

Pulmonary Edema



Seminar – August 31st 2015



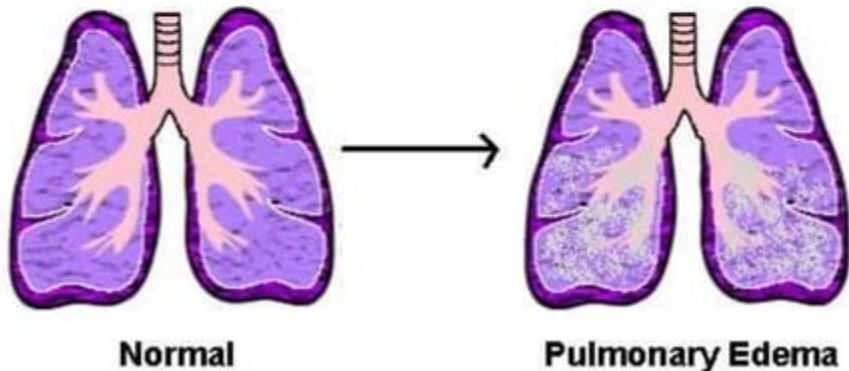
Presenter: Dr.Arun Vasireddy

Overview

- Definition
- Epidemiology
- Etiopathogenesis & Pathophysiology
- Classification & Staging
- Clinical Picture
- Complications
- Diagnosis & Management
- Prognosis

Definition

Pulmonary Edema is a condition characterized by fluid accumulation in the lungs caused by extravasation of fluid from pulmonary vasculature in to the interstitium and alveoli of the lungs.



Epidemiology

- Pulmonary edema occurs in about 1% to 2% of the general population.
- Between the ages of 40 and 75 years, males are affected more than females.
- After the age of 75 years, males and females are affected equally.
- The incidence of pulmonary edema increases with age and may affect about 10% of the population over the age of 75 years.

Etiopathogenesis

- Pulmonary edema can be caused by the following major pathophysiologic mechanisms:
 - Imbalance of Starling forces
 - increased pulmonary capillary pressure,
 - decreased plasma oncotic pressure,
 - increased negative interstitial pressure
 - Damage to the alveolar-capillary barrier
 - Lymphatic obstruction
 - Idiopathic (unknown) mechanism

Starling Forces

The extent to which fluid accumulates in the interstitium of the lung depends on the balance of hydrostatic and oncotic forces within the pulmonary capillaries and in the surrounding tissue.

❖ **Hydrostatic pressure**

-favors movement of fluid from the capillary into the interstitium

❖ **Oncotic pressure**

-favors movement of fluid into the vessel

➤ Net flow of fluid across a membrane is determined by applying the following equation

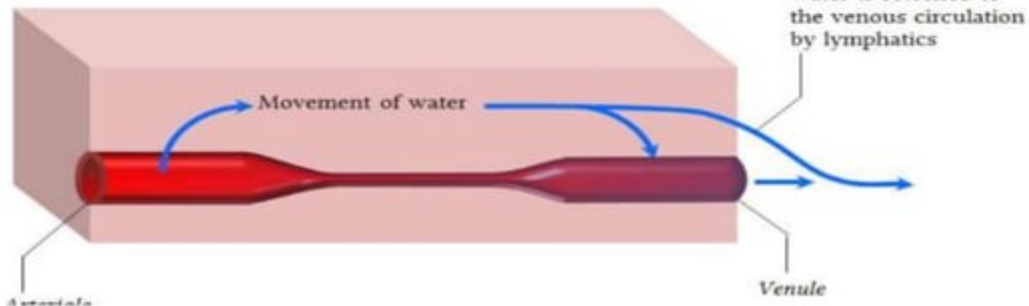
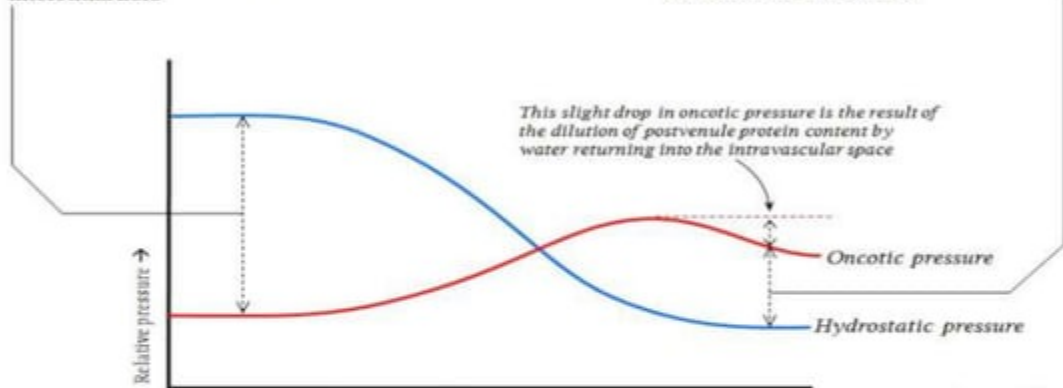
$$Q = K(P_{\text{cap}} - P_{\text{is}}) - I(P_{\text{cap}} - P_{\text{is}}),$$

➤ The net filtration of fluid may increase with changes in different parameters of the Starling equation.

THE CLASSICAL MODEL OF THE STARLING PRINCIPLE

In the precapillary arterioles, the hydrostatic pressure is greater than the oncotic pressure, favouring the movement of water into the interstitial fluid

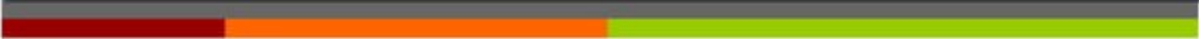
In the postcapillary venules, the oncotic pressure is greater than the hydrostatic pressure, favouring the movement of water out of the interstitial fluid and back into the venules



Role of Lymphatics

- The lymphatics play an important role in maintaining an adequate fluid balance in the lungs by removing solutes, colloid, and liquid from the interstitial space at a rate of approximately 10-20 mL/h.
- An acute rise in pulmonary arterial capillary pressure (ie, to >18 mm Hg) may increase filtration of fluid into the lung interstitium, but the lymphatic removal does not increase correspondingly.
- In contrast, in the presence of chronically **elevated LA pressure**, the rate of lymphatic removal can be as high as 200 mL/h, which protects the lungs from pulmonary edema.

Classification



Cardiogenic
Pulmonary Edema

Non-Cardiogenic
Pulmonary Edema

Cardiogenic pulmonary edema

- Defined as pulmonary edema due to increased Pulmonary capillary hydrostatic pressure secondary to **elevated pulmonary venous pressure**.
- Increased LA pressure increases pulmonary venous pressure and pressure in the lung microvasculature, resulting in pulmonary edema.
- Hydrostatic pressure is increased and fluid exits the capillary at an increased rate, resulting in interstitial and, in more severe cases, alveolar edema.
- Also called Hydrostatic pulmonary edema.



Cardiac disorders manifesting as CPE

➤ *Left Atrial outflow obstruction*

- This can be due to mitral stenosis or, in rare cases, atrial myxoma, thrombosis of a prosthetic valve, or a congenital membrane in the left atrium (eg, cor triatriatum).

➤ *LV systolic dysfunction*

- Systolic dysfunction, a common cause of CPE, is defined as decreased myocardial contractility that reduces cardiac output.
- The fall in cardiac output stimulates sympathetic activity and blood volume expansion by activating the renin-angiotensin-aldosterone system, which causes deterioration by decreasing LV filling time and increasing capillary hydrostatic pressure.



Cardiac disorders manifesting as CPE

➤ *LV diastolic dysfunction*

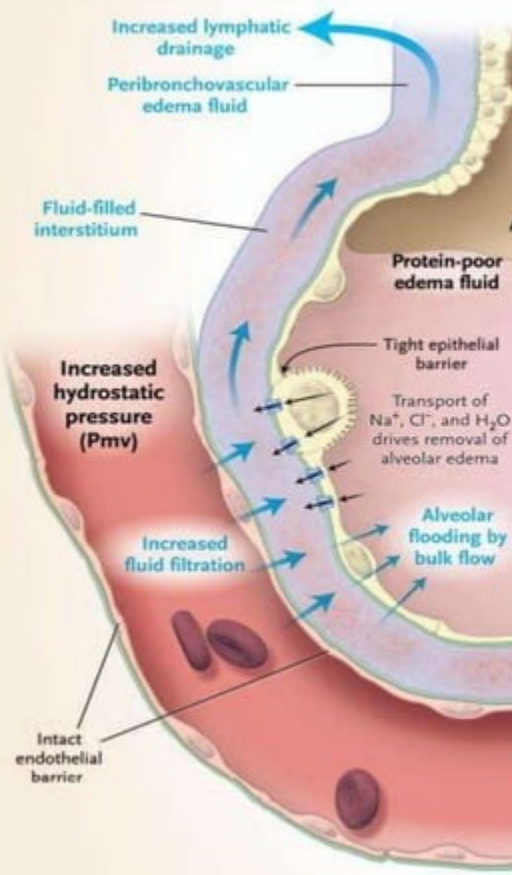
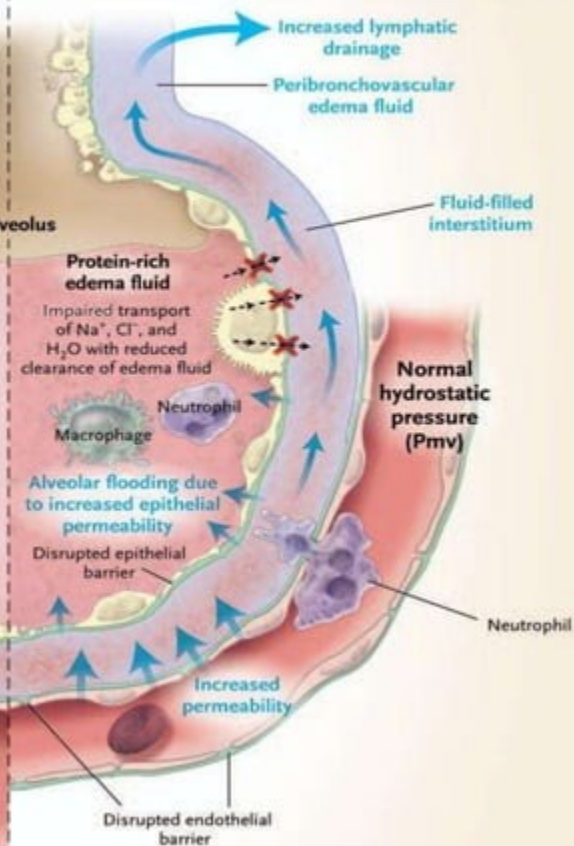
- Ischemia and infarction may cause LV diastolic dysfunction in addition to systolic dysfunction. With a similar mechanism, myocardial contusion induces systolic or diastolic dysfunction.

- **Chronic LV failure** is usually the result of congestive heart failure (CHF) or cardiomyopathy.



➤ Causes of acute exacerbations of CPE

- Acute myocardial infarction (MI) or ischemia
- Patient noncompliance with dietary restrictions (eg, dietary salt restrictions)
- Patient noncompliance with medications (eg, diuretics)
- Severe anemia with underlying cardiac illness
- Sepsis
- Thyrotoxicosis
- Myocarditis
- Myocardial toxins (eg, alcohol, cocaine, chemotherapeutic agents such as doxorubicin [Adriamycin], trastuzumab [Herceptin])
- Chronic valvular disease, aortic stenosis, aortic regurgitation, and mitral regurgitation

B**Cardiogenic pulmonary edema****C****Noncardiogenic pulmonary edema**

Cardiogenic PE Staging

The progression of fluid accumulation in CPE can be identified as 3 distinct physiologic stages.

➤ ***Stage 1***

- elevated LA pressure causes distention and opening of small pulmonary vessels.
- At this stage, blood gas exchange does not deteriorate, or it may even be slightly improved.



➤ *Stage 2*

- Fluid and colloid shift into the lung interstitium from the pulmonary capillaries, but an initial increase in lymphatic outflow efficiently removes the fluid.
- The continuing filtration of liquid and solutes may overpower the drainage capacity of the lymphatics. In this case, the fluid initially collects in the relatively compliant interstitial compartment, which is generally the perivascular tissue of the large vessels, especially in the dependent zones.
- The accumulation of liquid in the interstitium may compromise the small airways, leading to mild hypoxemia.
- Hypoxemia at this stage is rarely of sufficient magnitude to **stimulate tachypnea**.



➤ *Stage 3*

- As fluid filtration continues to increase and the filling of loose interstitial space occurs, fluid accumulates in the relatively noncompliant interstitial space.
- The interstitial space can contain up to 500mL of fluid. With further accumulations, the fluid crosses the alveolar epithelium in to the alveoli, leading to alveolar flooding.
- At this stage, abnormalities in gas exchange are noticeable, **vital capacity** and other respiratory volumes are substantially reduced, and hypoxemia becomes more severe.

Clinical features of CPE

- Early signs of pulmonary edema include exertional dyspnea and orthopnea.
- Chest radiographs show peribronchial thickening, prominent vascular markings in the upper lung zones, and Kerley B lines.
- As the pulmonary edema worsens, alveoli fill with fluid; the chest radiograph shows patchy alveolar filling, typically in a perihilar distribution, which then progresses to diffuse alveolar infiltrates.
- Increasing airway edema is associated with rhonchi and wheezes.



Non cardiogenic pulmonary edema

- caused by changes in permeability of the pulmonary capillary membrane as a result of either a direct or an indirect pathologic insult.

TABLE 47e-3 COMMON CAUSES OF NONCARDIOGENIC PULMONARY EDEMA

Direct Injury to Lung

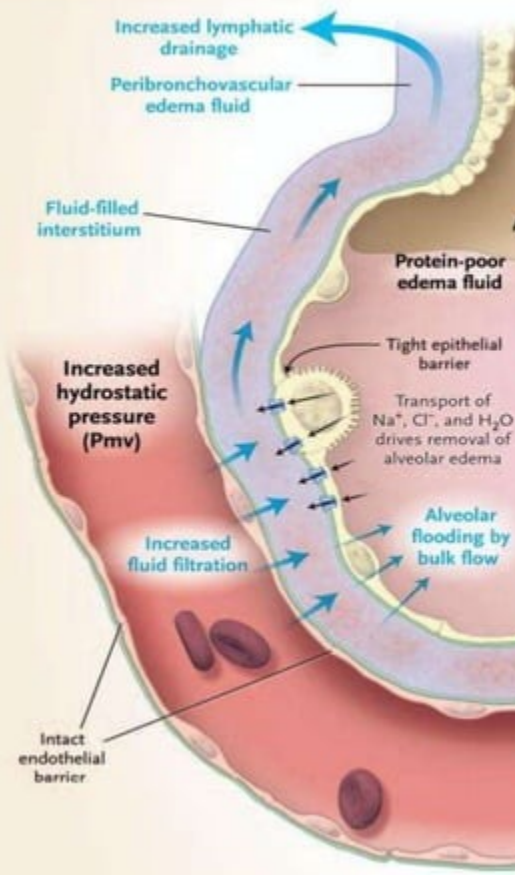
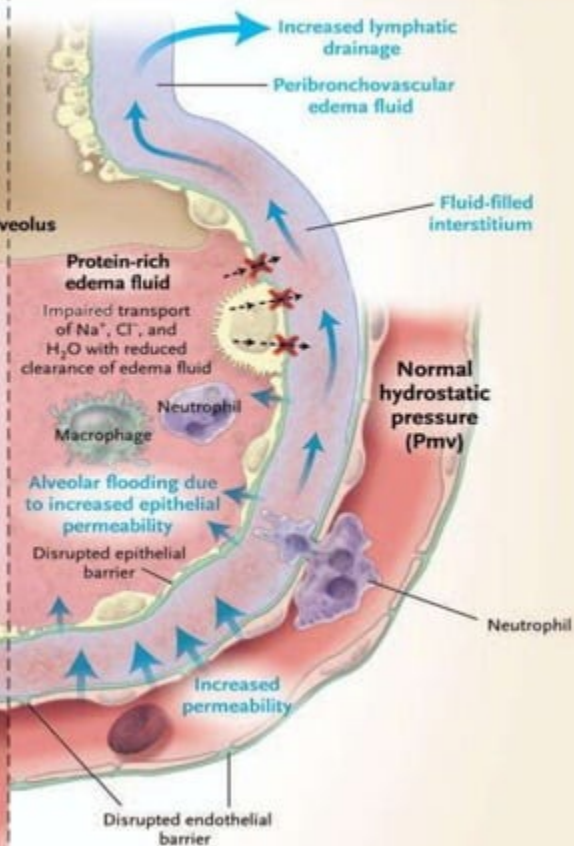
Chest trauma, pulmonary contusion
Aspiration
Smoke inhalation
Pneumonia
Oxygen toxicity
Pulmonary embolism, reperfusion

Hematogenous Injury to Lung

Sepsis
Pancreatitis
Nonthoracic trauma
Leukoagglutination reactions
Multiple transfusions
Intravenous drug use (e.g., heroin)
Cardiopulmonary bypass

Possible Lung Injury Plus Elevated Hydrostatic Pressures

High-altitude pulmonary edema
Neurogenic pulmonary edema
Reexpansion pulmonary edema

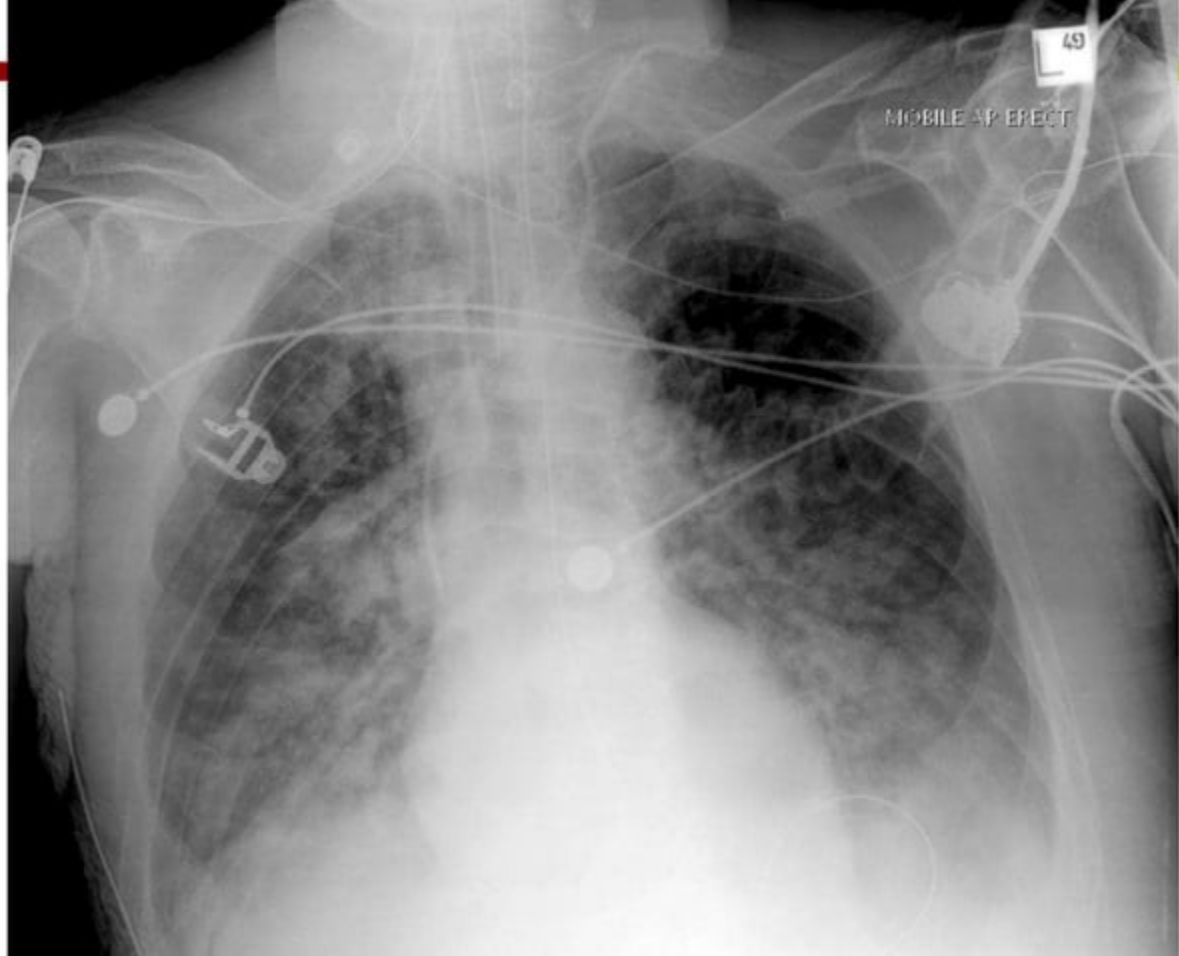
B**Cardiogenic pulmonary edema****C****Noncardiogenic pulmonary edema**

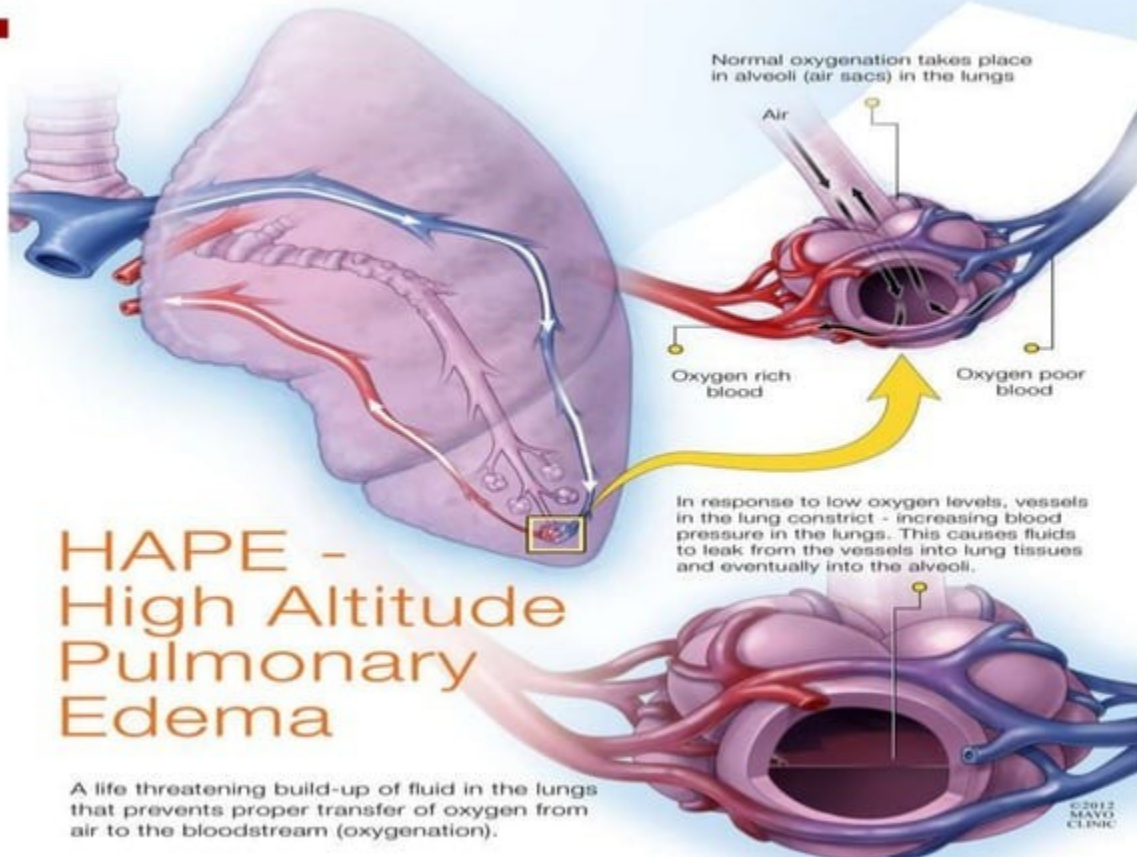
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- Physiologically, noncardiogenic pulmonary edema is characterized by intrapulmonary shunt with hypoxemia and decreased pulmonary compliance leading to lower functional residual capacity.
 - Clinically, the picture ranges from mild dyspnea to respiratory failure.
 - Auscultation of the lungs may be relatively normal despite chest radiographs that show diffuse alveolar infiltrates

ARDS

- Is associated with diffuse alveolar damage (DAD) and lung capillary endothelial injury.
- The early phase is described as being exudative, whereas the later phase is fibroproliferative in character.
- Early ARDS is characterized by an increase in the permeability of the alveolar-capillary barrier, leading to an influx of fluid into the alveoli.
- The main site of injury may be focused on either the vascular endothelium (sepsis) or the alveolar type 1 epithelium (eg, aspiration of gastric contents).
- Injury to the endothelium results in increased capillary permeability and the influx of protein-rich fluid into the alveolar space.

MOBILE AP ERECT





HAPE - Pathogenesis

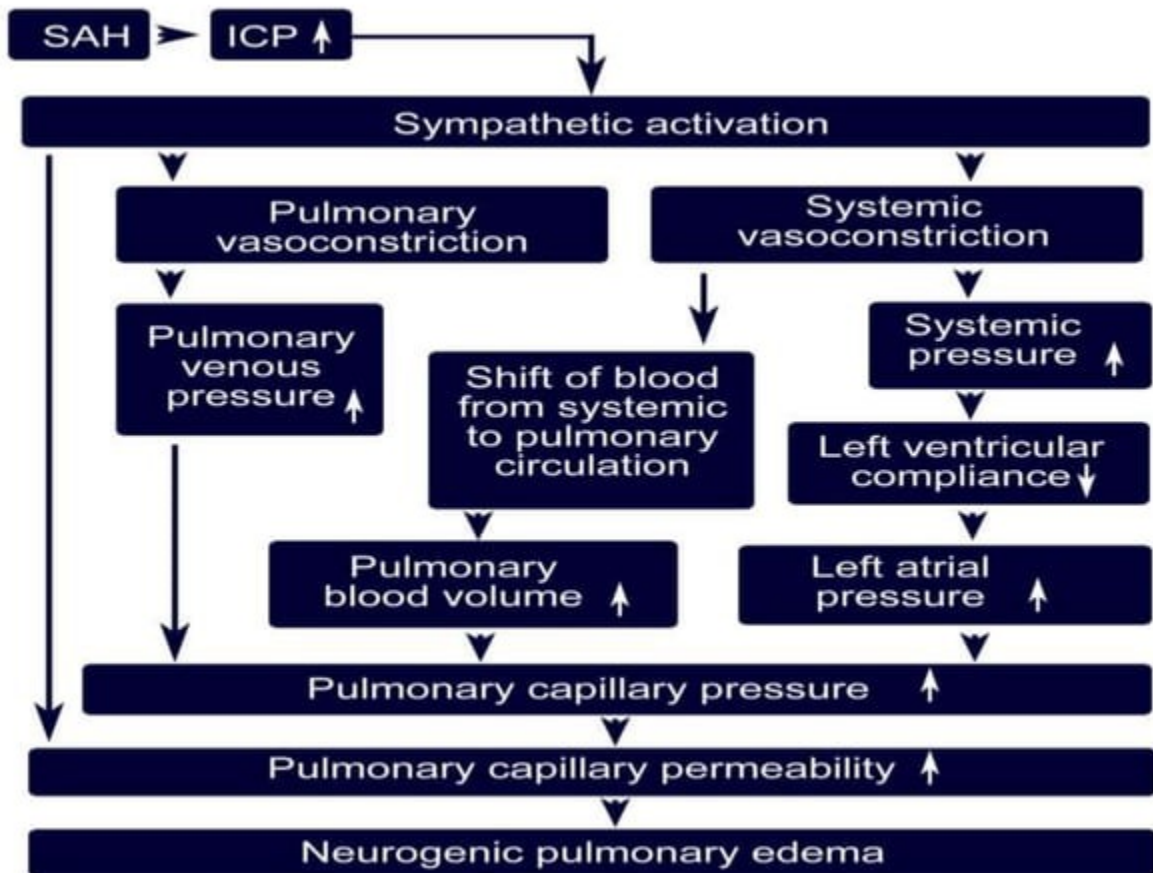
- Altered permeability of the alveolar-capillary barrier secondary to intense pulmonary vasoconstriction and high capillary pressure.
- This in turn induces endothelial leakage, which results in interstitial and alveolar oedema without diffuse alveolar damage.
- Reported clinical manifestations include:
 - dyspnea at rest
 - cough with frothy pink sputum production
 - neurological disturbances associated with concomitant brain oedema.

DER. PORT. SUPINO.



Neurogenic Pulmonary Edema

- (NPE) is a clinical syndrome characterized by the acute onset of pulmonary edema following a significant insult to the CNS.
- The etiology is thought to be a surge of catecholamines that results in cardiopulmonary dysfunction.
- **CNS events associated with NPE :**
 - spinal cord injury,
 - subarachnoid hemorrhage (SAH),
 - traumatic brain injury (TBI),
 - intracranial hemorrhage,
 - status epilepticus,
 - meningitis, and
 - subdural hemorrhage
- Although NPE was identified over 100 years ago, it is still underappreciated in the clinical arena.



Re-expansion pulmonary edema

- It occurs in the setting of rapid expansion of a collapsed lung, with acute onset shortness of breath usually occurring within hours of re-expansion.
- The onset of pulmonary oedema can be delayed by up to 24 hours in some cases.
- It occurs following approximately 1% of pneumothorax re-expansions or thoracentesis procedures.
- Patients may develop hypotension or oliguria resulting from rapid fluid shifts into lung.
- Thus, It is advised not to withdraw pleural fluid more than 1.2 liters.



Near drowning pulmonary oedema

- It results from the inhalation of either fresh or sea water resulting in lung damage and ventilation-perfusion mismatching.
- Near drowning It can be divided into three stages:
 - **stage I:** acute laryngospasm that occurs after inhalation of a small amount of water
 - **stage II:** victim still usually presents with laryngospasm but may begin to swallow water into the stomach
 - **stage III:**
 - in the remaining 85-90% of patients, the laryngospasm relaxes secondary to hypoxia and large amounts of water are aspirated
 - 10-15% of patients still present with dry drowning caused by persistence of the associated laryngospasm
- CXR features in **stages II and III** can be identical to pulmonary oedema from other non-cardiac causes

Special Considerations

➤ Eclampsia

- Multiple factors such as cerebral dysfunction with massive sympathetic discharge, hypervolemia, hypoalbuminemia and disseminated intravascular coagulation probably play a role in the pathogenesis.

➤ Post Cardioversion

- The mechanism of pulmonary edema which occasionally occurs after cardioversion of tachyarrhythmias, remains unknown.
- Ineffective left atrial function after cardioversion, left ventricular dysfunction and neurogenic mechanisms have all been suggested as contributing factors.



➤ Post anaesthesia

- In previously healthy subjects, pulmonary edema has been found in the early post anaesthesia period without a clear relationship to fluid overload or any evidence of left ventricular dysfunction.
- The mechanism of this disorder is unknown but some cases have been connected to the administration of naloxone.
- Upper airway obstruction due to laryngospasm is considered the most possible mechanism causing rapid changes in intrathoracic, alveolar and interstitial pressures, which recover within 48 hours after proper intervention.



➤ Post cardiopulmonary bypass

- NCPE is a rare adverse event that occurs in 0.2% of cardiopulmonary bypass patients, with mortality rates approaching 30%.
- Alterations in surfactant due to prolonged collapse of the lung, with subsequent need to apply high negative intrapleural pressures for reexpansion, hypotension, hemorrhagic shock, transfusion of fresh frozen plasma and packed red blood cells and possibly drugs (amiodarone) may be responsible for the pathogenesis.
- Complement activation or direct pharmacologic release of histamine by high concentrations of protamine (given for reversal of heparin anticoagulation), is the suspected cause.

Drug induced PE

- **Narcotic Overdose** – Heroin
- **Opaites**
- **Chemotherapeutic agents** - cytarabine, gemcitabine, interleukin 2, all-trans retinoid acid
- **Salicylate intoxication**
- **Calcium antagonist overdose** – (inhibition of prostacyclin release)
- **Hydrochlorothiazide Overuse** – (granulocytic infiltration into the lungs and IgG deposition in alveolar membranes)
- **Radiocontrast media** (fulminant PE)

Complications

- The major complications associated with CPE are respiratory fatigue and failure.
- Assisted ventilation is provided if the patient begins to show signs of respiratory fatigue (eg, lethargy, fatigue, diaphoresis, worsening anxiety).
- Sudden cardiac death secondary to cardiac arrhythmia is another concern, and continuous monitoring of heart rhythm is helpful in prompt diagnosis of dangerous arrhythmias.

Cardiogenic Vs. Non-cardiogenic Pul.Edema

- Finding suggesting cardiogenic edema
 - S3 gallop
 - elevated JVP
 - Peripheral edema
- Findings suggesting non-cardiogenic edema
 - Pulmonary findings may be relatively normal in the early stages
 - Clinical picture ranges from mild dyspnea to respiratory failure despite CXR showing diffuse alveolar infiltrates.

Hypoxemia

Cardiogenic

- Is due to ventilation perfusion miss match
- respond to administration of oxygen

Non-cardiogenic

- Is due to intrapulmonary shunting
- persists despite oxygen supplementation

Distinguishing features in X ray

Cardiogenic cause

- Cardiomegaly
- Kerley B lines and loss of distinct vascular margins
- Cephalization: engorgement of vasculature to the apices
- Perihilar alveolar infiltrate
- Pleural effusion

Non cardiogenic cause

- Heart size is normal
- Uniform alveolar infiltrate
- pleural effusion is uncommon
- lack of cephalization

Approach a Patient with Pulm.Edema

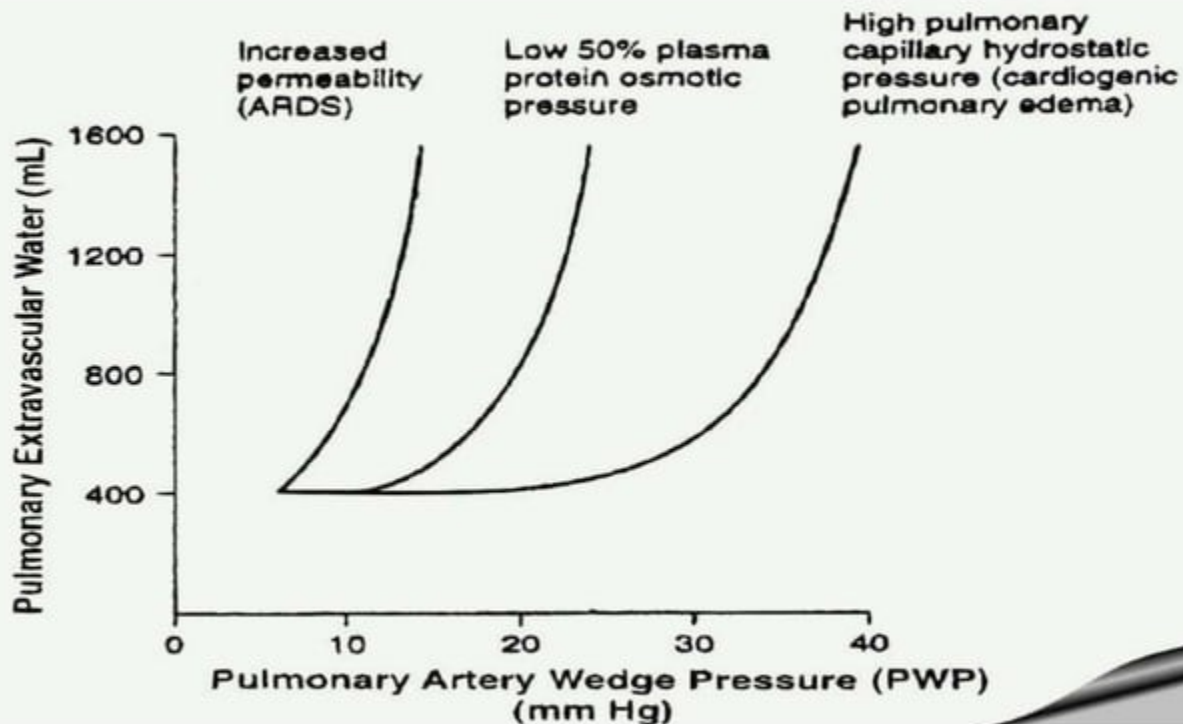
- Exertional Dyspnea
- Orthopnea
- Aspiration of food or foreign body
- Direct Chest injuries
- Walking High altitude
- Chest Pain(right or left)
- Leg pain or swelling(Pulmonary Embolism)
- A cough that produces frothy sputum that may be tinged with blood(cardiogenic)
- Palpitation
- Excessive sweating
- Skin color change-Pale skin
- Chest pain(if it is Cardiogenic)
- Rapid weight gain(cardiogenic)
- Fatigue
- Loss of appetite
- Smoking History

Laboratory Investigations

- ☐ Routine; CBC
- ☐ Liver function tests
- ☐ Renal Function Tests
- ☐ Arterial blood gas analysis
- ☐ Serum cardiac biomarkers

INVESTIGATION.....

- **Pulmonary artery catheterization** is indicated when;
 - Cause remains uncertain
 - Pulmonary edema which is refractory to therapy
 - PE accompanied by hypotension



Treatment approach

- Emergency management
 - Upright Sitting Posture
 - Support of oxygenation and ventilation
 - oxygen therapy
 - positive pressure ventilation
- Reduction of pre load & Inotrope support
 - loop diuretics
 - Nitrates(NTG)
 - Morphine
- condition that complicate PE must be corrected
 - Infection
 - Academia
 - Renal failure
 - Anemia

LMNOP

Lasix
Morphine
Nitrates (NTG)
Oxygen
Position (upright vs. flat)

Treatment approach

- Treatment is focused on three aspects:
 - improving respiratory function,
 - treating the underlying cause, and
 - avoiding further damage to the lung.
- Pulmonary edema, especially acute, can lead to fatal respiratory distress or cardiac arrest due to hypoxia.
- Patients with acute cardiogenic pulmonary edema generally have an identifiable cause of acute LV failure—such as arrhythmia, ischemia/infarction, or myocardial decompensation that may be rapidly treated, with improvement in gas exchange.
- In contrast, noncardiogenic edema usually resolves much less quickly, and most patients require mechanical ventilation.

Oxygen Therapy

- Support of oxygenation is essential to ensure adequate O₂ delivery to peripheral tissues, including the heart.
- When there is hypoxemia (PO₂ <60 mm Hg) without hypercapnia, enrichment of the inspired gas may suffice and can be given either by nasal prongs or Venturi mask with reservoir, depending upon the degree of oxygen enrichment required to elevate the PO₂ sufficiently.
- If PO₂ cannot be maintained at or near 60 mmHg despite inhalation of 100% v₂ at 20 liters per minute, or if there is progressive hypercapnia, mechanical ventilation is necessary

Non Invasive Ventilation

- Patients who do not have a response to initial therapy often require tracheal intubation and ventilation, with the associated potential for complications.
- Noninvasive methods of ventilation can avert tracheal intubation by resting the respiratory muscles, improving oxygenation, reducing the work of breathing, and increasing cardiac output.
- Common noninvasive methods
 - continuous positive airway pressure (CPAP) or
 - noninvasive intermittent positive-pressure ventilation (NIPPV)
- CPAP maintains the same positive-pressure support throughout the respiratory cycle.
- NIPPV increases airway pressure more during inspiration than during expiration.
- As compared with CPAP, NIPPV produces greater improvements in oxygenation and carbon dioxide clearance and a greater reduction in the work of breathing in patients with pulmonary edema.

Positive-Pressure Ventilation

- In refractory cases, mechanical ventilation can relieve the work of breathing more completely than can noninvasive ventilation.
- Mechanical ventilation with positive end-expiratory pressure can have multiple beneficial effects on pulmonary edema:
 - (1) decreases both preload and afterload, thereby improving cardiac function;
 - (2) redistributes lung water from the intraalveolar to the extraalveolar space, where the fluid interferes less with gas exchange; and
 - (3) increases lung volume to avoid atelectasis.

Reduction of preload

- In most forms of pulmonary edema, the quantity of extravascular lung water is determined by both the PCWP and the intravascular volume status.
- **Physical Methods** : In nonhypotensive patients, venous return can be reduced by use of the sitting position with the legs dangling along the side of the bed.
- **Diuretics** : furosemide(0.5-1 mg/kg) , bumetanide, and torsemide are effective in most forms of pulmonary edema, even in the presence of hypoalbuminemia, hyponatremia, or hypochloremia.
- **Nitrates** : Nitroglycerin(0.4 mg $\times$ 3 every 5 min) and isosorbide dinitrate act predominantly as venodilators but have coronary vasodilating properties as well.
- **Morphine**: Given in 2- to 4-mg IV boluses, morphine is a transient venodilator that reduces preload while relieving dyspnea and anxiety.
- **ACE inhibitors** reduce both afterload and preload and are recommended for hypertensive patients.



➤ Inotropic and Inodilator Drugs

- indicated in patients with cardiogenic pulmonary edema and severe LV dysfunction.
- Sympathomimetic amines dopamine and dobutamine are potent inotropic agents.
- Bipyridine phosphodiesterase-3 inhibitors (inodilators), such as milrinone (50 $\mu\text{g}/\text{kg}$ followed by 0.25–0.75 $\mu\text{g}/\text{kg}$ per min), stimulate myocardial contractility while promoting peripheral and pulmonary vasodilation.



➤ **Intraaortic Balloon Counterpulsation :**

- IABP or other LV-assist devices may help relieve cardiogenic pulmonary edema and are indicated when refractory pulmonary edema results from the etiologies discussed in the CS section, especially in preparation for surgical repair.



➤ Treatment of Tachyarrhythmias and Atrial-Ventricular Resynchronization

- Sinus tachycardia or atrial fibrillation can result from elevated left atrial pressure and sympathetic stimulation.
- Tachycardia itself can limit LV filling time and raise left atrial pressure further.
- In patients with reduced LV function and without atrial contraction or with lack of synchronized atrioventricular contraction, placement of an atrioventricular sequential pacemaker should be considered



➤ Risk of Iatrogenic Cardiogenic Shock

- In the treatment of pulmonary edema, vasodilators lower BP, and their use, particularly in combination, may lead to hypotension, coronary artery hypoperfusion, and shock .



➤ Acute Coronary Syndromes

- Acute STEMI complicated by pulmonary edema is associated with in-hospital mortality rates of 20–40%.
- After immediate stabilization, coronary artery blood flow must be reestablished rapidly.
- When available, primary PCI is preferable; alternatively, a fibrinolytic agent should be administered.
- Early coronary angiography and revascularization by PCI or CABG also are indicated for patients with non-ST elevation acute coronary syndrome.



➤ Extracorporeal Membrane Oxygenation

- For patients with acute, severe noncardiogenic edema with a potential rapidly reversible cause, ECMO may be considered as a temporizing supportive measure to achieve adequate gas exchange.
- Usually venovenous ECMO is used in this setting.



➤ Reexpansion pulmonary edema

- This can develop after removal of longstanding pleural space air or fluid.
- These patients may develop hypotension or oliguria resulting from rapid fluid shifts into the lung.
- Diuretics and preload reduction are contraindicated, and intravascular volume repletion often is needed while supporting oxygenation and gas exchange.



➤ High-altitude pulmonary edema

- It can be prevented by use of dexamethasone, calcium channel-blocking drugs, or long-acting inhaled β 2-adrenergic agonists.
- Treatment includes descent from altitude, bed rest, oxygen, and, if feasible, inhaled nitric oxide; nifedipine may also be effective.



➤ Stimulation of Alveolar Fluid Clearance

- A variety of drugs(cyclic adenosine monophosphate agonists) can stimulate alveolar epithelial ion transport and upregulate the clearance of alveolar solute and water, but this strategy has not been proven beneficial in clinical trials thus far.

Prognosis

- In-hospital mortality rates for patients with CPE are difficult to assign because the causes and severity of the disease vary considerably.
- In a high-acuity setting, in-hospital death rates are as high as 15-20%.
- Myocardial infarction, associated hypotension, and a history of frequent hospitalizations for CPE generally increase the mortality risk.
- Severe hypoxia may result in myocardial ischemia or infarction.
- Mechanical ventilation may be required if medical therapy is delayed or unsuccessful.
- Endotracheal intubation and mechanical ventilation are associated with their own risks, including aspiration (during intubation), mucosal trauma (more common with nasotracheal intubation than with orotracheal intubation), and barotrauma.

References:

- ☐ Harrison's principles of Internal Medicine 19th Ed.
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- ☐ Fishman's Pulmonary Diseases & Disorders 4th Ed.
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Thank You

