blood supply and it is not able to conduct the electrical impulses
- Other areas draw the depolarization away from the dead tissue

Wright, 2016
Now let us define axis in terms of degrees or the degree of deviation.

- Normal axis is between 0 and +90 degrees.
- Two leads are used to determine deviation: Lead I and AVF.

Wright, 2016
Axis Deviation

- **Lead I**
  - Remember in lead I, the left arm is positive and the right arm is negative.
  - The QRS is upright in lead one because the axis is pointing toward the patient’s left side (It starts out in the SA node and heads to the left and downward as it goes to the AV node).
  - If the QRS complex is negative or downward deflected, it means that the axis is pointing to the right (Right Axis Deviation).
  - Lead I is the best lead to detect right axis deviation.

*Wright, 2016*
Axis Deviation

- AVF
  - Remember: Left foot is positive and the heart is negative
  - QRS complex is positive or upright in AVF because the axis is downward and to the left (heading toward the patient’s left foot)
  - Downward QRS in AVF means that the QRS vector or axis points upward (Left axis deviation)
  - AVF is the best lead to detect left axis deviation

Wright, 2016
Remember...

- Axis is the direction of the mean QRS vector which is indicative of the direction of ventricular depolarization
Next Step…

- Now that we have determined normal, right or left axis deviation, we have to quantify it in terms of exact degrees.
- First step…Determine axis using mean QRS vector and quadrant method and you identify right, extreme right, left or normal.
- Second step…
Second Step

- Find the limb lead (I, II, III, AVR, AVL, AVF) where the QRS complex is most isoelectric
- Axis is about 90 degrees from the most isoelectric lead

Wright, 2016
Lead I

Depolarization

on EKG

Wright, 2016
Left Axis Deviation

- L: -90°
- A: -60°
- D: -30°
- 0°

Axis

- I: -90°
- AVR: -60°
- II: -30°
- AVF: 0°

Normal Range

- AVF: 0°
- III: +30°
- AVL: +60°
- I: +90°

Wright, 2016
12-Lead Example

Wright, 2016
Extreme Right Axis Deviation

- AVL: -120°
- III: -150°
- AVF: -180°

Right Axis Deviation

- AVF: +180°
- II: +150°
- AVR: +120°
- I: +90°

Wright, 2016
Right Axis Deviation

Wright, 2016
Axis Deviation

- Left: LVH, Inferior MI, WPW, or Atrial-septal defect, LBBB
- Right: Normal, Lateral MI, RVH, Acute Lung Disease, Chronic Lung Disease, Hyperkalemia, WPW,
Example

- If I is most isoelectric and you have already determined from the quadrant method that you have a left axis deviation, the axis is 90 degrees away into the L axis deviation quadrant-
  - The answer is -90 degrees.
Step 5: Hypertrophy

Wright, 2016
Hypertrophy

- **Definition:** Increase in size of the muscle mass of the heart
  - It implies that there is an increase in the thickness of the chamber wall
  - It also implies dilation
  - It is good to have a hypertrophied thigh, but not the myocardium. It takes up space and doesn’t allow as much blood to fill into the chamber

Wright, 2016
Atrial Hypertrophy

- P wave reflects depolarization of both atria (contraction)
- Look at the p wave for atrial hypertrophy
- Look at Lead V1 specifically because it sits directly over the atria of the heart
- Note: Atria tend to dilate more than they hypertrophy, therefore, most people now use atria enlargement as opposed to hypertrophy
P Wave as a Measurement of Atrial Enlargement

- With atrial enlargement, the p wave is usually diphasic (+ and -)
- Diphasic p wave in V1 tells you the patient has atrial enlargement
- If initial portion of p wave in lead V1 is larger- Right atrial enlargement
- If later portion of p wave is larger- Left atrial enlargement

Wright, 2016
P Wave as a Measurement of Atrial Enlargement

- Also: right atrial enlargement is also suspected if the p wave is $>2.5$ mm in any limb lead (I, II, III, AVF, AVR, AVL) even if it is not diphasic

Wright, 2016
Ventricular Hypertrophy

- Remember that the QRS complex reflects ventricular depolarization and contraction
- Let’s first look at Lead V1
  - Remember that in V1: the electrode is + and the heart is -
  - Ventricular depolarization travels downward-away from V1, therefore you would expect the QRS complex to be downward or negative in V1
  - Because the QRS is mostly downward, the R wave is small and the S wave is large

Wright, 2016
Right Ventricular Hypertrophy

- Look at V1
- Normally, the R wave is small
- With RVH - the R wave is large
- Think about why: With RVH, the right ventricle is large and thick. Hypertrophied muscle pulls depolarization toward it.
  - V1 electrode sits on the right anterior chest
  - The right ventricle is on the same side
  - Hypertrophied tissue would cause the R wave to be more upright because the depolarization is pulled more toward V1

Wright, 2016
Right Ventricular Hypertrophy

- QRS in V1 would be more upright or the R wave would be larger and the S wave smaller
- Another indication of RVH:
  - R wave: decreases in size as you move from V1-V4 because the depolarization is moving away from the right chest where the enlarged right ventricle is located
  - Normally: the R wave increases in size because normal depolarization moves down and toward the left

Wright, 2016
Right Ventricular Hypertrophy

Wright, 2016
Left Ventricular Hypertrophy

- Remember: depolarization begins in the right atria and progresses down through the ventricles toward the left chest
- Hypertrophy pulls depolarization toward it
- Looking again at V1
- V1: Electrode is positive, Heart is negative
- Normally: Because depolarization moves down and away from the right upper chest, the QRS should be negative in V1

Wright, 2016
Left Ventricular Hypertrophy

- LVH: QRS complexes have large exaggerated deflections (both height and depth) in the chest leads
  - Reason: Hypertrophied left ventricle will pull depolarization away from the V1 electrode.
  - Normally: S wave is deep or negative in V1 and there is a large R wave in V5
  - LVH: S is even deeper and R wave is even larger

Wright, 2016
Calculating LVH

- Add the depth of S in V1 and the height of R in V5
  - If > 35 mm (with each small box as 1 mm & each large box as 5 mm) - LVH

Wright, 2016
Left Ventricular Hypertrophy

Wright, 2016
Left Ventricular Hypertrophy

- Characteristic T wave
  - This is another finding often seen with LVH
  - Look at V5 and V6 because these 2 leads are located directly over the left ventricle
  - LVH: t wave in V5 or V6, there will be a gradual downward slope and a very steep return to baseline

Wright, 2016
Left Chest Leads

Inverted T wave

Wright, 2016
Other Clues to RVH and LVH

- RVH: Right axis deviation
- LVH: Left axis deviation
Myocardial Ischemia, Injury, and Infarct

- One of the most common reasons in primary care to obtain an ECG is chest pain.
- Important to remember that an ECG is not the most important thing to obtain, the history is.
- 90% of diagnoses are made with the history alone before even ordering an ECG or additional tests.
- If someone presents having an MI, only 60% will be diagnosed with 1st ECG.

Wright, 2016
Myocardial Ischemia, Injury, and Infarct

- However, when a study was conducted on 1578 people whom the clinician determined through history was most likely having “typical” ischemic chest pain-94% had an MI even when only 60% had changes on ECG suggestive of such

Wright, 2016
History

- Angina or Ischemic Pain
  - Ache
  - Lasting > 1 min but < 20
  - Associated with activity
  - Radiation
  - N/V
  - Diaphoresis
  - Tightness
  Pains that are sharp, jabbing, fleeting, superficial are rarely cardiac

Wright, 2016
Pathophysiology and Terminology

- Myocardium receives blood and oxygen from coronary arteries
- Plaques of cholesterol deposit in the lining of the arteries
- Plaques cause platelets and rbc’s to adhere to them causing thrombus/clot formation in the artery
- 90-95% of all MI’s and CVA’s are caused by a thrombus.
  - This is why the addition of 1 baby ASA/day is important

Wright, 2016
Pathophysiology and Terminology

- Thrombus significantly reduces or even occludes blood flow to heart muscle supplied by that vessel.
- Most common area of infarction is the left ventricle. Remember, this is the work horse of the heart. Infarction here can lead to serious arrhythmias because the infarcted tissue does not depolarize.

Wright, 2016
Ischemia

Wright, 2016
Ischemia

- Decreased blood supply and therefore, decreased oxygen
- Characterized by inverted t waves
- Because the chest leads are closest to the ventricles, t wave inversion is usually more pronounced in V1-V6

Wright, 2016
Injury

Wright, 2016
Injury

- More serious
- Indicates acuteness (now or recent infarct)
- ST elevation
- This tells us that myocardial infarction is acute. It is the earliest sign of an infarction to record on an ECG
- ST depression: can also indicate injury-subendocardial infarction
- >1mm - MI is imminent until proven otherwise

Wright, 2016
Injury: means acute or recent

Wright, 2016
Infarction

- Q waves make the diagnosis
- Q is the 1st downward stroke of the QRS complex
- It is never preceded by anything in the complex
- If there is anything + or upward before, the downward deflection is an S and the upward is an R wave

Wright, 2016
Infarction!

Q wave

Wright, 2016
Infarction
Q Waves

- **Physiologic**
  - \(<1\text{mm or }< 0.04 \text{ seconds}\)

- **Pathologic**
  - \(>1\text{mm wide or }1/3 \text{ height of entire QRS amplitude}\)

Wright, 2016
Significant Q waves

or

1 mm wide

$\frac{1}{3}$ of QRS amplitude
<table>
<thead>
<tr>
<th>Lead Name &amp; Standard Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Lateral</td>
</tr>
<tr>
<td>aVR</td>
</tr>
<tr>
<td>V1 Septal</td>
</tr>
<tr>
<td>V4 Anterior</td>
</tr>
<tr>
<td>II Inferior</td>
</tr>
<tr>
<td>aVL Lateral</td>
</tr>
<tr>
<td>V2 Septal</td>
</tr>
<tr>
<td>V5 Lateral</td>
</tr>
<tr>
<td>III Inferior</td>
</tr>
<tr>
<td>aVF Inferior</td>
</tr>
<tr>
<td>V3 Anterior</td>
</tr>
<tr>
<td>V6 Lateral</td>
</tr>
</tbody>
</table>

Wright, 2016
Determining Location of an Infarct

- **Anterior MI**
  - Left anterior descending is the blood vessel that supplies most of the circulation to the anterior myocardium
  - V1-V4 are the best leads to evaluate
  - Q waves in V1-V4: AWMI
  - Normally you will see insignificant Q waves in V5-V6
  - Q in V1-V2: Anterior-Septal MI
  - Q in V3-V4: Anterior-Lateral MI (Very deadly)
Determining Location of an Infarct

- **Lateral Infarct**
  - Circumflex supplies majority of blood
  - Q in I, AVL

- **Inferior Infarct**
  - Right coronary artery is dominant in 80-90%
  - Left coronary artery is dominant in 10-20%
  - Q in II, III, AVF

Wright, 2016
IWMI

Wright, 2016
Non-Q Wave Myocardial Infarction

- If the ST segment is elevated or depressed but is without associated Q waves, this may represent a non-Q wave infarction
- A non-Q wave infarction often involves the subendocardial tissue

Wright, 2016
Pericarditis

Findings: Widespread ST segment elevation
Chest pain – worse with lying down

Wright, 2016
Pulmonary Embolism

Findings:  Tachycardia, RAD, RBBB, T wave inversion V1 – V4
Thank You!
I Would Be Happy To Entertain Any Questions
Wendy L. Wright, MS, RN, ARNP, FNP, FAANP
 Same next day

12/22/2015 6:16:23 AM

Name: [Redacted]
DOB: 44 year(s)
Gender: Male

25 mm/sec 10 mm/mV  F: 1 Hz  W: -0.01 to 1 Hz

12-12-ECG