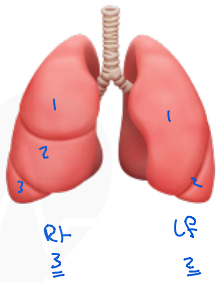
Respiratory system - Pathology1

Introduction

FUNCTION AND ANATOMY

Main function of the lung:
The major function of the lung is to replenish oxygen and remove carbon dioxide from blood.



COMPONENTS OF THE ALVEOLAR WALL (Alveolar Septa)

(from the blood side → air side)

1. **Capillary endothelium**

→ Thin layer of endothelial cells lining the blood capillaries within the alveolar wall.

2. **Basement membrane**

→ Separates the capillary endothelium from the interstitial space.

3. **Pulmonary interstitium**

→ The space between capillary and alveolar epithelium containing elastic fibers, collagen, and occasional fibroblasts.

💡 This area provides structural support and allows gas exchange.

4. **Alveolar epithelium** – consists of two main cell types:
   - **Type I pneumocytes (95%)**

→ Flat, thin cells responsible for gas exchange.

💡 They form the main part of the alveolar surface.

   - **Type II pneumocytes (5%)**

→ Rounded cells that produce pulmonary surfactant (reduces surface tension and prevents alveolar collapse).

→ Also play a role in repair of the alveolar epithelium after injury to Type I cells.

5. **Alveolar macrophages**

→ Mononuclear phagocytic cells that usually lie free within the alveolar space.

💡 They remove debris, microorganisms, and dust particles.

💡 SUMMARY NOTE:

The alveolar wall is extremely thin to allow efficient gas diffusion between air and blood.
Damage to any component (endothelium, interstitium, or epithelium) → impairs gas exchange → may lead to respiratory failure.

🫁 RESPIRATORY SYSTEM PATHOLOGY

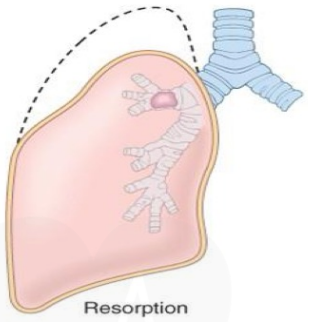
ATELECTASIS (LUNG COLLAPSE)

Definition:
Loss of lung volume caused by inadequate expansion of air spaces.

THREE TYPES OF ATELECTASIS:

1 Resorption Atelectasis

- Due to total obstruction of a bronchus preventing air from reaching distal airways.
- Most common cause: obstruction of a bronchus by:
- Intrabronchial mucus or mucopurulent plugs in postoperative patients
- Foreign body aspiration, especially in children
- Obstructive lung diseases such as:
- *Bronchial asthma*
- *Bronchiectasis*
- *Chronic bronchitis*
- *Intrabronchial tumors*

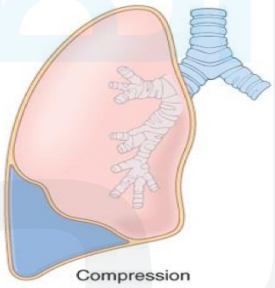


💡 When air trapped in alveoli distal to the obstruction is absorbed, the alveoli collapse.

2 Compression Atelectasis

- Caused by accumulation of fluid, blood, or air **within the pleural cavity**, which mechanically collapses adjacent lung.

Examples:
a. **Pleural effusion** (e.g., in congestive heart failure)
b. **Pneumothorax** (air in the pleural cavity)

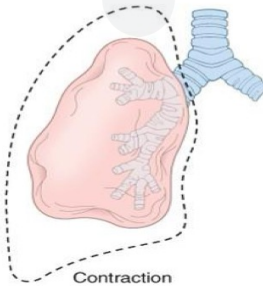


💡 The pressure from the pleural contents compresses the lung, preventing expansion.

3 Contraction Atelectasis (Cicatrization Atelectasis)

- Occurs due to local or generalized **fibrosis** of the lung or pleura that prevents full expansion of the lung.

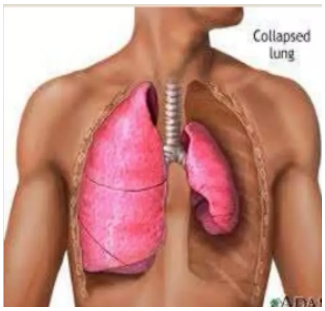
💡 This type is **irreversible** because fibrosis fixes the lung in a collapsed state.

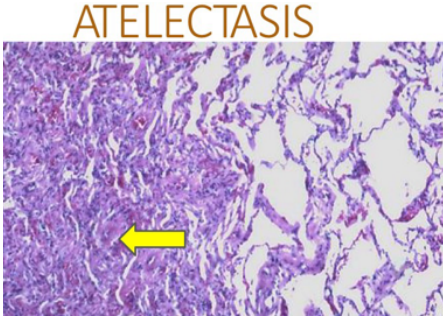


Important Note:

Atelectasis (except when caused by contraction) is potentially reversible and should be treated promptly to prevent:

- Hypoxemia (low oxygen in blood)
- Superimposed infection of the collapsed lung.

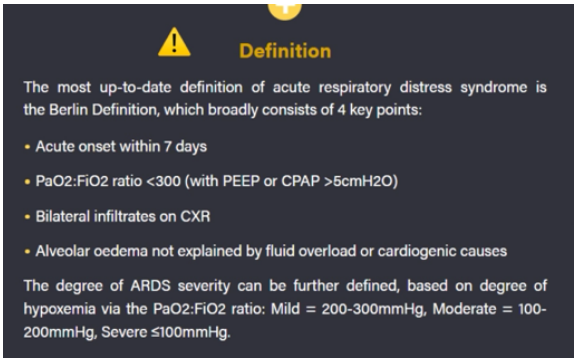




ACUTE RESPIRATORY DISTRESS SYNDROME (ARDS)

Definition:

Respiratory failure occurring within 1 week of a known clinical insult, with bilateral opacities on chest imaging, not fully explained by effusions, atelectasis, cardiac failure, or fluid overload.



Severe ARDS is characterized by:

a. Rapid onset of life-threatening respiratory insufficiency
b. Cyanosis
c. Severe arterial hypoxemia that becomes refractory to oxygen therapy
d. May progress to multisystem organ failure

ARDS – TRIGGERS (Causes)

- **Pneumonia (35%–45%)**
- Sepsis (30%–35%)
- Aspiration
- Trauma (including brain injury, abdominal surgery, multiple fractures)
- Pancreatitis
- Transfusion reactions

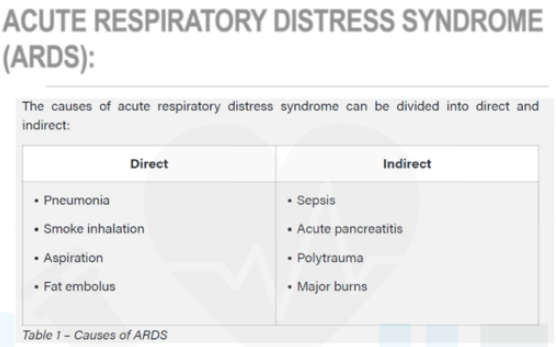


Table 1 – Causes of ARDS

💡 **Do not confuse with neonatal respiratory distress syndrome, which is caused by surfactant deficiency due to prematurity.**

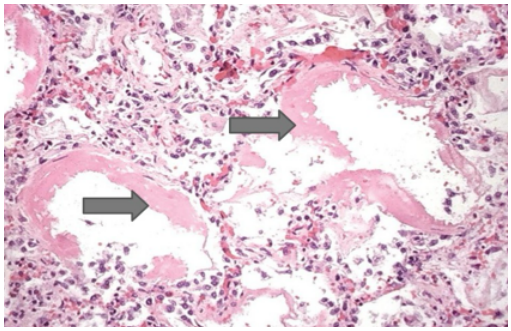
PATHOGENESIS OF ARDS

- The integrity of the alveolar-capillary membrane is compromised by endothelial and epithelial injury.
- Within 30 minutes after the acute insult:
- **Pulmonary macrophages** release **IL-8, IL-1, and TNF,** leading to:
- Endothelial activation
- Sequestration and activation of neutrophils in pulmonary capillaries

- Activated neutrophils release:
- Reactive oxygen species (ROS)
- Proteases
- These substances cause:
- **Damage to alveolar epithelium and endothelium**
- **Vascular leakiness** → leakage of protein-rich fluid
- **Loss of surfactant** → alveolar collapse (atelectasis)

💡 These destructive forces are normally balanced by anti-proteases and anti-oxidants.
The balance between destruction and protection determines the severity of ARDS.

🔬 HISTOLOGY

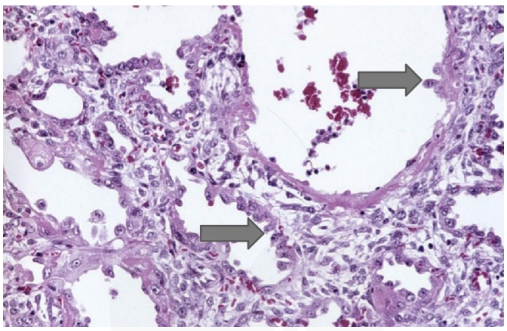


1️⃣ **Acute phase:**

- Most characteristic finding: presence of hyaline membranes

→ composed of fibrin-rich edema fluid mixed with necrotic epithelial cell debris.

(similar to neonatal respiratory distress syndrome)



2️⃣ **Organizing (late) stage:**

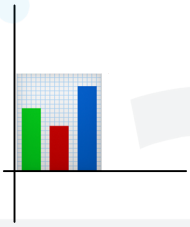
- Proliferation of Type II pneumocytes (for repair)
- Intraalveolar fibrosis due to organization of fibrin-rich exudates
- Marked thickening of alveolar septa because of:
- Proliferation of interstitial cells
- Collagen deposition

CLINICAL FEATURES

- Usually occurs in hospitalized patients with predisposing conditions (like **sepsis**, **trauma**, or **aspiration**)
- Profound dyspnea and tachypnea
- Progressive cyanosis and hypoxemia → **respiratory failure**
- Diffuse bilateral infiltrates on chest X-ray
- Hypoxemia is refractory to oxygen therapy

OUTCOME:

- Overall hospital mortality rate: **38.5%**
- Most survivors recover normal respiratory function within 6–12 months
- Some develop diffuse interstitial fibrosis → chronic respiratory insufficiency



PREDICTORS OF POOR PROGNOSIS:

1. Advanced age
2. Bacteremia (sepsis)
3. Development of multiorgan failure

COVID-19 & ARDS

- COVID-19 pandemic!
- Variable clinical presentations
- **COVID-19-associated ARDS – may have different pathogenesis and management considerations**

💡 Studies show ~**1/3** of COVID-19 patients with severe infection develop severe ARDS.

COVID-19 & ARDS (Acute Respiratory Distress Syndrome)

COVID-19, caused by SARS-CoV-2, can lead to severe lung injury and ARDS in some patients.
But unlike classic ARDS, COVID-19 ARDS often shows unique mechanisms and vascular complications.

Pathogenesis (How COVID-19 causes ARDS):

1. Endothelial Injury
2. Cytokine Storm
3. Pulmonary Embolism & Thrombosis

🦠 COVID-19 & ARDS (Acute Respiratory Distress Syndrome)

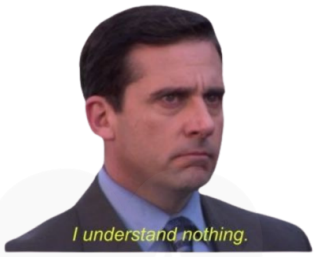
COVID-19, caused by SARS-CoV-2, can lead to severe lung injury and ARDS in some patients.
But unlike classic ARDS, COVID-19 ARDS often shows unique mechanisms and vascular complications.

Extra , high yield

Pathogenesis (How COVID-19 causes ARDS)

1. Endothelial Injury
   - The virus infects endothelial cells (lining blood vessels) via ACE2 receptors.
   - This causes endothelial dysfunction and capillary leak, leading to:
   - Increased vascular permeability
   - Pulmonary edema
   - Microthrombosis (tiny blood clots inside lungs)

💥 So instead of injury being only to alveoli (like in classic ARDS), COVID also heavily injures blood vessels in the lungs.



2. Cytokine Storm
   - The immune system becomes overactivated, releasing large amounts of pro-inflammatory cytokines (e.g. IL-6, TNF-α, IL-1β).
   - This cytokine storm causes:
   - Damage to alveolar epithelial cells
   - Diffuse alveolar damage (DAD)
   - Worsening capillary permeability
   - Multi-organ failure in severe cases

🧠 Think of it as the body's immune system "attacking itself" due to uncontrolled inflammation.

3. Pulmonary Embolism & Thrombosis
   - COVID-19 is highly prothrombotic (increases tendency for clotting).
   - Endothelial injury + inflammation + stasis → formation of microthrombi and large pulmonary emboli.
   - This causes ventilation–perfusion mismatch (V/Q mismatch), leading to:
   - Severe hypoxemia
   - Worsened ARDS picture

🩸 So in COVID-19, many patients have "thrombotic ARDS" — involving both inflammation and clotting.

CLINICAL CASE (MCQ)

A 58-year-old man with ischemic heart disease undergoes coronary artery bypass graft surgery under general anesthesia. Two days postoperatively, he experiences increasing respiratory difficulty with decreasing arterial oxygen saturation.

Examination findings:
- Heart rate: 78/min (regular)
- Respirations: 25/min
- Blood pressure: 135/85 mmHg
- Hemoglobin unchanged at 13.7 g/dL

After he coughs up a large amount of mucoid sputum, his condition improves.

Question:
Which type of atelectasis does he most likely have?

Options:
A) Compression
B) Contraction
C) Resorption ✅

💡 Because the obstruction of the bronchus by mucus plugs led to collapse of distal airways — and resolution after sputum was expelled.

Dr. Omar Hamdan
Done by : Raghad Mrayat