# Pathophysiological Changes In Pulmonary Embolism

Black: in male / female slides

Red : important

Pink: in female slides only

Blue: in male slides only

Green: notes

Gray: extra information

Editing File

# Objectives

❖ Pulmonary circulation

❖ Definition of pulmonary embolism

❖ Clinical significance of pulmonary embolism

❖ Sources, etiology & risk of pulmonary embolism

❖ Clinical presentation of pulmonary embolism

❖ Differential diagnosis

❖ Pathophysiological & hemodynamic changes of pulmonary embolism

# Pulmonary Circulation

## Pulmonary Circulation



**Pulmonary circulation** is a part of the circulatory system that is pumped from the right ventricle to the lungs carrying deoxygenated blood, & returns oxygenated blood to the left atrium of the heart.
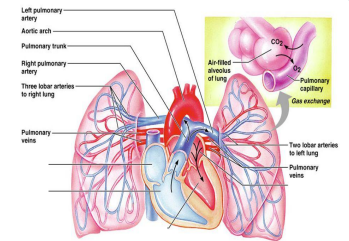
❖ **Deoxygenated blood**

Is pumped through the semilunar pulmonary valve into the left & right main pulmonary arteries ( one for each lung ), which branch into smaller pulmonary arteries that spread throughout the lungs.

❖ **Oxygenated blood**

Leaves the lungs through pulmonary veins to the left atrium completing the pulmonary cycle.

## Pulmonary Embolism



**Pulmonary embolism (PE)** is a thrombotic disorder where an occlusion occurs in a pulmonary artery by a blood clot preventing blood flow to the lungs
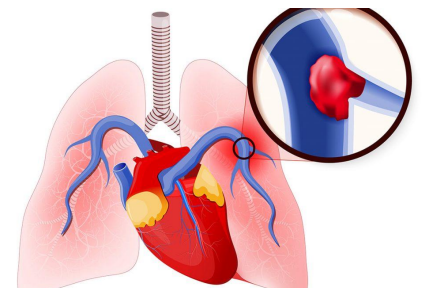
# Clinical Significance

- ❖ The incidence of diagnosed pulmonary embolism (PE) increases with age.

- ❖ The annual rate is about 1 in 10 000 in individuals below 40 years of age & can reach 1 in 100 in patients over 80 years.

- ❖ According to autopsy studies, the disease is clinically suspected in less than half of fatal cases.

- ❖ PE is one of the 3 leading causes of death related to the CVS (along with MI & stroke).

- ❖ Can lead to immediate death, or serious complications among survivors.

- ❖ Most episodes of pulmonary embolism carry a low mortality risk (about 1%) when properly diagnosed & treated (significance of early diagnosis).

- ❖ The most common preventable cause of death among hospitalized patients in the USA.

- ❖ High mortality rate (200,000 – 300.000) death annually in the USA.

- ❖ There is a lack of national data for incidence, prognosis, & rate of death of pulmonary embolism.

# Pathogenesis & Source of Pulmonary Embolism

**1** Pulmonary embolism can arise from any clot anywhere in the body.

Pulmonary emboli often arise from thrombi originating in the deep venous system of the lower extremities or pelvis. blood clot dislodges and is swept into the pulmonary circulation and lodges in a pulmonary artery. If the clot is large enough to obstruct large vessels in the lung, it can cause hemodynamic instability, along with right ventricular (RV) failure and possibly death. Currently, thrombolytic therapy for PE is still controversial.

**2** Clot move mostly from a dislodge of deep vein thrombosis (DVTs) in calf veins.



Pulmonary Embolism (PE)

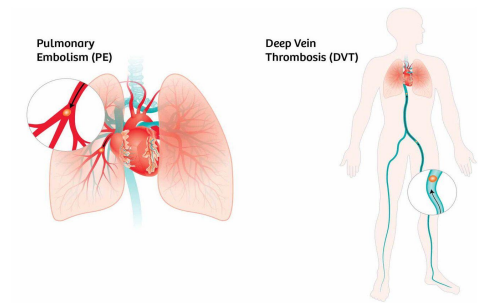Deep Vein Thrombosis (DVT)

**3** **Minor sources:**

- Fat embolism (droplet) (from atheroma).
- Air embolism (bubble) (from an unclear IV line).
- Amniotic fluid embolism (leakage to the blood from the placenta during delivery).
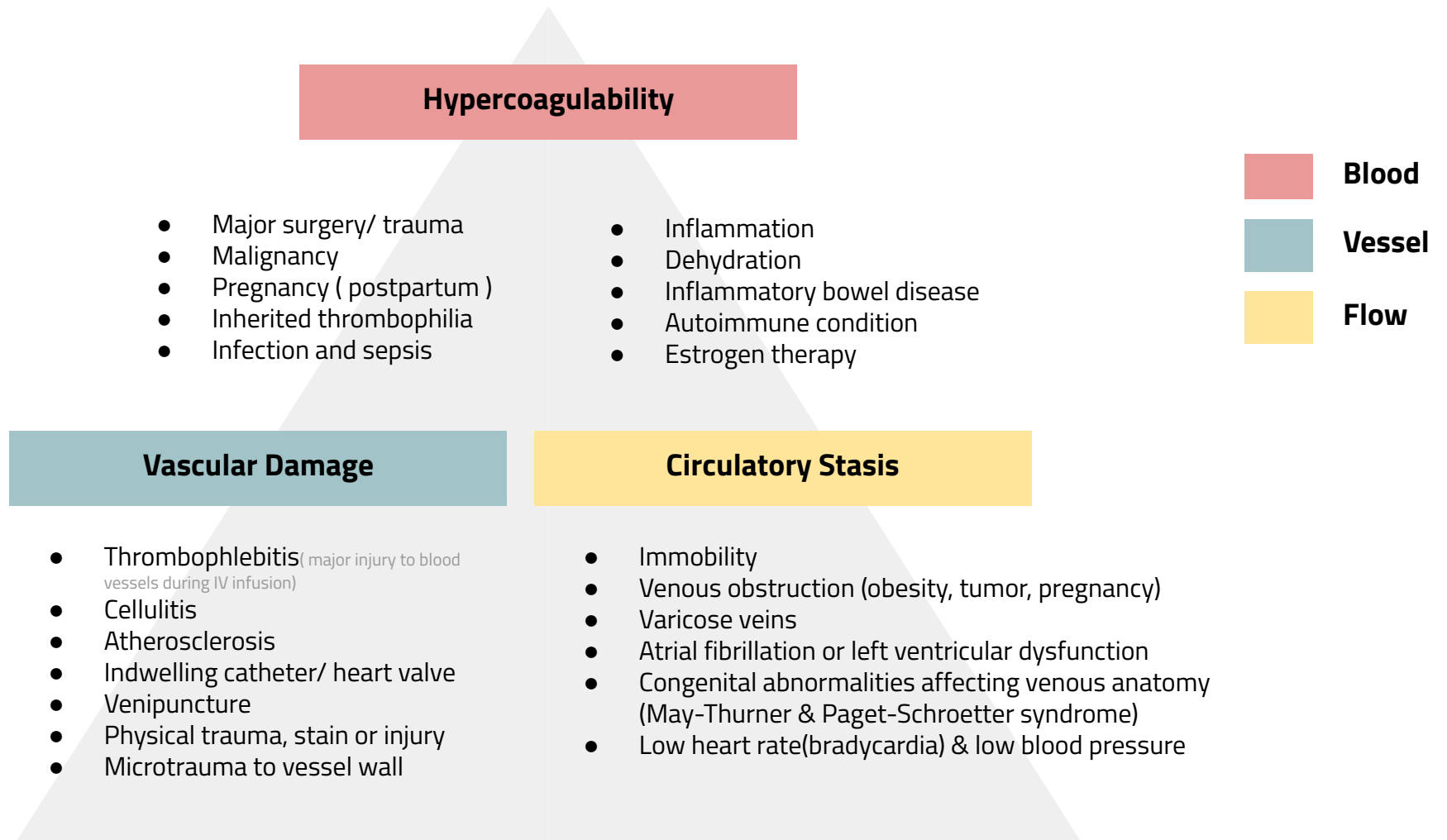- Septic embolism
- Tumor embolism

**4** To reach the lungs, thromboemboli travel through the right side of the heart.

# Etiology & Risk Factors of Clot Formation

## Virchow's Triad

The function of Virchow's triad is to demonstrate the underlying physiology that drives the formation of venous thrombus. Formation of clots within the vasculature places the patient at risk for thromboembolic events such as CVA, pulmonary arterial embolus or organ infarction, ischemia, and cell death

### Hypercoagulability

- Major surgery/ trauma
- Malignancy
- Pregnancy ( postpartum )
- Inherited thrombophilia
- Infection and sepsis

- Inflammation
- Dehydration
- Inflammatory bowel disease
- Autoimmune condition
- Estrogen therapy

### Vascular Damage

- Thrombophlebitis ( major injury to blood vessels during IV infusion)
- Cellulitis
- Atherosclerosis
- Indwelling catheter/ heart valve
- Venipuncture
- Physical trauma, stain or injury
- Microtrauma to vessel wall

### Circulatory Stasis

- Immobility
- Venous obstruction (obesity, tumor, pregnancy)
- Varicose veins
- Atrial fibrillation or left ventricular dysfunction
- Congenital abnormalities affecting venous anatomy (May-Thurner & Paget-Schroetter syndrome)
- Low heart rate(bradycardia) & low blood pressure

**Blood**

**Vessel**

**Flow**

# Clinical Presentation

The reduced blood flow to the lungs can cause debilitating symptoms including shortness of breath & can be life-threatening.

| Small PE | Moderate PE | Massive PE |
|---|---|---|
| • Asymptomatic<br>or<br>• Shortness of breath<br>• Chest discomfort | • Shortness of breath<br>• Tachycardia<br>• Tachypnea<br>• Haemoptysis<br>• Pleuritic chest pain<br>• Pleural rub | • Severe chest pain<br>• Pallor<br>• Sweating<br>• Central cyanosis<br>• Elevated JPV (jugular venous pulse)<br>• loud P2, S2 split, gallop rhythm<br>• Circulatory shock<br>• Syncope<br>• Death |

**Patient can also present with** Deep vein thrombosis (DVT) as the origin of the clot.

**Note:** Deep vein thrombosis (DVT) occurs when a blood clot (thrombus) forms in one or more of the deep veins in your body, usually in your legs. Deep vein thrombosis can cause leg pain or swelling, but also can occur with no symptoms.

# Differential Diagnosis

❖ Rib fracture

❖ Myocardial infarction

❖ Pneumonia

❖ Pneumothorax

❖ Bronchitis

❖ Pleurisy (Information of the plura)

❖ Costochondritis (Inflammation of the cartilage in the rib cage)

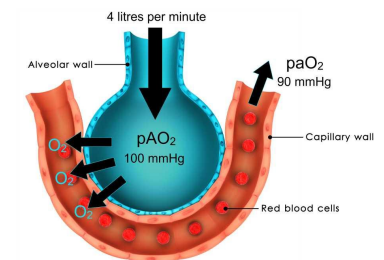# Hallmarks of Pathophysiological & Hemodynamic Events In PE

**Increased pulmonary vascular resistance.**

**Development of hypoxemia.**

**Ventilation perfusion defects.**

**Decreased pulmonary compliance.**

**Right ventricular failure.**
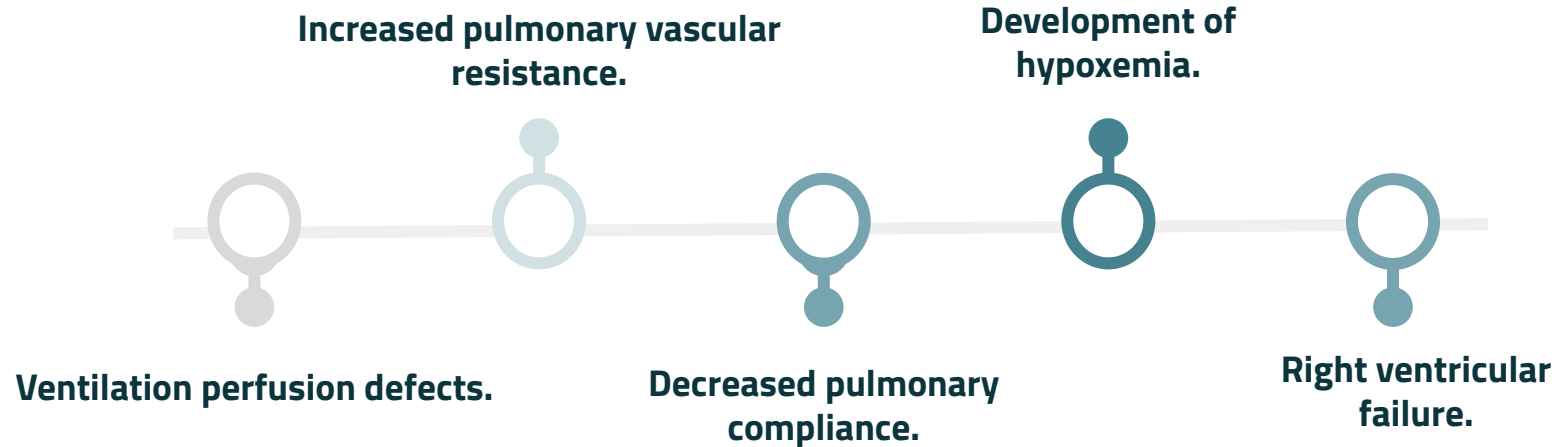
## 1. Ventilation Perfusion Defects V/Q Mismatch

❖ The optimal V/Q ratio is (**0.8**).

❖ Pulmonary embolism leads to a perfusion defect (due to wasted ventilation).

❖ Resulting in a segmental **Dead space** effect.

❖ Leading to pathological abnormalities of the alveolar arterial $O_2$ gradient.

❖ Eventually leading to the development of **hypoxemia**.

## Alveolar-Arterial $O_2$ Gradient

❖ A (alveolar) − a (arterial gradient) less than 10 mmHg is **optimal**. (up to 20 mmHg is considered **normal**).

❖ In PE, there is an abnormally increased value.

❖ This will lead to the development of hypoxemia.

❖ The severity of hypoxemia is related directly to the severity of mechanical obstruction (The clot burden).

4 litres per minute

Alveolar wall

$paO_2$
90 mmHg

$pAO_2$
100 mmHg

Capillary wall

$O_2$

Red blood cells

# Hallmarks of Pathophysiological & Hemodynamic Events In PE cont..

## 2. Increased Pulmonary Vascular Resistance

**due to :**

❖ Vascular obstruction.

❖ Release of vasoactive mediators from the platelets (neurohumoral reflex). **Neurohumoral** refers to increased activity of the sympathetic nervous system like renin-angiotensin system.

## Pulmonary Vascular Adaptation

❖ The normal pulmonary circulation adapts to the diverted blood flow through the recruitment & dilation of compliant pulmonary arterial vessels.

❖ These adaptive mechanisms fail when a greater proportion of the pulmonary circulation is compromised by larger emboli &/or by the elaboration of vasoconstricting mediators, at which point pulmonary vascular resistance & pulmonary arterial pressure increase.

## 3. Decreased Pulmonary Compliance

**due to :**

❖ Local hypo-perfusion interfering with surfactant production by alveolar type II cells.

❖ Surfactant is subsequently depleted, resulting in alveolar edema, alveolar collapse, & areas of atelectasis. **Atelectasis** is the collapse or closure of a lung resulting in reduced or absent gas exchange. Remember surfactant function? is to reduce compliance

# Hallmarks of Pathophysiological & Hemodynamic Events In PE cont..

### 4. Development of Hypoxemia

**due to** :

1. Defective V/Q ratio.

2. Decreased pulmonary compliance.

3. Loss of surfactant with the subsequent development of pulmonary edema & areas of atelectasis.

4. Increased pulmonary vascular resistance leading to increased blood diversion through the physiological shunts.

5. Decreased pulmonary capillary surface area resulting in decreased lung diffusion capacity.

6. Reflex **bronchoconstriction** causes due to stimulation of irritant receptors, increasing the work of breathing in some patients.

### 5. Right Ventricular Failure

**due to :**

❖ Large emboli, particularly in patients with compromised cardiac function, may cause an acute increase in pulmonary vascular resistance.(large emboli→immediate failure of R ventricle, scattered big emboli occluding smaller arteries→pulmonary hypertension→back pressure on R ventricle→R ventricle failure).

❖ This leads to an acute right ventricular strain & can lead to a fatal decrease in cardiac output.

❖ This is the most devastating & feared complication of acute pulmonary thromboembolism.

❖ In complete obstruction (saddle embolus), cardiac output may be reduced to zero, causing immediate cardiovascular collapse & death.

❖ Such dramatic presentations occur in less than 5% of cases & are virtually untreatable. This highlights the importance of primary prevention of venous thrombosis.

# Diagnosis of Pulmonary Embolism

**Pulmonary Embolism diagnosis is based on:**

**-Signs & symptoms.**

**-Investigations:**

- Blood tests.

- Electrocardiogram (ECG).

- Chest x-ray.

- Computerized tomography pulmonary angiography (CTPA). & CT scan.

- Ventilation-perfusion scan.

- Echocardiography

- Lower limb venous system ultrasonography & Doppler.



Lower limb venous system
ultrasonography & Doppler
(detect for venous thrombosis)

# Investigations

## 1 Blood tests

**CBC, Coagulation profile, ESR, LDH, ABG** (Arterial blood gas).

**Quantitative plasma D dimer ELIZA assay:**

* D-Dimer is a small fibrin protein degradation fragment.
* Marker of coagulation.
* D-Dimer is a very sensitive marker for clot formation but not specific for PE= A rule out test.
* D-Dimer level increased in the blood of all DVT sufferers.
* D-Dimer level increased in various other conditions as myocardial infarction, pneumonia, sepsis, & some types of cancer.

**Elevated cardiac biomarkers:**

* Cardiac troponin.
* May indicate a concomitant myocardial injury (MI).

## 2 ECG

Usually done to exclude other conditions that may have similar symptoms

**ECG:**
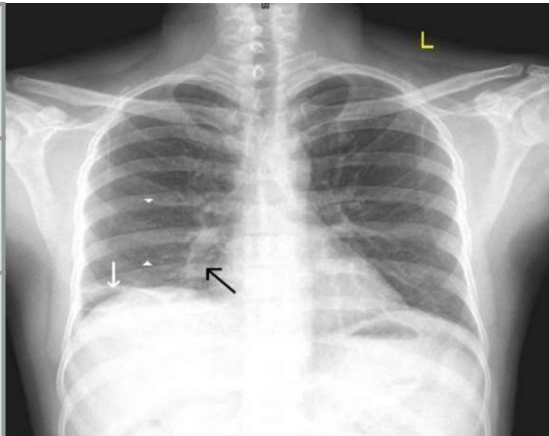
* Sinus tachycardia.
* Non specific ST segment & T wave changes.
* Right ventricular strain pattern
* ECG changes are specific but not sensitive.
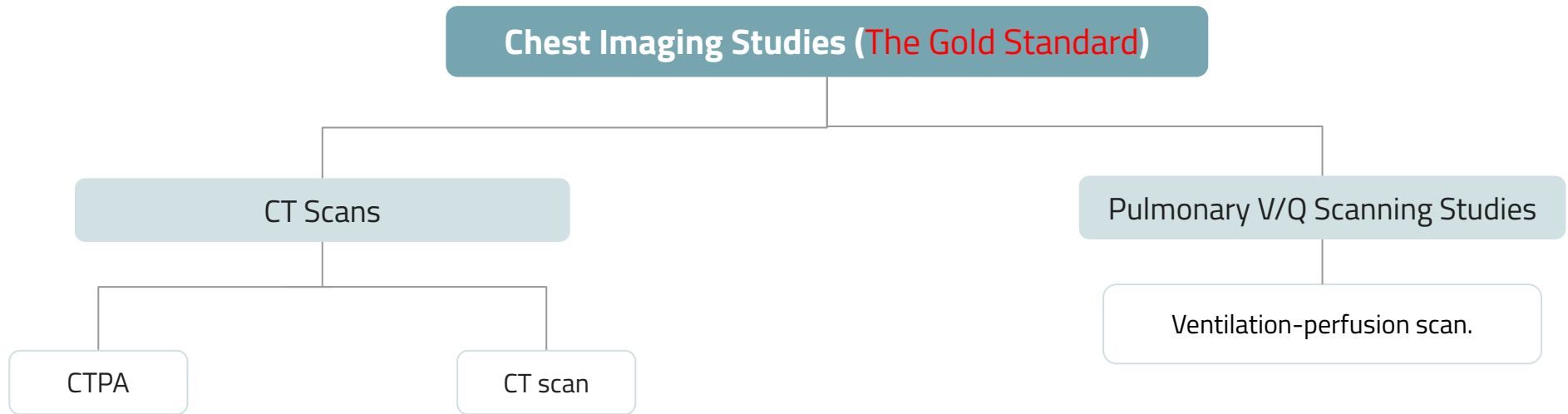* Present in around 60% of cases only.
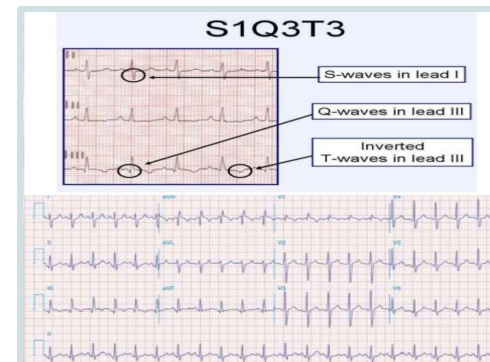
# Investigations cont..

❖ Usually done to exclude other conditions that may have similar symptoms.

❖ Atelectasis.

❖ Parenchymal infiltration.

❖ Elevated diaphragm.

❖ Enlarged mediastinum.

❖ Enlarged hilum.

❖ Cardiomegaly.

❖ Pulmonary edema.

❖ Pleural effusion.

❖ Oligemia (Westermark's sign→ opacity of the lower margin of the lung) (a specific sign).

❖ Prominent central pulmonary artery (Fleischner sign) (a specific sign).

❖ Wedge-shaped pleural-based area of increased opacity (Hampton's hump) (a specific sign).

| | |
|---|---|
| **white arrow** | **lateral wedge-shaped opacity (Hampton's hump),** |
| **space between white arrowheads** | **focal area of oligemia (Westermark's sign)** |
| **black arrow** | **prominent right descending pulmonary artery (Palla's sign).** |



Chest radiograph (posterior–anterior view)

# Investigations cont..

**Chest Imaging Studies (The Gold Standard)**

- CT Scans
  - CTPA
  - CT scan
- Pulmonary V/Q Scanning Studies
  - Ventilation–perfusion scan.

## CT scans

- Computerized tomography pulmonary angiography (CTPA) & CT scan.
- Invasive CT angiography, contrast enhanced or spiral chest CT scan.
- Done to visualize the pulmonary vessels & to scan the pulmonary emboli.



**CT angiography**

## Ventilation perfusion scan

- Inhaling a **slightly radioactive gas** that is visible during this scan can show the parts of the lungs with no blood supply. This may be caused by a pulmonary embolism.
- May be used in patients who cannot tolerate intravenous contrasts (segmental perfusion defect with normal ventilation).

# Management of Pulmonary Embolism

## Emergency management

**Oxygen therapy** to keep saturation > 90%

Insert **Iv access** & send **baseline blood** for testing

**Analgesia** (painkiller) (for chest pain)

Perform **ECG**

**Management of cardiogenic shock** (fluids & inotropes - **Dobutamine** )

## Further  management

Immediate **anticoagulation therapy (is the foundation of treatment)**

**Thrombolytic therapy**

**Inferior vena cava filters** (to filter the clot)

**Surgical treatment**

Maintaining **adequate circulatory** support

---

**anticoagulation Therapy**
▪ Low molecular weight heparin (LMWH), unfractionated heparin (UFH) or fondaparinux intravenously (IV).
▪Followed by long term oral anticoagulation (Warfarin).
▪ Fibrinolysis: recombinant tissue plasminogen activator tPA).

**Thrombolytic  Therapy**
to relieve pulmonary vascular obstruction, improve right ventricular efficacy, & correct hemodynamic instability.
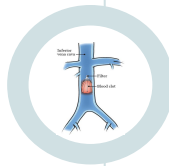
**Inferior vena cava filters**
may be used in selected cases, especially if the anticoagulation is contraindicated.

**Pulmonary embolectomy** or **pulmonary thrombo-endarterectomy** (Catheter embolectomy) (use a catheter to remove the emboli) and it is applied in massive life threatening pulmonary embolism.

## Assessment of Clinical Probability:

- Well's Score " or "Geneva rule"

- to follow up Improvements of signs, symptoms & risk factors from a baseline.

- Improvements in diagnostic non-invasive D-dimer tests.

## Prognosis of Pulmonary Embolism

- The prognosis of pulmonary embolism is greatly influenced by the premorbid vascular condition.

- Patients without pre existing cardiopulmonary disease can accommodate occlusion of up to roughly one third of the pulmonary circulation with a negligible increase in pulmonary vascular resistance & pulmonary arterial pressure.

- Normal adaptive mechanisms are ineffective in patients with pre existing cardiovascular abnormalities (e.g., Atherosclerosis & pulmonary hypertension), making them susceptible to significant instability with any subsequent impairment of the pulmonary vasculature.

**Prevention:**

- Compressive stockings.
- Aspirin
- Anticoagulation
- Management of risk factors.
- Follow up.
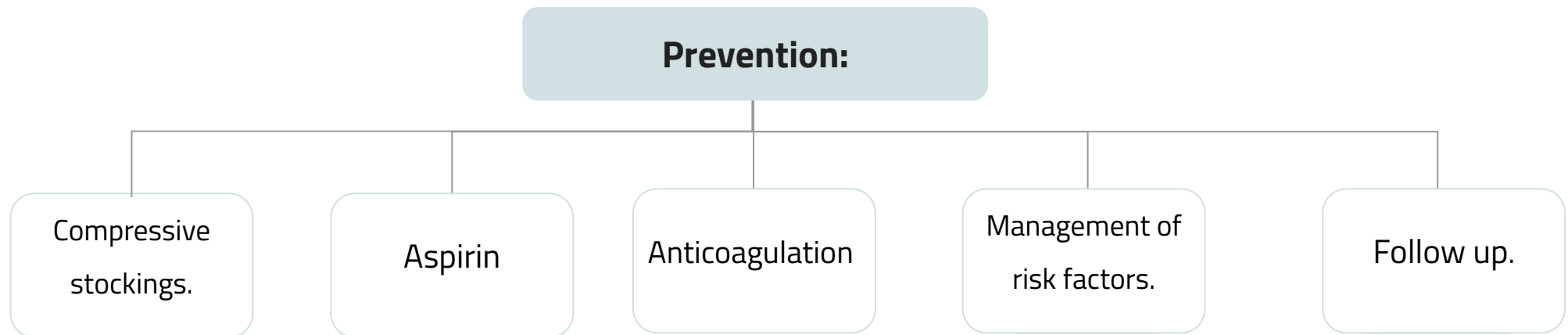
# Quiz:

**1-Part of the circulatory system that is pumped from the right ventricle to the lungs carrying deoxygenated blood, & returns oxygenated blood to the left atrium of the heart.**
A) Pulmonary circulation
B) Systemic circulation
C) Portal circulation
D) Coronary circulation

**2- Thrombotic disorder where an occlusion occurs in a pulmonary artery by a blood clot preventing blood flow to the lungs**
A) Atherosclerosis
B) Pulmonary embolism
C) Angina
D) Hypertension

**3-All of the following are clinical presentations of small PE except**
A) Asymptomatic
B) Shortness of breath
C) Chest discomfort
D) Tachycardia

**4-Hypoxemia is developed due to**
A) Normal V/Q ratio
B) Vascular obstruction
C) Local hypoperfusion
D) Decreased pulmonary compliance

**5-Oxygen therapy is not used for the Management of Pulmonary Embolism**
A) True
B) False
C) depends
D) IDK

**6-what is the optimal V/Q ratio**
A) 0.8
B) 0.5
C) 1.8
D) 1.5

**7- One of the advantages of using V/Q scan :**
A) Can be used when anticoagulation therapy is contraindicated
B) Done to exclude other conditions that have similar symptoms
C) Can be used when the patient cannot tolerate intravenous contrast
D) It's the most accurate way to diagnose PE

**8-Which of these biomarkers can be elevated in the case of PE?**
A) ALT
B) Troponin
C) Cystatin C
D) A and B

**9-A 70 years old man presented with severe chest pain , pallor and sweating . Investigations revealed that he has a PE. His doctor want to start an anticoagulation therapy but it turns out that the patient is contraindicated to it. Which one of these is the best to be use instead?**
A) Surgical treatment
B) Fibrinolytic  therapy
C) Inferior vena cava filters
D) Antianginal therapy

**10- A chest X-Ray done to a 76 years old patient who has a PE. What do you expect to see?**
A) Pulmonary nodules in the hilar area
B) Consolidation and cavities in the upper lobe
C) Some parts are showing with no blood supply
D) Prominent central pulmonary artery

# Quiz:

**1- List the minor sources of pulmonary embolism.**

**2- List the hemodynamic events in pulmonary embolism.**

**3-list 3 ways for Investigations?**

**4- enumerate 2 causes for decreased Pulmonary Compliance?**

**5- list the emergency management steps of pulmonary embolism**

**A1:** Fat embolism (droplet), Air embolism (bubble), Amniotic fluid embolism, Septic embolism, Tumor embolism

**A2:** Ventilation perfusion defects, Increased pulmonary vascular resistance, Decreased pulmonary compliance, Development of hypoxemia, Right ventricular failure.

**A3:** slide 12-14

**A4:** Local hypo-perfusion, Surfactant is subsequently depleted

**A5: :** Oxygen therapy , Insert Iv access & send baseline blood for testing , analgesia , perform ECG  , Management of cardiogenic shock.

# Team Leaders

Teif Almutairi           Abdulaziz Alsuhaim

# Sub-Leaders

Sarah AlQahtani       Sadem Al Zayed

## Members:

**Abdullah Alsubaihi**
**Abeer Awwad**
**Abdulrahman Barashid**
**Yasmine alQarni**

## Reviewer:

Shatha Aldhohair