Physiology and Pathology of Pleural Space - Including Management of Chest Bottles

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Anatomy and Physiology of Pleura

Introduction of Pleural Space

- **Definition**
  - The thin, fluid-filled gap between the visceral and parietal pleurae

- **Functions**
  - Facilitates lung expansion and contraction
  - Reduces friction during breathing
  - Maintains lung position within the thoracic cavity.

Anatomy of Pleurae

- **Visceral Pleura**
  - Covers the surface of the lungs.
  - Blood supply from bronchial arteries
  - The visceral pleura is **devoid of somatic innervation**

- **Parietal Pleura**
  - Lines the inner surface of the thoracic cavity.
  - Blood supply from systematic circulation
  - The parietal pleura has **a rich network of somatic, sympathetic, and parasympathetic innervation**.

- **Pleural cavity**
  - Space between the visceral and parietal pleurae.
  - Visceral pleura and parietal pleura fuse at the hilum

Anatomy of Pleura

Submesothelial Connective Tissue (Visceral Pleura)

Mesothelial Cells (Visceral Pleura)

Elastic Layer

Submesothelial Connective Tissue

Mesothelial Cells (Parietal Pleura)

Anatomy of Pleura

- **Mesothelial Cells (Visceral Pleura)**
  - The outermost layer of the visceral pleura
  - Consist of a single layer of mesothelial cells.

- **Submesothelial Connective Tissue (Visceral Pleura)**
  - Connective tissue beneath the mesothelial cells of the visceral pleura
  - Offer support and elasticity.

Anatomy of Pleura

- **Mesothelial Cells (Parietal Pleura)**
  - The outermost layer of the parietal pleura
  - Consist of a single layer of mesothelial cells.

- **Submesothelial Connective Tissue**
  - A layer of connective tissue beneath the mesothelial cells of the parietal pleura
  - Provide structural support

Anatomy of Pleura

- **Elastic Layer**
  - A layer rich in elastic fibers
  - Facilitates he flexibility and stretch of the pleura during respiration

Pleural Pressure

- **Negative Pressure**
  - Normally, the pleural pressure is **slightly negative** compared to atmospheric pressure (-5 cm H2O at rest).

- **Importance**
  - Negative pleural pressure helps keep the lungs expanded and facilitates lung compliance.

Mechanism of Breathing

- **Inspiration**
  - During inspiration, the **diaphragm and intercostal muscles contract**, expanding the thoracic cavity.
  - Pleural Pressure Changes: **Pleural pressure becomes more negative**, causing the lungs to expand and air to flow into the alveoli.

- **Expiration**
  - **Relaxation of the diaphragm and intercostal muscles** leads to a decrease in thoracic volume, causing expiration.

Pleural Fluid

- Most of the fluid that accumulates in the pleural space is **derived from the lung** and is **absorbed by the parietal pleura**.

- **Composition**
  - A thin layer of fluid (about 10-20 mL) composed primarily of water, electrolytes, proteins, and lipids.

- **Functions**
  - **Lubricates** the pleural surfaces, facilitates smooth lung movement during respiration, and helps maintain negative pressure within the pleural space.

Pleural Fluid

- **Exudate**
  - Occurs due to inflammation or **injury to the pleura**, leading to increased permeability of pleural surfaces or impaired lymphatic drainage.

- **Transudate**
  - Results from systemic factors that alter the **balance of oncotic and hydrostatic pressures**, typically without direct pleural disease.

Pleural Fluid

- **Light's Criteria**
  - Pleural fluid is considered an **exudate if one or more of the following are met**
  - Pleural fluid protein/serum **protein ratio > 0.5**
  - Pleural fluid LDH is more than **two-thirds the upper limit of normal for serum LDH**
  - Pleural fluid LDH/serum **LDH ratio > 0.6**

Pleural Fluid

	Exudate	Transudate
Protein content	> 3.0 g/dL	< 3.0 g/dL
Serum-to-pleural fluid protein ratio	> 0.5	< 0.5
Lactate dehydrogenase (LDH) level	> 200 IU/L or > 2/3 the upper limit of normal serum LDH	< 200 IU/L or < 2/3 the upper limit of normal serum LDH
Serum-to-pleural fluid LDH ratio	> 0.6	< 0.6
Glucose level	Often low	Similar to serum glucose
pH level	< 7.30	Usually > 7.30
Appearance	Often cloudy or bloody	Clear or straw-colored
Common causes	Pneumonia, malignancy, tuberculosis, pulmonary embolism, pancreatitis	Congestive heart failure, cirrhosis, nephrotic syndrome

Disease of Pleura

Diseases Affecting the Pleural Space

- **Pneumothorax**
  - Presence of air in the pleural space, leading to lung collapse
- **Pleural Effusion**
  - Accumulation of excess fluid in the pleural cavity, often due to inflammation or infection
- **Empyema**
  - Presence of pus in the pleural space, usually caused by bacterial infection
- **Mesothelioma**
  - Cancer affecting the pleura, often associated with asbestos exposure.

Pneumothorax

- **Definition**
  - Pneumothorax is the presence of air in the pleural cavity causing the lung to collapse.

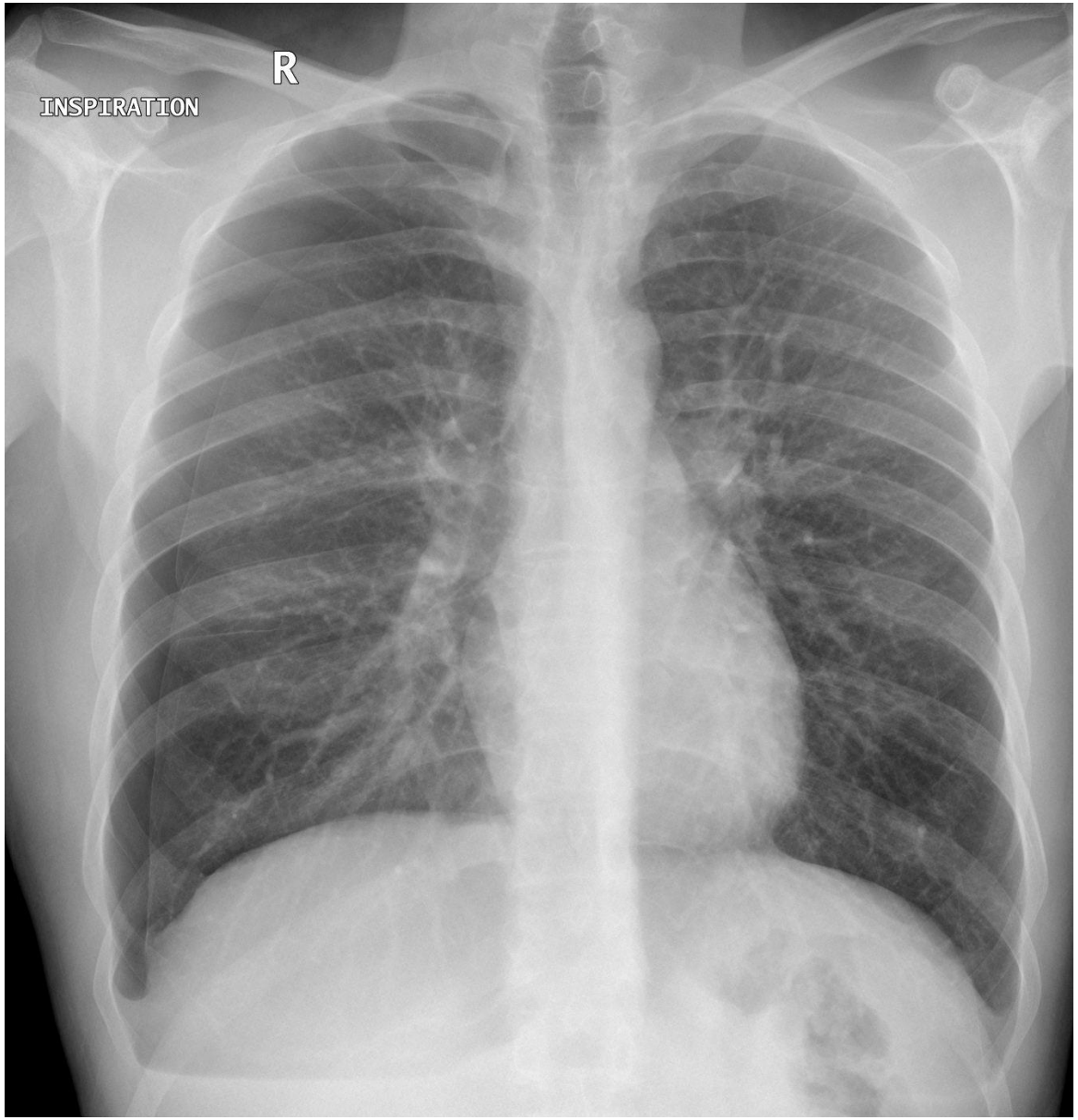
- **Types**
  - **Spontaneous** Pneumothorax
    - **Primary** : No underlying lung disease, often in tall, thin young males.
    - Secondary : Due to existing lung diseases (e.g. COPD, cystic fibrosis, or tuberculosis)

  - **Traumatic** Pneumothorax
    - Blunt or penetrating chest injury
    - Medical procedures like lung biopsies, central line placement

Pneumothorax

- **Symptoms**
  - Sudden chest pain
  - Shortness of breath
  - Rapid heart rate
  - Fatigue
  - Cyanosis

- **Diagnosis**
  - Physical Examination : **Decreased breath sounds** on the affected side.
  - Imaging : Chest X-ray, CT scan, or ultrasound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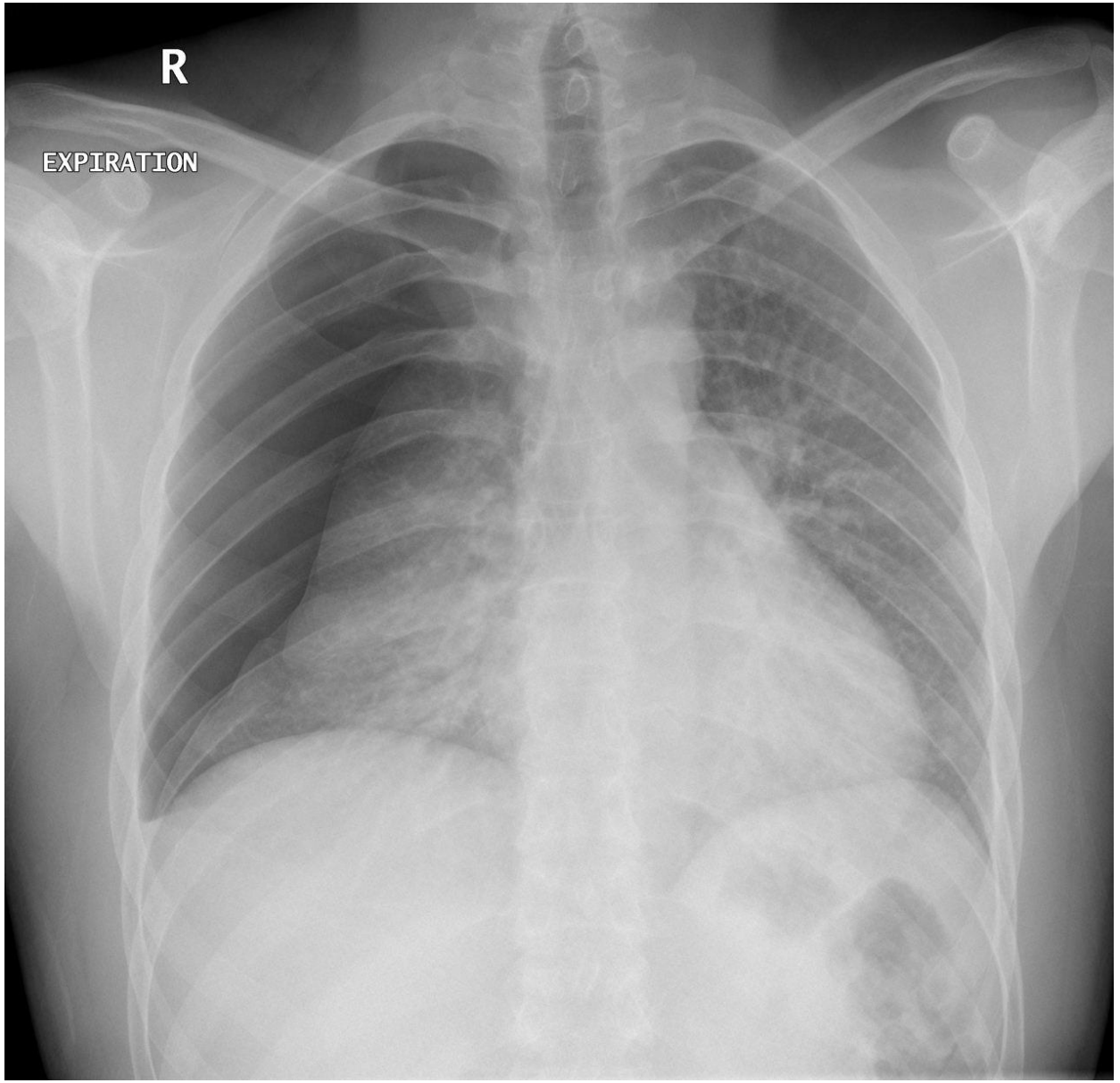
INSPIRATION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EXPIRATION

Pneumothorax

- **Treatment**
  - Small Pneumothorax : monitoring and oxygen therapy.
  - Large or Symptomatic Pneumothorax : Needle aspiration or **chest tube insertion**
  - Surgery

- **Preventive Measures**
  - **Smoking cessation**
  - Careful monitoring and management of underlying lung conditions.

Indications of Surgery for Pneumothorax

- **Recurren**t Pneumothorax

- Persistent **Air Leak**
  - Continuous air leak for more than 5-7 days despite conservative treatments.

- **Bilateral** Pneumothorax

- **Occupational** or Lifestyle Considerations:
  - Individuals in high-risk professions (e.g., pilots, divers) may require surgery after a first episode to avoid recurrence during critical activities.

- **Tension Pneumothorax:**
  - While typically an emergency managed with immediate decompression, surgery may follow to prevent recurrence and treat any underlying issues.

Pneumothorax

- **Preventive Measures**
  - **Smoking cessation**
  - Careful monitoring and management of underlying lung conditions.

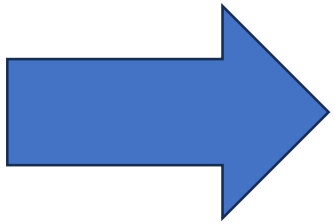
Pleural Effusion

- **Definition**
  - Accumulation of excess fluid between the layers of the pleura outside the lungs

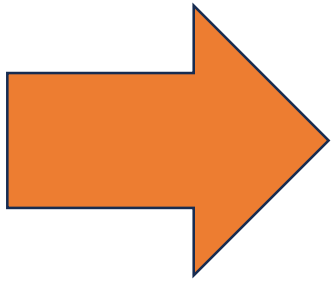
- **Types**
  - **Transudative Effusion**
    - Caused by systemic factors
  - **Exudative Effusion**
    - Result of local factors

Pleural Effusion

- **Causes**
  - Heart failure
  - Liver cirrhosis
  - Kidney disease
  - Pneumonia
  - Cancer
  - Pulmonary embolism
  - Tuberculosis



Transudate



Exudate

Pleural Effusion

- **Symptoms**
  - Shortness of breath
  - Chest pain, especially during inhalation
  - Cough
  - Fever (if infection is present)
  - Reduced breath sounds on affected side

Pleural Effusion

- **Diagnosis:**
  - Physical examination
  - Imaging: Chest X-ray, CT scan, ultrasound.
  - Thoracentesis: Procedure to remove and analyze pleural fluid.


A
B

Pleural Effusion

- **Treatment:**
  - **Underlying Cause :** Treat the primary
  - **Thoracentesis :** Therapeutic removal of fluid to relieve symptoms.
  - **Chest Tube Insertion**
  - **Pleurodesis:** Prevent recurrent effusions, often in cancer patients.
  - **Surgery:** VATS for diagnostic or therapeutic purposes in complex cases.

Empyema

- **Definition**
  - Accumulation of pus in the pleural cavity

- **Causes**
  - Usually a complication of pneumonia, thoracic surgery, trauma, or infection spreading from nearby structures.

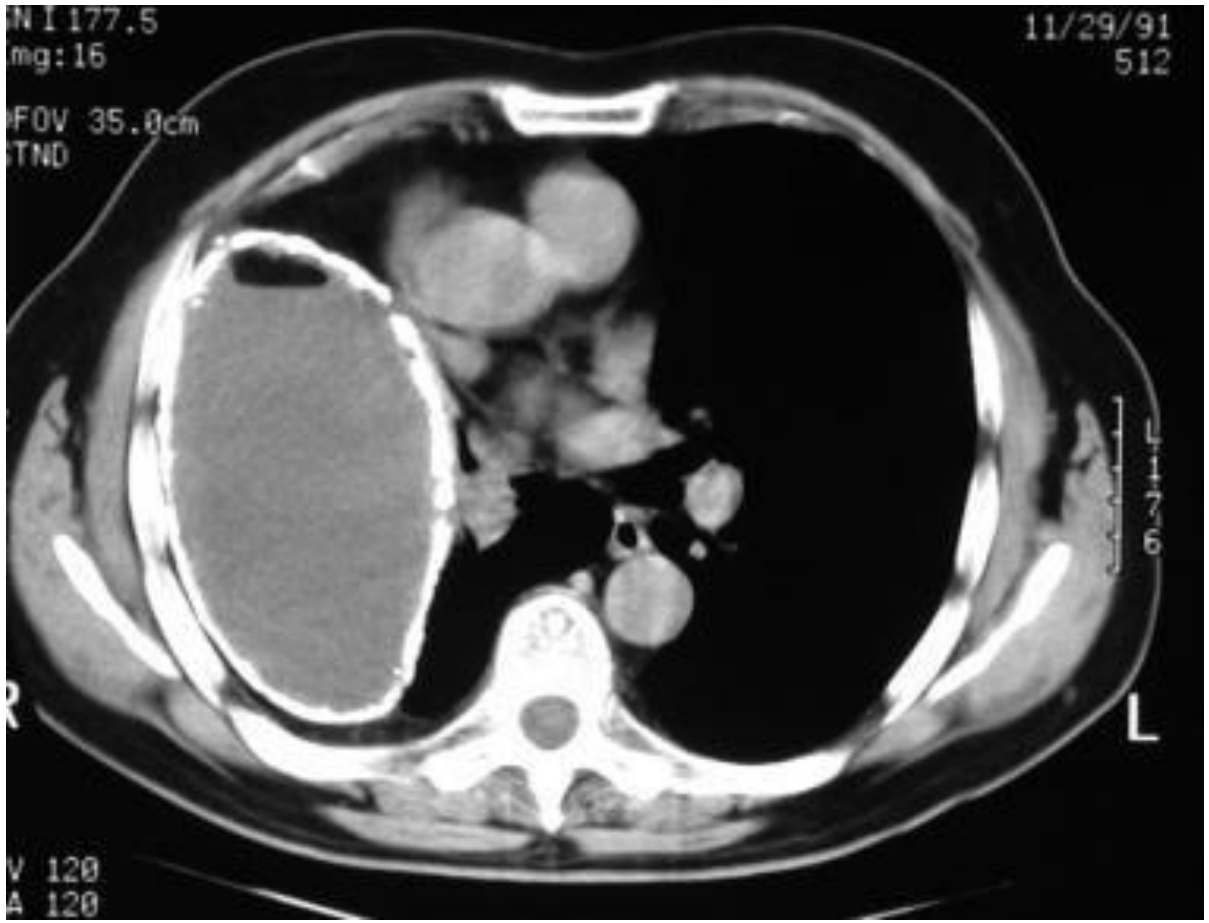
- **Mechanism**
  - Bacterial infection leading to inflammation, pus formation, and fibrin deposition in the pleural space.
  - Common Bacteria: Streptococcus pneumoniae, Staphylococcus aureus, and anaerobes.

Empyema

- **Symptoms**
  - Fever
  - Chest pain
  - Cough
  - Shortness of breath

- **Diagnosis**
  - Chest X-ray
  - Chest CT
  - Pleural fluid analysis

Empyema



Empyema

- **Exudative Stage**
  - Inflammatory fluid accumulation without significant pus
  - Thin, free-flowing fluid

- **Fibrinopurulent Stage**
  - Pus and fibrin deposition, leading to loculated pleural effusions.
  - Thicker fluid, formation of septations and loculations

- **Organizing Stage**
  - Fibroblasts grow into the pleural fluid, forming a thick peel
  - Characteristics: Encapsulation of the lung, restrictive lung movement.

Empyema

- **Medical treatment**
  - Antibiotics
  - Pleural drainage
  - Fibrinolytics

- **Indications for operation**
  - **Failure of Medical Management**
  - Loculated Effusion: When fibrinolytics are ineffective.
  - **Thickened Pleura** (Organizing Stage): Preventing lung expansion.

Empyema

- **Surgical treatment**
  - Video-Assisted Thoracoscopic Surgery (VATS)
    - Minimally invasive
    - Used in the fibrinopurulent stage
  - Open Thoracotomy
    - More invasive
    - Required in the organizing stage for decortication
  - Decortication: Removal of the fibrous layer covering the lung to allow re-expansion.

Mesothelioma

- **Definition**
  - Mesothelioma is a rare, aggressive form of cancer that develops in the mesothelial cells lining the lungs, abdomen, or heart.
  - Primary Site: Pleura (lining of the lungs) is the most common site

- **Primary Cause:** Asbestos exposure.

- **Mechanism**: Inhaled or ingested asbestos fibers become lodged in the mesothelium, causing inflammation and genetic mutations that lead to cancer.

Mesothelioma

- **Diagnosis**
  - **Imaging Tests**
    - CT scan
    - MRI
    - PET scan
  - **Biopsy**
    - Needle biopsy
    - Thoracoscopy
  - **Blood tests**
    - Mesomark assay for soluble mesothelin-related peptides (SMRPs)

Mesothelioma

- **Surgery**
  - Pleurectomy/decortication (P/D)
  - Extrapleural pneumonectomy (EPP)

- **Chemotherapy**
  - Common agents: Pemetrexed and cisplatin.

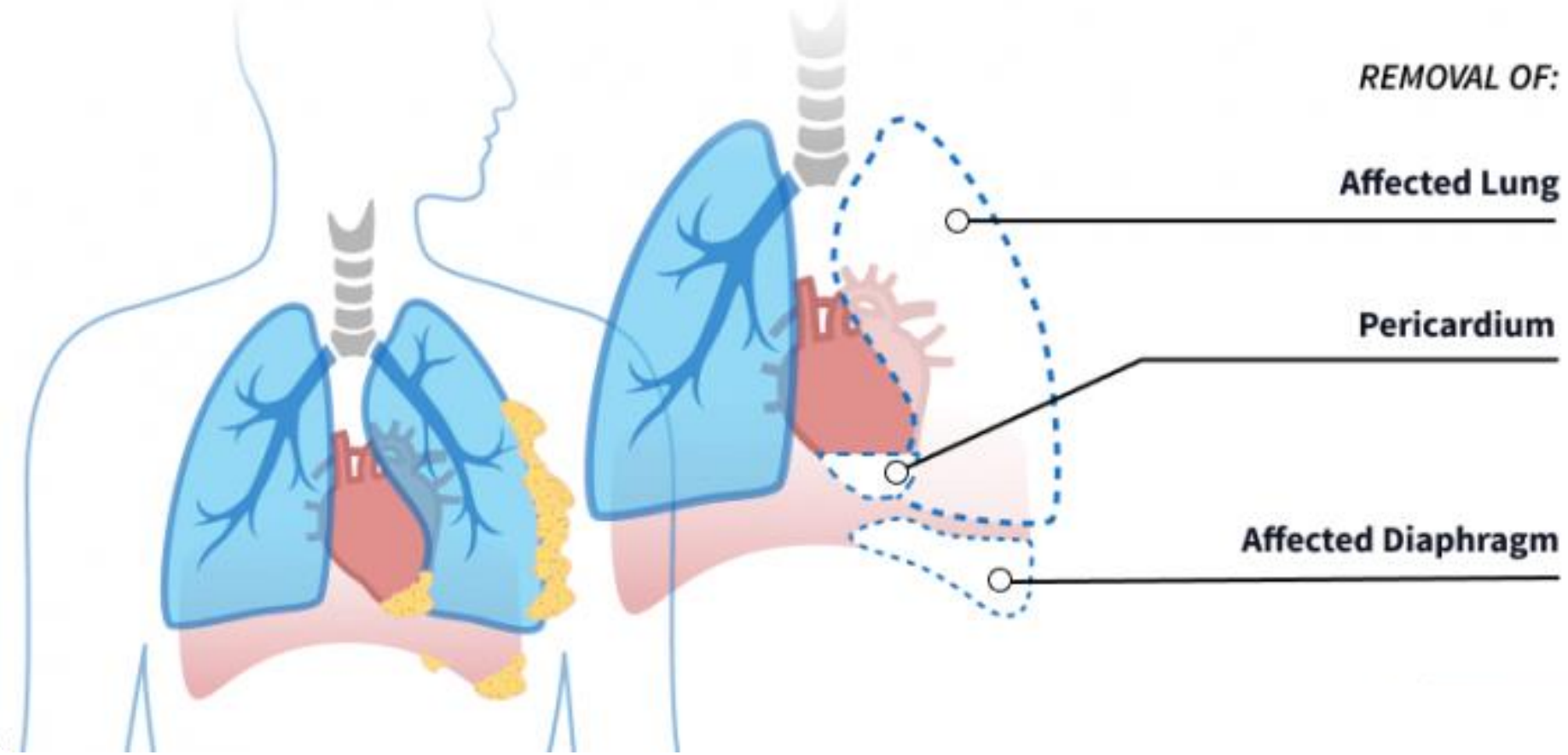
- Radiation Therapy
  - Used to shrink tumors or relieve symptoms.

- Multimodal Therapy

Extrapleural Pneumonectomy

- **Removal of Pleura**
  - The parietal pleura and the visceral pleura are removed.
- **Lung resection**
  - The affected lung is detached and removed.
- **Other structures**
  - The pericardium and the diaphragm are partially or completely removed if they are involved by the tumor.
  - A synthetic or biological patch may be used to reconstruct the pericardium and the diaphragm.

Extrapleural Pneumonectomy (EEP)



Chest Tube and Chest Bottle

Chest Tube

- **Maintenance**
  - **Monitoring**
    - Regular assessment of the **insertion site**, tube patency, and **the amount and nature of drainage**.
  - **Suction**
    - Often applied to help re-expand the lung
  - **Preventing Complications**
    - Ensure the tube does not become kinked or dislodged.
    - Prevent infection through regular dressing changes and sterile techniques.

Chest Tube Removal

- **Criteria for Removal**
  - **Resolution of the underlying issue**
    - Confirmed by imaging
  - **Drainage**
    - Minimal drainage, typically less than 200 ml over 24 hours.
  - **Air Leak**
    - No air leak during a cough or Valsalva maneuver.

- **Procedure for Removal**
  - The tube is pulled out quickly while the patient performs a Valsalva maneuver to prevent air entry.
  - The site is then covered with an occlusive dressing.

Chest Bottle

- **1 bottle system**
  - Collection
  - **Water Seal**
  - Air and Fluid
    - As the patient exhales or as the lung re-expands, air and fluid are expelled from the pleural space into the bottle.
  - **Air Escape**
    - Air bubbles through the water and exits through the vent tube
  - **Fluid Collection**

Chest Bottle

- 1 bottle system Advantages and Disadvantages
  - Advantages
    - Simplicity
    - Portability
  - Disadvantages
    - Limited Capacity
    - Lack of Suction Regulation

- Indications for Use
  - Simple Pneumothorax
  - Low-Volume Drainage

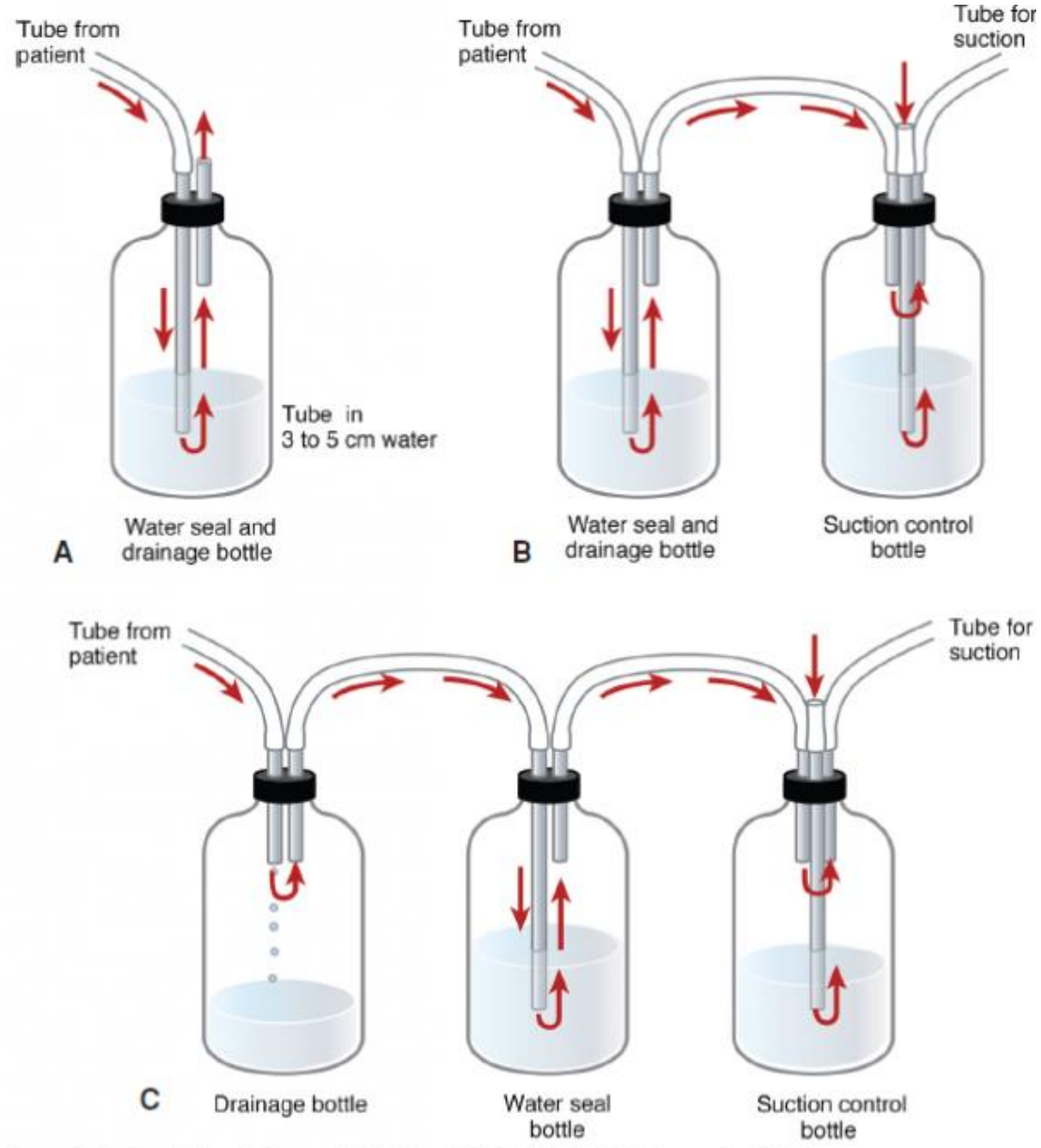
Chest Bottle

- **2-Bottle System**
  - **Components**
    - **Collection Bottle**
    - **Water Seal Bottle**

  - **Function:**
    - **Drainage:** Fluid from the pleural space collects in the first bottle.
    - **Water Seal:** The second bottle allows air to escape but not return, ensuring a one-way flow out of the chest.

Chest Bottle

- **3-Bottle System**
  - **Components:**
    - **Collection Bottle**
    - **Water Seal Bottle**
    - **Suction Control Bottle**
  - **Function:**
    - **Collection:** Similar to the 2-bottle system, fluid collects in the first bottle.
    - **Water Seal:** The second bottle serves the same function, preventing air from re-entering.
    - **Suction Control:** The third bottle contains water and controls the level of suction by the height of the water column, ensuring consistent and safe suction pressure.



Source: D. J. Sugarbaker, R. Bueno, Y. L. Colson, M. T. Jaklitsch, M. J. Krasna, S. J. Mentzer, M. Williams, A. Adams: *Adult Chest Surgery*, 2nd Edition: www.accesssurgery.com

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