Systematic ECG analysis and interpretation

1- Calibration / speed
2- Rate
3- Rhythm / Regularity
4- Cardiac Axis
5- P wave
6- QRS Complex
7- T wave
8- U wave
9- PR interval
10- QT interval
11- PR segment
12- ST segment
13- Other waves (delta, osborne, epsilon, pacing spikes, artifacts)
Case 1

A 65-year-old man known hypertensive and CRF, presented with generalized weakness, muscle cramps and palpitation

O/E:
Pulse: 100/m
B.P: 180/90

The T waves are tall especially in lead V3; they are symmetric, narrow, pointed and tented, as if pinched from above. These findings are characteristic of hyperkalemia.
CAUSES OF HYPERKALEMIA

- Renal failure
- Hypoaldosteronism (Addisons disease)
- Drugs
  - ACE- inhibitors
  - Potassium-sparing diuretics
- Obstructive uropathy
- Redistribution of potassium
  - acidosis
  - hyperkalemic periodic paralysis (familial)
  - hypertonicity (mannitol, hyperglycemia)
  - cellular damage - burns, crush injury
  - severe physical exertion

Pseudohyperkalemia

*hemolysis during blood sampling or centrifuging
ECG CHANGES

ECG signs may be absent if the onset of hyperkalemia is slow - as seen in chronic renal failure - even though the serum potassium is in the range of 7 - 7.5 meq/L;

**Acute hyperkalemia** can produce ECG signs at much lower serum potassium levels.

- **Serum K⁺ > 5.5 mEq/L** is associated with **repolarization abnormalities**:
  - Peaked T waves (usually the earliest sign of hyperkalaemia)

- **Serum K⁺ > 6.5 mEq/L** is associated with **progressive paralysis of the atria**:
  - P wave widens and flattens
  - PR segment lengthens
  - P waves eventually disappear

- **Serum K⁺ > 7.0 mEq/L** is associated with **conduction abnormalities & bradycardia**:
  - Prolonged QRS interval with bizarre QRS morphology
  - High-grade AV block with slow junctional and ventricular escape rhythms
  - Any kind of conduction block (bundle branch blocks, fascicular blocks)
  - Sinus bradycardia or slow AF
  - Development of a **sine wave** appearance (a pre-terminal rhythm)

- **Serum K⁺ > 9.0 mEq/L** causes **cardiac arrest** due to:
  - Asystole
  - Ventricular fibrillation
  - PEA with bizarre, wide complex rhythm
Acute STEMI, the T wave is initially tall and is called hyperacute T wave changes — “more acute than acute.” In such a case, the T wave is symmetric but not narrow, not pointed, and not tented.

T waves are tall in leads V3 and V4; they are not symmetric (the upstroke takes more time than the downstroke) and they are not narrow. In some patients, tall T waves like those shown are normal.
Hyperkalemia
Sinus rhythm
The QRS complexes are wide even for the RBBB.
The PR interval is long.
T waves are tall, tented, and pointed, especially in V4
The patient is an elderly man who presented to the emergency ward with dizziness and new renal failure.

- Hyperkalemia (7.6 mEq/L) secondary to renal failure. Widening of the QRS complex. There is also peaking of the T waves with prolongation of the PR interval and flattening of the P waves.

- Note the wide QRS complexes with no evident P waves.
- CK was normal and ST elevations were likely due to hyperkalemia.
Systemic hypothermia. The arrows (V3 through V6) point to the characteristic convex J waves, termed Osborn waves. Prominent sinus bradycardia is also present.
HYPOKALEMIA

ECG changes in hypokalemia

1. Flattened T waves and prominent U waves (apparent QT interval prolongation)

Note the prominent U wave in leads V3 and V4 giving the conjoined T-U wave the appearance of a "camel's hump"
2. Prominent U waves combined with depressed ST segments and flattened T waves (“roller-coaster effect”)

- note the depressed ST segments with flattened/equiphasic T waves in leads V4 and V5 and V6
- note the small flattened T wave in leads V2 and V3 and how the ST segment dips down slightly (just after the flattened T wave) before rising to the prominent U wave (that has merged with the following P wave) creating a "roller-coaster" effect

Case. A 22 year old lady with prolonged vomiting.

This lady's serum potassium was 1.8 mmol/L.
Causes of Hypokalemia

Inadequate intake
• diet very low in potassium

Excessive gastro-intestinal loss
• secretory diarrhea
• GIT fistula or small bowel enterostomy
• malabsorption syndrome
• excessive, voluminous vomiting
• laxative abuse

CAUSES OF HYPOKALEMIA

Excessive urinary loss
• hyperaldosteronism - primary or secondary
• osmotic diuresis
• diuretic drugs
• renal tubular diseases
CAUSES OF HYPOKALEMIA

Redistributional

- acute insulin administration during DKA => rapid potassium uptake by the cells
- beta-sympathomimetic therapy
- hypokalemic periodic paralysis - familial or associated with thyrotoxicosis
- excessive sweating or skin loss secondary to extensive burns

Determining the cause of the hypokalemia

Diuretic therapy is the most common cause of hypokalemia in ED patients
Alcoholism is also a common cause of hypokalemia in ED patients

Drug-induced hypokalemia

- beta agonists
- theophylline
- caffeine
- verapamil intoxication
- insulin overdose
- thiazides
- furosemide

- Mineralocorticoids
- aminoglycosides (Gentamycin)
- chewing tobaccos
- glucocorticoids
  High dose antibiotics
  - penicillin
  - ampicillin
  - carbenicillin
case. 30-yr-old man, not on medication, he had severe hypokalemia (1.5 mEq/L) due to diarrhea. Calcium and magnesium were normal.

- There are prominent U waves with Q-T(U) prolongation.
- This acquired-type long-QT(U) syndrome puts subject at risk for torsade de pointes.

31-year-old woman with ECG simulating ischemia. What metabolic abnormality should you suspect?

- K+ here was 2.2 mEq/L.
- Very severe hypokalemia can cause ST depressions and T-wave inversions as seen here, mimicking ischemia. But also note large U wave (positive deflection after ST-T and before P).
Normal tracing with a juvenile T wave inversion pattern in leads V1, V2, and V3, as well as early repolarization pattern manifested by ST segment elevation in leads I, II, aVf, V4, V5, and V6.
A 71-year-old woman in the ER with end stage renal disease developed mental status changes and had this ECG.

• "CVA-T wave pattern," especially with intracranial bleeds
• This ECG shows massive diffuse, very broad T wave inversions with marked QT or QT-U prolongation (see lead V3).

HYPERCALCEMIA

• Hypercalcemia is defined as a serum calcium > 10.5 mg/dl and severe hypercalcemia is defined as a serum calcium > 14 mg/dl (> 3.5 mmol/L)
ECG CHANGES IN HYPERCALCEMIA

- ECG may demonstrate a shortened QT interval and bradyarrhythmias

Case. 49-year-old man who presented with progressive muscle weakness, paresthesias, and constipation.

- Very short ST segment with a consequently short QT interval; and prominent U waves (esp. in V3). These changes are very suggestive of hypercalcemia.

- This patient's serum calcium was 16 mg/dl. He was found to have hyperparathyroidism.
case. 35-yr-old female in the ICU just admitted with suspected intestinal obstruction

Classic ECG for hypercalcemia (13.9 mg/dl here). Note the very abbreviated ST segment such that the T wave looks like it takes off directly from QRS in some leads.

Risk factors for hypercalcemia

- Hyperparathyroidism
- Malignancy
- Granulomatous disease
- Non-parathyroid endocrine disorders
  - hyperthyroidism
  - adrenal insufficiency
  - pheochromocytoma
Risk Factors for Hypercalcemia

- Vitamin D intoxication
- Vitamin A intoxication
- Mild alkali syndrome
- Chronic renal insufficiency, or dialysis patients taking vitamin D replacement therapy
- AIDS
- Drugs
  - lithium
  - aminophylline
  - thiazide diuretics

Hypocalcemia
ECG CHANGES

• Prolongation of the QT interval (ST segment portion) is typical of hypocalcemia.

Case. 34 yr Male, with muscle cramping & carpopedal spasms post thyroidectomy

Check the calcium level = was low 8.2 mg/dl in patient post thyroidectomy.
ECG shows QT prolongation. Most important is that QT is long in this case because the ST segment is stretched out.
CAUSES OF HYPOCALCEMIA

1. It may be consequence of thyroid or parathyroid surgery.
2. If phosphate raised then either:
   - Chronic renal failure
   - Hypoparathyroidism or pseudoparathyroidism.
3. If phosphate is normal or low then either:
   - Osteomalacia or pancreatitis

Hyperkalemia and Hypocalcemia (Ch. Renal Failure)
The QT interval is prolonged, especially in leads II, III, aVF, and V4-6, typical features of hypocalcemia. The T wave is typically left unchanged. T waves are tall, symmetric, narrow, and tented and are typical of hyperkalemia.
This combination of electrolyte problems is common in patients with renal failure.
SYMPTOMS OF HYPOCALCEMIA

- Symptoms include **muscle cramping or carpopedal spasms**, distal extremity paresthesia, positive Chvostek's and Troussseau's sign
- Smooth muscle contraction can cause laryngeal stridor, dysphagia and bronchospasm
- Altered mental status or seizures may occur

Digitalis effect

- Shortened QT interval
- Characteristic down-sloping ST depression, reverse tick appearance
- Dysrhythmias
A 64 year old lady on digoxin

THANK YOU