

Coronary circulation

Editing File

Objectives:



Dr matt,
Dr mike



Dr.Ahmad farid



To identify the Coronary circulation & areas of their supply in the heart.



To understand Coronary dominance And collateral circulation.



To understand the Normal and facts of Coronary blood flow And factors affecting it.



To understand the mechanisms of control of Coronary blood flow And Discuss regulation of coronary blood flow.



Coronary blood flow in systole And diastole.



Explain and differentiate between angina and myocardial infarction.

We recommend you to study “ Anatomy: coronary circulation “ first for better understanding

Coronary circulation & its Importance

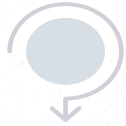
Coronary circulation

It's the circulation of blood in arterial blood vessels that supply / transport oxygenated blood to the heart muscle (myocardium) (this Mix F+M)

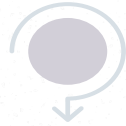
its Consists of: **Female's slide**



Arterial supply



Venous drainage



Lymphatic drainage



Coronary arteries supply oxygenated blood to myocardium.



Cardiac veins drain away deoxygenated blood from and to the cardiac muscle.



Coronary circulation "major importance" is not only to its own tissues but to the entire body and even to the level of consciousness of the brain from moment to moment.

Male's slide



Heart uses primarily free fatty acids as source of energy and to lesser extent glucose and lactate for metabolism

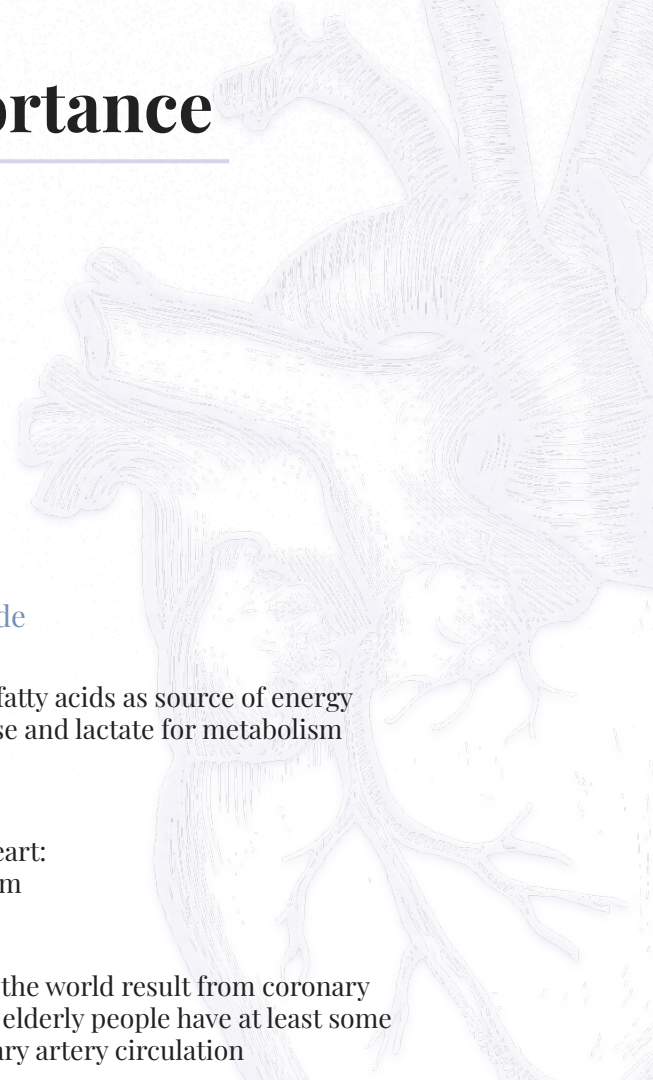


Capillary Density in the heart:
2900 - 4000 capillaries/mm



Important! Why?

One third of all deaths in the world result from coronary artery disease. Almost all elderly people have at least some impairment of the coronary artery circulation



Coronary Circulation

Cardiac muscle is supplied by two coronary arteries:

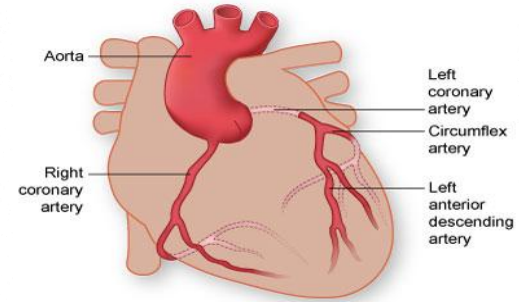
- 1 Right coronary artery (RCA)
- 2 Left coronary artery (LCA)

Origin:

Both arise from the coronary sinus at the aortic root, just superior to the aortic valve cusps.

Branch:

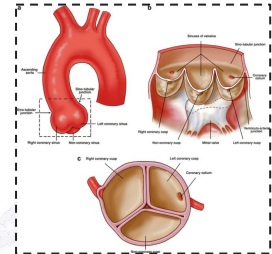
They wrap with their branches around the outside of the heart to supply all cardiac muscle with blood.



Aortic valve has three cusps:

- 1 Left coronary cusp (LCC)
- 2 Right coronary cusp (RCC)
- 3 Posterior non-coronary cusp (NCC)

Coronary sinus is just above the corresponding cusps, where the coronary ostia arise. There may be variations in the number, shape, and location of coronary ostia or origins of the coronary arteries, most of which are of no clinical significance. Coronary arteries deliver oxygenated blood to the cardiac muscle.



Coronary Arteries

Right coronary artery

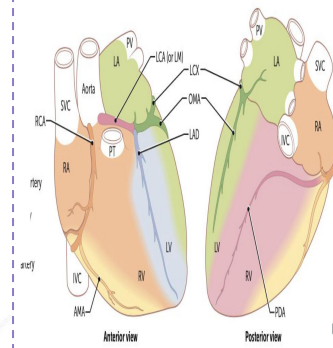
- » **Size:**
Smaller than the left coronary artery.
- » **Origin:**
Arises from the right coronary sinus.
- » **Distribution:**
curves posteriorly and descends downward on the posterior surface of the heart, Terminates by anastomosing with the left coronary artery
- » **Supply:**
Supplies blood to the right atrium, the SA (sinoatrial) and AV (atrioventricular) nodes, right ventricle, bottom portion of both ventricles and back of the septum
- » **Main 2 branches:** M+F slide first 2
 - 1- **Right posterior descending artery (RPD)** (Also called posterior interventricular artery).
 - 2- **Right acute marginal artery (AM).**
 - 3- **Smaller arteries branches,** such as :
 - **Atrial branch:** gives off SA nodal artery, which supplies the **SA-node** in 60%(-50-73%) of hearts & the surrounding myocardium.
 - **Right conus arteriosus artery.**
 - **Right anterior ventricular artery.**
 - **Septal perforator (SP) artery.**

Left coronary artery

Also known as the left main coronary artery (LMCA)

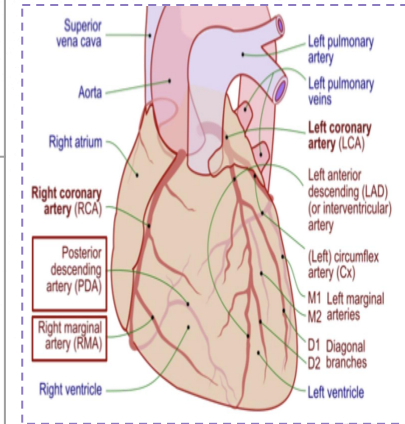
- » **Size:**
Larger than the right coronary artery
- » **Origin:**
Arises from the left coronary sinus.
- » **Distribution:**
Runs for 10-25 mm before bifurcating, Then Terminates by anastomosing with the right coronary artery.
- » **Supply:**
Supplies blood to the left side of the heart muscle (left ventricle and left atrium).
- » **Main branches:** M+F slide
 - 1- **Left anterior descending artery (LAD)** (Also called anterior interventricular artery) **Considered the most critical vessel in terms of myocardial blood supply.**
 - 2- **Circumflex artery (CX).**

Key:
 AMA = Acute marginal artery
 LAD = Left anterior descending artery
 LCA (or LM) = Left (main) coronary artery
 LCX = Left circumflex artery
 OMA = Obtuse marginal artery
 PDA = Posterior descending artery
 PT = Pulmonary trunk
 PV = Pulmonary vein
 RCA = Right coronary artery



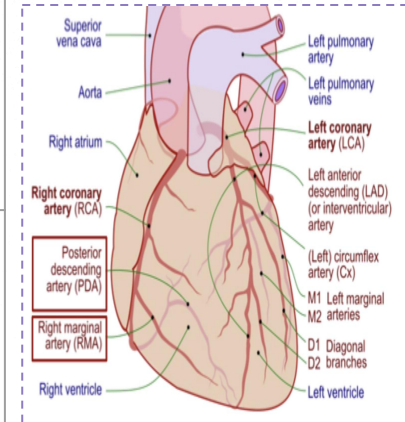
Branches of Right Coronary artery

Right posterior descending artery (RPD) (AKA: <u>posterior</u> interventricular artery)	Right acute marginal artery (AM)
<p style="text-align: center;">Distribution:</p> <p>Curves posteriorly and descends downward on the posterior surface of the heart.</p>	<p style="text-align: center;">Distribution:</p> <p>Runs down the right margin of the heart.</p>
<p style="text-align: center;">Supply:</p> <ul style="list-style-type: none"> - Supplies blood to the right atrium, right ventricle, bottom portion of the left ventricle and posterior 1/3 of the Interventricular (IV) septum. - Branches into AV nodal artery, which supplies the AV-node (in 60-90% of hearts) and the surrounding myocardium. 	<p style="text-align: center;">Supply:</p> <ul style="list-style-type: none"> - Supplies blood to the right margin of the right ventricle with minimal supply to the apex.



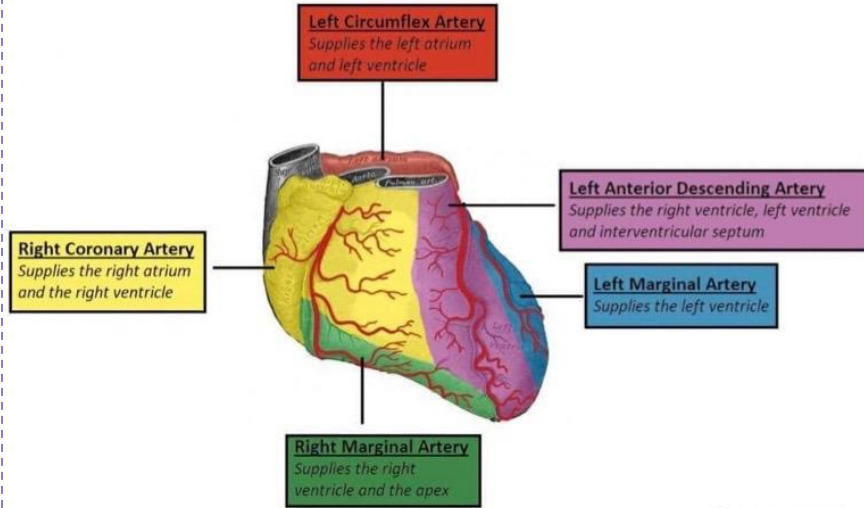
Branches of Left Coronary artery

Left anterior descending artery	Circumflex artery
<p>Supplies:</p> <ul style="list-style-type: none"> -Supplies 45-55% of the left ventricle (anterior & apical parts of the heart): -The Anterolateral of the left ventricle -Apex of the heart. - Supplies the anterior 2/3 of the Interventricular (IV) septum. - Supplies the right & left bundle branches. Supplies the front of the right ventricle 	<p>Supplies:</p> <ul style="list-style-type: none"> .Encircles the heart muscle. - Supplies blood to the lateral & posterior surface of the heart: left atrium and the posterolateral of the left ventricle
<p>Small branches:</p> <ul style="list-style-type: none"> • Diagonal arteries (D1, D2) • Left Conus Arteriosus artery • Septal Perforator (SP) artery 	<p>Small branches:</p> <p>Left obtuse marginal (OM) artery (OM1, OM2), which supplies the left ventricle.</p> <ul style="list-style-type: none"> • SA nodal artery, which supplies the SA- node in ~40% of hearts & the surrounding myocardium. • Left branch to the AV- Bundle. • Posterior ventricular branch • Anterior ventricular branch

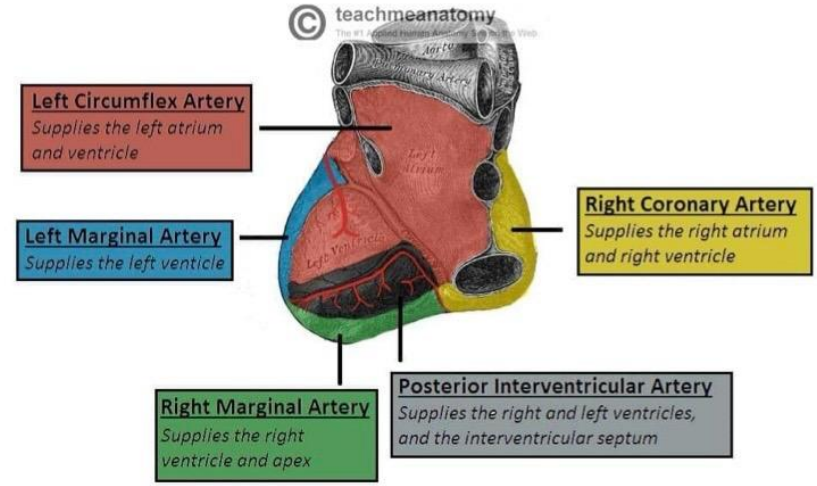


Coronary Circulation: Areas of Distribution

Front view



Back view



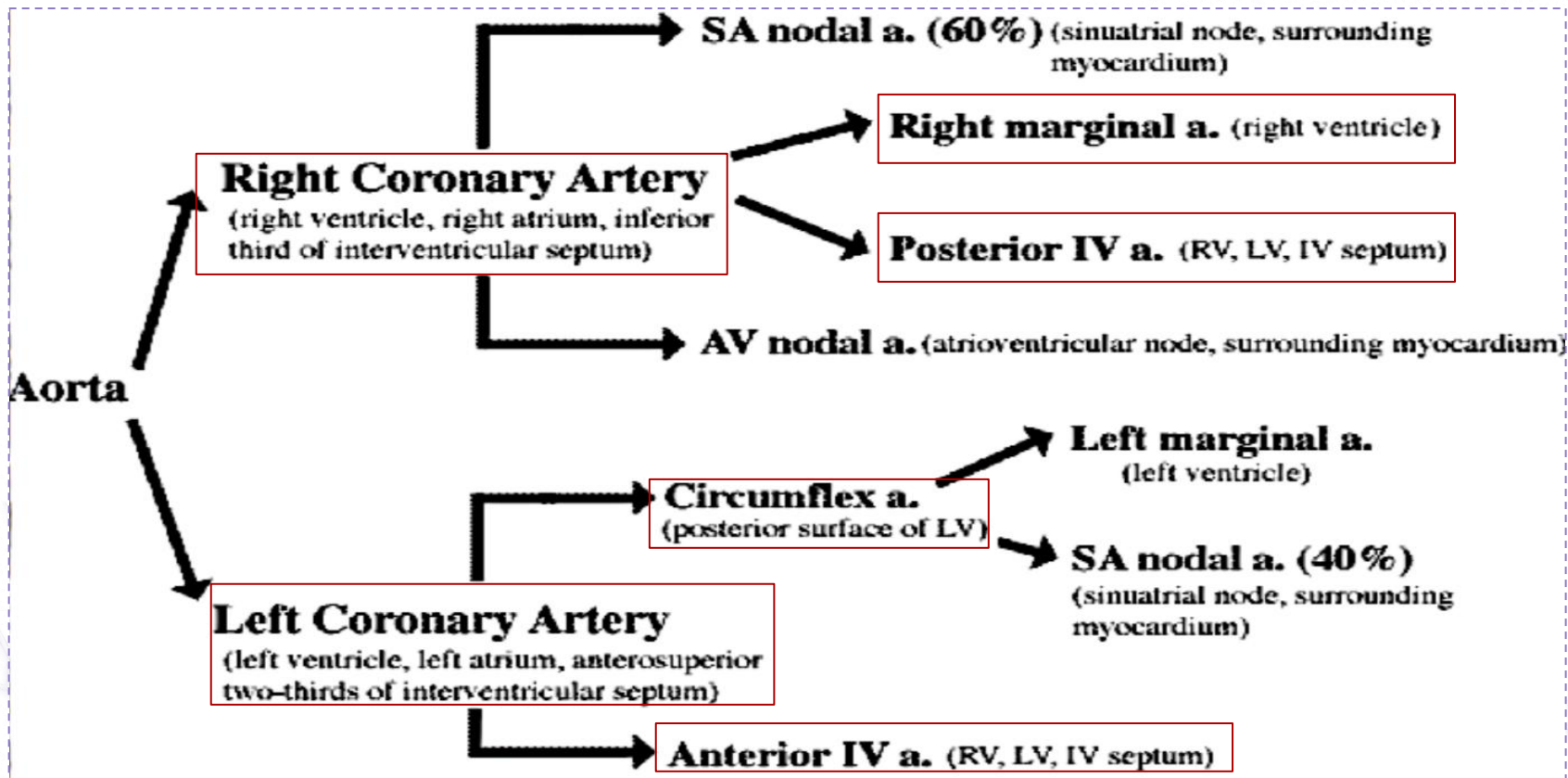
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Understanding the distribution of coronary circulation is essential in diagnosing, treating, and preventing heart disease, as well as advancing cardiovascular research. Knowing the areas of the heart that are supplied by different coronary arteries can help identify which artery is blocked or narrowed in case of a heart attack or other cardiovascular conditions. This information is crucial in making decisions about treatment options and interventions



443 Mele Dr note: this is the most important thing in this slide

Summary : Coronary arteries branches And areas of supply





Anastomosis and Collateral Circulations



Cardiac anastomosis

Female's slide

- The two coronary arteries anastomose (connect) in the myocardium
- Extra-cardiac anastomosis, the two coronary arteries anastomose with :
 - The bronchial arteries.
 - Vasa vasorum (small vessels) of the aorta.
 - Vasa vasorum of pulmonary arteries.
 - Internal thoracic arteries.
 - Phrenic arteries.

Collateral Circulations

- Definition: Collateral circulation is a network of extra-cardiac channels formed of tiny blood vessels. (plan B)
- **Under normal conditions it is not open, it opens only in emergencies when the coronary arteries are blocked** or when the coronary arteries become narrow to the point that blood flow to the heart muscle is limited (eg. coronary artery disease), collateral vessels may enlarge & become active, this allows blood to flow around the blocked artery to another artery nearby or to the same artery past the blockage, and protecting the heart tissue from injury.

Venous Drainage Of The Heart

● Venous drainage brings deoxygenated cardiac blood back to the heart.

● Most of the venous blood returns to the heart into the right atrium through the coronary sinus via the cardiac veins.

● 5-10% drains directly into heart chambers, right atrium and right ventricle, by the **anterior cardiac vein and by the small veins that open directly into the heart chambers.**

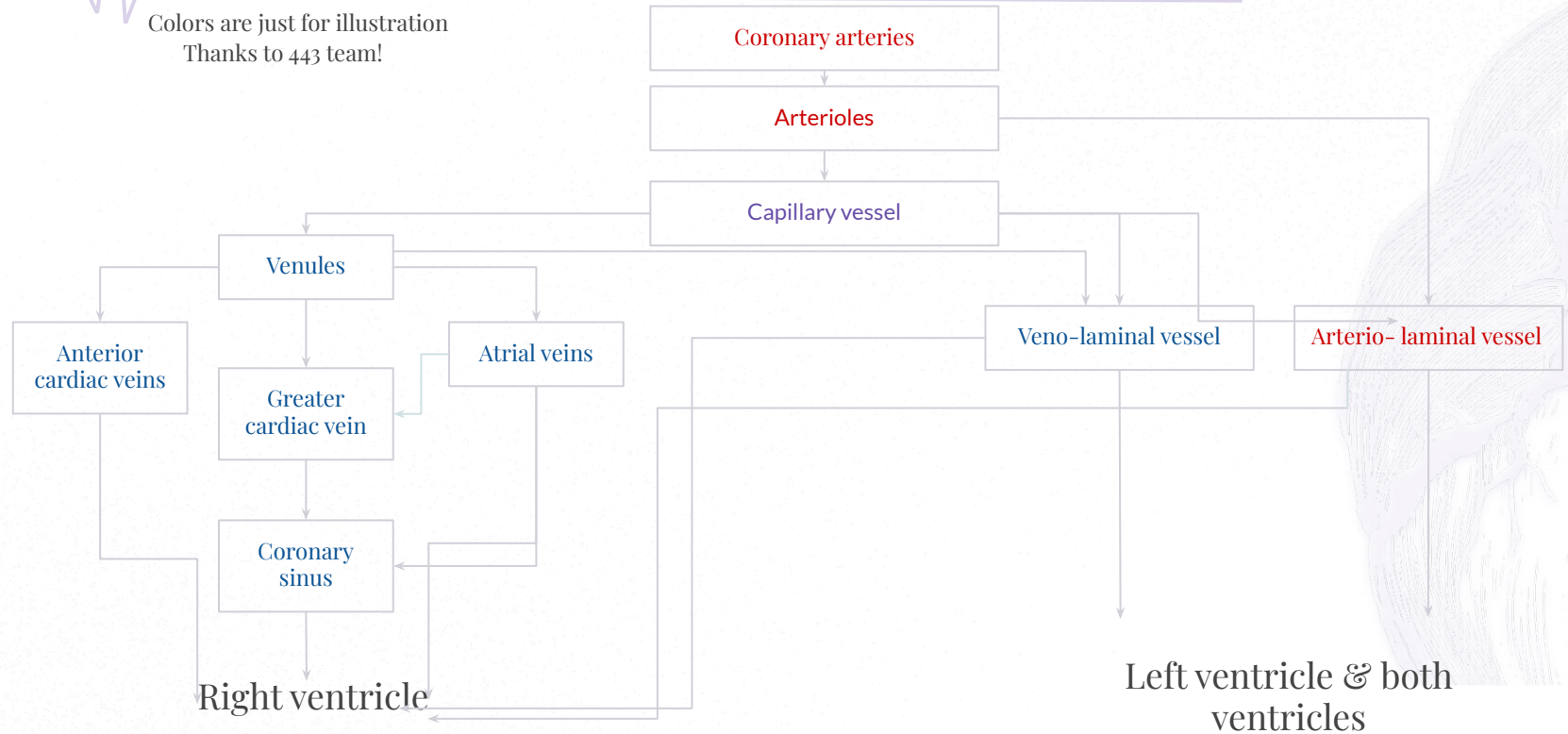
● Cardiac venous drainage occur through: **Female's slide**

- Coronary sinus, which lies in the posterior part of the atrioventricular groove and is a continuation of the great cardiac vein
- Anterior (great), middle, and small cardiac veins.
- Smallest cardiac veins (Venae Cordis Minimae).



Summary

Colors are just for illustration
Thanks to 443 team!



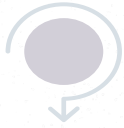
Great Cardiac Venous System (GCVS)
Capacity : 73%

Small Cardiac Venous System (SCVS)
Capacity : 27%

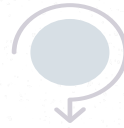


Lymphatic Drainage Of The Heart

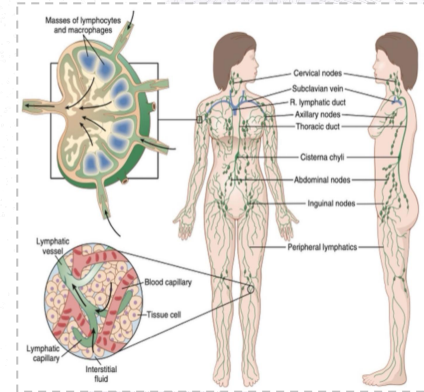
Lymphatics of the heart accompany the two coronary arteries and form two trunks:



The **left** trunk:
ends into the tracheobronchial lymph nodes at the bifurcation of the trachea.



The **right** trunk:
ends in the brachiocephalic node.



The lymphatic system is essential for immune function as it contains lymphocytes, fluid balance (absorb the excess fluid in the body and return it to the bloodstream), nutrient absorption, and cardiovascular health. Dysfunction of the lymphatic system can lead to a range of health problems, including infections, lymphedema (swelling due to lymphatic blockage), and cardiovascular disease.

Coronary Dominance

Coronary dominance depends on which artery (or arteries) supplies the AV node. Usually, **the right coronary artery** is the **dominant** artery in **85-90% of hearts**, as it supplies the AV- node.

A person can be :

1 **Right dominant (85-90%)**

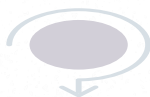
2 **Left dominant (8-10%), through the CX branch**

3 **Co-dominant “balanced” (7-10%)**

The Posterior Inter- Ventricular artery is formed by both the Right coronary & Left CX arteries.

Coronary artery	Cardiac muscle	Conduction system
RCA	- Lateral, posterior wall of RV - Inferior wall of LV	- SA node (45%)* - AV node (90%)* - Bundle of his - Right bundle
LAD	- Anterior wall of RV - Septum, apex, anterior wall of LV	- Left bundle
LCx	- lateral, posterior wall of LV	- Left bundle - SA node (55%)* - Av node (10%)*

* Represents the percentage of the population in which this feature occurs



Clinical importance :

- In case of left dominance, a block in LCA will affect the entire left ventricle & Interventricular (IV) septum
- In case of right or balanced dominance, a block in RCA will at least spares part of the septum (2/3) & the left ventricle.

سليخان ريك رب العزة

Dr:

In case there is an injury in the heart, the first thing will be affected is your dominant artery, so if you are a right domain, the Av node will be affected but the left ventricle and contractility will be intact. Unlike if you are a left domain, it's worse and everything will be affected

Coronary blood flow

- Two-thirds of coronary blood flow occurs during **beginning of diastole** .
- Coronary blood flow (CBF) at rest in human is about 225-250 ml/min, about 5% of cardiac output.
- At rest, the heart extract 60-70% of oxygen from each unit of blood delivered to the heart (other tissues extract only 25% of O₂).
- During times of extreme demand, the coronary arteries can dilate up to four times greater than normal

Why heart is extracting 60-70% of O₂?

- Because heart muscle has more mitochondria, **up to 40% of cell is occupied by mitochondria**, which generate energy for contraction by aerobic metabolism, therefore, heart needs O₂.
- CBF increases in proportion to exercise **or work output**. When more oxygen is needed, O₂ can be increased to heart only by increasing blood flow.

Changes in Coronary Blood Flow (CBF)



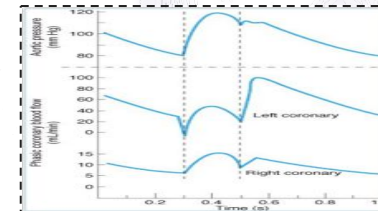
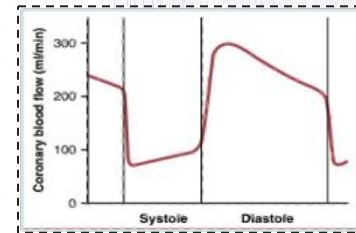
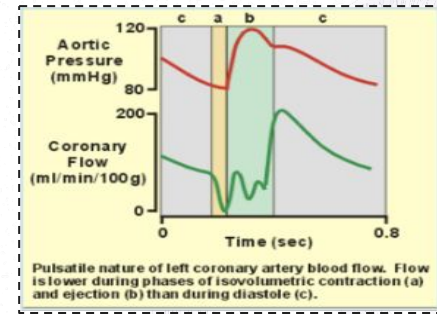
During systole / When heart muscle contracts, coronary arteries are compressed & the blood flow to the left ventricle is reduced and increased during diastole

CBF to the right side of the heart is not much affected during systole & so more blood will flow to the right ventricle than the left one.

Blood flows to the subendocardial portion of Left ventricle, which occurs only during diastole & is not there during systole.

Explanation: Pressure difference between the aorta & the right ventricle is greater during systole (95 mmHg) than during diastole (80 mmHg), therefore more blood flow to right ventricle occurs during systole

Explained more in the upcoming slides.



Coronary Vascular Resistance

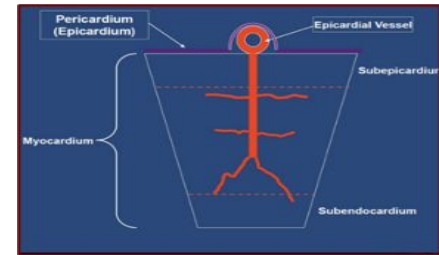
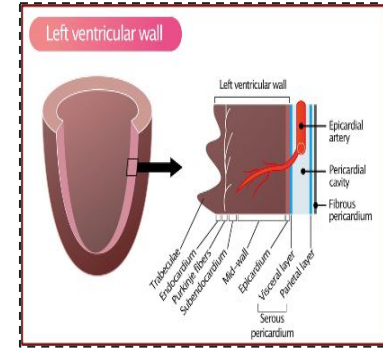
Epicardial conductance vessels:
Contribute only to a small % of resistance.

As we know during systole blood flow to subendocardial surface of left ventricle is almost not there. **((Therefore, this region is prone to ischemic damage and most common site of Myocardial infarction.(M+F SLIDE)))**

Intramyocardial vessels (arterioles):
Contribute most to total coronary vascular resistance.

So Important!! focus on it
What's the reason that make subendocardium layer most common site of MI & prone to ischemic damages ?

The subendocardium is located in the innermost layer of the heart muscle, which is furthest from the blood supply. Inside the heart will be supplied by EDV, and outer side which is less resistant, it will be supplied at the end of systole. But the subendocardium only gets its supply in the diastole. So when there is an increase heart rate → will lead to decrease the diastolic periods → subendocardial portion won't get its blood & O₂ → hypoxia → MI



Factors Affecting Regulation of Coronary Blood Flow (CBF)



Metabolic control
(Chemical factors)



Endothelial control of coronary
vascular tone



Pressure in the aorta



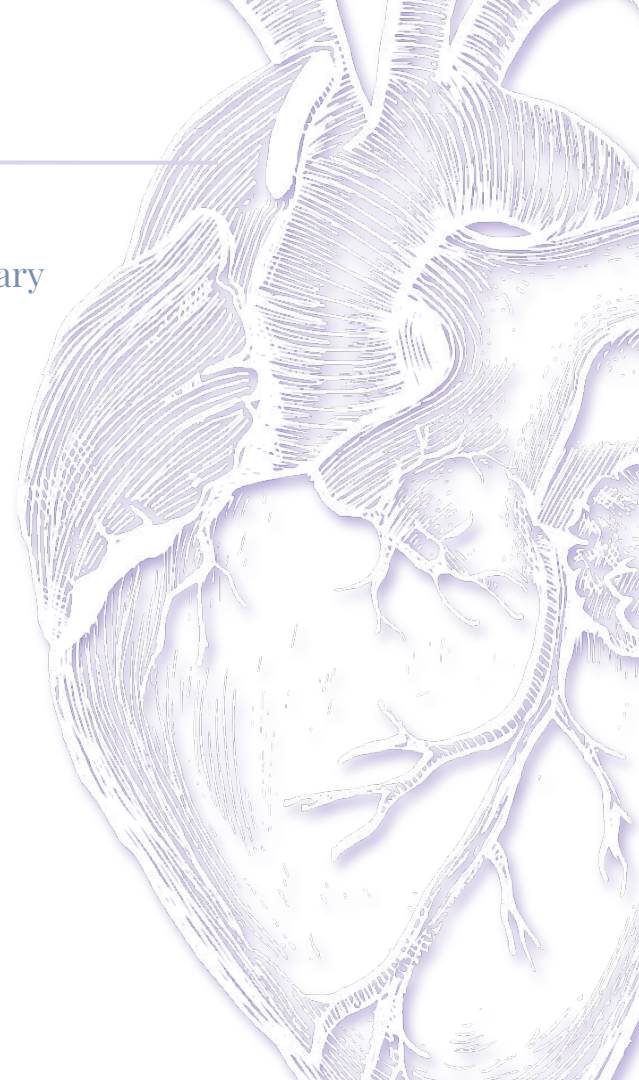
Neural control



Autoregulation



Extravascular compressive forces



Effect of Pressure Gradient between Aorta & Different Chambers of the Heart On Coronary Blood Flow

	Pressure (mmhg) in			Pressure difference (mmhg) in	
	Aorta	LF VENTRICLE	RF VENTRICLE	LF VENTRICLE	RT VENTRICLE
Systole	120	120	25	0	95
Diastole	80	0-2	0-2	80	80

Dr:

When the pressure difference is zero, the net flow will be zero (No flow). And the higher pressure difference the higher flow will be. So right ventricle during systole gets the higher flow (blood supply), while left ventricle only get its flow (blood supply) during diastole.

In general, maximal coronary blood flow occurs during the early part of diastole (Isometric Relaxation Phase); however, CBF for the right ventricle could be better during systole (difference of 95 mmHg).

Factors Affecting Regulation of Coronary Blood Flow (CBF)



Metabolic control	Autoregulation	Endothelial control of coronary vascular tone	Extravascular compressive force
<p>1. Coronary circulation is very sensitive to myocardial tissue oxygen tension.</p> <p>2. Increased oxygen demand results in a lower tissue oxygen tension.</p> <p>- This causes vasodilation and increased blood flow by chemical factors like:</p> <ul style="list-style-type: none"> • Lack (±) of oxygen. • High (±) conc. of CO₂. • High (±) conc. of Nitric oxide • High (±) local conc. of H⁺ion. • High (±) local conc. of K⁺ion. • High (±) local conc. of Lactate, Adenine nucleotides, Prostaglandin, Adenosine (Adenosine, which is formed from ATP during cardiac metabolic activity, causes coronary vasodilatation). <p>- Note: An increase in Ca²⁺ conc. does not increase the Coronary blood flow (CBF).</p>	<p style="text-align: center;">Male's slide except in pink</p> <p>1. Ability of a vascular network to maintain constant blood flow over a range of arterial pressures. Example: Auto-coronary dilation in atherosclerosis.</p> <p>2. Auto regulation is an independent determinant of coronary blood flow.</p> <p>3. Direct effects of nervous stimuli on the coronary vasculature. Sympathetic greater effects than parasympathetic.</p> <p>4. The set point at which coronary blood flow is maintained depends on myocardial oxygen consumption (MVO₂)/Local muscle metabolism is the primary controller: Oxygen demand is major regulatory factor of coronary blood flow.</p> <p>5. Factors increasing myocardial O₂ consumption :</p> <ul style="list-style-type: none"> - Increased Heart Rate. - Increased Inotropy (Contractility). - Increased Afterload. Or preload. <p>Changes in preload affect myocardial oxygen consumption less than do changes in the other factors.</p> <p>- Percentage of O₂? Calculate it by : Laplace law: T= P*r/h T: wall tension, P: pressure, r: radius, h: wall thickness</p>	<p style="text-align: center;">Male's slide</p> <p>- Damage to endothelial cells will lead to:</p> <ol style="list-style-type: none"> 1. Decreased Nitric Oxide and Prostacyclin production. 2. Increased Endothelin production. 3. Increased pro-coagulant factors production such as: (Willebrand factor) 4. Vasoconstriction (vasospasm) (ET₁). - ET₁ refers to endothelin-1, which is a peptide hormone that is involved in the regulation of blood vessel constriction and dilation. ET₁ is produced by endothelial cells, and acts on the blood vessel walls to cause constriction. 5. Thrombosis 	<p style="text-align: center;">Male's slide</p> <p>1. In left ventricle :</p> <ul style="list-style-type: none"> • Early Systole: Initial Flow Reversal. • Remainder of Systole : Flow follows aortic pressure curve, but at a much reduced pressure. • Early Diastole : Abrupt pressure rise (80-90% of LV flow occurs in early diastole). • Remainder of Diastole : Pressure declines slowly as aortic pressure decreases. <p>2. In right ventricle :</p> <ul style="list-style-type: none"> • Lower pressure generated by thin right ventricle in Systole • No reversal of blood flow during early systole. • Systolic blood flow constitutes a much greater proportion of total blood flow.

Factors Affecting Regulation of Coronary Blood Flow (CBF)



Neural Factors (Control)

- Coronary blood flow is controlled predominantly by local metabolic, auto regulatory, and endothelial factors.
- Neural control of the coronary circulation complements the above local effects.

Coronary arteries have:

- **Alpha Adrenergic receptors**, which mediate **V.C (more epicardial)**
- **Beta Adrenergic receptors**, which mediate **V.D (more intramuscular)**
 - Beta 1 in **conduit** arteries, **coronary** arteries.
 - Beta2 in **resistance** arterioles.

- Effect of Sympathetic (Catecholamines (EP,NE)) & parasympathetic (Acetylcholine) Stimulation on CBF and **the effect of tachycardia** :

Sympathetic		Parasympathetic	Tachycardia
Direct	Indirect	- Vagal stimulation causes coronary V.D in healthy subjects (intact endothelium)	Female's slide
- Experimentally, injection of noradrenaline after blocking the Beta-adrenergic receptors in unanesthetized animals elicits coronary vasoconstriction.	Female's slide - Sympathetic stimulation in intact body will lead to release of adrenaline & noradrenaline, increasing heart rate (HR) & force of contraction. However, coronaries will vasodilate due to the release of vasodilator metabolites. Example: Athletes.	- V.C in patients with atherosclerosis (damaged endothelium). - However, parasympathetic distribution is not great. - There is more sympathetic innervation of coronary vessels.	- Coronary blood flow (CBF) is reduced with tachycardia. - Why? With tachycardia, the diastolic period will be shortened.

Benefits if indirect effects if Not-Adrenergic discharge : **Female's slide**

When the systemic blood pressure (BP) decreases (very low), it will cause:

- A reflex increase of noradrenergic discharge.
- This will lead to an increase in the Coronary blood flow (CBF) secondary to metabolic changes in the myocardium.
- In this way, circulation of the heart is preserved, while the flow to other organs is compromised.

Diseases

ANGINA

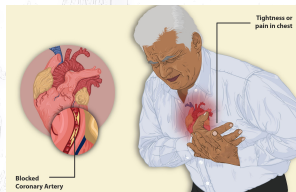
Definition:

Chest pain caused by **reduced blood flow** to the heart muscles. (like pressure, tightness, Squeezing in your chest)

Investigation:

- ECG may be normal between attacks.
- Exercise ECG – 75% positive.

Normal results does not exclude the condition.



Treatment for attack:

1. Stop exercise
2. Glyceryl trinitrate 0.5mg under the tongue.
(side effects → headache)

Myocardial infarction

Definition:

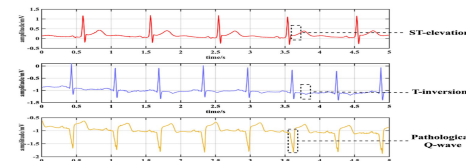
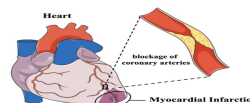
The **irreversible death** (necrosis) of heart muscle due to a lack of oxygen. Most common cause of death

Clinical features:

- Chest pain, even at rest & last for hours.
 - Severe pain, sudden onset, but can develop gradually.
- Associated with: sweating, vomiting and hypotension.

Investigators:

- Increased troponin and CK enzymes (Blood test)
- **Elevated ST segment (ECG)**



(a)

(b)

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



Sorry but if you will not check it راحت عليكم المليون

MCQs:



Answers

For more question check our summary file!

1 Left anterior descending artery supplies blood to ?

A	Right margin of the right ventricle	B	Right and left bundle branch	C	Minimal supply to the apex	D	A&C
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2 Right acute marginal artery supplies blood to ?

A	Right margin Of the right ventricle	B	Minimal supply to the apex	C	Right atrium	D	A&B
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3 Which of the following blood vessels is responsible for transporting the majority of venous blood flow that leaves the ventricular heart muscle

A	Coronary sinus	B	Bronchial veins	C	Azygos vein	D	Anterior cardiac veins
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MCQs:



Answers

0/9
4/5
1/1

For more question check our summary file!

4 What is the percentage of O₂ consumption in coronary arteries by the myocyte in resting state?

- | | | | | | | | |
|---|-----|---|-----|---|-------|---|-----|
| A | 65% | B | 20% | C | 100%. | D | 40% |
|---|-----|---|-----|---|-------|---|-----|

5 Which of the following can directly mediate vasoconstriction of the coronary arteries?

- | | | | | | | | |
|---|--------------------|---|--------------------|---|-------------------|---|--------------|
| A | ALPHA 1 adrenergic | B | BETA 2 adrenergic. | C | Beta 1 adrenergic | D | None of them |
|---|--------------------|---|--------------------|---|-------------------|---|--------------|

6 What part of the left ventricle is most prone to ischemic damage?

- | | | | | | | | |
|---|----------------|---|----------------|---|-----------------|---|-------------|
| A | Mid myocardium | B | Sub epicardium | C | Subendocardium. | D | Pericardial |
|---|----------------|---|----------------|---|-----------------|---|-------------|

SAQ

List the importance of Coronary Circulation?

Slide 4

Why right coronary artery is the dominant artery in 85-90% of hearts?

Because it supplies the AV-node.

Mention 3 factors affecting regulation of the coronary blood flow

Answer is
1- Autoregulation 2- neural control 3- metabolic control

Why heart is extracting 60-70% of O₂?

Answer is :
Because heart muscle has more mitochondria to generate energy for contraction therefore needs O₂

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 :



Turki Alaskar

Lina Aljameel

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



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