12 Lead ECG Workshop

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Learning Objectives

• Explain the purpose of a 12 lead ECG, the importance of proper lead placement and what the leads represent.

• Identify key characteristics of axis deviation, pericarditis, electrolyte disturbances, hypertrophy and bundle branch block.

• Analyze changes in the ECG which represent myocardial ischemia, infarct or injury.
In This Handout.....

• Color Coded Map of Leads, ST Elevation and Reciprocal changes
• Review of components of waveforms
• Summary of 12 Lead ECG Features
• 12 Lead ECGs
• Calipers
P Wave

• Electrical
  – Atrial Depolarization- right and left sequential activation
  – Normally upright in I, II, aVF, V4-V6
  – Duration < 0.12 seconds
  – Amplitude < 2.5 mm
  – May see notched or biphasic P waves in frontal plane

• Mechanical
  – Blood is ejected from the atria through the Tricuspid Valve (RA) and the Mitral Valve (LA)
PR Interval

• **Electrical**
  – The time it takes for the energy to spread through the atria and pass through the AV junction

• **Mechanical**
  – Ventricular filling time
  – S1 is the sound of the atrial valves closing in the cardiac cycle.
  – Normally .12-.20 seconds and isoelectric
QRS Complex

• Electrical
  – Ventricular depolarization- simultaneous activation of both
  – Energy passing through the Bundle of His, down Bundle Branches and out through Purkinje Fibers.

• Mechanical
  – Blood is ejected out of the ventricles, through the semi lunar valves (Pulmonary RV and Aortic LV).
  – S2 is the sound of these two valves closing in the cardiac cycle.

• Normally .06-.10 seconds
• Small, narrow Q wave in I, aVL, aVF, V5 and V6 normal
### QRS Complex

<table>
<thead>
<tr>
<th><strong>Q Wave</strong></th>
<th>The first negative deflection following the P wave, before the R wave.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R Wave</strong></td>
<td>First positive deflection following the P wave. A second positive deflection is R prime (R’).</td>
</tr>
<tr>
<td><strong>S Wave</strong></td>
<td>The second negative deflection following the P wave, or the first negative deflection after the R wave.</td>
</tr>
</tbody>
</table>
ST Segment

• Electrical
  – Beginning of ventricular repolarization
  – Usually flat on the tracing
  – Refractory period for cells

• Mechanical
  – Passive filling of ventricle
T wave

• Electrical
  – Part of the repolarization of the ventricles
  – Usually a positive deflection
  – Asymmetrical tent shape

• Mechanical
  – Passive refilling of the ventricles
QT Interval

- Measured from onset of QRS complex to end of T wave: includes ventricular depolarization and repolarization
- Rule of thumb: QT is 1/2 of the preceding R-R for NSR
- QT interval length depends on rate, physiology and medications: normal is generally .36-.44
- QTc = QT Corrected
  - Males > .45 seconds is abnormal
  - Females > .47 seconds is abnormal
Why Take a 12-LEAD ECG?

- Gold standard for the diagnosis of arrhythmias
- Guides therapy and risk stratification for patients with suspected myocardial infarction
- Helps detect electrolyte disturbances (e.g. hyperkalemia and hypokalemia)
- Allows for the detection of conduction abnormalities (e.g. right and left bundle branch block)
- Used as a screening tool for ischemic heart disease during a cardiac stress test
- Occasionally helpful with non-cardiac diseases (e.g. pulmonary embolism or hypothermia)
What Does Each Lead “See”?

<table>
<thead>
<tr>
<th>Lead</th>
<th>Lateral</th>
<th>aVR</th>
<th>V1 Septal</th>
<th>V4 Anterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Lateral</td>
<td>aVR</td>
<td>V1 Septal</td>
<td>V4 Anterior</td>
</tr>
<tr>
<td>II</td>
<td>Inferior</td>
<td>aVL Lateral</td>
<td>V2 Septal</td>
<td>V5 Lateral</td>
</tr>
<tr>
<td>III</td>
<td>Inferior</td>
<td>aVF Inferior</td>
<td>V3 Anterior</td>
<td>V6 Lateral</td>
</tr>
</tbody>
</table>

http://www.ivline.org/2010/05/quick-guide-to-ecg.html

http://www.clinicaljunior.com/cardiologyecg.html
Axis Deviation - Quick Check

http://quizlet.com/54883985/ekg-review-from-someone-else-flash-cards/
Hypertrophy: Normal, Concentric & Eccentric
Hypertrophy

• The ECG criteria for diagnosing hypertrophy are very insensitive: ~50% of those with hypertrophy will NOT have expected ECG changes.......

• **BUT** the criteria are very specific: >90% of patients with expected ECG changes are very likely to have hypertrophy
Right Ventricular Hypertrophy (RVH)
Right Ventricular Hypertrophy (RVH)

RIGHT VENTRICULAR HYPERTROPHY
Large R wave in leads V1 and V2,
Wide S wave in leads V1 and V2, wide R wave in V5 and V6

Left Ventricular Hypertrophy (LVH)

http://www.unm.edu/~lkravitz/EKG/ventricularhyper.html
Left Ventricular Hypertrophy (LVH)

Left Ventricular Hypertrophy (LVH)

Large S wave in leads V1 and V2, large R wave in V5 and V6
Criteria for LVH

• Increased QRS amplitude
  – In lead facing the hypertrophied ventricle (V5 or V6) a tall R wave and in lead facing the negative side of the activation (V1 or V2) a deep S wave is present. When added together is $\geq 35\text{mm}$.
    – $R$ in I + $S$ in III $>25\text{ mm}$
    – $S$ in V1 or V2 $\geq 30\text{ mm}$
    – $R$ in lead V5 or V6 $\geq 30\text{ mm}$
.....More Criteria for LVH

• Sokolow + Lyon (*Am Heart J, 1949;37:161*)
  – S V1+ R V5 or V6 > 35 mm

• Cornell criteria (*Circulation, 1987;3: 565-72*)
  – SV3 + R avl > 28 mm in men
  – SV3 + R avl > 20 mm in women

• Framingham criteria (*Circulation,1990; 81:815-820*)
  – R avl > 11mm, R V4-6 > 25mm
  – S V1-3 > 25 mm, S V1 or V2 +
  – R V5 or V6 > 35 mm, R I + S III > 25 mm
Bundle Branch Block

• Anatomic or functional discontinuity in one of the bundle branches preventing or slowing conduction, resulting in ventricle on affected side becoming activated late.

• Transient bundle branch block may occur with tachycardia, bradycardia, pulmonary embolism, anemia, infection, myocardial ischemia or infarction, congestive heart failure, metabolic disorders/changes, hypoxia, and others.
Right Bundle Branch Block (RBBB)
Right Bundle Branch Block (RBBB)

**RIGHT BUNDLE-BRANCH BLOCK**

QRS duration greater than 0.12 s
Wide S wave in leads I, V5, and V6

Left Bundle Branch Block (LBBB)
Left Bundle Branch Block (LBBB)

**LEFT BUNDLE-BRANCH BLOCK**

- QRS duration greater than 0.12 s
- Wide S wave in leads V1 and V2, wide R wave in V5 and V6

## Miscellaneous Changes

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>Suggestive of</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P Waves</strong></td>
<td>Hyperkalemia</td>
</tr>
<tr>
<td>• wide, flat P waves</td>
<td></td>
</tr>
<tr>
<td>• no P waves</td>
<td></td>
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<tr>
<td><strong>QRS Complexes</strong></td>
<td>Hyperkalemia</td>
</tr>
<tr>
<td>• widening of QRS</td>
<td>Hypokalemia</td>
</tr>
<tr>
<td>• merging QRS and T</td>
<td>Hypercalcemia</td>
</tr>
<tr>
<td>• widening of QRS</td>
<td>Hypocalcemia</td>
</tr>
<tr>
<td>• prolonged QT interval</td>
<td>Digitalis Toxicity</td>
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<tr>
<td>• short QT interval</td>
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<tr>
<td><strong>ST Segments</strong></td>
<td>Hyperkalemia</td>
</tr>
<tr>
<td>• disappearing ST segments</td>
<td>Hypokalemia</td>
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<tr>
<td>• ST depression</td>
<td>Digitalis Toxicity</td>
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<tr>
<td>• sloping ST segments</td>
<td></td>
</tr>
<tr>
<td>• depressed, “scooped” ST segments</td>
<td>Pericarditis</td>
</tr>
<tr>
<td>• elevated, concave ST segments</td>
<td></td>
</tr>
<tr>
<td><strong>T Waves</strong></td>
<td>Hyperkalemia</td>
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<td>• tall, peaked T waves</td>
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<td>• flattening of T wave</td>
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<td>• diphasic or inverted T waves</td>
<td>Hypokalemia</td>
</tr>
<tr>
<td><strong>U Waves</strong></td>
<td>Hypokalemia</td>
</tr>
<tr>
<td>• development of U waves</td>
<td></td>
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</tbody>
</table>
Miscellaneous Changes

Pericarditis:
upsloping, elevated
ST segments in
many leads
Myocardial Ischemia, Injury, & Infarct
**Myocardial ischemia**
- T-wave inversion
- ST-segment depression

**Myocardial injury**
- ST-segment elevation
- T-wave inversion

**Myocardial infarction**
- Q waves
- ST-segment elevation
- T-wave inversion
Localization of Infarct

Evolution of an Acute MI

The evolution of an infarct on the ECG. ST elevation, Q wave formation, T wave inversion, normalisation with a persistent Q wave
12 Lead EGCs

Let the Practice Begin......
Case #1: 47 y/o male

23-JAN-1963 (47 yr)
Male
Vent. rate 61 BPM
PR interval 136 ms
QRS duration 98 ms
QT/QTc 390/392 ms
P-R-T axes 46 74 36

***age and gender specific ECG analysis***
Normal sinus rhythm
Normal ECG

Technician:
Test ind: STEMI

Referred by:
Unconfirmed
NOTIFIED T.
Case #2: 86 y/o with dyspnea + Parkinson’s

Rate: 60 bpm  
QRS: 100 ms  
R Axis: -60  
Sinus Arrhythmia

PRI: 280 ms  
QT/QTC: 440 ms/440 ms  
Left Axis Deviation
Case #3: 64 y/o man with COPD

Rate: 80 bpm  QRS: 80 ms  R Axis: +120  Normal Sinus Rhythm
PRI: 240 ms  QT/QTc: 380/439 ms  Right Ventricular Hypertrophy
Right Axis Deviation
Case #4: 30 y/o male runner

Rate: 94 bpm  
QRS: 110 ms  
PRI: 210 ms  
QT/QTc: 380 ms/478 ms  
R Axis:+110  
Normal SR  
Left Ventricular Hypertrophy  
Slight Right Axis Deviation
Case #5: 61 y/o man with intermittent CP
Case #6: 82 y/o female with DM; pre-op exam
Case #7a: 48 y/o female with fatigue

- Vent. rate: 180 BPM
- PR interval: * ms
- QRS duration: 82 ms
- QT/QTc: 254/439 ms
- P-R-T axes: * 42 -23

Diagnoses:
- Atrial fibrillation with rapid ventricular response
- Non-specific ST abnormality
- Abnormal QRS-T angle, consider primary T wave abnormality
- Abnormal ECG

No previous ECGs available.
Case #7b: 79 y/o with chest pain

Rate: 150 bpm  QRS: 80 ms  R Axis: +30  Atrial Flutter; 2:1 Conduction
PRI: N/A  QT/QTc: 300/474 ms
Case #7c: 65 y/o on HF medications

Rate: 50bpm  QRS: 60 ms  R Axis: +60  Atrial Fibrillation with slow rate
PRI: N/A  QT/QTc: 320/292 ms  ST depression multiple leads
Case #8a: 22 y/o with palpitations

Rate: 220 bpm  
QRS: 60 ms  
R Axis: 0  
Supra Ventricular Tachycardia

PRI: N/A  
QT: 250 ms
Case #8b: 61 y/o with fast heart rate

19-SEP-1949 (61 yr)
Male
PR interval * ms
QRS duration 210 ms
QT/QTc 348/580 ms
P-R-T axes *-78 101

***age and gender specific ECG analysis***
Left axis deviation
Ventricular tachycardia (ventricular or supraventricular with aberration)
Abnormal ECG

Technician
Test ind: FEVER CHILLS

Referred by: NOTIFIED W:
Confirmed By: NOTIFIED T:

25mm/s 10mm/mV 40Hz 7.1.1 12SL 233 CID: 2
Case #9: 33 y/o on hemodialysis
Case # 11a: 84 y/o new patient

12-JAN-1927 (84 yr)
Female
Room: 157
Loc: 203

Vent. rate 100 BPM
PR interval 104 ms
QRS duration 172 ms
QT/QTc 380/490 ms
P-R-T axes -62 -70 107

AV sequential or dual chamber electronic pacemaker
When compared with ECG of 20-FEB-2011 04:09,
PREVIOUS ECG IS PRESENT

Technician: EL
Test ind WITH MAGNET

Refereed by: NOTIFIED W:
Confirmed By: NOTIFIED T:
Case #12: 86 y/o new patient

15-AUG-1925 (86 yr)
Female
Room: ICU2
Loc: 208

15-AUG-1925 (86 yr)
Female
Room: ICU2
Loc: 208

Vent. rate 83 BPM
PR interval * ms
QRS duration 88 ms
QT/QTc 420/493 ms
P-R-T axes * -59 150

Atrial fibrillation
Left axis deviation
Inferior infarct, age undetermined
Anterolateral infarct, age undetermined
Abnormal ECG

When compared with ECG of 08-NOV-2011 12:13, PREVIOUS ECG IS PRESENT

Technician: LB
Test ind: ROUTINE

Referred by: CV-WHO
CV-TIME 7.0605

Confirmed By
Case #13a: 54 y/o female with SOB
Case #13b: 63 y/o with chest pain

Rate: 41 bpm  
QRS: 100 ms  
R Axis: -30  
*Acute Inferoposterolateral MI  
Complete Heart Block  
Slight Left Axis Deviation

QT/QTc: 400 ms/331 ms

PRI: N/A
Case #13c: 23 y/o male with CP

Rate: 100 bpm  QRS: 80 ms  R Axis: 0  ST elevation in Multiple leads
PRI: 120 ms  QT/QTc: 360 ms/465 ms  Consider Pericarditis
“When is it time to want more?”
Case #4b: 56 year old with HTN (Extra LVH)

08-FEB-1955 (56 yr)
Male
Vent. rate 103 BPM
PR interval 152 ms
QRS duration 110 ms
QT/QTc 380.497 ms
F-R-T axes 48 2 128
Sinus tachycardia
Left ventricular hypertrophy with repolarization abnormality
Abnormal ECG
No previous ECGs available

Technician:
Test ind: ALOC

CV-WHO ?:

CV-TIME ?:

Referred by:

Confirmed By: ER DOCTOR READ ON CHART

25mm/s 10mH/mV 150Hz 71.1 125L 241 HD CID: 209
Case #5b: 81 y/o male (Extra RBBB)

Vent. rate: 44 BPM
PR interval: 230 ms
QRS duration: 158 ms
QT/QTc: 514/439 ms
P-R-T axes: 90 -41 -4

Marked sinus bradycardia with 1st degree A-V block
Left axis deviation
Right bundle branch block
T wave abnormality, consider lateral ischemia
Abnormal ECG

When compared with ECG of 23-NOV-2010 12:56,
PREVIOUS ECG IS PRESENT
Case #7d: 82 y/o smoker with dyspnea (MAT)

Rate: 145 bpm  
QRS: 60 ms  
R Axis: +60  
Multifocal Atrial Tachycardia

PRI: N/A  
QT/QTc: 300ms/460 ms
Case #8c: 18 y/o with dizziness (AVNRT)

Rate: 250 bpm  QRS: 50 ms  R Axis: +60  AV Nodal Rentry Tachycardia
PRI: N/A  QT: 260 ms
Case #8c: Continued........ (Post Vagal SVT to SR)

Rate: 90 bpm  
QRS: 50 ms  
R Axis: +60  
Sinus Rhythm

PRI: 160 ms  
QT/QTc: 360 ms/441 ms
Case #8d: 66 y/o with fast heart rate (VT)

Rate: 176 bpm
QRS: 120 ms
QT/QTc: 300 ms/ 510 ms

Ventricular Tachycardia
Right Axis Deviation
Case #8e: 24 y/o with palpitations (WPW)

Rate: 80bpm  
QRS: 100 ms  
R Axis: +30  
Wolff Parkinson White Syndrome

PRI: 80 ms  
QT/QTc: 400 ms/462 ms
Case #9b: 83 y/o female with HF

Rate: 80 bpm  
QRS: 200 ms  
Hyperkalemia  
PRI: N/A  
QT: 540 ms  
Right Axis Deviation
Case #11b: 60 y/o f/u appt with HF

Rate: 75 bpm  
QRS: 240 ms  
PRI: 120 ms  
QT/QTc: 460 ms/514 ms  
R Axis: +150  
Bi-Ventricular Pacemaker  
Right Axis Deviation
76 y/o post-op hip surgery (Mobitz I)
50 y/o with chest pain (Mobitz II)
53yo with dizziness (CHB)
77 y/o with headache (TBI)
24 y/o for routine physical (Dextrocardia)
90 y/o unresponsive man (Hypothermia)
<table>
<thead>
<tr>
<th>ASSESSMENT</th>
<th>LOOK AT</th>
<th>LOOK FOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Patient, Chart</td>
<td>Clinical condition, Changes over time</td>
</tr>
<tr>
<td>Rhythm and Rate</td>
<td>Rhythm Strip (Lead II)</td>
<td>Arrhythmias, Threats to perfusion</td>
</tr>
<tr>
<td>Ischemia/Infarction</td>
<td>All Leads, V1-V4 (anterior), V5-V6, aVL, I (latera), II, III, aVF (inferior)</td>
<td>ST changes, T wave changes, Q waves, Loss of R waves</td>
</tr>
<tr>
<td>Axis</td>
<td>Leads I and aVF</td>
<td>QRS upright in I and aVF (normal axis), QRS up in I, down in aVF (LAD), QRS down in I, up in aVF (RAD), QRS down in I and aVF (ERAD)</td>
</tr>
<tr>
<td>Chamber Enlargement</td>
<td>Atrial Enlargement</td>
<td>Diphasic P; Initial deflection is larger (RAE), Terminal deflection is larger (LAE)</td>
</tr>
<tr>
<td></td>
<td>V1—</td>
<td>Unusual P Morphology: Tall, peaked P wave (RAE), Notched P wave (LAE)</td>
</tr>
<tr>
<td></td>
<td>II—</td>
<td>High-Amplitude QRS Complexes: R wave longer than S (RVE), Extremely deep S (LVE)</td>
</tr>
<tr>
<td></td>
<td>Ventricular Enlargement</td>
<td>S wave larger than R (RVE), Extremely tall R (LVE)</td>
</tr>
<tr>
<td>Intraventricular Conduction Defects</td>
<td>V1—</td>
<td>Wide QRS: Notched R wave (REBB), Deep, slurred S wave (LBBB)</td>
</tr>
<tr>
<td></td>
<td>V6—</td>
<td>Broad S wave (RBBB), Broad notched R wave (LBBB)</td>
</tr>
<tr>
<td>Miscellaneous Abnormalities</td>
<td>All Leads</td>
<td>Tall, peaked T waves, Wide, flat P waves, Widening of QRS, Disappearing ST segment, Merging QRS and T</td>
</tr>
<tr>
<td><strong>Hyperkalemia</strong></td>
<td>All Leads</td>
<td>Flat T waves, Increasingly prominent U waves</td>
</tr>
<tr>
<td><strong>Hypokalemia</strong></td>
<td>All Leads</td>
<td>Prolonged QT interval (for rate)</td>
</tr>
<tr>
<td><strong>Hypercalcemia</strong></td>
<td>All Leads</td>
<td>Short QT interval (for rate)</td>
</tr>
<tr>
<td><strong>Hypocalcemia</strong></td>
<td>All Leads</td>
<td>Sloping ST segment, Diphasic or inverted T wave, ST depression, Short QT interval</td>
</tr>
<tr>
<td><strong>Digitalis Toxicity</strong></td>
<td>All Leads</td>
<td>Elevated, concave ST segment, Diffuse ST changes not correlated to coronary vessels</td>
</tr>
<tr>
<td><strong>Pericarditis</strong></td>
<td>All Leads</td>
<td>Diphasic or inverted T wave, Short QT interval, Sloping ST segment, Diphasic or inverted T wave, Short QT interval, Elevated, concave ST segment, Diffuse ST changes not correlated to coronary vessels</td>
</tr>
</tbody>
</table>
Websites/Videos

• http://www.youtube.com/watch?v=URBREKIUAlk
• http://www.youtube.com/watch?v=YsiNFaDtTYo
• http://www.youtube.com/watch?v=Mu71NqijEu0
• http://ecg.utah.edu/
• http://www.ecglibrary.com/ecghome.html
• http://lifeinthefastlane.com/resources/ecg-database/
• http://www.12leadecg.com/full/ecgindex.aspx
THANK YOU!!!

QUESTIONS?