Objectives

At the end of this lecture, the participant will be able to:

1. identify appropriate laboratory tests for patient care,
2. describe normal laboratory values in the newborn period, and
3. formulate a plan of care for infants undergoing laboratory data monitoring.

I. Introduction

A variety of laboratory tests are done in the neonatal period on a routine basis, many as point-of-care testing. Nurses often are the first health care providers to view the results of these tests. Therefore, an understanding of the various blood tests obtained in the neonatal period, along with the ability to interpret the clinical significance of these results is imperative in the provision of care.

II. Blood Tests Commonly Drawn in the Newborn Period

- Blood Glucose
- CBC with Differential
- Acute Phase Reactants/C-Reactive Protein
- Blood Cultures
- Blood Type and Rh
- Coombs Test
- Blood Gases
- Bilirubin
- Electrolytes/Calcium/Magnesium

III. Blood Sampling Sites

- Heel Stick
  - Appropriate Heel Stick Sites
- Venipuncture
  - Venipuncture Technique
- Arterial Puncture
  - Modified Allen's Test
IV. Clinical Laboratory Tests

A. Blood Glucose

- Primary fuel source for the developing brain
- Accounts for more than 90% of total body oxygen consumption in early fasting
- Infants have a greater glucose requirement than adults because of their larger brain-to-body size ratio
- While all organs need glucose, the brain exclusively uses glucose for energy
- The liver plays a role in glucose homeostasis by mobilizing glucose stored within hepatocytes as glycogen and/or by converting lactate, glycerol, and amino acids into glucose (this is known as gluconeogenesis)
- In the newborn, hepatic (liver) glucose production rates are ~ 6 mg/kg/minute (3 to 6 times greater than in the adult)
- Normal blood glucose levels in a term newborn:
  - 0 - 24 hours: > 35 mg/dL
  - > 24 hours: > 45 mg/dL
  - Many now use 50 mg/dL as the cutoff value
- Hypoglycemia:
  - If glucose production does not meet glucose requirements, plasma glucose concentration falls, and this eventually leads to brain energy shortage due to hypoglycemia
  - Babies most at risk for hypoglycemia include:
    - Infant of a diabetic mother (IDM); due to too much insulin production
    - Small for gestational age (SGA) babies; due to poor glycogen stores
    - Premature babies (< 37 weeks); due to poor glycogen stores, immature hepatic function, decreased intake
  - Other causes of Hypoglycemia
    - Inborn errors of metabolism
    - Increased glucose utilization
    - Altered hormone regulation
    - Severe hemolytic disease
    - Asphyxia
    - Cold stress
    - Sepsis
    - Liver disease
    - Some birth defects
o Symptoms of Hypoglycemia
  ▪ Apnea
  ▪ Tremors/jitteriness
  ▪ Sweating
  ▪ Hypothermia
  ▪ Lethargy
  ▪ Abnormal cry
  ▪ Poor feeding
  ▪ Poor tone
  ▪ Tachypnea/respiratory distress
  ▪ Tachycardia
  ▪ Cyanosis
  ▪ Seizures

o Treatment for Hypoglycemia
  ▪ D10W at 2 mL/kg slow IV Push
  ▪ May also use glucagon (converts glycogen to blood sugar)
  ▪ If otherwise healthy, might just feed and recheck
  ▪ Important to follow unit protocols strictly; especially with checking and documenting follow-up levels

B. Complete Blood Count (CBC) with Differential

  ▪ Indications for obtaining a CBC:
    o Check for anemia (low RBC count)
    o Look for thrombocytopenia (TCP; low platelet count)
    o Evaluate for sepsis
  ▪ Measures:
    o Red blood cells (RBCs) (Erythrocytes)
      • Needed to carry oxygen to the tissues
    o White blood cells (WBCs) (Leukocytes)
      • Fight infection and invasion by foreign materials
    o Hemoglobin (Hgb)
      • Iron-containing protein in the RBCs that carries oxygen; also carries carbon dioxide and nitric oxide
    o Hematocrit (Hct)
      • Percentage of red blood cells in the full volume of blood
    o Platelets (Plts) (Thrombocytes)
      • Help with clotting
      • Also a natural source of growth factors
  ▪ The differential measures all WBC types:
    • Granulocytes (Neutrophils, Basophils, Eosinophils)
    • Agranulocytes (Lymphocytes, Monocytes, Macrophages)
- **Total WBC Count**
  - No established norms
  - 5,000 to 30,000 mm$^3$ as a general guide
    - Preterm: 6,000 – 19,000 mm$^3$
    - Term: 10,000 – 26,000 mm$^3$
  - Limited value in diagnosing infection
  - Very low WBC counts may be more concerning than high WBC counts

- **Differential (Granulocytes, Monocytes, Lymphocytes)**
  - **Granulocytes**
    - Neutrophils: 70% during 1st few weeks, then lymphocytes predominate
    - Primary defense against bacteria; often seen during acute bacterial infection
    - Go to the inflamed area and engulf the organism (phagocytosis)
    - It takes the body ~ 13 – 15 days to release a mature neutrophil; a “left shift” follows the development of a neutrophil:
      - Myeloblast
      - Promyelocyte
      - Myelocyte
      - Metamyelocyte
      - Band
      - Segmented Neutrophil

To calculate the Immature/Total (I/T) Neutrophil Ratio:
Add up all the immatures and divide by the total

Example: Neutrophils = 35% Segs  
15% Bands  
3% Metas  
53%

Immature Neutrophils (bands + metas + myelos)  
All Neutrophils (segs + bands + metas + myelos)  

\[
\frac{15 \text{ (bands)} + 3 \text{ (metas)}}{35 \text{ (segs)} + 15 \text{ (bands)} + 3 \text{ (metas)}} = 0.34
\]

- < 0.2 is normal
- > 0.2 – 0.25 may be suggestive of infection
- > 0.8 carries a higher risk of death
To calculate absolute neutrophil count (ANC) (cells/mm$^3$):

Multiply WBC by all neutrophil percentages

Example:

WBC = 10,000
Neutrophils = 35% Segs
15% Bands
3% Metas
53%

$10,000 \times 0.53 = 5,300$

- 0 – 24 hours: > 2,000
- After 24 hours: > 7,000
- A count < 1500 is suggestive of infection
  (Sources vary; some say < 2000; some say < 1000)

♦ Eosinophils: 1% – 3%
  - Seen with allergic response, parasitic infections

♦ Basophils: < 1%
  - Seen with allergic response; during healing phase of inflammation

- Monocytes: 4% – 8%
  - 2nd line of defense against bacterial infections
    - Engulf invaders and destroy with powerful enzymes
    - Seen in response to viral and chronic bacterial infections

- Lymphocytes: 30%; increases to 60% in 1st few weeks
  - Increased with viral infections
  - Provide cellular (T cells) and humoral (B cells = antibiotics) immunity
    - IgG – crosses the placenta, protects babies in the 1st months, major immunoglobulin – about 75%
    - IgM – about 10%, early antibody, produced by fetus in response to intrauterine infection
    - IgA – about 20%, predominantly seen in mucous/saliva, secretions, passed in human milk
    - IgD – < 1% - unknown function
    - IgE – trace, exact function unknown
- **Platelets**
  - Help with clotting
  - Mostly stored in the bone marrow, liver, and spleen
  - 150,000 – 450,000 mm$^3$ (same as adult values)
  - On day 3 – 5, may be only > 80,000 mm$^3$
  - Non-specific, late sign of infection
  - May be decreased with fungal infections

C. **Acute Phase Reactants: C-Reactive Protein (CRP)**

- Measures the amount of protein in the blood, signaling acute inflammation
- CRP is one of the first serum acute phase reactants to rise in response to sepsis
- Generally returns to normal within 2 – 7 days of successful treatment
- A persistent rise may indicate a persistent infection; may also indicate meningitis
- Used by many to help monitor therapy and determine the length of antibiotic treatment

D. **Blood Cultures**

- Obtained when evaluating for sepsis
- Drawn using venipuncture or arterial puncture technique
- Minimum of 1 mL blood should be collected

**Gram Stain**

- Divides organisms into 2 main groups: Gram Positive or Gram Negative
- Identifies the shape of the organism: Rods or Coccus
- Classifies the organism so antibiotic therapy can be started
  - Gram + Cocci in Pairs: Strep or Staph
  - Gram + Cocci in Chains: Strep
  - Gram + Cocci in Clusters: Staph
  - Gram – Club-shaped rods: E. Coli
  - Gram – Diploid: Neisseria

**Timeline**

- By day 1 → early, preliminary report of culture
- Will be read at specific intervals: 24, 48, 72 hours; with a final report on day 5 – 14 (depending on the lab)
- Once the organism is identified, sensitivity testing is done
- The organism is tested against certain antibiotics to see which one will effectively inhibit it
Sensitivities

- Minimum Inhibitory Concentration (MIC):
  - The least amount of antibiotic needed to inhibit bacterial growth

E. Blood Type and Rh

- Four Major Blood Types:
  - A, B, O, AB
  - A and B are most common
- Rh Factor (Rh+, Rh-)
  - Refers to the D antigen (just 1 of 50 blood antigens)
  - Antigens are what trigger antibodies by the immune system
- Rh Incompatibility
  - Rh- mother, Rh+ fetus
  - Fetus’ blood enters the mother’s circulation
  - The mother’s immune system treats the Rh+ fetal cells as if they were a foreign substance and makes antibodies against them
  - These anti-Rh antibodies may cross the placenta into the developing fetus, where they destroy the fetus’ circulating red blood cells
  - Leads to anemia, release of bilirubin, and jaundice in the newborn

F. Coombs Test

- Includes both the indirect Coombs and the direct Coombs
- The indirect Coombs is used to screen pregnant women for antibodies that may cause hemolytic disease of the newborn (such as in the case of ABO or Rh incompatibility)
- The direct Coombs looks for autoimmune hemolytic anemia

G. Blood Gases

- Normal function of all body cells depends on a narrow range of biochemical balance
- Acids (H+ Ions) are the byproducts of the metabolism of proteins, fats, and glucose and are constantly released into the body
- Measurement of free Hydrogen Ions is expressed in terms of pH
- pH is the negative logarithm of the hydrogen ion concentration, therefore the hydrogen concentration determines the pH of blood
- The more Hydrogen Ions in a solution, the lower the pH (the more acid the solution)
- The fewer Hydrogen Ions in a solution, the higher the pH (the more alkalotic the solution)
Hydrogen is carried in the form of:

- Carbonic Acid (H$_2$CO$_3$)

**Fixed Acids**
- Sulfuric Acid
- Lactic Acid
- Pyruvic Acid
- Phosphoric Acid
- Ketoacids

**Normal pH**
- Neutral: 7.0
- Normal is 7.35 – 7.45
- Acidosis: < 7.35
- Alkalosis: > 7.45

**Gas exchange**
- Refers to the exchange of oxygen and carbon dioxide between air and blood and then blood and tissue
- The exchange of oxygen is reflected in the PaO$_2$ (partial pressure of oxygen) in arterial blood
- The exchange of PaCO$_2$ (partial pressure of carbon dioxide) is a direct reflection of the adequacy of alveolar ventilation
- Factors affecting gas exchange might include:
  - Blood flow
  - Cardiac output
  - Metabolic rate
  - Diffusion
  - Shunting
  - Gas concentration of inspired air
- Oxygen Diffusion and Transport
  - Through breathing, oxygen is transferred from the atmosphere to the lungs, and carbon dioxide is transferred from the lungs to the atmosphere
  - Oxygen diffuses into the blood in the pulmonary capillaries and is carried throughout the body and diffuses from systemic capillary blood into the interstitial fluid and cells
  - Fetal Hemoglobin (HgbF)
    - HgbF has a greater affinity for oxygen, meaning that the blood is better saturated at lower PaO$_2$s
    - This allows the transfer of oxygen from the mother’s blood, which contains adult Hgb (HgbA), and therefore a lower affinity for oxygen
    - The healthy term newborn replaces its HgbF with HgbA by about 6 months of age
- Hypoxemia
  - Decrease in the amount of oxygen in the arterial blood which may be due to a decrease in FIO$_2$, alveolar hypoventilation, diffusion impairment, anatomic shunts, and ventilation/perfusion (V/Q) mismatch
- **Hypoxia**
  - Decrease in the amount of oxygen available to the tissues; four categories:
    - Hypoxemic hypoxia
    - Anemic hypoxia
    - Circulatory hypoxia
    - Histologic hypoxia
- **Carbon Dioxide Transport**
  - Carbon dioxide diffuses from the cells through the interstitial fluid to the blood in systemic capillaries, and to the lungs where it diffuses into alveolar gas
- **Normal Blood Gas Values**
  - **pH:** 7.35 – 7.45
    - ↓ pH = acidosis
    - ↑ pH = alkalosis
  - **PaCO\(_2\):** 35 – 45 mmHg
    - ↑ PaCO\(_2\) = respiratory acidosis
    - The baby is not breathing effectively enough; needs to blow off more CO\(_2\)
    - Need to help the baby breathe (ventilate)
    - ↓ PaCO\(_2\) = respiratory alkalosis
    - The baby is breathing too hard or too fast (labored breathing; tachypnea)
    - Need to calm the baby down, slow down his breathing, wean ventilator support
  - **PaO\(_2\):** 50 – 80 mmHg (term)
  - **PaO\(_2\):** 45 – 65 mmHg (preterm)
  - **HCO\(_3^-\):** 22 – 26 mEq/L
    - Bicarb is a buffer that keeps the blood in a normal acid-base balance
    - In newborns, we often see low bicarb due to renal immaturity (they are pee ing out their bicarb)
    - Usually will resolve in a few days when renal function improves
    - ↑ HCO\(_3^-\) = metabolic alkalosis
    - ↓ HCO\(_3^-\) = metabolic acidosis
  - **Base Deficit/Excess:** -2 – +2 mEq/L
    - Base excess (a positive number) indicates too much buffer (metabolic alkalosis)
    - Base deficit (a negative number) indicates too little buffer (metabolic acidosis)
  - **O\(_2\) Saturation:** 92% – 94%
Metabolic Acidosis

Occurs when a disorder adds acid to the body or causes alkali to be lost faster than the buffer system, lungs or kidneys can regulate the load. Characterized by:

- ↓ pH
- normal CO₂
- ↓ HCO₃⁻

Causes of Metabolic Acidosis

- Diarrhea
- Small bowel drainage
- Hyperalimentation
- Ingestion of Chloride-containing compounds
- Renal Tubular Acidosis
- Renal Failure
- Carbonic Anhydrase Deficiency
- Lactic Acidosis
- Tissue Hypoxia
- Sepsis
- Neonatal Cold Stress
- Ketoacidosis
- Diabetes Mellitus
- Starvation
- Ingestion of Toxins
- Inborn Errors of Metabolism

Metabolic Alkalosis

Occurs whenever acid is excessively lost or alkali is excessively retained. Characterized by:

- ↑ pH
- normal CO₂
- ↑ HCO₃⁻

Causes of Metabolic Alkalosis

- Vomiting
- Nasogastric Suctioning
- Congenital Chloride-Wasting Diarrhea
- Dehydration
- Diuretic Therapy
- Steroid Therapy
- Cushing’s Syndrome
- Bartter’s Syndrome
- Sodium Bicarbonate Use
- Hypokalemia
- Hypochloremia
- Chewing Tobacco
- Massive Blood Transfusion
- Cystic Fibrosis Infants Fed Regular Formula or BM
Respiratory Acidosis

Occurs when CO₂ is not adequately removed by the lungs. Characterized by:

- ↓ pH
- ↑ CO₂
- normal HCO₃⁻

Causes of Respiratory Acidosis

- Lung Disease
- Upper Airway Obstruction
- Small Airway Obstruction
- Chronic Obstructive Disease
- Pneumonia
- Pulmonary Edema
- RDS, ARDS
- Aspiration
- Pulmonary Hypoplasia
- Impaired Lung Motion
- Pleural Effusion
- Pneumothorax
- Thoracic Cage Abnormalities
- Apnea
- Neurologic or Neuromuscular Disorders Affecting Respiration

Respiratory Alkalosis

Occurs when CO₂ is excreted by the lungs in excess of its production. Characterized by:

- ↑ pH
- ↓ CO₂
- normal HCO₃⁻

Causes of Respiratory Alkalosis

- Anxiety
- Fever
- Sepsis
- Hypoxemia
- Pneumonia
- Atelectasis
- Pulmonary Emboli
- Congestive Heart Failure
- Asthma
- Central Nervous Syndrome Disorders
- Liver Failure
- Reye’s Syndrome
- Hyperthyroidism
- Salicylate Poisoning
- Mechanical Ventilation
Blood Gas Practice Examples
H. Bilirubin

- Normal breakdown product of red blood cells
- Produced from the catabolism of heme-containing proteins
- Hemoglobin accounts for 70% – 80% of bilirubin production
- Higher in infants due to a higher turnover and shorter lifespan of RBCs
- Two different forms:
  - Unconjugated (indirect); Lipid Soluble
  - Conjugated (direct); Water Soluble
- The body can only eliminate the conjugated form, so the liver needs to convert it first

Bilirubin Metabolism and Excretion

- In utero, unconjugated fetal bilirubin is transported across the placenta and excreted by the maternal circulation
- After birth, the newborn liver must metabolize bilirubin, however, it can only excrete conjugated bilirubin, and therefore must first convert the unconjugated form to the conjugated form (phototherapy works by changing bilirubin to the water soluble, or conjugated form)
- Once conjugated, the bilirubin is passed through the intestines where it is converted into urobilinogen by bacterial enzymes, then excreted
- A carrier molecule (albumin) is needed to transport bilirubin to the liver
- If the rate of bilirubin production exceeds the liver’s ability to conjugate and eliminate it, or if albumin binding sites are saturated or scarce, unconjugated bilirubin will rise and jaundice will develop

I. Sodium

- Normal is 135 – 145 mEq/L
- Helps conduct neuromuscular impulses
- Maintains intravascular osmolality
- Regulates acid-base balance (NaCl, NaHCO₃⁻)
- If abnormal, can cause seizures, venous sinus thrombosis, CNS hemorrhage
- Abnormalities can be life threatening, especially if:
  - < 120 mEq/L
  - > 155 mEq/L
- Hyponatremia
  - Can be dilutional (too much fluid)
  - Can be due to too little intake
  - Can be due to renal losses
    - Renal immaturity, polyuria, diuretic therapy
  - Can be due to GI losses
    - Vomiting, diarrhea
• Hypernatremia
  o Can be due to excessive intake, sodium bicarb or saline administration
  o Can be due to dehydration
    ▪ Urinary losses
    ▪ GI losses
    ▪ Evaporation through the skin

J. Potassium
• Normal is 3.5 – 5.5 mEq/L
• Responsible for cardiac and skeletal muscle contraction
• Helps maintain acid-base balance
• Needed for all cell functions to take place
• If abnormal, can cause weakness, arrhythmias/EKG changes, death
• Hypokalemia
  ▪ Can be due to too little intake
  ▪ Can be due to renal losses
    o Renal immaturity, polyuria, diuretic therapy
  ▪ Can be due to GI losses
    ▪ Vomiting, diarrhea
• Hyperkalemia
  o Can be due to excessive intake, blood cell hemolysis, excessive bruising, acidosis, multiple blood transfusions

K. Chloride
• Normal is 96 – 111 mmoL/L
• Works with Na⁺ to maintain acid/base balance, transmit nerve impulses, and regulate fluid in and out of cells

L. Calcium
• Most abundant mineral in the human body
• Needed for bone mineralization
• 99% of total Ca²⁺ is contained in bone—this is true for all ages
• The Ca²⁺ we are measuring in serum represents just 1% of the total body Ca²⁺
• Because dietary intake is decreased in the first few days, serum concentration decreases in the first day of life
• In term infants, ICa²⁺ reaches its nadir of 1.10 – 1.36 mmol/L at ~ 24 hours of age; ~ 30% will develop “early” hypocalcemia (within the first 2 days of life)
  • For term infants, hypocalcemia is defined as:
    † ICa²⁺ < 1.10 mmol/L or
    † Total serum Ca²⁺ < 8.0 mg/dL
  • In preterm infants, hypocalcemia is defined as:
    † ICa²⁺ < 1 mmol/L or
    † Total serum Ca²⁺ < 7.0 mg/dL
• Usually temporary and will improve in 1 – 3 days due to:
  ▪ ↑ Ca++ intake in feedings
  ▪ ↑ Renal P excretion
  ▪ Improved parathyroid function

- Hypercalcemia
  o Total Ca++ > 10.8 mg/dL
  o Can be asymptomatic or cause nonspecific signs including:
    • Poor feeding
    • Constipation
    • Polyuria
    • Dehydration
    • ↓ muscle tone
    • Lethargy
    • Bradycardia
      o If prolonged, can lead to metastatic calcifications; primarily nephrocalcinosis (kidney stones)

M. Phosphorus

- Normal is 5 – 7.8 mg/dL
- Needed for bone mineralization, erythrocyte function, cell metabolism and the generation and storage of energy
- ~ 85% of the total P is in skeleton
- The remaining 15% is found in soft tissues and extracellular fluid
- ~ 2/3 is organic (phospholipids); the remainder is inorganic
- Inorganic is what we are measuring
  • 85% is ionized
  • 5% is complexed
  • 10% is protein bound
- Serum concentration varies widely and is dependent on intake and renal excretion
- Levels are low at birth, but rise rapidly after birth
- Higher levels are seen in formula fed babies than in breast fed babies
- An inverse relationship between serum ICa++ and serum P exists

N. Magnesium

- Normal is 1.6 – 2.8 mg/dL
- Distributed primarily in bone and muscle
- Needed for energy production, cell membrane function, and protein synthesis
- ~ 1% of body Mg++ is in the extracellular fluid
- Hypomagnesemia
  o Mg++ < 1.6 mg/dL
  o Usually asymptomatic until < 1.2 mg/dL
- Signs/Symptoms:
  - Irritability
  - Tremors
  - Seizures
- Hypomagnesemia is frequently seen with hypocalcemia
  - Need to correct the hypomagnesemia in order to correct the hypocalcemia
- Hypermagnesemia
  - Mg\(^{++}\) > 2.8 mg/dL
  - Often due to excessive Mg\(^{++}\) administration
  - Generally will return to normal after a few days
- Treatment:
  - Hydration
  - +/- Diuretics
References


