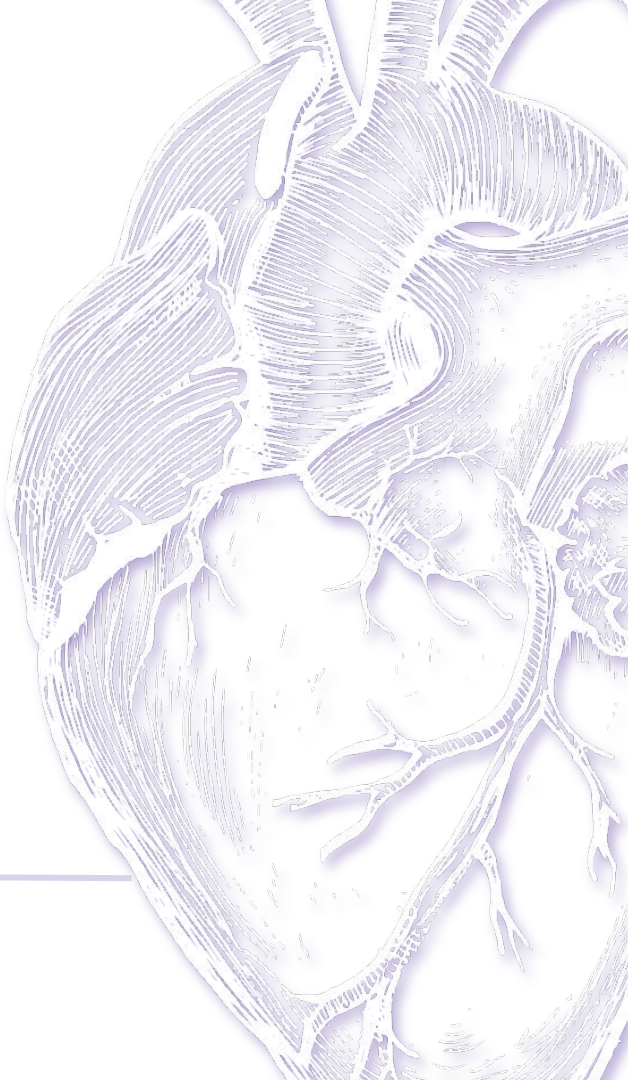
MAWEEN ALRUWAIDY · JOOD ALJUFAN · KHALID ALQHTALI · MESHARI ALHARBI

Physiology team

MED444
KING SAUD UNIVERSITY



Pathophysiological Changes in Pulmonary Embolism

Editing File

Main text Female's slide Male's slide Important text Doctor's note Extra

Objectives:

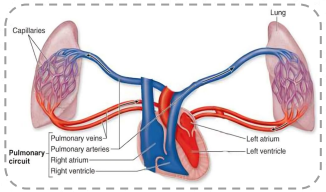
- Pulmonary circulation.
- Definition of pulmonary embolism.
- Clinical significance of pulmonary embolism.
- Sources, etiology & risk factors of pulmonary embolism.
- Clinical presentation of pulmonary embolism.
- Differential diagnosis.
- Pathophysiological & hemodynamic changes of pulmonary embolism.

Pulmonary Circulation

Pulmonary Circulation

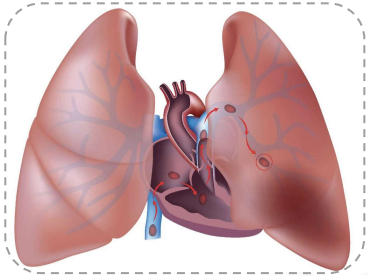
is a part of the **circulatory system** that is pumped from the **right ventricle to the lungs** carrying **deoxygenated** blood, and returns oxygenated blood to the left atrium of the heart.

- **Deoxygenated blood** Is pumped through the **semilunar pulmonary valve** into the left and 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 (PE)

is a **thrombotic disorder** where an occlusion occurs in pulmonary artery by a blood clot preventing blood flow to the lungs.



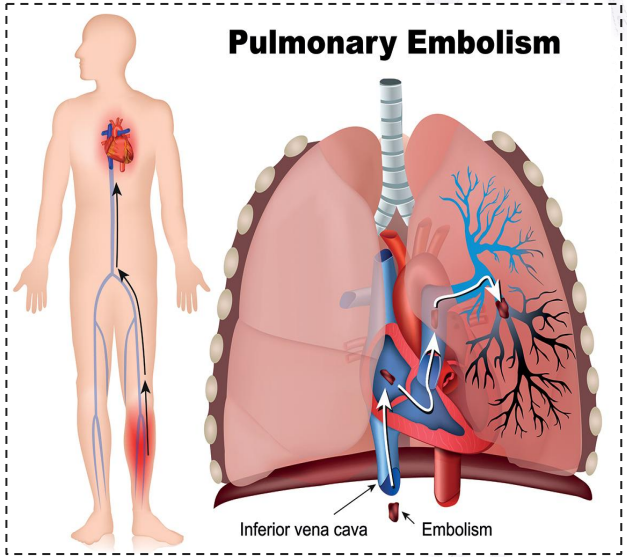
Clinical Significance

M-Dr: just a kind of completion of the topic..

1. The incidence of diagnosed pulmonary embolism (PE) increases with age.
2. The annual rate is about 1 in 10 000 in individuals below 40 years of age and can reach 1 in 100 in patients over 80 years.
3. According to autopsy (التشريح بعد الوفاة) studies, the disease is clinically suspected in less than half of fatal cases.
4. PE is one of the 3 leading causes of death related to the CVS (along with MI & stroke).
5. Can lead to immediate death, or serious complications among survivors.
6. Most episodes of pulmonary embolism carry a low mortality risk (about 1%) when properly diagnosed and treated.
7. The most common preventable cause of death among hospitalized patients in the USA.
8. High mortality rate (200,000 – 300.000) death annually in the USA.
9. There is a lack of national data for incidence, prognosis, and rate of death of pulmonary embolism.

Pathogenesis & Source of Pulmonary Embolism

Pulmonary embolism **can arise from any clot anywhere** in the body. To reach the lungs, thromboemboli travel through the right side of the heart.



Minor sources :

- Fat embolism (droplet).
- Air embolism (bubble).
- Amniotic fluid embolism.
- Septic embolism.
- Tumor embolism.

To differentiate between them, look at Patho L5.

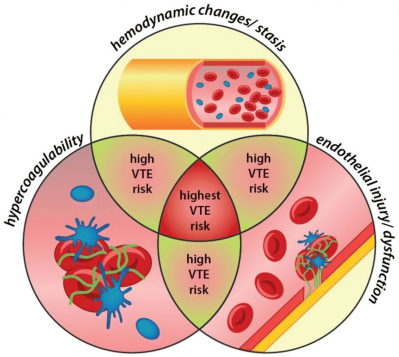
Clot move mostly from a dislodge of deep vein thrombosis (DVTs) in calf veins. (All causes of PE is considered from DVT, unless it's proven otherwise)

وَسُبْحَانَ اللَّهِ رَبِّ الْعَالَمِينَ

Etiology & Risk Factors of Clot Formation (Virchow's Triad)

Virchow's Triad : postulates the presence of three factors that predisposes a person to develop vascular thrombosis. These factors include:

Hypercoagulability (Blood) قابلية الدم للتجلط	⇒ Major surgery/ trauma. ⇒ Pregnancy (postpartum). ⇒ Infection and sepsis. ⇒ Dehydration. ⇒ Autoimmune condition.	⇒ Malignancy. ⇒ Inherited thrombophilia. ⇒ Inflammation. ⇒ Inflammatory bowel disease. ⇒ Estrogen therapy.
Vascular Damage (Vessel)	⇒ Thrombophlebitis. ⇒ Cellulitis. ⇒ Atherosclerosis. ⇒ Indwelling catheter / heart valve. ⇒ Physical trauma, stain or injury.	⇒ Microtrauma to vessel wall. ⇒ Venipuncture.
Circulatory Stasis (Flow)	⇒ 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



Clinical Presentation

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

- Deep vein thrombosis (DVT).

Small PE	Moderate PE	Massive PE
❖ Mostly Asymptomatic. ❖ Shortness of breath. ❖ Chest discomfort. ❖ Calf pain.	❖ Pleuritic chest pain (Pleural rub). ❖ Shortness of breath ❖ Tachycardia. ❖ Tachypnea. ❖ Cough. ❖ Haemoptysis. ❖ Calf pain.	❖ Severe chest pain. ❖ Pallor. ❖ Sweating. ❖ Central cyanosis. ❖ Elevated JVP. ❖ S2 split (Loud P2), gallop rhythm. ❖ Circulatory shock. ❖ Syncope. ❖ Death.

Differential Diagnosis

- ❑ Myocardial infarction (MI).
- ❑ Pneumonia.
- ❑ Pneumothorax.
- ❑ Bronchitis.
- ❑ Pleurisy.
- ❑ Costo-chondritis.
- ❑ Rib fracture.

Very Important slide

Hallmarks of Pathophysiological and Hemodynamic Events In PE

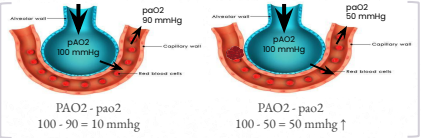
Ventilation perfusion defects

- The optimal V/Q ratio is 0.8, the ratio is increased during pulmonary embolism due to impaired O2 transfer to pulmonary capillaries.
- leads to a perfusion defect (due to wasted ventilation). Resulting in increase segmental Dead space.
- Leading to pathological abnormalities of the alveolar arterial (O2) gradient.
- Eventually leading to the development of hypoxemia.

Alveolar - Arterial O_2 gradient :

- Alveolar - Arterial gradient (A - a gradient) Is insensitive & non-specific test. 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 (clot Burden).

Extra



PAO2 - pao2
100 - 90 = 10 mmhg

PAO2 - pao2
100 - 50 = 50 mmhg ↑

Increased pulmonary vascular resistance

It's due to:

- Vascular obstruction.
- Release of vasoactive mediators from the platelets (neurohumoral reflex).

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 and/or by the elaboration of vasoconstricting mediators, at which point pulmonary vascular resistance & pulmonary arterial pressure **increase**.

Decreased pulmonary compliance

It's due to:

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

2. Surfactant is subsequently depleted, resulting in :

- Alveolar edema
- Alveolar collapse
- Atelectasis (collapse)

Development of hypoxemia

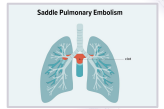
It's due to:

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 due to stimulation of irritant receptors, increasing the work of breathing in some patients.

Right ventricular failure (Most fatal)

It's due to:

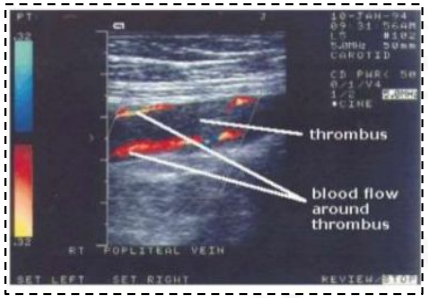
1. Large emboli, particularly in patients with compromised cardiac function, may cause an acute increase in pulmonary vascular resistance which will increase the RV afterload.
2. This leads to an acute right ventricular strain & can lead to a fatal decrease in cardiac output and cardiogenic shock.
3. This is the most devastating & feared complication of acute pulmonary Thromboembolism.
4. In complete obstruction (saddle embolus), cardiac output may be reduced to zero, causing immediate cardiovascular collapse & death.
5. Such dramatic presentations occur in less than 5% of cases & are virtually untreatable, this highlights the importance of primary prevention of venous thrombosis.
6. This highlights the importance of primary prevention of venous thrombosis.



Diagnosis of Pulmonary Embolism

Diagnosis of Pulmonary Embolism (PE) is based on :

Signs and Symptoms	Shortness of breath, chest pain, cough, rapid heart rate and hypotension.
Investigations	❖ Blood tests. ❖ Electrocardiogram (ECG). ❖ Chest x-ray. ❖ Computerized tomography pulmonary angiography (CTPA) & CT scan **(gold standard test)** ❖ Ventilation-perfusion scan **(gold standard test)** ❖ Echocardiography ❖ Lower limb venous system ultrasonography & Doppler.



Investigations

Investigations :

1. Blood tests
2. ECG
3. Chest X-Ray
4. Chest Imaging Studies (The Gold Standard)
6. Echocardiography
7. Lower limb venous system ultrasonography & Doppler

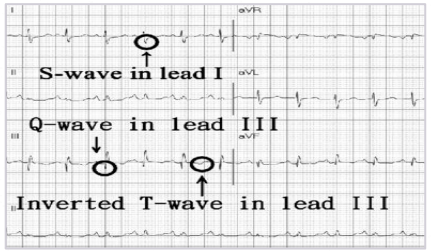
- **Complete blood count** (CBC).
- Coagulation profile.
- **Erythrocytes sedimentation rate** (ESR).
- LDH.
- **Arterial blood gases (ABG) = low oxygen saturation.**
- **Quantitative plasma D-dimer ELIZA assay : Elevated level.**
  - D-Dimer is a small fibrin protein degradation fragment.
  - Marker of coagulation.
  - D-Dimer is a very **sensitive marker for clot formation** but **not specific** = A rule out test.
  - D-Dimer level increased in the blood of all deep vein thrombosis (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 infarction (MI) or injury .

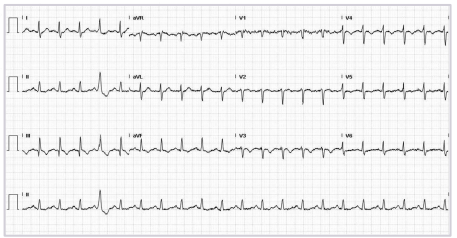
Investigations

Investigations :

1. Blood tests
2. ECG
3. Chest X-Ray
4. Chest Imaging Studies (The Gold Standard)
6. Echocardiography
7. Lower limb venous system ultrasonography & Doppler

- ECG is usually done to exclude other conditions that may have similar symptoms.
- **ECG findings :**
  - Sinus tachycardia.
  - Nonspecific ST segment & T wave changes (S1Q3-T3)
  - Right ventricular strain pattern.
  - Right bundle branch block
- ECG changes are specific but not sensitive.
- Present in around 60% of cases only.





Investigations

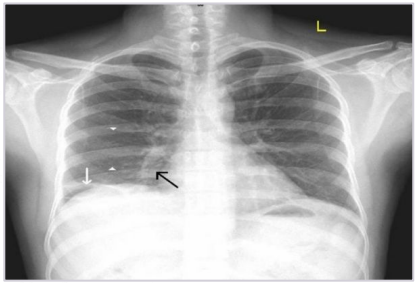
Investigations :

1. Blood tests
2. ECG
3. Chest X-Ray
4. Chest Imaging Studies (The Gold Standard)
6. Echocardiography
7. Lower limb venous system ultrasonography & Doppler

C.X-R is usually done to exclude other conditions that may have similar symptoms.

Chest X-Ray findings (not sensitive) :

- Atelectasis. (Partial or complete collapse of lung)
- Parenchymal diffuse infiltration (abnormal accumulation of fluid or cells throughout the lung tissue)
- Elevated diaphragm.
- Enlarged mediastinum.
- Enlarged hilum.
- Cardiomegaly.(Enlargement of the Heart)
- Pulmonary edema.
- Pleural effusion.
- Oligemia (Westermark's sign).
- Prominent central pulmonary artery (Fleischner sign).
- Wedge-shaped pleural-based area of increased opacity (Hampton's hump).



Chest radiograph (posterior–anterior view)

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).

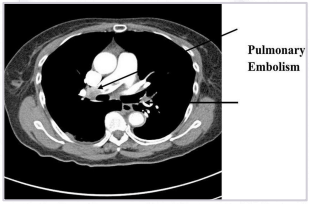
Investigations

Investigations :

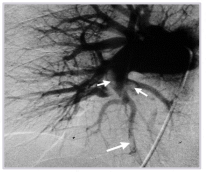
1. Blood tests
2. ECG
3. Chest X-Ray
4. Chest Imaging Studies (The Gold Standard)
6. Echocardiography
7. Lower limb venous system ultrasonography & Doppler

4. CT Scans (sensitive)

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



The blood in CT should be light and clear (appear in white) but since there is an embolism we see a dark areas, which represent the clot



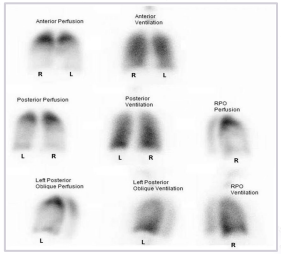
angiography

which is contrast agent injected into a blood vessel and images are taken to show the flow of blood through the vessel

5. Pulmonary V/Q Scanning Studies

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).



During a V/Q scanning study, a small amount of radioactive material is then inhaled as a gas, this material is then detected by a scanner that produces images of the lungs ventilation. After some time, the material is injected into a vein in the arm, this material is then detected by a scanner that produces images of the lungs perfusion. The ventilation portion of the study evaluates how well air flows through the lungs, while the perfusion portion evaluates how well blood flows through the lungs.

Management of Pulmonary Embolism

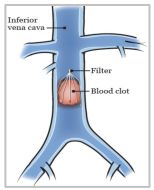
Management of Pulmonary Embolism

Emergency management

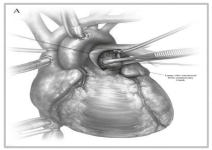
- Oxygen therapy to keep saturation > 90%
- Analgesia
- Management of cardiogenic shock (fluids & inotropes - Dobutamine)
- Insert Iv access & send baseline blood for testing
- Perform ECG.
- Immediate anticoagulation therapy.

Further management

- Immediate anticoagulation therapy
  - is the foundation of treatment :
    - 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.



- Maintaining adequate circulatory support.
- Surgical treatment
  - Pulmonary embolectomy, or pulmonary thromboendarterectomy (Catheter embolectomy).
    - Is applied in massive life-threatening pulmonary embolism



Assessment of Clinical Probability

- Clinical decision rules are made using the following models "Well's Score" or "Geneva rule".
- Improvements of signs, symptoms & risk factors.
- Improvements in diagnostic non-invasive & D-dimer tests.
- Well's Criteria: High > 6 , Moderate= 2-6, Low < 2. PE likely > 4, PE unlikely < 4.
- Geneva Score: Low probability < 2.

F-Dr: The details it just for your information, if I ask you I will give you the score and ask you about the probability..

Well's score[7] for DVT		Well's score[8] for PE		Revised Geneva score[9] for PE	
Items	Points	Items	Points	Items	Points
Cancer	+1	Previous PE or DVT	+1.5	Age >65 years	+1
Paralysis or recent plaster cast	+1	Heart rate >100 BPM	+1.5	Previous DVT or PE	+3
Bed rest >3 days or surgery <4 weeks	+1	Recent surgery or immobilization	+1.5	Surgery under general anesthesia or fracture of the lower limbs <1 month	+2
Pain on palpation of deep veins	+1	Clinical signs of DVT	+3	Active malignancy (solid or hematological malignancy, currently active or considered as cured for <1 year	+2
Swelling of entire leg	+1	Alternative diagnosis less likely than PE	+3	Unilateral lower limb pain	+3
Diameter difference on affected calf >3 cm	+1	Hemoptysis	+1	Hemoptysis	+2
Pitting edema (affected side only)	+1	Cancer	+1	Heart rate 75-94 BPM	+3
Dilated superficial veins (affected side)	+1			Heart rate >95 BPM	+5
Alternative diagnosis at least as possible as DVT	-2			Pain lower limb deep vein palpation and unilateral edema	+4
Clinical probability		**Clinical probability**		**Clinical probability**	
Low probability	0	Unlikely	<=4	Low	0-3
Intermediate	1-2	Likely	>4	Intermediate	4-10
High probability	>=3			High	>=11

BPM = Beats per minute, DVT = Deep venous thrombosis, PE = Pulmonary embolism.

وَصَوَّرَكُمْ فَأَحْسَنَ صُوَرَكُمْ

Prognosis & Prevention of Pulmonary Embolism

Pulmonary Embolism Prognosis

- 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.

Pulmonary Embolism Prevention :

- Compression stockings
- Aspirin
- Anticoagulation
- Management of risk factors.
- Follow up & assessment of clinical probability

Compression stockings can help prevent blood from pooling in the legs and reduce the risk of developing deep vein thrombosis (DVT), which can lead to pulmonary embolism.

Check here for our summary
Highly recommended !!!!!

Sorry but if you will not cheack it راحت عليك المليون

MCQs:

Answers

For more question check our summary file!

1/B
2/C
3/B

1 **Which one of the following events is the most fatal event of Pulmonary embolism ?**

A	Development of hypoxemia	B	Right ventricular failure	C	Ventilation perfusion defects	D	Decreased pulmonary compliance

2 **Which one of the following Investigations is the gold strand of detecting pulmonary embolism ?**

A	D-dimer level	B	Chest X-ray	C	Chest CT-scan	D	ECG

3 **Which one of the following is Not clinical presentations of small PE ?**

A	Shortness of breath	B	Tachycardia	C	Asymptomatic	D	Chest discomfort

MCQs:

Answers

For more question check our summary file!

4/A
5/B
6/B

4 Which one of the following are risk factors for pulmonary embolism ?

A	Immobility	B	High heart rate	C	High blood pressure	D	Hydration

5 What is the most common cause of pulmonary embolism ?

A	Fat embolism	B	Deep Vein thrombosis	C	Septic embolism	D	Air embolism

6 Which of these biomarkers can be elevated in the case of PE ?

A	ALT	B	Troponin	C	Cystatin C	D	A and B

SAQ

Enumerate the hallmarks of pathophysiological & hemodynamic events in PE and explain each one ?	Slide 8
List the causes of hypoxemia in PE ?	Slide 8
Enumerate 2 causes for decreased Pulmonary Compliance ?	Slide 8
Enumerate 2 causes for Increased pulmonary vascular resistance ?	Slide 8

Finally you have arrived , we have been waiting for you !!

Meet our team !

Team leaders

Rimaz Alhammad

Noreen Almaraba

Rayan Alshehri

Omar Albaqami

Aljoharah Alyahya

Heroes of the lecture :

Abdulaziz Alobathani

Aleen muneif

Did you like the lecture ? we mean our work :)

Contact with us! physiology.444ksu@gmail.com