NORMAL AND ARRHYTHMIC ECG INTERPRETATION

THE ELECTROCARDIOGRAM – LOOKING AT THE HEART OF ELECTRICITY

- The electrocardiogram or ECG (sometimes called EKG) is today used worldwide as a relatively simple way of diagnosing heart conditions. An electrocardiogram is a recording of the small electric waves being generated during heart activity.

EINTHOVEN’S TRIANGLE

THE P WAVE

- The P wave
- Normal atrial activation is over in about 0.10s, starting in the right atrium. A good place to look at P waves is in II, where the P shouldn't be more than 2.5mm tall, and 0.11 seconds in duration.
- A tall P wave (3 blocks or more) signifies right atrial enlargement, a widened bifid one, left atrial enlargement:

CAUSES OF RIGHT ATRIAL ENLARGEMENT

- Causes of right atrial enlargement include COPD, mitral stenosis, mitral regurgitation, or pulmonary emboli. Because RAE is so frequently seen in chronic pulmonary disease, the peaked P wave is often called “P pulmonale.”

P-PULMONALE, WHICH IS AN INDICATION OF RIGHT ATRIAL
P-MITRALE, WHICH IS INDICATIVE OF LEFT ATRIAL ENLARGEMENT.

RVH CRITERIA

- RVH Criteria
  R in V1 > 7 mm or > S wave
  T in V1 inverted
  Right axis deviation
  S waves in V5-V6
- True posterior infarction may also cause a tall R wave in V1, but the T wave is usually upright, and there is usually some evidence of inferior infarction (ST-T changes or Qs in II, III, and F).
LVH

- SOKOLOW LYON INDEX
- $SvI+(Rv5 \text{ or } Rv6)>35\text{mm}$
- CORNELL VOLTAGE CRITERIA
- $Sv3+RaVL>28\text{mm in males and }>20\text{mm in fem}$
- $R\text{ I}+S\text{ III}>25\text{mm}$
- $R\text{ in aVL}>11\text{mm}$

BIVENTRICULAR HYPERTROPHY (BVH)

One ventricle is hypertrophied the ECG signs reflecting the other ventricle are usually diminished thus if the ECG shows mean or increased values for the other ventricle then BVH is present. Another criterion is abnormal summated voltages in V4 - usually greater than 60 mm.

ECG IN MI

ELECTROLYTE DISTURBANCES

- The normal state of cardiac cell membrane polarization is dependent upon the
maintenance of a normal ionic balance across the membranes, with K+ being the most important.

- Because changes in intracellular K+ concentration are proportionately much smaller than changes in extracellular K+ concentration, it follows that the **absolute level of extracellular K+ concentration is the single most important factor** affecting the cell membranes.

**HYPERKALAEMIA**

- All of the ECG changes that occur with a raised K+ concentration are non-specific and may affect any part of the ECG.

**The typical progressive changes of hyperkalemia are as follows:**

- Appearance of tall, pointed, narrow T waves.
- Decreased P wave amplitude, decreased R wave height, widening of QRS complexes, ST segment changes (elevation/depression), hemiblock (esp. left anterior) and 1st degree heart block.
- Advanced intraventricular block (very wide QRS with RBBB, LBBB, bi- or tri-fascicular blocks) and ventricular ectopics.
- Absent P waves, very broad, bizarre QRS complexes, AV block, VT, VF or ventricular asystole.

**HYPOKALAEMIA**

- ECG changes in decreasing order of frequency are:
  - ST segment depression, decreased T wave amplitude, increased U wave height
  - Cardiac arrhythmias
  - Prolongation of the QRS duration, increased P wave amplitude and duration
  - Various types of arrhythmias may occur in hypokalaemia. These may include atrial and ventricular ectopics, atrial tachycardia, heart blocks, VT and VF.
HYPERCALCAEMIA

- The main change is **reduction in the Q-T interval** on the ECG. The T wave duration is unaffected but the ST segment duration is shortened. Patients with hypercalcaemia have an increased sensitivity to digitalis and may present with a variety of arrhythmias.

HYPOCALCAEMIA

- The main ECG change is **prolongation of the Q-T interval**. There is no increase in T wave duration but the ST segment is prolonged.

HYPMAGNESAEIA

- In hypomagnesaemia, there is flattening of the T waves, ST segment...
depression, prominent U waves and, occasionally, a prolonged P-R interval occurs.

**HYPERMAGNESAEAMIA**

- In hypermagnesaemia, there may be a prolonged P-R interval and widened QRS complexes.

**ECG CHANGES IN SYSTEMIC DISORDERS**

- The electrocardiogram can be altered by various conditions that are external to the heart.
- Some of these ECG changes are caused by direct cardiac involvement, whereas others result from undetermined mechanisms.
- These external conditions include physical changes to the heart's position in the thoracic cavity, temperature effects on the heart, abnormal neurologic input to the heart, hormonal abnormalities, increased pressure within the cardiovascular system, or the interposition of fluid or tissues between the heart and the electrodes of the ECG.
- These ECG findings are often of low sensitivity and specificity in the diagnosis of the noncardiac disease and they may add confusion to arriving at a correct diagnosis.
- Mimics of acute myocardial infarction (AMI) could, for example, lead to unnecessary thrombolytic therapy with serious consequences.
- Some ECG findings are helpful in arriving at the correct noncardiac diagnosis.

**ACUTE PULMONARY EMBOLISM**

- The patient who has suspected PE often has chest pain and dyspnea, and an ECG invariably is obtained as part of the initial evaluation.
- The differential diagnosis in these cases often includes acute coronary syndrome.
- The ECG is still useful, however, when evaluating a patient who has suspected PE.
- Certain specific ECG abnormalities can make an alternative diagnosis more likely or may be used to assess the severity or prognosis of a PE.
- This causes right atrial enlargement and right ventricular dilation. This leads to a right ventricular strain pattern and acute right bundle branch block or incomplete RBBB.
- In addition, right atrial enlargement manifests as increased height and width of the initial component of the P wave. This is best seen in leads II and V1.
- Right ventricular enlargement may cause a directional change of the QRS complex waveform from positive to negative in lead I and from predominantly negative to positive in lead V6.
• Other ECG findings can mimic ACS, such as slight ST segment elevation and shallow T-wave inversion in the inferior leads.

**ECG OF PE**

![ECG Image]

**Fig. 1.** A 40-year-old woman with acute pulmonary embolism. ECG demonstrates sinus rhythm, RBBB, and ST segment/T-wave changes concerning for myocardial ischemia.

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**P.E.**

• Studies have found that in non-massive PE the most common ECG manifestation is normal sinus rhythm.

• RBBB or incomplete RBBB is a highly variable finding, with a range of 6%–67%, and is likely caused by the size and hemodynamic impact of the PE.

• Other changes associated with PE but lacking sufficient sensitivity or specificity to be helpful, are atrial fibrillation or flutter, sinus tachycardia, axis change, transition zone shift, and ST segment and T-wave changes.

• The 12-lead ECG is of limited value in the diagnosis of PE, because there are no ECG findings that are unequivocally diagnostic of PE.

The usefulness of the ECG in the patient who has suspected PE is in excluding the diagnosis of other conditions, such as acute MI, cardiac ischemia, and pericarditis. Although the ECG in patients who have massive PE is more specific, the clinical presentation is likely more helpful in arriving at the correct diagnosis.

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**PULMONARY HYPERTENSION**

• Pulmonary hypertension (PH) is an elevation of the pressure in the right side of the heart and the final hemodynamic abnormality resulting from many different etiologies.

• In the early stages the disease is difficult to recognize, but the ECG findings may offer a clue.

• Common findings include those that reflect a significant increase over normal in the contribution of the right-sided cardiac structures to the ECG.

**PAH**
• As the left ventricular mass normally is three times that of the right ventricle, a doubling or tripling of right ventricular mass is required to pull the electrical forces anteriorly and to the right to produce recognizable ECG changes.

• The ECG manifestations of right ventricular hypertrophy or enlargement include right axis deviation, incomplete RBBB, prominent R-wave amplitude in lead V1 (R > OS-wave amplitude), qR pattern in lead V1, and rS complexes in the left precordial leads.

• False patterns of RV hypertrophy can occur in patients who have posterior-wall MI, complete RBBB with LPFB, and Wolff-Parkinson-White syndrome.

**ECG of PAH**

![ECG of PAH](image)

*Fig. 2. A 21-year-old woman with pulmonary hypertension. ECG demonstrates rightward deviation of the QRS axis, a qR pattern in lead V1, and S wave > R wave amplitude in lead V6—all consistent with RVH. Echocardiography confirmed the diagnosis.*

**AORTIC DISSECTION**

• Aortic dissection is the most common acute disease of the aorta and it is a diagnosis that should be considered in all patients presenting with chest pain or back pain.

• It is caused by blood dissecting into the aortic media after a transverse tear of the aortic intima.

• An ECG is useful in excluding MI but can be misleading in some cases.

• A study from Japan of 89 patients who had acute aortic dissection demonstrated that 55% of the type A dissections had acute ECG changes.

• These included ST segment depression or elevation and T-wave changes.

• Only 22% of type B dissections had acute ECG changes, none with ST elevation.

• The most common complication in type A patients was cardiac tamponade (45%)

**ECG of AD**
• The most important use of the ECG is to distinguish acute ST segment elevation MI from AD.

• Both conditions can coexist, however, when an aortic dissection proceeds retrograde and involves the coronary artery ostium, most commonly the right coronary artery, causing acute proximal coronary artery occlusion.

• This can produce ST segment elevation in the territory of the occluded coronary artery.

• Most patients who have AD and ACS have nonspecific ST segment/T-wave changes rather than ST elevation.

• As hypertension is common in these patients, the ECG can show left ventricular hypertrophy.

• Dissection also can extend proximally into the atrial septum and atrioventricular (AV) conduction system and cause heart block.

• In addition, blood can track into the pericardium, causing decreased voltage on the ECG and perhaps hemodynamic compromise.

Central Nervous System Disease

• Acute central nervous system (CNS) events, such as intracranial hemorrhage, trauma, increased intracranial pressure, and nonhemorrhagic strokes, often produce various ECG abnormalities.

• The most common ECG abnormalities are diffuse repolarization abnormalities, such as T-wave changes, ST segment alterations, QT interval prolongation and dispersion, and U-wave changes.

CNS DISEASES

• Subarachnoid hemorrhage (SAH) produces ECG changes in up to 80% of patients.

• The physiologic basis of these abnormalities is controversial but may involve increases in sympathetic and vagal tone that are CNS mediated or actual myocardial
The most common ECG findings include widening and inversion of T waves in the precordial leads, prolonged QT interval, and bradycardia.

**ECG OF ICH**

- Increased intracranial pressure, often associated with intracranial hemorrhage (ICH), produces morphologic ECG changes and rhythm disturbances.
- Morphologic changes include prominent U waves, ST segment/T-wave changes, notched T waves, and shortening or prolongation of QT intervals.
  - A recent study of 50 patients who had ICH demonstrated that increased QT dispersion on the initial ECG is an important prognostic factor.
  - QT dispersion is the difference between the longest and shortest QT intervals on a 12-lead ECG. Increased QT dispersion is associated with an increased risk for arrhythmia.
  - Patients who had brainstem involvement had the largest QT dispersion and the highest mortality but not necessarily from arrhythmias.
  - A case has been published of a patient who had a brainstem hemorrhage, prolonged QT interval, and torsades de pointes.
  - The patient developed T-wave alternans, which is related to ventricular electrical instability and is a marker of vulnerability to ventricular arrhythmias. It is believed that increased catecholamine release is implicated in this process.

**STROKE**
• Acute ischemic stroke at times is associated with ECG findings of acute myocardial infarction or atrial fibrillation. Patients who have an acute ischemic stroke and an abnormal ECG have significantly higher 6-month mortality when compared with stroke patients who have a normal ECG.

• Thromboembolic stroke patients often demonstrate prolonged QT intervals, ST segment/T-wave abnormalities, and prominent U waves. In addition, these stroke patients often experience ventricular ectopy.

**HYPOTHERMIA**

• In hypothermia a number of specific changes can be seen:
  • Sinus bradycardia
  • Prolonged QTc-interval
  • ST segment elevation (inferior and left precordial leads)
  • Osborne-waves (slow deflections at the end of the QRS-complex)

A 12 lead ECG of a patient with a body temperature of 32 degrees Celsius. Note the sinus bradycardia, the prolonged QT interval (QTc is not prolonged) and the Osborne J wave, most prominently in leads V2-V5

An ECG of a patient with a body temperature of 28 degrees Celsius

**COCAINE INTOXICATION**

• The QRS complexes are somewhat bizarre in appearance, and demonstrate a rightward axis. The causes of an irregular rhythm at a normal rate with wide QRS intervals include an irregular rhythm (such as atrial fibrillation) with aberrancy, hyperkalemia, and drug toxicity. The QRS morphology is not typical of usual aberrant patterns
such as bundle branch block.

**VARIOUS DISORDERS CAUSING INSIGNIFICANT ECG CHANGES**

- **Hyperthyroidism**
  - ECG manifestations of hyperthyroidism frequently are encountered, although no abnormality is pathognomonic for this condition. Sinus tachycardia is the most common cardiac arrhythmia observed in patients who have hyperthyroid conditions and occurs in approximately 40% of cases[1,35]. Atrial fibrillation occurs in 10%–22% of hyperthyroid patients and usually is associated with a rapid ventricular response.

- **Hypothyroidism**
  - The ECG manifestations of hypothyroidism include sinus bradycardia, low voltage complexes (small P waves or QRS complexes), prolonged PR and QT intervals, and flattened or inverted T waves. Pericardial effusions occur in up to 30% of hypothyroid patients and may be responsible for some of the ECG manifestations.

**DIABETES MELLITUS**

- ECG of a 64-year-old woman with type 2 diabetes mellitus without other risk factors. Note the deep S-wave (arrow) in LIII (19 mm) and the high R-wave in aVL (15 mm); ECG indicates basal left ventricular hypertrophy.

**MESSAGE**
• Do not rely entirely on ECG.
• Correlate the ECG findings with the clinical assessment.
• Always remember that it is the patient who should be treated, not the ECG.
• An ECG is an aid to diagnosis, not a substitute for further thought.

Thanks