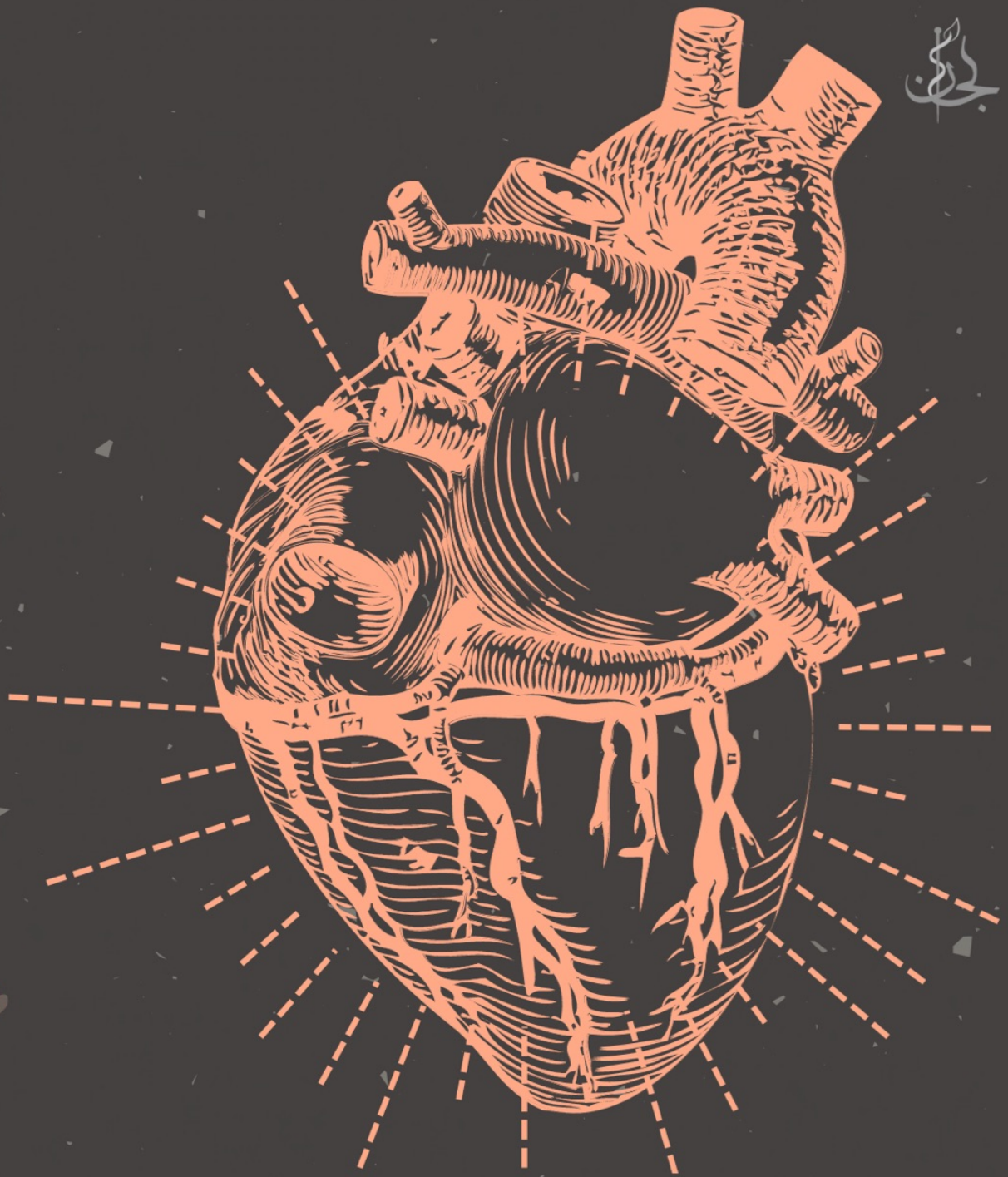


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PATHOLOGY

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Embolism

An embolus is a detached intravascular solid, liquid, or gaseous mass that is carried by the blood to a site *distant* from its point of origin.

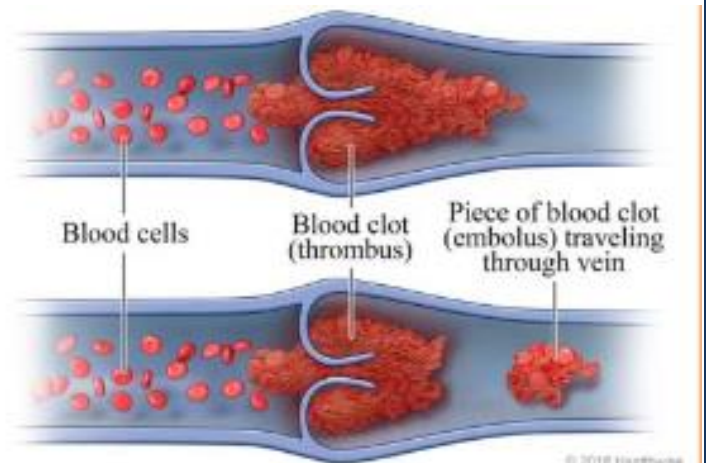
❖ Types of emboli

Emboli are classified according to their composition into 4 major types

- I. **Thromboembolism**, which makes 99% of all cases,
 - II. **Fat** embolism,
 - III. **Air** embolism,
 - IV. **Amniotic** embolism.
- } These make the remaining 1%

❖ Thrombus vs Thromboembolus

- **Thrombus** is a blood clot that occurs inside the cardiovascular system.
- **Thromboembolus** is a piece that is **dislodged** of the original thrombus and is now travelling inside the circulation, it can go to **distant** sites away from its site of origin and once it's there it can produce the main clinical symptoms.
- **Thromboembolism** is the first type of emboli according to the composition of the embolus.



❖ Clinical significance

- The clinical significance of a thromboembolus is exactly the same as a thrombus.
- They could result in partial or complete vascular occlusion consequently leading to infarction (ischemic necrosis) of downstream tissue.

❖ Circulation

There are two types/sides of circulation:

➤ **Venous:**

The circulation that transport the deoxygenated blood from the Right ventricle of the heart to the lungs through pulmonary arteries and brings back oxygenated blood from lungs to left Atrium of the heart through pulmonary veins

The direction of blood in the venous side of circulation is from tissues toward the heart specifically the **right** side of the heart, and then towards the lungs. In order to get oxygenated

➤ **Arterial:**

The circulation that transport blood from the left Ventricle to almost every part of the body through Arch of Aorta

It starts with the heart and the direction of blood is from the heart towards different body tissues.

Emboli can also be classified according to site of their origin, meaning the location where they are first formed. Therefore, emboli can either be **venous** or **arterial**.

Venous thromboembolism

- A thrombus is formed inside the **venous** side of circulation and starts fragmenting. It's now forming a venous embolus. This venous embolus travels along with the blood toward the right side of the heart and from there it will pass through the pulmonary arteries into the lungs. They are more common than Arterial thromboembolism.

مكان الانطلاق

The **origin** of most venous emboli is the **lower limbs**, specifically "the deep veins" causing what is known as deep vein thrombosis (DVT).

Thanks to gravity

95% originate from deep veins thrombi of Lower Limbs (DVT)

المكان الذي رايحة عليه و
رج بين فيه الـ defects

The **target** of most venous emboli are **lungs**.

- The consequence of venous emboli depends on the **size** and exact **location** inside the lungs.

❖ Special terms regarding pulmonary thromboembolism

- **saddle embolus** is a large embolus capable of occluding the bifurcation of **pulmonary artery trunk**, leading to loss of blood supply to the lungs, which is usually **fatal**. [Causes Cardiovascular collapse and death]

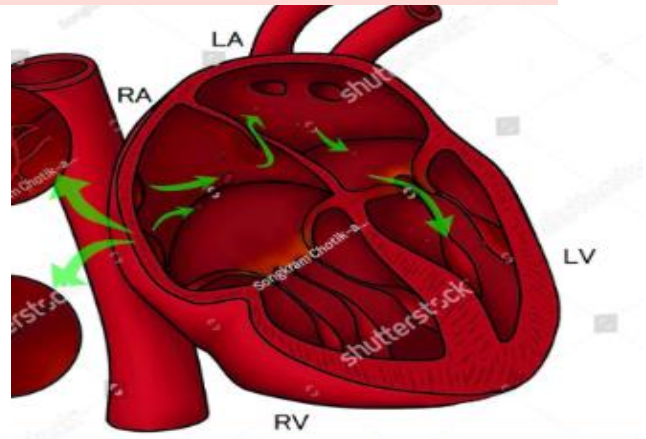
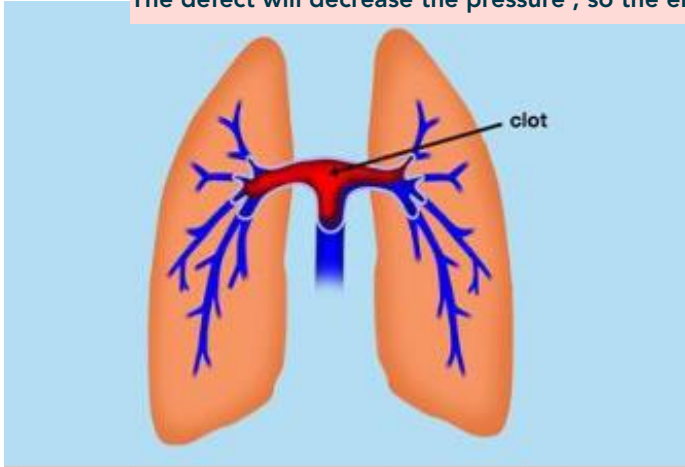
We are talking about venous circulation

The blood can't reach the lung so the level of blood that should be oxygenated in the lung will be decrease.

- **paradoxical embolus** is the passage of an embolus from the venous side of the heart to arterial side of the heart through a defect inside the heart, this defect could be a patent **foramen ovale**, atrial septal defect (ASD) or a ventricular septal defect (VSD). In this condition, the **origin** of the embolus is the **venous circulation**, but the **target** would be on the **arterial** side of the circulation (and that is the paradox)

There is a defect between the right and left heart .
So the embolus can reach the left heart and then go by the aorta (systemic circulation) and causes arterial diseases

The defect will decrease the pressure , so the embolus can go to the left side of the heart easily



❖ Clinical consequences of pulmonary thromboembolism

- Mainly dependent on the ¹size of the embolus and the exact ²location inside the pulmonary vasculature ³the condition is Acute or chronic ⁴One embolus or multiple ?
- ^{60%- 80%} **Most** of these emboli are **very small** therefore would be totally **asymptomatic**. (but can lead to **organization** -this is not mentioned by the doctor-)
- **Larger** emboli cause symptoms including **pulmonary infarction**. (**Ischemia**)
- Obstruction of **medium sized arteries** in the lung could lead to **pulmonary hemorrhage**.
- If more than **60%** of pulmonary vessels are obstructed this could lead to **right ventricular failure (RVF)**, **Cardiovascular (CV) collapse** which ultimately leads to sudden death.
- If multiple small emboli keep forming over a long period of time, we call this "**showers of emboli**". This leads to **pulmonary hypertension** and **right ventricular failure**.

Common in patients with hypercoagulability

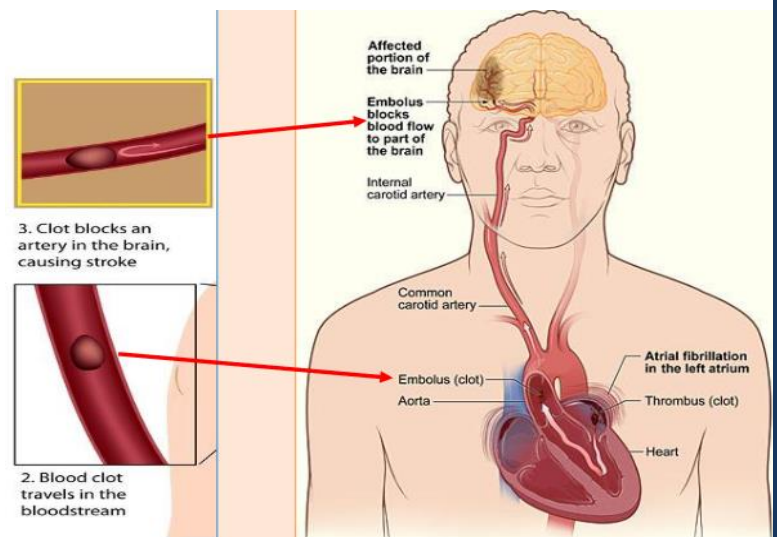
Arterial thromboembolism

To lesser extent, Aorta; to lesser extent in Arteries.

- The **origin** of most arterial emboli are the **heart chambers**, from there it continues its flow with the direction of blood until it reaches its target, which could be any kind of tissue that receives blood from an arterial circulation.
- Target of arterial thromboembolism could be **any organ that has arterial supply**, but the major targets are:
 - Lower limbs (75%), Brain (10%), Intestines, Kidneys, Spleen, Lungs...Etc.

These numbers are related to Statistical issues , but any organ can be at risk

- The figure to the right illustrates a thrombus formed inside the left atrium that fragments and sends an emboli, which goes with the direction of blood into the left ventricle and then through the aorta reaching anywhere in the arterial circulation. In this example, it goes through the common carotid → internal carotid → brain vasculature → leading to occlusion of artery causing **ischemic necrosis** (stroke).

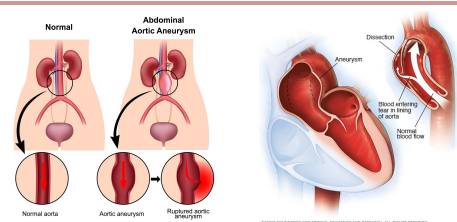


❖ Causes of Arterial thromboembolism

- Most of the time (80%), it is due to **intracardiac mural thrombi** (inside the heart).
- There are numerous causes for such thrombi (intracardiac). These include:
 - 2/3 Left ventricular failure.
 - 1/4 Left atrial dilatation.
 - Presence of complicated ulcerated atherosclerotic plaque.
 - Aortic aneurysm.
 - Valve vegetation. *arrhythmia, valvulitis*
- The remaining 20% originate from arteries like the aorta for example.

Extra: 

aortic aneurysm is a balloon-like bulge in the aorta. Having an aortic aneurysm increases the risk of developing a tear in the inner layer of the wall of the aorta (aortic dissection).



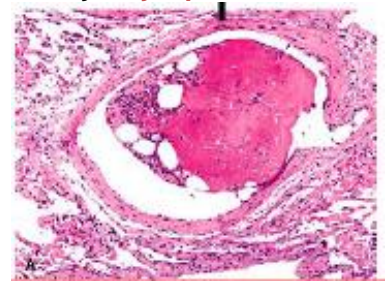
Fat embolism

- This is the second type of emboli according to the composition of the embolus.
- **Fat globules** enter the circulation and go to different tissue targets, leading to occlusion of blood vessels and ischemic necrosis.

❖ Causes

The most important cause

- Most commonly due to **Skeletal injuries** such as **fractures** of long bones. Almost **90%** of skeletal injuries result in fat embolisms but they are usually **asymptomatic**, only **10%** or less have actual clinical findings called the fat embolism syndrome (will be discussed later).
- Rarely due to **adipose tissue injury** such as the massive fat necrosis happening after acute pancreatitis.



❖ Results

1. physical effect : like a thrombus
2. Inflammatory effect : (Systemic, metabolic , toxic)

- Mechanical **obstruction** of blood vessels and ischemia.
- Presence of free fatty acids released from fat globules, could illicit local toxic injury and immune reaction leading to a systemic immune reaction.

❖ Fat embolism syndrome

The term is used to describe **clinically significant** manifestations resulting from fat embolism.

Symptoms **don't instantaneously** appear after a bone injury. They're usually **delayed** and take 1-3 days to appear.

Fat embolism = Fat globules + Hematopoietic cells (from bone marrow due to bone fractures)

❖ Characteristics

Usually go by venous circulation and to the lung so the diseases are related to the venous circulation

- Pulmonary insufficiency (rapid breathing and shortness of breath).
- Neurologic symptoms (mental confusion, lethargy, coma).
- Petechial rash (pinpoint rash, found on chest, head and neck area due to bleeding under skin).
- Fever.
- Anemia.
- Thrombocytopenia. Due to bone marrow toxicity or the damage of the hematopoietic cells
- Death in 10% of the cases with this **syndrome**.

Diagnosis of the Fat embolism syndrome: Clinical diagnosis by these symptoms

Control:

1. rapid Control of the fractures
2. The patients Need supportive care to reduce the effect of inflammation

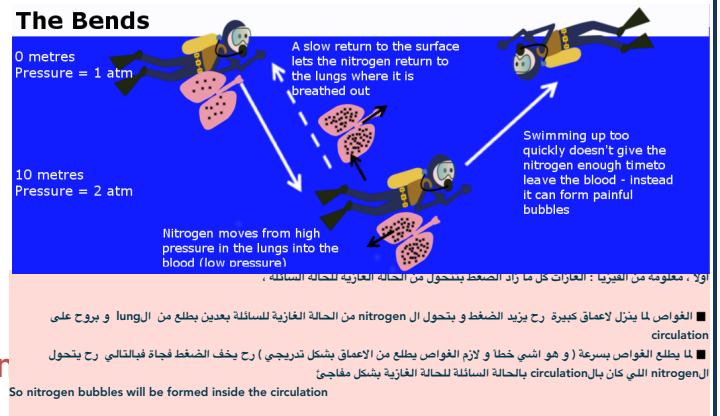
Air embolism

This is the third type of emboli according to the composition of the embolus.

An **air bubble** is formed and is travelling inside the circulation. It can have a mechanical effect like any other thromboemboli, therefore it can lead to vascular occlusions and clinical symptoms.

❖ Causes

- Surgical and obstetric procedures,
- Vascular catheterization,
- Traumatic chest wall injury,
- Decompression sickness: it occurs in scuba deep-sea drivers and mainly due to **nitrogen**



❖ Decompression sickness (nitrogen embolism)

Due to differences in atmospheric pressure and underwater pressure, when the diver goes deep into the sea, Nitrogen moves from **high** pressure in the lungs into the blood which has **lower** pressure and it gets **dissolved** there.

Now, if the diver **quickly swims up to the surface**, this wouldn't let nitrogen (which is now dissolved in blood) leave the blood and go to lungs resulting in painful air bubbles.

Instead, a professional diver would **slowly swim up** to the surface, giving enough time to the nitrogen dissolved in his blood to return back to the lungs, where it can be breathed out. **The effect can appear in the lung , and CNS**

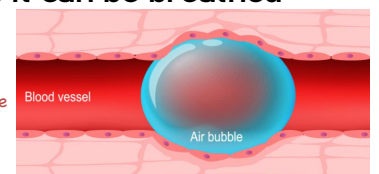
❖ Clinical consequences of air embolism

This depends on the **amount** of air that has been trapped inside the circulation in the form of bubbles. Based on that, it might be asymptomatic or could have serious complications. **Studies found that 5ml/kg is required for clinical manifestations to happen.**

- **Painful joints** due to rapid formation of gas bubbles within skeletal muscles and supporting tissues
- **Focal ischemia** in brain and heart
- **Respiratory distress** (chokes) occurs when massive amount of air enters the circulation. Leading to lung edema, hemorrhage, atelectasis, emphysema
- **Caisson disease**: another name for decompression sickness, where gas emboli in the bones leads to multiple foci of ischemic necrosis, usually in the heads of femurs, tibias, and humeri.

The Bubbles after a period of time will go back to the lung and the problem will be solved. But there are variations between people

Notice the bubbles in the circulation



Amniotic fluid embolism

Due to injury in the maternal blood vessels

- It occurs as a result of the **infusion of amniotic fluid** into **maternal** circulation via tears in placental membranes and rupture of uterine veins. (**Complicated labor**).
- This is the fourth type of emboli according to the composition of the embolus.
- It is a very **rare** complication of labor.
- It has **high** mortality rate => around 20% - 40%. **Highly fatal**

❖ Symptoms

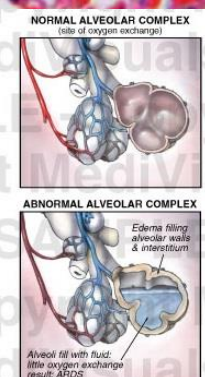
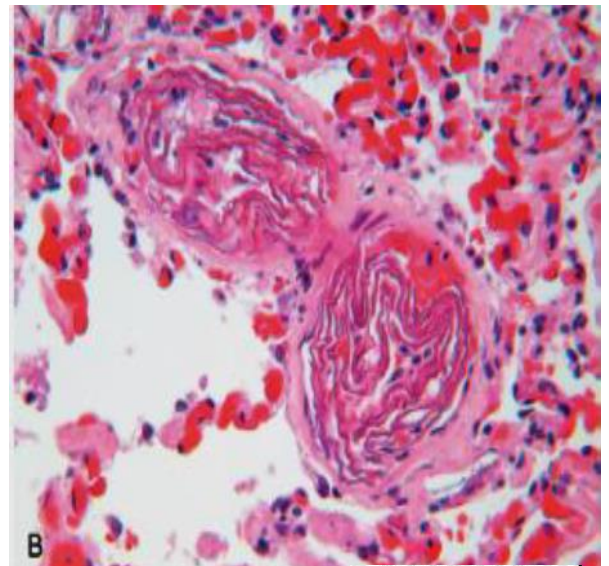
- Mechanical effects of vascular occlusion as in any other emboli.
- Associated with unique manifestations that are all related to **DIC** (Disseminated intravascular coagulation).
- Sudden severe dyspnea, cyanosis, ARDS, and hypotensive shock, followed by seizures, DIC and coma. These symptoms arise due to the **allergic reactions that take place against the fetal components**.

Will cause inflammatory, metabolic reaction against the fluid content

❖ Microscopic findings seen upon autopsy

- In this picture, we are looking into the pulmonary arterioles from the autopsy of a mother dying because of amniotic fluid embolism
- Presence of **fetal components** within the maternal pulmonary microcirculation is diagnostic of this condition, and by “fetal components” we mean **fetal squamous cells** and other components such as **lanugo hair**, **fat**, **keratin**, **mucin** Etc..
- In the image to the right, we can see keratin and fetal squamous cells.
- Note that this condition affects maternal and not fetal circulation.

AMNIOTIC FLUID EMBOLUS: KERATIN AND FETAL SQUAMOUS CELLS IN PULMONARY ARTERIOLES



Infarction

- The complications of thromboembolisms are **mainly** attributed to the ischemic necrosis of the tissue.
- Infarcts are the **hallmark** of tissue ischemia
- **An infarct** is an area of ischemic necrosis caused by the occlusion of arterial supply or venous drainage in a tissue.
- **99%** of infarcts result from thrombi/emboli, but there are other mechanisms:
 - Vasospasm,
 - Extrinsic compression of the vessel (by a tumor for example),
 - Vessel twisting (examples include testicular torsion, volvulus),
 - Traumatic vessel rupture.

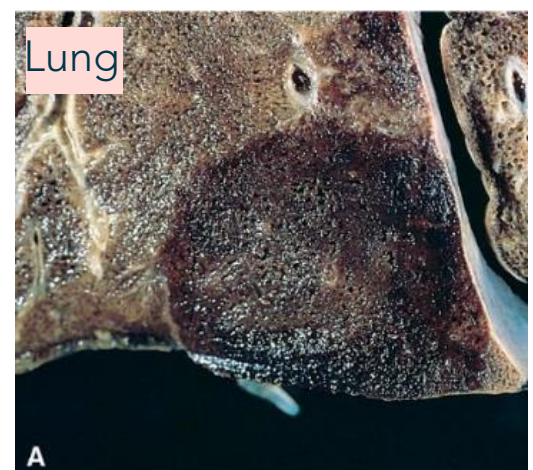
❖ Morphology of infarcts

- Infarcts may be either **red** (hemorrhagic, full of blood) or **white** (anemic), depending on the **amount of blood** left in the necrotic tissue. They also could be either septic or bland.
- Tend to be **wedge** shaped where the occluded vessel is at the **apex** and the periphery of the organ forming the **base**.
- Margins of the infarct tend to become better defined with time.
- histologic **hallmark** of infarction is **ischemic coagulative necrosis**! The brain here is an exception as it undergoes **liquefactive necrosis**.
- most infarcts are eventually replaced by **scar** tissue.

❖ Red infarcts

Here the necrotic tissue is filled with ^{Hemorrhage} **blood** (like the picture on the right representing lung tissue with red infarct) and it occurs in the following scenarios:

- **Venous occlusions** (e.g. ovarian torsion).
- **Loose tissues** (e.g. lung) that allow blood to collect in the infarcted zone.
- Tissues with **dual circulations**, because one vessel is occluded while the other keeps the blood going to the necrotic area (e.g. lung and small intestine).
- Previously congested tissues because of ^{And Liver} **sluggish venous outflow**.
- When flow is re-established to a site of **previous arterial occlusion** and necrosis.



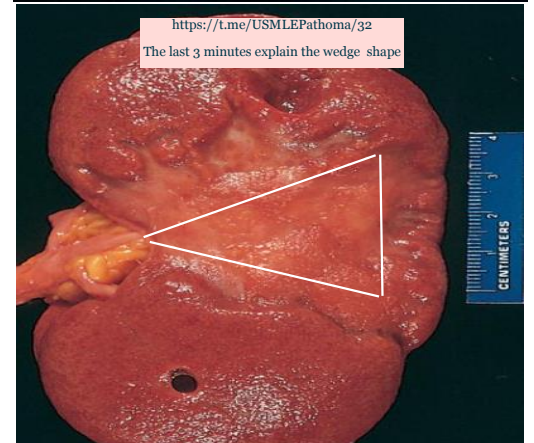
❖ White infarcts

Here, there is little to no amount of blood in the necrotic tissue, it occurs in:

- Arterial occlusions.
- Solid organs (such as heart, spleen, and kidney).

The image to the top-right shows white infarction in spleen, while the one on the bottom-right shows a white infarct in the kidney replaced by a fibrotic scar tissue.

- Remember that red and white infarcts are new descriptions of the color of the infarct. However, they both represent ischemic tissue necrosis.



kidney infarct replaced by a large fibrotic scar

❖ Septic infarctions

It is an area of infarcted tissue where the infarct is superimposed by an **infection**. examples:

- Infected **vegetations** on the cardiac valve.
- Microbes **seed** an area of necrotic tissue.
- Infarct is converted into **abscess** with a greater inflammatory response.

❖ Factors that influence development of an infarct

- **Nature** of vascular supply (whether the occluded vessel is an artery or a vein)
- **Rate** of occlusion development (presence of collateral circulation)
- Tissue **vulnerability** to **hypoxia**, some tissues are more **resistant** to hypoxia while other are very vulnerable. For example:
 - **Neurons** undergo irreversible damage within **3 to 4 minutes** of ischemia.
 - **Myocardial** cells die after only **20 to 30 minutes** of ischemia
- **Oxygen** content of blood

New questions added in 020 lecture:

Q1: If we have an embolus in the pulmonary artery, will the embolus be considered of venous or arterial origin and will its final target be the lungs ?

A: Embolus in pulmonary arteries belongs to venous embolism and the main target is the lung itself.

It is a bit confusing, but remember that pulmonary artery carries venous blood from the right side of the heart to the lungs, so it's quite the opposite to what do arteries do.

Q2: Can pulmonary embolism be of an arterial origin?

A: Yes, the lung can be a target of both types venous and arterial embolism. It depends on the side of the circulation it originated from. So if the embolus is coming from the venous circulation and is reaching the lung through the right side of the heart, it is a venous embolus. On the other hand, if the embolus is coming out of the left side of the heart and reaching the lung through bronchial circulation, then it is an arterial embolus.

"That which does not kill us makes us stronger" -Friedrich Nietzsche

Good luck

1. cassion disease is caused by:

- a. thromboembolism
- b. nitrogen embolus
- c. saddle embolus
- d. amniotic fluid embolus
- e. fat embolus

2. Systemic thromboembolism:

- a. pulmonary artery
- b. femoral artery

3. The most common cause of pulmonary thromboembolism:

- a. Thromboembolism
- b. Fat embolism
- c. Air embolism
- d. Nitrogen embolism
- e. Cholesterol embolism

4. All of the following regarding pulmonary thromboembolism are true EXCEPT:

- a. Arises in most of the cases from deep vein thrombosis of the lower limb
- b. Organization is seen in most of the cases.
- c. Saddle embolus is an embolus that occurs in the arch of the aorta
- d. Pulmonary hemorrhage occurs when medium sized arteries are obstructed
- e. Paradoxical embolus can pass into the systemic circulation due to ventricular septal defect

5. The major target of systemic thromboembolism is:

- a. Brain
- b. Lower limbs
- c. Intestine
- d. Kidney
- e. Spleen

6. Which of the following is wrong:

- a. paradoxical embolus means saddle shaped thrombi obstruct the pulmonary bifurcation
- b. lines of Zahn indicate antimortem thrombi
- c. DVT is main cause of pulmonary thrombus
- d. Immobilization causes secondary hypercoagulability

7. Wrong about amniotic fluid embolism:

- a. presence of Luongo hair within mother pulmonary circulation
- b. cause ARDS and DIC
- c. cause caisson disease
- d. highly mortality
- e. Mainly appears in the venous side

8. Wrong about fat embolism:

- a. symptoms need 1-3 days after injury to appear
- b. it causes anemia and thrombocytopenia
- c. Fat globules cause toxic injury
- d. May be due to acute pancreatitis
- e. Fat embolism syndrome occurs in 90% of tibia injury cases

Answers :

1. *b*

2. *a*

3. *a*

4. *c*

5. *b*

6. *a*

7. *c*

8. *e*

يَارِبُّ أَنْزِلْ عَلَى الطَّلَابِ غَايَةً..
مِنَ السَّدَادِ بِمَا جَدَّوْا وَمَا عَمِلُوا.

الْعِلْمُ عِلْمُكَ... وَ الْأَفْهَامُ عَاجِزَةٌ..
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