Respiratory System Assessment

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Lecture Outlines

- Physiological Facts
- Ventilation-Perfusion Matching
- Oxyhemoglobin Dissociation Curve
- Respiratory Assessment
  - Health History
  - Symptom assessment
  - Physical Examination
Lecture Outlines

- Arterial Blood Gas (ABG)
- Respiratory acidosis & Alkalosis
- Metabolic acidosis & Alkalosis
- Basic Spirometry:
  - Peak Expiratory Flow
- Bedside Pulmonary Function Tests
- CBC
- Sputum studies
- Chest Radiograph (chest x-ray)
- Chest computed tomographic imaging (CT scan):
  - Ventilation-perfusion scan
  - Pulmonary angiography
- Pulse Oximetry (SpO2):
  - Bronchoscopy
  - Thoracentesis
Respiratory system

- The cells of the human body require a constant stream of oxygen to stay alive. The respiratory system provides oxygen to the body’s cells while removing carbon dioxide, a waste product that can be lethal if allowed to accumulate.

- There are 3 major parts of the respiratory system: the airway, the lungs, and the muscles of respiration.

- The airway, which includes the nose, mouth, pharynx, larynx, trachea, bronchi, and bronchioles, carries air between the lungs and the body’s exterior.
Humans have two lungs, a right lung and a left lung. The right lung consists of three lobes while the left lung is slightly smaller consisting of only two lobes (the left lung has a "cardiac notch" allowing space for the heart within the chest).

Together, the lungs contain approximately 2,400 kilometres (1,500 mi) of airways and 300 to 500 million alveoli.

The lungs together weigh approximately 1.3 kilograms (2.9 lb), with the right lung weighing more than the left.
Respiratory system

- The pleural cavity is the potential space between the two serous membranes, (pleurae) of the lungs; the parietal pleura, lining the inner wall of the thoracic cage, and the visceral pleura, lining the organs themselves—the lungs.

- Trachea: hollow tube, connects larynx and bronchi

- Trachea divides at carina into 2 bronchi: Rt bronchi wider and shorter → it is the most common site of aspiration

- Then, lobar and segmental bronchi → bronchioles → terminal bronchioles → resp. Bronchioles → alveolar ducts → alveolar sacs.
Respiratory system

• Ventilation: movement of air between atmosphere and the alveoli
  – Expansion and relaxation of diaphragm and respiratory muscles

• Diffusion: of O2 & CO2 between pulmonary capillaries and alveoli
  – O2 from alveoli to pulmonary capillaries, and diffusion of CO2 from pulmonary capillaries to the alveoli.
  – This process occur from area of high to low concentration.

• Transport: O2 & CO2 in the blood to and from cells.
  – The gas exchange require constant flow of blood through respiratory airways.
  – Pulmonary capillaries form a dense network around alveolar wall, making efficient structure for gas exchange to take place
• Respiration is controlled by two types of chemoreceptors:
  – Central
    • 70-80% of regulatory chemoreceptors
    • Located in the ventrolateral surface of the medulla
    • They detect H+ ions and pH of the brain
    • Increased CO₂ will ↑ H+ ions → stimulate respiratory drive
    • Decrease CO₂ level → ↓ the drive to breath
  – Peripheral
    • Located in the aortic arch and bifurcation of the carotid arteries
    • They sense PaO₂ and PaCO₂ & pH of the arterial blood
    • Stimulate the central chemoreceptors through the cranial and vagus nerves
Physiological Facts

- Total Lung Capacity (TLC): total amount of air in the lung after a maximal inspiration
- Tidal Volume (TV): volume of air inhaled or exhaled with each breath during normal breathing
- Vital Capacity (VC): total amount of air exhaled after a maximal inspiration
- Inspiratory Capacity (IC): maximal amount of air that can be inspired after normal exhalation
- Inspiratory Reserve Volume (IRV): maximal volume of air inspired after a normal inspiration
Physiological Facts

- **Functional Residual Capacity (FRC):** volume of air left in the lungs at the end of a normal expiration
- **Residual Volume (RV):** volume of air left in the lungs after a maximal expiration
- **Expiratory Reserve Volume (ERV):** maximal volume of air expired after a normal expiration
- **IC = TV + IRV**
- **FRC = ERV + RV**
- **VC = IRV + TV + ERV**
- **TLC = IRV + TV + ERV + RV**
Lung Volumes

<table>
<thead>
<tr>
<th>Volume (ml/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>80</td>
</tr>
</tbody>
</table>

- **Inspiratory Reserve Volume (IRV)**
- **Inspiratory Capacity (IC)**
- **Vital Capacity (VC)**
- **Total Lung Capacity (TLC)**
- **Tidal Volume (TV or Vr)**
- **Expiratory Reserve Volume (ERV)**
- **Functional Residual Capacity (FRC)**
- **Residual Volume (RV)**
## Lung Volumes

### Lung capacities in healthy adults in Liters

<table>
<thead>
<tr>
<th>Volume</th>
<th>In men</th>
<th>In women</th>
<th>Derivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital capacity</td>
<td>4.6</td>
<td>3.1</td>
<td>IRV plus TV plus ERV</td>
</tr>
<tr>
<td>Inspiratory capacity</td>
<td>3.5</td>
<td>2.4</td>
<td>IRV plus TV</td>
</tr>
<tr>
<td>Functional residual capacity</td>
<td>2.3</td>
<td>1.8</td>
<td>ERV plus RV</td>
</tr>
<tr>
<td>Total lung capacity</td>
<td>5.8</td>
<td>4.2</td>
<td>IRV plus TV plus ERV plus RV</td>
</tr>
</tbody>
</table>

### Average lung volumes in healthy adults in Liters

<table>
<thead>
<tr>
<th>Volume</th>
<th>In men</th>
<th>In women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspiratory reserve volume</td>
<td>3.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Tidal volume</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Expiratory reserve volume</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Residual volume</td>
<td>1.2</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Ventilation-Perfusion Matching

- **Ventilation/ perfusion ratio (or V/Q ratio)** is a measurement used to assess the efficiency and adequacy of the matching of two variables.
- It is defined as: the ratio of the amount of air reaching the alveoli to the amount of blood reaching the alveoli.
  - "V" – ventilation – the air that reaches the alveoli
  - "Q" – perfusion – the blood that reaches the alveoli
Ventilation-Perfusion Matching

• Perfusion: total blood flow to the lung depends on:
  – Gravity
  – Cardiac output
  – Pulmonary vascular resistance

• Perfect ventilation-perfusion matching (V/Q) means: each alveolus would receive an equal amount of ventilation and perfusion (v/q = 1)

• In reality, $V = 4\text{L/min}$ & $Q = 5\text{L/min}$ → $V/Q = 0.8\text{L/min}$

• Any alteration in the perfusion or ventilation will lead to alteration in gas exchange
Ventilation-Perfusion Matching

• Alteration of perfusion or ventilation is called V/Q mismatch
  1. Intrapulmonary Shunting: perfusion of unventilated or collapsed alveoli (e.g. increase airway secretions)
  2. Alveolar dead space ($V_{DA}$): alveoli are ventilated but not perfused (e.g. pulmonary embolism)
  3. Silent unit: When both ventilation and perfusion are decreased, a silent unit occurs. A silent unit is seen with pneumothorax and severe ARDS

• Gases move across the alveolar capillary membrane through diffusion
• $CO_2$ diffuses 20-24 time more rapid than $O_2$
• $O_2$ transports by combination with hemoglobin (97%) or dissolved in the plasma (3%)
• Saturation of hemoglobin with $O_2$ ($SaO_2$) is the amount of $O_2$ carried by the hemoglobin
• $PaO_2$: describes the amount of $O_2$ dissolved in the plasma
V-Q mismatch

A: Normal
   - Alveolus
   - Air
   - Capillary flow

B: Shunt
   - Blockage of alveolus
   - Blood flow

C: Dead space
   - Air
   - Alveolus

D: Silent
   - Blockage of alveolus
   - Blockage of blood flow
Oxyhemoglobin Dissociation Curve

- Oxyhemoglobin dissociation curve: the relationship between \( \text{PaO}_2 \) & \( \text{SaO}_2 \) (see figure 14-12)

  - Factors increase \( \text{O}_2 \) affinity (shift to the Lt):
    - ↓Temperature
    - ↓\( \text{PaCO}_2 \)
    - ↑pH
  
  - Increased affinity: less \( \text{O}_2 \) released at the tissue level & at the lung level Hb picks up more \( \text{O}_2 \)

  - Factors decrease \( \text{O}_2 \) affinity (shift to the Rt):
    - ↑Temperature
    - ↑\( \text{PaCO}_2 \)
    - ↓pH

  - Decreased affinity: \( \text{O}_2 \) unloaded rapidly at the tissue level & at the lung level Hb picks up less \( \text{O}_2 \)

  - Normally, \( \text{PaO}_2 \) is 100mm Hg & Mixed venous oxygen (\( \text{PvO}_2 \)) is 40 mm Hg

  - \( \text{PaCO}_2 \) is 46 mm Hg and Mixed venous CO\(_2\) is 40mm Hg
Oxyhemoglobin Dissociation Curve

(Haldane effect: O₂ displaces CO₂ from Hb)

↑ pH
↓ DPG
↓ Temp

↓ pH
↑ DPG
↑ Temp

(Bohr effect: ↑ CO₂, ↓ pH)
Oxyhemoglobin Dissociation Curve

- **CO₂** is transported by three methods:
  1. Dissolved in the plasma (5-10%)
  2. Combined to Amino acid in the blood (5-10%)
  3. As HCO₃ (70-90%)

  - In the plasma CO₂ enters RBC and formed Carbonic acid (H₂CO₃) under influence of carbonic anhydrase enzyme (CA)
  - Transport of CO₂ to the lung for remove:

    » →
    
    - CO₂ + H₂O ↔ H₂CO₃ + HCO₃⁻ + H⁺

  - Release of CO₂ at lung level

    ←
    
    - CO₂ + H₂O ↔ H₂CO₃ + HCO₃⁻ + H⁺
Respiratory Assessment

• Health History (see chart 15-1)
  – Chief complain
  – Medication allergies
  – History of present illness
  – Past history
  – Past surgical history
  – Medications
  – Social history
  – Family history
  – Symptom assessment
Symptom Assessment

- **Breathlessness** (Shortness of Breath)
  - **Dyspnea**: subjective report of shortness of breath-SOB (see chart 15-4 for specific questions related to dyspnea)
  - Types of dyspnea:
    - **Paroxysmal nocturnal dyspnea**: sudden awakening with SOB → may caused by asthma, LV HF or airway obstruction
    - **Orthopnea**: SOB while laying flat and relief in setting → may caused by CHF, asthma, COPD, or ascites
    - **Trepopnea**: more comfortable breathing in lateral position → may caused by HF & unilateral lung disease
Symptom Assessment

- **Cough:** can be subjective or objective (see chart 15-5 for specific questions related to cough)
  - Productive cough: associated with sputum
  - Describe the amount, Color, Consistency, & Smell
  - Any associated symptoms: pain, fever, weight loss
  - Associated with most of respiratory disorder

- **Hemoptysis:** coughing up of blood
  - Differentiate between coughing blood and vomiting blood (hematemesis)
  - Describe the amount, any sputum with it & color
  - May be associated with bronchitis, cystic fibrosis, lung cancer, anticoagulants therapy, coagulation disorder, tuberculosis,
Symptom Assessment

- **Chest Pain:** may be from different origins (see table 15-1)
  - Musculoskeletal
    - Sharp and localized
    - Rib fracture, tumor, thoracic incision, ligament strains
  - Pleuropulmonary
    - Stabbing in lateral aspect of the chest
    - Pneumothorax
  - Airways
    - Sudden-onset, crushing mediasternal pain
    - Acute pulmonary embolism, tacheobronchitis
Physical Examination

• **Inspection:** (see chart 15-6)
  - General appearances
  - Head-to-toes approach
    - Head & neck
    - Extremities
    - Thorax
  - **Thorax**
    - Respiratory rate & pattern → inspect both the spontaneous & ventilator rate, deep & pattern (see table 15-2)
    - **Tachypnea:** fever, pain, anxiety, etc
    - **Bradypnea:** sedation & metabolic disorders
    - **Apnea:** stroke or depression of respiratory center
    - **Cheyne-stokes:** change of blood flow to the respiratory center
    - **Kussmaul’s:** associated with metabolic acidosis
    - **Biot’s:** head trauma, stroke, usually require intubation
Abnormal breathing patterns

- Kussmaul’s
- Rapid shallow breathing
- Apnea Biot’s
- Bradypnea
- Cheyne-Stokes
- Hyperpnea
- Apnea
Normal respiration

Biot's respiration
aka ataxic respiration
- Periodic breathing:
  - hyperpnoea (or normopnoea) and apnoea
  - Poor prognosis
  - Neuron damage

Kussmaul breathing
- Metabolic acidosis (Diabetes mellitus)
- Hyperpnoea
  K = Ketones (Diabetic ketoacidosis)
  U = Uremia
  S = Sepsis
  S = Salicylates
  M = Methanol
  A = Aldehydes
  L = Lactic acid/Lactic acidosis

Cheyne-Stokes respiration
- Periodic breathing:
  - Gradual hyperpnoea/hypopnoea and Apnoea
  - Sleep/Hypoxemia/Drugs
  - Hypoperfusion of the brain (respiratory center)
Examination

- **Palpation**
  - Tenderness
  - Crepitation
  - Quality of tactile fremitus

- **Percussion** (table 15-3)
  - Dull sound over fluid and consolidated lung tissue
  - Hyperresonant sound: pneumothorax

- **Auscultation** (see table 15-7)
  - Crackles-fine
  - Crackles-course
  - Atelectatic crackles
  - Pleural friction rub
  - Wheeze
  - Stridor
  - See table 15-8 for summery of respiratory disorders and their physical examination findings
Arterial Blood Gas (ABG)

• Assess the coagulation status including
  – Special tests: PT, PTT, ACT
  – Disorders: hemophilia, thromocytopenia
  – Medications: heparin, warfarin, streptokinase
  – Oxygenation status: Fraction of inspired O₂ (FI O₂), mode of ventilation

• Arterial Blood Gas
  – Indications:
    • Respiratory failure - in acute and chronic states.
    • Any severe illness which may lead to a metabolic acidosis - for example:
      – Cardiac failure.
      – Liver failure.
      – Renal failure.
      – Hyperglycaemic states associated with diabetes mellitus.
      – Multiorgan failure.
      – Sepsis.
      – Burns.
      – Poisons/toxins.
      – Ventilated patients.
Arterial Blood Gas (ABG)

- **pH measures:**
  - Acidemia: pH < 7.35
  - Alkalemia: pH > 7.45

- **Volatile acidemia:** respiratory system cleared 98%-99% within 24hrs

- **Nonvolatile acidemia (also known as a fixed acid or metabolic acid):**
  - Is an acid produced in the body from sources other than carbon dioxide, and is not excreted by the lungs, cleared by kidneys
  - They are produced from e.g. an incomplete metabolism of carbohydrates, fats, and proteins.
  - All acids produced in the body are nonvolatile except carbonic acid, which is the sole volatile acid.
  - Common nonvolatile acids in humans are lactic acid, phosphoric acid, sulfuric acids
Arterial Blood Gas (ABG)

- 3 systems are involved in acid-base balance
  1. Chemical buffers
     - Minimize pH changes but can’t prevent the strong changes
     - Total bicarbonate (53%) and total non-bicarbonate (47%)
     - Plasma & RBC HCO₃
     - Inorganic & organic phosphates and plasma proteins
  2. Respiratory regulation
     - Regulate arterial CO₂ by increasing and decreasing in the ventilation
  3. Renal regulation
     - The most powerful system of regulating the H⁺
     - It takes 48-72 hours to reach its maximum effect
     - Regulate the pH by increasing or decreasing the urinary excretion of HCO₃ or H⁺
Arterial Blood Gas (ABG)

- Physiologic effects of acidemia & alkalemia (see table 24-3)
  - Cardiopulmonary
  - CNS
  - Associated Symptoms
- Hypercapnia or hypercarbia: $\text{PaCO}_2 > 45\text{mmHg} \rightarrow$ hypoventilation
- Hypocapnia or hypocarbia: $\text{PaCO}_2 > 35\text{mmHg} \rightarrow$ hyperventilation
- Bicarbonate is mainly regulated by kidneys
- Base Excess: metabolic parameter ($0 \pm 2 \text{mEq/L}$) $\rightarrow$ negative = base deficit; positive = base excess
- Compensation (see box 24-11)
Respiratory Acidosis

- Associated with alveolar hypoventilation (e.g. respiratory failure, pulmonary edema, CNS depression)
- Chronic respiratory acidosis: COPD, Cystic fibrosis
- ABG findings:
  - pH: 7.4 – 7.0
  - PaCO2: 45 – 120 mm Hg
  - HCO3: normal or slightly elevated
  - BE: upper normal
  - ↑ K
- Treatment:
  - Improve ventilation
  - Treat the underlying causes
- With chronic respiratory acidosis nurse should observe metabolic alkalosis for ventilated patients
Respiratory Alkalosis

- Associated with alveolar hyperventilation (e.g. excessive mechanical ventilation, hypermetabolic state, pregnancy, anxiety, pain)

- **ABG findings:**
  - pH: >7.45
  - PaCO₂: < 35
  - HCO₃: normal or slightly decreased
  - BE: normal or low in chronic alkalosis
  - ↓ K and Ca

- **Treatment:**
  - Treat the underlying causes
Metabolic Acidosis

- Fixed or nonvolatile gain of acid or excess of base (e.g. renal failure, ketoacidosis, prolonged diarrhea, salicylate intoxication)
  - Increase anion gap: ↑or retention of unmeasured anion
  - Normal anion gap: excessive loss of HCO3

- ABG findings:
  - pH: < 7.35
  - PaCO2: < 35
  - HCO3: < 22 mEq/L
  - ↑K
  - BE: negative

- Treatment:
  - Treat the underlying causes
  - Slow infusion of HCO3
  - (Desired HCO3 – actual HCO3) x 0.60 (body weight Kg)
Metabolic Alkalosis

- Fixed or nonvolatile gain of strong base or excess loss of acid (e.g. acute vomiting or nasogastric suction, liver disease, excess administration of HCO₃⁻)

- **ABG findings:**
  - pH: > 7.45
  - PaCO₂: normal or high
  - HCO₃: > 26 mEq/L
  - Normal or low K
  - BE: positive

- **Treatment:**
  - Treat the underlying causes
  - Slow infusion of K may be needed

- *See box 24-9, box 24-10 for interpretation of ABG results*
Oxygenation Parameters

- **Hypoxia**: inadequate O2 supply to the tissue to meet tissues’ metabolic needs.
- **Hypoxemia**: arterial PaO2 < 80mm Hg at FiO2 21%
- **Relative Hypoxemia**: 60 – 80 mmHg
- **Severe Hypoxemia**: < 60 mm Hg
  - Ventilation perfusion mismatch
  - Anatomic right-to-left shunt
  - Alveolar hypoventilation
- **Acceptable PaO2 for a given FiO2** = FiO2 x 5
- **O2 saturation**: percent of Hgb bound with O2
- **SaO2** is normally \( \geq 95\% \)
  - Greatly affected when PaO2 > 60mm Hg
  - Should be interpreted in relation to Hgb level
- **PvO2**: 38 – 42 mm Hg \( \rightarrow \) > 35 mm Hg indicate inadequate O2 delivery or ↑ O2 extraction
- **SvO2**: taken from the pulmonary artery, normally 70 - 76%
Pulmonary Function Testing

• Basic Spirometry:
  – Measures lung volumes
  – FEV\textsubscript{1}: the amount of air patient can exhale in the first second → decrease FEV\textsubscript{1} indicates airway obstruction
  – FEV\textsubscript{1}/FVC\% normally about 75\%, → decreased in airway obstruction

• Peak Expiratory Flow
  – Patient is instructed to inhale deep breathing, then quickly and forcefully exhale into expiratory flowmeter
  – This is repeated 3 times and the highest is recorded
  – For patient with bronchospasm they usually develop cough or reduced value

• Bedside Pulmonary Function Tests
  – Lung volumes and minute ventilation are routinely monitored
  – Dead space ventilation (V\textsubscript{D})
  – Normally anatomical dead space (V\textsubscript{an}) about 33\% of TV
  – Alveolar dead space (V\textsubscript{A}): proportion of TV at the alveolar level that does not participate in gas exchange
  – V\textsubscript{D}: increased in reduce CO and pulmonary embolism
Spirometry

Patient blows into spirometer. The device measures and records maximum air flow, lung volume, and other parameters which are important in understanding the individual's pulmonary (lung) function.
Other Laboratory Tests

- **CBC (see table 16-9)** assess:
  - Polycythemia
  - Anemia
  - WBC

- **Sputum studies**
  - Culture & sensitivity (e.g. acid-fast bacilli → for tuberculosis
  - Cytologic examination → for malignancy

- **Chest Radiograph (chest x-ray)**
  - In critical care settings portable anteroposterior (AP) is very common to identify:
    - Lung’s pathological conditions
    - Catheter placement & endotracheal tube
    - Pleural effusion
    - Pneumothorax
    - Cardiac silhouette
  - See table 16-10 for detailed examination of the chest x-ray
Normal Chest X-ray
Catheter placement & endotracheal tube
Other Tests

• Chest computed tomographic imaging (CT scan):
  – Multiple cross-sectional images of the chest
  – Can be done with contrast
  – Useful to examine small lesions in the lung parenchyma
  – Done in the radiology department

• Ventilation-perfusion scan
  – Used radiolabeled gases → assess matching of ventilation and perfusion (e.g., pulmonary embolism)

• Pulmonary angiography
  – Can be both diagnostic or interventional procedure
  – Just like cardiac catheterization, injection of special dye into the pulmonary artery
  – Useful for diagnosing and treating pulmonary embolism
Other Laboratory Tests

- **Pulse Oximetry (SpO2):**
  - Uses two wavelengths of light to detect the amount of unsaturated Hgb
  - The result is described as saturated Hgb
  - It is considered a good estimate with an accuracy of ± 2%

- ** Bronchoscopy**
  - Endoscopic procedure provides direct visualization of the trachea, bronchi
  - Bronchoalveolar lavage may be used for culture
  - Vital signs, SpO2, respiratory status
  - Useful for diagnosing lesions, mucous plugs
  - After the procedure, assess for bleeding, respiratory distress

- **Thoracentesis**
  - Can be both diagnostic or interventional procedure
  - Pleural effusion is an abnormal collection of fluid in the pleural space
  - Sample of this fluid is withdrawn for laboratory analysis
  - For treatment: chest tube may be inserted
  - Usually performed in the setting position with local anesthesia
  - Respiratory status assessment is required during and after the procedure
Pulse Oximetry
Bronchoscopy
Thoracentesis

Syringe on catheter removing fluid from around the lung

Vacuum bottle collecting pleural fluid
Questions and answers