THE ELECTROCARDIOGRAM
A UBQUITOUS AND COST-EFFECTIVE DIAGNOSTIC TOOL
FOR THE FAMILY MEDICINE REFRESHER COURSE
MARCH 8, 2019
Major Clinical Disorders
Pulmonary Embolism
69 y/o woman with dyspnea and an unremarkable chest film

- Sinus tachycardia
- RV conduction delay in V1 (rSR')
- S1Q3 pattern
- Pulmonary embolism
Q3T3/S1 Pattern

- S-waves in lead I
- Q-waves in lead III
- Inverted T-waves in lead III
39 y/o man with dyspnea and a muscle strain in his left leg

- Sinus tachycardia
- Right precordial T wave inversion
- Late QRS transition in the precordial leads
- Peaked P-wave in lead II

Pulmonary embolism

There is no “classic” ECG pattern for pulmonary embolism
Pericardial Disease
36 y/o man with chest pain

- Diffuse ST-segment elevation
- Depression of the PR segment best seen in II, III aVF, and V4-V6

Acute pericarditis
29 y/o with chest pain and dyspnea

- Diffuse ST-segment elevation
- PR-segment displacement
- Sinus tachycardia
- Low voltage QRS

Consider cardiac tamponade
62 y/o with increasing dyspnea

- Sinus tachycardia
- Low voltage QRS
- Electrical alternans, best seen in V3 and V4

Cardiac tamponade
Coronary Artery Disease
51 y/o man with chest pain prior to this ECG

- NSR with diffuse, deep, symmetric T wave inversions
- Sometimes called Wellens’ waves

Acute myocardial ischemia caused by proximal LAD lesion.

This patient found to have a non-obstructive LAD plaque and global hypokinesis in cath lab.

Possible coronary embolism
Elderly woman with known LBBB

- Sinus bradycardia
- LBBB
- Concordant T-wave direction in inferior leads, rather than the expected T-wave discordance
- "Sgarbossa's criteria"

Inferior ischemia/myocardial infarction in presence of LBBB
34 y/o man with chest pain

- NSR
- Anterior and lateral ST-segment elevation
- Inferior lead reciprocal ST-depression

Hyperacute anterior wall myocardial infarction
47 y/o man with chest pain and history of HBP and elevated lipids

This tracing has right sided precordial lead placement where V1R is equivalent to V2 in conventional left-sided lead placement

- NSR
- ST-elevation with q waves in the inferior leads
- ST-depression and T wave inversion in I and aVL are reciprocal
- ST-depression in V1 and V2R are consistent with posterior infarction
- ST elevation of ≥ 1 mm in V4R is consistent with RV free-wall infarction
53 y/o woman with jaw pain

- NSR
- ST elevation in leads I and aVL
- Reciprocal T-wave inversion in II, III, and aVF

Acute high lateral myocardial infarction (circumflex artery occlusion)
78 y/o man with paroxysmal nocturnal dyspnea. He has had this pattern for 5 years

- NSR
- First degree AV block
- Left atrial abnormality
- RBBB
- Pathologic anterior q-waves
- ST elevation V1-V5, I, and aVL

Findings are consistent with old anteroseptal myocardial infarction and LV anteropical aneurysm
41-year old with dizziness and dyspnea

- Sinus bradycardia with LBBB
- Sgarbossa criteria are satisfied in the inferior leads.
- The T waves are concordant rather than discordant with QRS complex
- Patient experiencing an acute inferior myocardial infarction
Pre-excitation
59 y/o woman with sudden palpitations and lightheadedness

Atrial fibrillation with pre-excitation through a WPW bypass tract

- Note the delta waves and exceptionally fast rate.

-Differential Diagnosis
VT, SVT with aberrancy, WPW with Afib

-Treatment
Digoxin, verapamil, diltiazem, and adenosine may result in acceleration of conduction across the bypass

Treatment of choice: IV procainamide or DCCV
44 y/o man with chest pain

- NSR with WPW conduction

The WPW Triad

Short PR interval

Wide QRS complex

Delta wave

In this tracing, the delta waves are positive in the precordial leads and in II, III, and aVF. The delta wave is negative in aVL. This is indicative of a left lateral bypass tract.
39 y/o man with very abnormal ECG

- NSR with WPW conduction

See again the WPW triad

The delta wave is downgoing in II, III, and aVF, and have upward orientation in I, aVL, and V2-V5 consistent with a posterior bypass tract

The WPW pattern may be mistaken for LVH or a bundle branch block
51 y/o woman with palpitations

- Atrioventricular reentrant tachycardia (the most common form of reentrant tachycardia in WPW)
- The down-going limb uses the AV node and the limb returning to the atria is retrograde across a bypass tract (no delta wave)
- Notice retrograde P-waves in the ST segment (inverted in II, III, and aVF, and upright in AVR)
- Notice the long R-P interval

Differential diagnosis

- AV nodal reentrant tachycardia with prolonged retrograde (fast pathway) limb
- Low atrial tachycardia with exceptionally long PR interval
Narrow Complex Tachycardias
60 y/o woman with sudden onset of palpitations

- AV nodal reentrant tachycardia (AVNRT)
- Very regular
- Very fast
- Caused by reentry loop in AV node
- The atria and ventricles are stimulated almost simultaneously
- Retrograde P-waves in this tracing are in the QRS complex
- Retrograde P-waves may be seen just before or after the QRS as well.
- Responds to vagal maneuvers, adenosine, diltiazem, verapamil, and sometimes beta blockers
Elderly man with severe aortic stenosis

- Multifocal atrial tachycardia
- Irregular narrow complex tachycardia
- P waves before each QRS
- 3 or more P-wave morphologies—see II, III, and aVF
Elderly woman with CAD risk factors

- Wandering atrial pacer
- 3 or more P-wave morphologies and PR intervals
- Rate less than 100 bpm
- Can be seen in setting of high vagal tone and during sleep
- No therapy required
Elderly woman with recurrent palpitations

- AV nodal reentrant tachycardia
- Pseudo S-waves in II and pseudo r waves in aVR and V1 are retrograde P-waves
Elderly man with palpitations

- Atrial fibrillation with RVR
- Notice the large fibrillatory waves in V1 which could be mistaken for p-waves or flutter waves
54 y/o man with palpitations who had a MV replacement

- Paroxysmal supraventricular tachycardia 160 bpm
- Note the P waves embedded in the T-waves in lead II
- The differential diagnosis includes atrial flutter (no flutter waves seen), sinus tachycardia (too fast), atrial fibrillation (too regular), MAT (too regular)
64 y/o man with hypertension and palpitations

- Atrial flutter at 270 bpm with 2:1 block
- Note the negative flutter waves in II, III, and aVF and positive flutter waves in V1 and V2
- This is typical or clockwise atrial flutter
QT/QU Disorders
49 y/o man with progressive muscle weakness and constipation

- NSR with very short ST segment and QT interval < 300 msec

- The differential diagnosis of a short QT interval includes Hypercalcemia, Digoxin therapy, and hereditary short QT syndrome, a channelopathy associated with ventricular arrhythmias and sudden cardiac death

- Hypercalcemia can be associated with AV block, sinus arrest, sino-atrial block, VT, and cardiac arrest when IV calcium is injected rapidly.

- This patient's calcium was 16
Young Asian adult man with Grave’s Disease and weakness

- Sinus tachycardia with very long QT interval, really the QU interval. The P-waves are superimposed on the QU waves. See V3 and V4.
- Consistent with hypokalemia
- There is an association between Graves disease and hypokalemia known as thyrotoxic periodic paralysis reported in Asians.
- This patient’s potassium was 1.9.
- What arrhythmia is this ECG associated with?
- Long QTc caused by tricyclics
- Torsade de pointes type of polymorphic VT would be most common arrhythmia
Young man resuscitated from sudden death episode. What is the treatment?

- NSR with Brugada Type 1 ECG pattern
- Sodium channel channelopathy
- Treatment is an AICD
What is the one serum lab test you should order in this case?

- NSR with long QT interval with long ST-segment
- Caused by hypokalemia
Bradycardia and Conduction Block
Elderly man with dizziness and renal failure

- NSR with first degree AV block, flat P waves, very long QRS duration and peaked T-waves
- Consistent with hyperkalemia and K of 7.6.
- Further elevation of K will have P-waves become flat (sino-ventricular rhythm) and eventually a sinusoidal wave and cardiac arrest.
69 y/o woman with atrial tachycardia following one procedure and before another

- Atrial tachycardia with more than one focus and complete (3rd degree) AV block
- The deep T-wave inversions are memory T-waves as the patient had been paced from the RV apex before this procedure
61 y/o man with bradycardia

- NSR with 2:1 AV block and LBBB
- There is IWI in background
- Location of block probably infra-nodal because of wide QRS and only minimal first degree AV block
60 y/o woman with chest pain and the antiphospholipid syndrome

- NSR with 4:3 AV nodal Wenkebach (Mobitz I) block
- Acute evolving infero-posterior myocardial infarction
Asymptomatic 85 year old man

- NSR with 2:1 AV block, LVH, LAE
- Notice normal PR-interval and narrow QRS complex
- Location of block may be in His bundle
Middle-aged man with dizziness and lightheadedness several weeks after AV replacement

- NSR with 2:1 AV block and right bundle branch block
- Also notice LVH, LAE, and long QT interval
- Deep T-wave inversions are not ischemic and may sometimes be seen in brady-arrhythmias and syncope and are thought to be neural in origin.
Critically ill man

- NSR with long first degree AV block
- There is intermittent complete LBBB, not Accelerated idioventricular rhythm. Abrupt normalization of conduction at about the same heart rate.
- What’s interesting is that there is an acute IWMI present with ST-elevation (aVF) can be seen in the presence of the complete LBBB and that’s unusual
86 y/o man with slow pulse and fatigue

- Atrial fibrillation with slow, regular ventricular response
- This reflects complete heart block with junctional escape rhythm
- The QT interval is long and there are U waves present
- Look for reversible causes of AV block such as beta blockers, calcium channel blockers, or digoxin. If none he will require a ventricular pacemaker and anticoagulation
- Digoxin not likely, since it shortens the QT interval
Elderly man with profound weakness

- Sinus tachycardia with 4:3 Mobitz 2 second degree AV block
- Notice the RBBB and left anterior fascicular block and possible LVH
Ventricular Arrhythmias
74 y/o woman with palpitations

- Sustained monomorphic ventricular tachycardia at 130 beats per minute
- Notice the RBBB configuration making a LV origin likely
- The ST depression and T-inversion could reflect ischemia or it may not.
- Not seeing AV-dissociation or capture beats does not exclude VT
- This patient had a posterior wall LV aneurysm as the site of origin of the VT, and which could account for its severe right axis deviation
Patient with palpitations

- NSR with alternating wide QRS complexes.
- This is ventricular bigeminy with coupled PVC’s fusing with every other conducted beat. The PVC morphology is that of RBBB.
- The differential diagnosis of an alternating rhythm includes
  - WPW syndrome, but there are no delta waves
  - Intermittent RBBB
  - Electrical alternans in tamponade—usually sinus tachycardia with normal QRS duration and 2:1 alternation of QRS height
67 y/o man who is having an acute antero-septal myocardial infarction

- Accelerated idioventricular rhythm. There is an atypical RBBB pattern. There is an anterior injury current present
- The rate is 83 beats per minute which is too slow for VT and too fast for complete heart block
- AIVR can be a marker for reperfusion in acute myocardial infarction
This ECG was obtained during a treadmill stress test

- Bidirectional ventricular tachycardia
- It is a polymorphic VT with alternating left and right axis deviation
- It may be seen in digitalis intoxication
- Or as in this it may be caused by an inherited calcium channel channelopathy known as catecholaminergic ventricular tachycardia which is precipitated by exercise and emotional stress
- Treatment starts with beta blocker, then flecainide, an IVCD, or left stellate ganglion sympathetic ablation
74 y/o woman with syncope

- Atrial fibrillation with ventricular pacing and failure to sense (seen throughout tracing)
- Polymorphic ventricular tachycardia of the torsade de pointes type
- Often caused by meds or inherited as a potassium channel channelopathy
- Prolonged repolarization with early afterdepolarizations
Tracing recorded during cardiac resuscitation

- Ventricular fibrillation
- Note the absence of any atrial activity excluding a fib or flutter with aberrancy or preexcitation
- Note the regularization in the right side of tracing often referred to as ventricular flutter
Anatomical Lesions
25 y/o woman with atypical chest pain

- NSR with dextrocardia

-Dextrocardia is the rotation of the heart so that the left atrium (LA) and ventricle are on the right side of the right atrium (RA) and right ventricle (RV). The apex of the heart is formed by the left ventricle (LV) that faces the right axillary line in the right side of the chest

-The ECG findings are inverted p-waves in I and aVL, negative p-waves and QRS in I, and progressively decreasing voltage across the precordium

The differential diagnosis of negative P waves may be seen with arm lead reversal.

-Note that the qrs and T waves in lead II look like what you might express in lead III

-Dextrocardia in adults usually accompanied by situs inversus of the abdominal viscera.

-The presence of the heart in the right side of the chest with the LA and LV remaining to the left of the RA and RV is called dextroversion when this is a primary process and dextroposition when it results from hyperinflation of the lungs.
A middle-aged woman with murmur since childhood and dyspnea

- NSR with LAE, dominant r wave in V1 consistent with RV conduction delay, and RAD
- Suggests coexistence of left atrial and RV enlargement and is common in mitral stenosis
- Note the patient has a S1Q3T3 pattern and does not have acute pulmonary embolism
To refresh your memory, this is what a tracing looks like in pulmonary embolism:

- Sinus tachycardia
- RV conduction delay with r′/r ratio >1 in V1
- Q3T3S1
- Right precordial T wave inversion
- p-pulmonale
- There is no RAD in this tracing
68 y/o man with dyspnea

- Low grade sinus tachycardia
- Peaked P-wave in II (p-pulmonale) with a right ward p-wave axis (inverted p-wave in aVL)
- Persistent rS complexes to V3 or beyond
- Vertical frontal plane axis +85 degrees, but not RAD
- Tracing reflects RV dilatation
35 y/o man with systolic heart murmur

- NSR with prominent septal voltage in V1 and V2
- Deep q-waves across the precordium
- Typical tracing in hypertrophic obstructive cardiomyopathy (HOCM or IHSS)
Bundle Branch Blocks
The Normal Sequence of Activation of the Heart

<table>
<thead>
<tr>
<th>Normal Activation Sequence</th>
<th>Structure</th>
<th>Conduction velocity (m/sec)</th>
<th>Pacemaker rate (beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SA node</td>
<td>&lt; 0.01</td>
<td>60 – 100</td>
</tr>
<tr>
<td>2</td>
<td>Atrial myocardium</td>
<td>1.0 – 1.2</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>AV node</td>
<td>0.02 – 0.05</td>
<td>40 – 55</td>
</tr>
<tr>
<td>4</td>
<td>Bundle of His</td>
<td>1.2 – 2.0</td>
<td>25 – 40</td>
</tr>
<tr>
<td>5</td>
<td>Bundle branches</td>
<td>2.0 – 4.0</td>
<td>25 – 40</td>
</tr>
<tr>
<td>6</td>
<td>Purkinje network</td>
<td>2.0 – 4.0</td>
<td>25 – 40</td>
</tr>
<tr>
<td>7</td>
<td>Ventricular myocardium</td>
<td>0.3 – 1.0</td>
<td>None</td>
</tr>
</tbody>
</table>
Sequence of Activation in RBBB (Vector Cardiogram)
Sequence of Activation in LBBB (Vectorcardiogram)
The Left Sided Conduction Fascicles

Hemiblock / Fascicular Block

- The Left Bundle Branch divides into 3 separate fascicles
  - Septal fascicle innervates the ventricular septum
  - The anterior fascicle runs toward the anterolateral papillary muscle and projects anterior, leftward, and superior
  - The posterior fascicle runs toward the posterior papillary muscle and projects posterior, rightward, and inferiorly
  - Normal electrical activation of the LV spreads simultaneously from the base of the two papillary muscles
Left Anterior Fascicular Block

The direction of the activation is initially inferior and later superior.
Left Posterior Fascicular block

The direction of the activation is initially superior and later inferior.
Thank you for listening