After this presentation, the learner will be able to describe the following:
- Labs used to evaluate renal function
- Life-threatening electrolytes
- CBC with differential
- Cardiac panel
- Coagulation studies
- Urine studies
- Labs used to identify sepsis

Labs Used to Evaluate Renal Function

Creatinine
- Creatinine is a chemical waste molecule that is generated from muscle metabolism.
- Creatinine is produced from creatine, a molecule of major importance for energy production in muscles.
- Approximately 2% of the body's creatine is converted to creatinine every day.
- Creatinine is transported through the bloodstream to the kidneys. The kidneys filter out most of the creatinine and dispose of it in the urine.

Creatinine
- The kidneys maintain the blood creatinine in a normal range.
- Creatinine has been found to be a fairly reliable indicator of kidney function.
- Elevated creatinine level signifies impaired kidney function or kidney disease.

BUN
- Blood urea nitrogen (BUN) test reveals how the kidneys and liver are working.
- BUN test measures the amount of urea nitrogen that is in the blood.
- Here's how the body typically forms and gets rid of urea nitrogen:
  - Liver produces ammonia — which contains nitrogen — after it breaks down proteins used by the body's cells.
  - Nitrogen combines with other elements, such as carbon, hydrogen and oxygen, to form urea, which is a chemical waste product.
  - Urea travels from the liver to the kidneys through the blood.
  - Healthy kidneys filter urea and remove other waste products from the blood.
  - The filtered waste products leave your body in the urine.
- BUN reveals whether urea nitrogen levels are higher than normal, suggesting that the kidneys or liver may not be working properly.

Normal Levels of Creatinine
- 0.6 to 1.2 milligrams/mL (adult males)
- 0.5 to 1.1 milligrams/mL (adult females)

Normal Levels of BUN
- 6 - 20 mg/dL
**BUN / Creatinine Ratios**

**Clinical Significance**
- The BUN/creatinine ratio is useful in the differential diagnosis of acute or chronic renal disease.

**BUN / Creatinine Ratio**

**Creatinine Clearance**
- A more precise measure of the kidney function can be estimated by calculating how much creatinine is cleared from the body by the kidneys.
- This is referred to as creatinine clearance.
- It estimates the rate of filtration by kidneys (glomerular filtration rate, or GFR).

**Creatinine Clearance**
- The creatinine clearance can be measured in two ways:
  - Calculation
  - Direct measurement from urine

**Calculation: Creatinine Clearance Rate**
- Cockcroft – Gault Formula
- Formula uses age, weight, gender, creatinine level

\[
C = \left(\frac{140 - \text{Age}}{\text{Weight} \times \text{Creatinine} \times \text{Factor}}} \right) \times \text{Factor}
\]

- Normal values are:
  - Male: 97 to 137 ml/min.
  - Female: 88 to 128 ml/min.

**Urine Studies**

**Urine Osmolality**
- The osmolality urine test measures the concentration of particles in urine.
- Osmolality (particles per kilogram of water) and osmolarity (particles per liter of solution) are sometimes confused.
- But for dilute fluids such as urine, they are essentially the same.

**Urine Osmolality**
- Normal values are as follows:
  - Random specimen:
    - 50 to 1200 milliosmoles per kilogram (mOsm/kg)
    - > 12 to 14 hour fluid restriction
    - > 850 mOsm/kg
High Urine Osmolality
- Heart failure
- Loss of body fluids (dehydration)
- Narrowing of the kidney artery (renal artery stenosis)
- Shock
- Sugar, or glucose, in the urine
- Syndrome of inappropriate ADH secretion (SIADH)

Low Urine Osmolality
- Damage to kidney tubule cells (renal tubular necrosis)
- Drinking too much fluid
- Kidney failure
- Severe kidney infection (pyelonephritis)

Life-Threatening Electrolytes

Electrolytes: Learning Objective
The learner will describe the following important electrolytes:
- Potassium
- Magnesium
- Sodium
- Calcium

Potassium
- The normal range is 3.7 to 5.2 mEq/L.
- Note: mEq/L = milliequivalent per liter
- Values vary slightly among different laboratories.

Hyperkalemia
- Too much potassium in the blood.
- Body needs a delicate balance of potassium to help the heart and other muscles work properly.
- Too much potassium can lead to dangerous, and possibly deadly, changes in heart rhythm.

Definitions of Hyperkalemia
Hyperkalemia
- Serum potassium level > 5.5 mEq/L.

Moderate hyperkalemia is a
- Serum potassium > 6.0 mEq/L.

Severe hyperkalemia
- Serum potassium > 7.0 mEq/L.

Causes of Hyperkalemia
- Kidneys do not work properly and cannot remove potassium from the body or if the body’s cells release too much potassium
- A hormone called aldosterone tells the kidneys when to remove potassium. Diseases that decrease the production of this hormone, such as Addison’s disease, can lead to hyperkalemia.

Causes of Hyperglycemia
- Sometimes, cells release too much potassium.
- Breakdown of red blood cells, called hemolysis
- Breakdown of muscle tissue, called rhabdomyolysis
- Burns, trauma, or other tissue injury
- Uncontrolled diabetes
Summary: Causes of Hyperkalemia
- Causes of high levels of potassium
  - Addison’s disease
  - Blood transfusion
  - Certain medications
  - Crushed tissue injury
  - Hypoaldosteronism
  - Kidney failure
  - Metabolic or respiratory acidosis
  - Red blood cell destruction
  - Too much potassium in your diet

Symptoms of Hyperkalemia
- Arrhythmias
  - Slow heart rate
  - Weakness

Arrhythmias
- Increased extracellular potassium reduces myocardial excitability, with depression of both pacemaking and conducting tissues.
- Progressively worsening hyperkalemia leads to suppression of impulse generation by the SA node and reduced conduction by the AV node and His-Purkinje system, resulting in bradycardia and conduction blocks and ultimately cardiac arrest.

Effects of Hyperkalemia on the EKG
- Peaked T waves (usually the earliest sign)
- P wave widens and flattens
- PR segment lengthens
- P waves eventually disappear
- Prolonged QRS interval
- AV block
- Bundle branch blocks
- Sinus bradycardia or slow AF
- Asystole
- Ventricular fibrillation
- PEA with bizarre, wide complex rhythm

Magnesium
- About half of the body’s magnesium is found in bone. The other half is found inside cells of body tissues and organs.
- Magnesium is needed for nearly all chemical processes in the body.
- It helps maintain normal muscle and nerve function, and keeps the bones strong.
- Magnesium is also needed for the heart to function normally and to help regulate blood pressure.
- Magnesium also helps the body control blood sugar level and helps support the body’s defense (immune) system.
- The normal range is 1.7 to 2.2 mg/dL.
- Value ranges may vary slightly among different laboratories.

Hypokalemia
- Causes of low levels of potassium
  - Chronic diarrhea
  - Cushing syndrome (rare)
  - Diuretics such as hydrochlorothiazide, furosemide, and indapamide
  - Hyperaldosteronism
  - Not enough potassium in the diet
  - Renal artery stenosis
  - Renal tubular acidosis (rare)
  - Vomiting

Peaked T Waves
- The normal range is 1.7 to 2.2 mg/dL.
- Value ranges may vary slightly among different laboratories.
High Magnesium Level

A high magnesium level may indicate:

- Addison disease
- Chronic renal failure
- Dehydration
- Diabetic acidosis
- Oliguria

Low Magnesium

- 10-20% of all hospital patients and 86-88% of patients in the ICU have hypomagnesemia.
- Low levels of magnesium in blood may mean that there is not enough magnesium in the diet, the intestines are not absorbing enough magnesium, or the kidneys are excreting too much magnesium.

Low Magnesium Level

- 10-20% of all hospital patients and 60-65% of patients in the ICU have hypomagnesemia.
- Low levels of magnesium in blood may mean that there is not enough magnesium in the diet, the intestines are not absorbing enough magnesium, or the kidneys are excreting too much magnesium.

S&S of Low Magnesium

- Deficiency of causes
- Weakness
- Muscle cramps
- Cardiac arrhythmia
- Increased irritability of the nervous system
- Confusion
- Hypertension
- Tachycardia
- Tetany

Arhythmia: Torsades de Pointes

Sodium

- The normal range for blood sodium levels is 135 to 145 mEq/L.
- Value ranges vary among different laboratories.

Ranges of Hyponatremia

- Mild hyponatremia: Between 130 and 135 mmol/L
- Moderate Hyponatremia: Between 125 and 129 mmol/L
- Profound hyponatremia: Less than 125 mmol/L

Hypernatremia

- Higher than normal sodium level may be due to:
  - Adrenal gland problems such as Cushing syndrome or Hyperaldosteronism
  - Diabetes insipidus (kidneys unable to conserve water)
  - Increased fluid loss (sweating, diarrhea, diuretics, burns)
  - Too much salt or sodium bicarbonate intake
  - Medicines (birth control pills, corticosteroids, laxatives, lithium, and NSAIDs)

Hyponatremia

- Lower than normal sodium level may be due to:
  - Addison disease (low cortisol, low aldosterone)
  - Ketonuria (fat breakdown)
  - Increase in body water (CHF, kidney diseases, or liver cirrhosis)
  - SIADH (Syndrome of inappropriate antidiuretic hormone secretion)
  - Increase hormone vasopressin
  - Medicines (diuretics, MSO4, SSRI antidepressants)
Treatment of Hyponatremia

For serious symptomatic hyponatremia:
- Hypertonic saline (1.5%, 2%, 3%)
  - Increase of 6 mmol/L over 24 hours
  - Additional 8 mmol/L during every 24 hours thereafter
  - Until sodium reaches 130 mmol/L
- Determine cause
  - Urine osmolality
  - Urine sodium
  - Vasopressin levels (dx SIAD)

SIAD Treatment
- Fluid restriction
- Loop diuretics and oral sodium chloride
- 0.9% saline 0.5 to 1.0 mL/kg per hour

Calcium

- Normal values range from 8.5 to 10.2 mg/dL.
- Ranges vary among different laboratories.

High Calcium Level

Causes of hypercalcemia
- One of the most common causes of high calcium levels (hypercalcemia), is an overproduction of parathyroid hormone, or hyperparathyroidism.
- Malignancy is a common cause of elevated blood calcium. Up to 20% of individuals with cancer will develop hypercalcemia at some point in their disease.

Low Calcium Level

Causes:
- Disorders that affect absorption of nutrients from the intestines
  - Hypoparathyroidism
  - Kidney failure
  - Low albumin
  - Liver disease
  - Magnesium deficiency
  - Osteomalacia
  - Pneumonitis
  - Vitamin D deficiency

High Calcium

Conditions associated with hypercalcemia include:
- Cancers, especially lung cancer and breast cancer
- Immobilization over a long period of time
- Kidney failure
- Hyperthyroidism or excessive thyroid hormone intake
- Medications such as the thiazide diuretics
- Inherited kidney or metabolic conditions
- Excessive vitamin D levels from vitamins, excessive dietary calcium, or from diseases that may result in excess vitamin D production

Arrhythmias

- In severe cases, the elevated calcium levels can cause abnormal heart rhythms.

CBC with Differential: Learning Objectives

The learner will be able to:
- Interpret components of a CBC and differential
- Interpret abnormal WBC and Neutrophil findings
- Identify Anemias / Polycythemas
- Explain the term “Shift to the Left”
- State guidelines for a blood transfusion

Introduction

The cells in the bloodstream are generally divided into three types:
- White blood cells (leukocytes)
- Red blood cells (erythrocytes)
- Platelets (thrombocytes)
**Introduction**

- High or low blood cell counts indicate the presence of many forms of disease.
- Therefore, blood counts are amongst the most commonly performed blood tests.

**Complete Blood Count (CBC)**

A CBC usually includes:
- White blood cell count (WBC)
- White blood cell types (WBC differential)
- Red blood cell count (RBC)
- Hematocrit (HCT)
- Hemoglobin (Hgb)
- Red blood cell indices
- Platelet (thrombocyte) count
- Mean platelet volume (MPV)

**White Blood Cell**

- White blood cells are known as leukocytes.
- WBCs protect the body against infection.
- When an infection occurs, WBCs attack and destroy the bacteria, virus, or other organism causing infection.
- The number of white blood cells is used to find an infection or to see how the body is dealing with treatment.
- When a person has a bacterial infection, the number of white cells rises very quickly.
- WBCs are bigger than red blood cells, but fewer in number.

**Types of White Blood Cells**

- The major types of white blood cells are:
  - Neutrophils
  - Lymphocytes
  - Monocytes
  - Eosinophils
  - Basophils
- Immature neutrophils, called band neutrophils, are also part of this test.
- Each type of cell plays a different role in protecting the body.

**Types of White Blood Cells**

- The numbers of each one of these types of white blood cells give important information about the immune system.
- Too many or too few of the different types of white blood cells can help find an infection, an allergic or toxic reaction to medicines or chemicals, and many conditions, such as leukemia.

**White Blood Cells**

White blood cells are classified into two main groups:
- **granulocytes**
- **nongranulocytes (AKA agranulocytes)**

**Granulocytes**

- The granulocytes have granules in their cell cytoplasm.
  - These include:
    - Neutrophils
    - Eosinophils
    - Basophils
- They have a multi-lobed nucleus.
- As a result, they are also called polymorphonuclear leukocytes or "polys."
- The nuclei of neutrophils also appear to be segmented, so they may also be called segmented neutrophils or "segs."

**Picture of WBCs**

- The picture shows different types of white blood cells, including neutrophils, lymphocytes, monocytes, eosinophils, and basophils.
Agranulocytes

- The nongranulocyte white blood cells do not have granules and have nonlobular nuclei.
- These include:
  - Lymphocytes
  - Monocytes
- They are sometimes referred to as mononuclear leukocytes.

Function of WBCs

- The lifespan of WBC ranges from 13 to 20 days, after which time they are destroyed in the lymphatic system.
- When immature WBCs are first released from the bone marrow into the peripheral blood, they are called "bands" or "stabs.
- WBCs fight infection through a process known as phagocytosis.
- During phagocytosis, the WBCs surround and destroy foreign organisms.
- WBCs also produce, transport, and distribute antibodies as part of the body's immune response.

WBC Physiology

- In response to an acute infection, trauma, or inflammation, white blood cells release a substance called colony-stimulating factor (CSF).
- CSF stimulates the bone marrow to increase white blood cell production.
- In a person with normally functioning bone marrow, the numbers of white blood cells can double within hours if needed.

Measurement of WBCs

- Total number of WBCs: reported as an absolute number of "X" thousands of white blood cells.
- Percentage of each of the five types of white blood cells. This test is known as a differential or "diff".

Normal WBC

- Total WBC: > 4,500-10,000 per microliter (mcL).

Increased WBCs

- Any infection or acute stress increases the number of white blood cells.
- High white blood cell counts may be due to inflammation, an immune response or blood diseases such as leukemia.
- An abnormal increase in one type of white blood cell can cause a decrease in the percentage of other types of white blood cells.

WBC Differential

- Determines if WBCs are present in normal proportion to one another or if immature cells are present.
- Used to help diagnose or monitor diseases and conditions.
### Differential

Each differential always adds up to 100%.
- To make an accurate assessment, consider both relative and absolute values.
- For example, a relative value of 70% neutrophils may seem within normal limits; however, if the total WBC is 20,000, the absolute value (70% x 20,000) would be an abnormally high count of 14,000.

### Normal Differential

**Normal Results (labs vary)**
- **Neutrophils**: 40% to 60%
- **Lymphocytes**: 20% to 40%
- **Monocytes**: 2% to 8%
- **Eosinophils**: 1% to 4%
- **Basophils**: 0.5% to 1%
- **Band (young neutrophil)**: 0% to 3%

### Shift to the Left

- An increased need for neutrophils, as with an acute bacterial infection, will cause an increase in both the total number of mature neutrophils and the less mature bands or stabs to respond to the infection.
- The term “shift to the left” is often used when determining if a patient has an inflammatory process such as acute appendicitis or cholecystitis.
- This term is a holdover from days in which lab reports were written by hand.
- Bands or stabs, the less mature neutrophil forms, were written first on the left-hand side of the laboratory report.
- Today, the term “shift to the left” means that the bands or stabs have increased, indicating an infection in progress.

### Neutrophils

- Neutrophils are so named because they are not well stained by either eosin, a red acidic stain, nor by methylene blue, a basic or alkaline stain.
- Neutrophils are also known as “seg,” or “polys” (polymorphonuclear).
- Primary defense against bacterial infection and physiologic stress.
- Most circulating blood are in a mature form, with the nucleus of the cell being divided or segmented.
- Because of the segmented appearance of the nucleus, neutrophils are sometimes referred to as "segs."
- The neutrophil forms native neutrophils in the bone marrow, but has a less mature neutrophils - those that have recently been released from the bone marrow into the bloodstream - are known as “bands” or “stab.”
- Stab is a German term for rod.

### High Count: Neutrophilia

- Acute bacterial infections
- Infections caused by viruses, fungi
- Inflammation:
  - Inflammatory bowel disease
  - Rheumatoid arthritis
  - Tissue death (necrosis)
  - Trauma
  - Major surgery
  - Heart attack
  - Burns
- Physiological (stress, rigorous exercise)
- Smoking
- Pregnancy - last trimester, labor
- Chemot leukemia

### Low Count: Neutropenia

- Myelodysplastic syndrome
- Severe infection (sepsis-neutrophils are used up)
- Reaction to drugs (e.g., penicillin, ibuprofen, phenytoin, etc.)
- Autoimmune disorder
- Chemotherapy
- Cancer that spreads to the bone marrow
- Aplastic anemia

### Lymphocytes

- Acute viral infections (hepatitis, chicken pox, CMV, EBV, herpes, rubella)
- Certain bacterial infections (e.g., pertussis, tuberculosis)
- Lymphocytic leukemia
- Lymphoma

### High Count: Lymphocytosis

- Acute viral infections (hepatitis, chicken pox, CMV, EBV, herpes, rubella)
- Certain bacterial infections (e.g., pertussis, tuberculosis)
- Lymphocytic leukemia
- Lymphoma

### Low Count: Lymphopenia

- Autoimmune disorders (e.g., lupus, rheumatoid arthritis, vasculitis)
- Infections (e.g., HIV, TB, hepatitis, influenza)
- Bone marrow damage (e.g., chemos, radiation)
- Immune deficiency

### Monocytes

- Chronic infections (e.g., tuberculosis, fungal infection)
- Infections within the heart (fungal endocarditis)
- Collagen vascular diseases (e.g., lupus, dermatomyositis, rheumatoid arthritis, vasculitis)
- Inflammatory bowel disease
- Myelogenous leukemia
- Chronic myelomonocytic leukemia
- Juvenile myelomonocytic leukemia
- Low Count: monocytopenia
- Usually, monocytosis is not medically significant.
- Increased monocytosis can indicate:
  - Bone marrow damage or failure
  - hairy-cell leukemia

### Eosinophils

- Asthma, allergies such as hay fever
- Drug reactions
- Inflammation of the skin (e.g., eczema, dermatitis)
- Parasitic infections
- Inflammatory disorders (e.g., ulcer disease, inflammatory bowel disease)
- Certain malignancies/cancers
- Aplastic anemia

### High Count: Eosinophilia

- Aplastic anemia
- Numbers are normally low in the blood
- Low value not medically significant
Basophils

- **High Count:** basophilia
  - Rare allergic reactions (e.g., hives, food allergy)
  - Inflammation (rheumatoid arthritis, ulcerative colitis)
  - Some leukemias

- **Low Count:** basopenia
  - Normally low in the blood
  - Low value not medically significant

RBC

- **Red Blood Cell (RBC) Count**
  - Carry O2 from lungs to rest of the body.
  - Carry CO2 back to lungs so it can be exhaled.
  - If the RBC count is low (anemia), the body may not be getting the oxygen it needs.
  - If the RBC count is too high (a condition called polycythemia), there is a chance that the red blood cells will clump together and block tiny blood capillaries.

Hematocrit (HCT)

- Also known as packed cell volume (PCV)
- Measures the amount of space (volume) red blood cells take up in the blood.
- The value is given as a percentage of red blood cells in a volume of blood.
- For example, a hematocrit of 38% means that 38% of the blood's volume is made of red blood cells.
- Hematocrit and hemoglobin values are the two major tests that show if anemia or polycythemia is present.

Hemoglobin (Hgb)

- The hemoglobin molecule fills up the red blood cells.
- It carries oxygen and gives the blood cell its red color.
- The hemoglobin test measures the amount of hemoglobin in blood.
- It is a good measure of the blood's ability to carry oxygen throughout the body.

Red Blood Cell Indices

- mean corpuscular volume (MCV)
- mean corpuscular hemoglobin (MCH)
- mean corpuscular hemoglobin concentration (MCHC)

These numbers help in the diagnosis of different types of anemia.

- Red cell distribution width (RDW) shows if the cells are all the same or different sizes or shapes.
- Blood cells with different shapes or sizes can help diagnose many blood diseases, such as sickle cell disease.

Red Blood Cell Indices (continued)

- MCV
  - Measured to assess red blood cell size
- MCH
  - Measures the amount of hemoglobin in an average red blood cell
- MCHC
  - Measures the concentration of hemoglobin in an RBC

Platelet Count

- Platelets:
  - Also known as thrombocytes
  - The smallest type of blood cell
  - Important in blood clotting
  - When bleeding occurs, the platelets swell, clump together, and form a sticky plug that helps stop the bleeding.
  - Too few platelets, uncontrolled bleeding may be a problem.
  - Too many platelets, there is a chance of a blood clot forming in a blood vessel.
  - Platelets are involved in atherosclerosis
Mean Platelet Volume (MPV)

- Measures the average amount volume (size) of platelets.
- Platelet size is larger when the body is producing increased numbers of platelets.
- Used to make inferences about platelet production in bone marrow or platelet destruction problems.
- High MPV
  - Inflammatory bowel disease
  - Immune thrombocytopenic purpura (ITP)
  - Thrombocytopenia
  - Aplastic anemia
- Low MPV
  - Thrombocytopenia
  - Aplastic anemia

Guidelines for Blood Transfusion

- Transfusion of blood and blood components (i.e., RBCs, platelets, plasma, and cryoprecipitate) is one of the most common medical procedures performed in the developed world.
- The decision to transfuse or not to transfuse is one of the more complex decisions made by medical practitioners.
- Risks should be offset or justified by immediate or long-term benefits.

Guidelines for Platelet Transfusion

- Currently, randomized, controlled clinical trial evidence to guide plasma transfusion practice is lacking.
- Expert opinion supports the transfusion of plasma for:
  - Active bleeding (when coagulation factor deficiencies)
  - Massive transfusion
  - Disseminated intravascular coagulation
  - Emergency reversal of warfarin (active bleeding in settings where prothrombin complex concentrate with adequate levels of factor VII is not available)
- Replacement fluid when performing plasma exchange (thrombotic thrombocytopenic purpura)

Guidelines for Plasma Transfusion

- Hemoglobin level
  - < 7 g/dL: Nonbleeding medical and surgical patients
  - < 8 g/dL: Hematocrit of active acute coronary syndrome
  - < 10 g/dL: Patients being treated for sepsis during the first 8 hours of resuscitation

Blood Donation


Cardiac Panel: Learning Objectives

- The learner will be able to:
  - Describe cardiac enzymes
  - Describe BNP
  - Describe ProBNP
  - Identify ischemia versus infarction on an EKG
  - Distinguish STEMI from NSTEMI

Cardiac Panel

Cardiac Enzymes

Cardiac enzyme studies measure the levels of enzymes and proteins that are linked with injury of the heart muscle. These include the enzymes:
- Creatine phosphokinase (CPK)
- Creatine kinase (CK)
And the proteins:
- Troponin I (TnI)
- Troponin T (TnT)
Physiology: Cardiac Enzymes

- Low levels of these enzymes and proteins are normally found in the blood, but if the heart muscle is injured, such as from an MI, the enzymes and proteins leak out of damaged heart muscle cells, and the levels in the bloodstream rise.

Cardiac Enzymes

- **Troponin**
  - Normal values:
    - TnI: Less than 0.35 micrograms per liter (mcg/L)
    - TnT: Less than 0.2 mcg/L
  - Total CPK normal values:
    - 0–120 micrograms per liter (mcg/L)

- **CK-MB (creatine kinase)**
  - Normal values:
    - 0–3 micrograms per liter (mcg/L)

Troponins

- The most sensitive and specific test for myocardial damage. Because it has increased specificity compared with CK-MB, troponin is a superior marker for myocardial injury.
- Isoforms of the protein, T and I, are specific to myocardium.
- After myocyte injury, troponin is released in 2–4 hours and persists for up to 7 days.

Comparison

- **BNP**
  - Brain natriuretic peptide (BNP), now known as B-type natriuretic peptide is an amino acid polypeptide secreted by the ventricles of the heart in response to excessive stretching of heart muscle cells (cardiomyocytes).
  - The release of BNP is modulated by calcium ions. BNP is named as such because it was originally identified in extracts of porcine brain, although in humans it is produced mainly in the cardiac ventricles.

BNP Results

- BNP levels:
  - below 100 pg/mL indicate no heart failure.
  - 100-300 pg/mL suggest heart failure is present.
  - above 300 pg/mL indicate mild heart failure.
  - above 600 pg/mL indicate severe heart failure.

ProBNP

- N-terminal-pro-B-type Natriuretic Peptide (NT-proBNP)
  - "Non-traditional" blood protein made in the heart and found in the blood.
  - High levels are associated with increased risk of cardiovascular disease, heart attack and heart failure development.
  - Elevated levels are associated with development of heart failure and worse prognosis.

  - Goal values:
    - Less than 125 pg/mL

Ischemia vs. Infarction on an EKG

1. Assess for ST segment elevation first
   - ST elevation and need for reperfusion

2. Assess for T wave inversion next
   - Non STEMI (non biomarkers)
   - Unstable angina (ischemia) (normal biomarkers)

3. Assess for ST segment depression third
   - STEMI

STEMI vs. NSTEMI

- STEMI
  - "Upward" pattern involving some form of ST or J point elevation

- NSTEMI
  - T wave inversion (symmetrical or terminal)
Coagulation Studies: Learning Objectives

The learner will be able to describe:
- The clotting cascade
- The right lab test for the right medication
- aPTT
- PT
- INR
- D-dimer
- Disseminated Intravascular Coagulopathy

The Clotting Cascade

- There are two separate clotting pathways, the intrinsic and extrinsic.
- These eventually join together to form the common pathway.

The Intrinsic Pathway

- Begins in the bloodstream.
- It is basically activated when blood is exposed to collagen (or other damaged surfaces, but collagen is the main thing involved).
- Factor XII is activated to XIIa by exposed collagen

The Extrinsic Pathway

- Begins in the vessel wall.
- Damaged endothelial cells will release factor III (tissue factor), and the greater the amount of damage, the more is released.
- This combines with calcium, and activates factor VII and turns it into factor VIIa.
- This VIIa-tissue factor complex is quickly inactivated by antithrombin III

The Common Pathway

- Prothrombinase is activated.
- Prothrombin turns into thrombin.
- Thrombin will then activate fibrinogen to fibrin.
- Fibrin strands will begin to join together to cause the cross-linking of fibrin strands.
- Fibrin stabilizing factor is activated.

aPTT

- Activated partial thromboplastin time
- Measures the efficacy of both the "intrinsic" and the common coagulation pathways.
- Apart from detecting abnormalities in blood clotting, it is also used to monitor the treatment effects with heparin, a major anticoagulant.
- Normal range: 30 - 50 seconds

PT

- Prothrombin time (PT)
- Measures the extrinsic pathway
- Used to determine the clotting tendency of blood in the measurement of warfarin dose, liver damage and vitamin K status.
- Normal range: 12-13 seconds

INR

- International normalized ratio
- Normal range between 1.0 and 2.0.

\[
INR = \left( \frac{PT_{\text{test}}}{PT_{\text{normal}}} \right)^{1.41}
\]
D-dimer

- D-dimer
  - Fibrin degradation product (or FDP).
  - A small protein fragment present in the blood after a blood clot is degraded by fibrinolysis.
  - It is so named because it contains two crosslinked D fragments of the fibrin protein.

Labs of Sepsis

Labs of Sepsis: Learning Objectives

The learner will be able to describe:
1. Cultures Gram stains and sensitivities
2. Lactate Levels

Lactate Levels

What is Lactate?

- Lactate is a product of cell metabolism.
- Mainly produced in muscle cells and red blood cells.
- Forms when the body breaks down carbohydrates to use for energy during times of low oxygen levels.
- The lactate test is ordered to determine if someone has lactic acidosis, a high level of lactate in the blood.
- Lactic acidosis is commonly caused by an inadequate amount of oxygen in cells and tissues (hypoxia).

Normal Blood Levels

- 4.5 to 19.8 mg/dL
- 0.5-2.2 mmol/L

Clinical Significance

- A high lactate level means that the disease or condition is causing lactate to accumulate.
- The greater the lactate level…the greater the severity of the condition.
- When associated with hypoxia, an increase in lactate can indicate that organs are not functioning properly (organ dysfunction).

High Lactate Associated with Hypoxia

- Shock from trauma
- Shock from extreme blood loss (hypovolemia)
- Sepsis
- Heart attack
- Congestive heart failure
- Severe lung disease
- Respiratory failure
- Pulmonary edema
- Severe anemia

Other Conditions Associated with High Lactate

- Liver disease
- Kidney disease
- Uncontrolled diabetes
- Leukemia
- AIDS
- Glycogen storage diseases
- Drugs: salicylates, cyanide, methanol, metformin
- Forms of muscular dystrophy
- Strenuous exercise, as with marathon runners
Monitoring Lactate

- The lactate test is ordered at intervals to help monitor hypoxia and response to treatment.
- Decreasing concentrations of lactate over time reflect a response to treatment.

Lactate Levels in Sepsis

- Lactate is ordered as part of an initial evaluation of someone who is suspected of having sepsis.
- If lactate level is above normal, treatment will be initiated without delay.
- If sepsis can be diagnosed and treated promptly, chances of recovery are significantly improved.

Sampling Considerations

- A prolonged application of a tourniquet is the most common cause of a falsely elevated lactate.
- Clenching the fist or having the elastic band on longer than two minutes can result in a false increase in lactic acid level.
- Consider drawing blood without a tourniquet.

Lactate Levels in Sepsis

<table>
<thead>
<tr>
<th>Lactate Level (mmol/L)</th>
<th>Mortality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;4.0</td>
<td>27%</td>
</tr>
<tr>
<td>2.5-4.0</td>
<td>7%</td>
</tr>
<tr>
<td>&lt;2.5</td>
<td>&lt;5%</td>
</tr>
</tbody>
</table>

Procalcitonin

- The level of procalcitonin rises in response to a proinflammatory stimulus, especially of bacterial origin.
- In this case, it is produced mainly by the cells of the lung and the intestine. It does not rise significantly with viral or non-infectious inflammations.

Meningitis

- Meningitis is an inflammation of the meninges.
- The meninges is a collective name for the three membranes that cover the brain and spinal cord (central nervous system).
- The meninges’ main function, alongside the cerebrospinal fluid is to protect the central nervous system.

<table>
<thead>
<tr>
<th>Cause of Meningitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meningitis is generally caused by infection of viruses, bacteria, fungi, parasites, and certain organisms.</td>
</tr>
<tr>
<td>In the majority of cases, the cause is a virus.</td>
</tr>
<tr>
<td>Meningitis can be life threatening because of the inflammation's proximity to the brain and spinal cord.</td>
</tr>
<tr>
<td>The condition is classified as a medical emergency.</td>
</tr>
</tbody>
</table>
Signs and Symptoms of Meningitis

The most common symptoms of meningitis are:
- headache
- neck stiffness associated with fever
- confusion or altered consciousness
- vomiting
- inability to tolerate light (photophobia) or loud noises (phonophobia)
- Children often exhibit only nonspecific symptoms, such as irritability and drowsiness

Tests for Meningitis

Tests for Meningitis: Learning Objectives

The learner will be able to describe:
1. Cerebral Spinal Fluid (CSF)
2. Lumbar Tap

Blood Culture

Blood cultures
- Blood drawn from a vein is sent to a laboratory and placed in a special dish to see if it grows microorganisms, particularly bacteria.
- A sample may also be placed on a slide to which stains are added (Gram's stain), then examined under a microscope for bacteria.

Imaging

Imaging
- X-rays and computerized tomography (CT) scans of the head, chest or sinuses may reveal swelling or inflammation.
- These tests can look for infection in other areas of the body that may be associated with meningitis.

Lumbar Puncture

Spinal tap (lumbar puncture)
- Definitive diagnosis of meningitis requires an analysis of cerebrospinal fluid (CSF), collected during a spinal tap.
- A needle is inserted into the spinal canal to extract a sample of CSF.
- CSF sent to the laboratory for staining with special dyes that reveal the organism leading to meningitis.
- Significantly increased CSF lactate levels suggest bacterial meningitis.
- Normal or slightly elevated CSF lactate levels are more likely to be due to viral meningitis.

Diagnostic Tests for Meningitis

With meningitis, CSF shows:
- Low glucose level
- Increased white blood cell count
- Increased protein
- CSF analysis may identify the exact bacterium that’s causing the illness.
- If viral meningitis is suspected:
  - DNA-based test known as a polymerase chain reaction (PCR) amplification or a test to check for antibodies against certain viruses to check for the specific causes of meningitis.

Other Tests to Diagnose Meningitis

- CBC to detect infection (raised WBCs)
- Urine culture to detect organisms
- Nasal swab and stool for virology, if virus is suspected
- PCR testing (Polymerase chain reaction) for N. meningitidis
- Blood antigen tests for Cryptococcus
- Blood tests for syphilis, if syphilis is suspected
### Treatment
- The first treatment in acute meningitis is antibiotics
- Antiviral drugs
- Corticosteroids to prevent complications from excessive inflammation.

### Complications of Meningitis
Meningitis can lead to serious long-term consequences if not treated quickly:
- Deafness
- Epilepsy
- Hydrocephalus
- Cognitive deficits

### Prevention of Meningitis
Some forms of meningitis may be prevented by immunization, such as:
- Meningococci,
- *Haemophilus influenzae* type B
- Pneumococci
- Mumps virus

---

### Types of Meningitis
- Viral meningitis
- Bacterial meningitis

### Viral Meningitis
- Viral meningitis is the most common
- Rarely a serious infection.
- Caused by a number of different viruses, such as mosquito-borne viruses.
- There is no specific treatment for this type of meningitis.
- In the majority of cases, resolves itself within a week without any complications.

### Bacterial Meningitis
- Bacterial meningitis is generally a serious infection.
- Caused by three types of bacteria:
  - *Neisseria meningitidis*
  - *Streptococcus pneumoniae*
  - *Haemophilus influenzae* type b (*Hib*)

---

### Types of Bacterial Meningitis
- *Neisseria meningitidis*
- Causes meningococcal meningitis
- *Streptococcus pneumoniae*
- Causes pneumococcal meningitis
- *Haemophilus influenzae* type b (*Hib*)
- Twenty years ago, *Hib* was the main cause of bacterial meningitis
- This is not the case now due to new vaccines routinely administered to children.

### Meningococcal meningitis
#### Introduction
- Meningococcal meningitis is a serious bacterial infection.
- Unlike viral meningitis, it can potentially kill an otherwise healthy young person within 1 day after the first symptoms appear.
- Meningococcal disease can be difficult to recognize because symptoms are similar to those of more common viral illnesses.

### Complications of Meningococcal Meningitis
- People who survive meningococcal meningitis can suffer permanent consequences, such as:
  - Amputation of limbs, fingers, or toes
  - Severe scarring
  - Brain damage
  - Hearing loss
  - Kidney damage
  - Psychological problems
Voices of Meningitis

- They thought he just had a virus...

Risk Factors

- Teens and young adults are at the highest risk
- Even people who are healthy, such as athletes or college students
- Spread by:
  - Kissing
  - Sharing utensils and drinking glasses
  - Living in close quarters (dormitories or summer camps)
  - Smoking or being exposed to smoke

Preventative Care

- Get vaccinated
- If you suspect meningitis, go to the emergency room right away

Treatment

- Third-generation cephalosporin antibiotics should be used to treat a suspected or culture-proven meningococcal infection before antibiotic susceptibility results are available.
- Example: cefotaxime, ceftriaxone

Viral Encephalitis

Introduction

- Encephalitis is an inflammation of the brain.
- Caused by one of several different viruses.
- Virus causes inflammation of nerve cells (encephalitis) or surrounding membranes (meningitis).
- Encephalitis is different from meningitis, but these two brain infections often happen together.

Most Common Causes

- Herpes viruses
  - Varicella zoster virus, which causes chicken pox and shingles
  - Epstein-Barr virus, which causes mononucleosis
- Childhood viruses: Measles (rubella), German measles (rubella), Mumps
- Viruses from a mosquito bite

Types of Encephalitis

- Primary: virus attacks the brain and spinal cord directly.
- Secondary: virus invades another part of your body and travels to your brain.

Signs and Symptoms

- Encephalitis:
  - Fever, chills, headache, vomiting, confusion, disorientation
  - Seizures, agitation, hallucinations, delirium

- Encephalitis w/ Meningitis:
  - Headache, stiff neck, vomiting, sensitivity to light

- Severe Encephalitis:
  - Marked disorientation (mild confusion to coma)
  - Disorientation
  - Delirious with possible hallucinations
  - Agitation
  - Personality changes
Other Signs and Symptoms
- Depends on which area of the brain is most affected.
- Seizures (up to 50%)
- Trouble using or understanding words
- Coordinating voluntary muscle movements
- Muscle weakness or partial paralysis on one side of the body
- Uncontrollable tremors or movements
- Not being able to regulate body temperature

Risk Factors
- Being very young or an older adult
- Being exposed to mosquitoes or ticks
- Having a weakened immune system
- Not being vaccinated against measles, mumps, and rubella
- Traveling to areas where viral encephalitis is common

Diagnosis
- Physical exam
- Blood test -- finds viruses in the blood
- Spinal tap (lumbar puncture) -- finds viruses in the fluid around the brain and spinal cord
- MRI and CT scan to see whether swelling is present in the brain
- Electroencephalogram (EEG) -- finds abnormal brain waves

Preventative Care
- Protect yourself from mosquitoes.
- Use insect repellent, wear long pants and long sleeves.
- The most effective bug sprays use DEET or picaridin.
- Do not apply insect repellent to children under 2 yrs.
- Make sure your child is vaccinated against diseases such as the measles, mumps, and rubella (MMR).
- Eat a healthy diet to keep your immune system healthy.

Medications
- Medications used to treat viral encephalitis include:
  - Acyclovir (Zovirax) -- treats encephalitis caused by HSV, VZV, and EBV
  - Ganciclovir (Cytovene) -- treats encephalitis caused by cytomegalovirus and herpes simplex
  - Anticonvulsant medications -- prevent and treat seizures that may happen with encephalitis

Pregnancy
- Most cases of encephalitis in newborns are caused by when the baby passes through the birth canal of a mother who is infected with herpes simplex virus 2 (HSV-2).
- This infection in newborns is often severe and fatal.
- Pregnant women with a history of HSV-2 infection may be advised to have a cesarean section, even if there is no sign of an active infection.

Questions

References

Electrolytes
http://www.webmd.com/a-to-z-guides/hyperkalemia-causes-symptoms-treatments
http://lifeinthefastlane.com/ecg-library/basics/
http://www.medicinenet.com/creatinine_blood_test/article.htm
http://www.mayoclinic.org/tests-procedures/blood-urea-nitrogen/basics/definition.resENTRYID=23299
References
CBC
- http://www.webmd.com/a-to-z-guides/complete-blood-count-cbc

References
Blood Transfusion
http://aphanatoxbook.hematologylibrary.org/content/2013/1/638/T1.expansion.html

References
Lactate
- http://labtestsonline.org/understanding/analytes/lactate/tab/test/

References
Meningitis
- http://www.mayoclinic.org/diseases-conditions/meningitis/basics/tests-diagnosis/con-20019713

References
Viral Encephalitis
- http://umm.edu/health/medical/altmed/condition/viral-encephalitis
- http://www.uvm.edu/health/medical/altmed/condition/viral-encephalitis