Coronary circulation

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

- Facts about Coronary blood flow.
- Normal coronary blood flow.
- Coronary blood flow in systole and diastole.
- Discuss the regulation of coronary blood flow .
- Explain and differentiate between angina and myocardial infarction
- Coronary circulation & areas of supply.
- Coronary collateral circulation.
- Coronary dominance.
- Coronary blood flow & factors affecting it .
- Control of coronary blood flow.

General info about this lecture

-Prevalence of coronary artery disease :

- 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.

-Facts about coronary blood flow (CBF) :

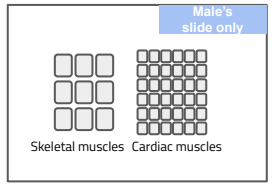
- Two-thirds of coronary blood flow occurs during Diastole . Maximal flow occurs during early diastole. (isometric relaxation phase) however, CBF for the right ventricle could be better during systole (difference of 95 mmHg).

- Coronary blood flow in humans at rest is about 225-250 ml/min , about 5% of cardiac output.

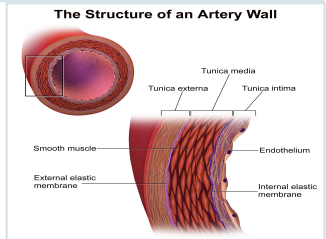
- CBF increases in proportion to **exercise** or **work output**.

- 60-70% of O_2 is extracted from the blood by the myocardial tissues of the heart, while the rest of the body tissues is only 25%. (the heart has more mitochondria (40% of the cell), which means it needs more O_2)
  - During times of extreme demand, coronary arteries can dilate up to 4 times greater than normal.
  - During increased heart rate (Tachycardia), diastole is shorter, so coronary blood flow will be reduced

- Comparing Capillary Density in the Cardiac Muscle with Skeletal Muscles , Heart uses primarily **free fatty acids** and to **lesser extent glucose** and **lactate** for metabolism.



Arterial wall :
The wall of an artery consists of three layers. The innermost layer, the tunica intima (also called tunica interna), is simple squamous epithelium surrounded by a connective tissue basement membrane with elastic fibers. The middle layer, the tunica media, is primarily smooth muscle and is usually the thickest layer, the outermost layer, which attaches the vessel to the surrounding tissue, is the tunica externa or tunica adventitia. This layer is connective tissue



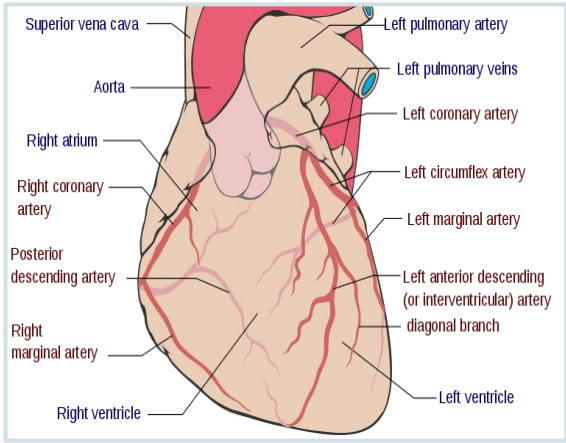
Coronary Circulation

Coronary circulation

is the circulation of blood in the blood vessels that supply the heart muscle (myocardium).

Consists of:

- Arterial supply.
- Venous drainage.
- Lymphatic drainage.



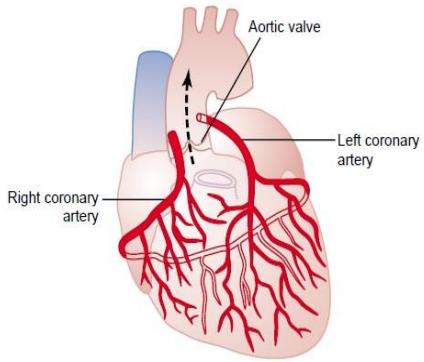
- Coronary arteries supply oxygenated blood to the heart muscle, while cardiac veins drain away the blood once it has been deoxygenated.
- Coronary circulation is of major importance not only to its own tissues but to the entire body & even to the level of consciousness of the brain from moment to moment.

Coronary Circulation

1-Arterial Supply :

Cardiac muscle is supplied by two coronary arteries:

- Lift coronary artery (LCA.)
- Right coronary artery (RCA.)

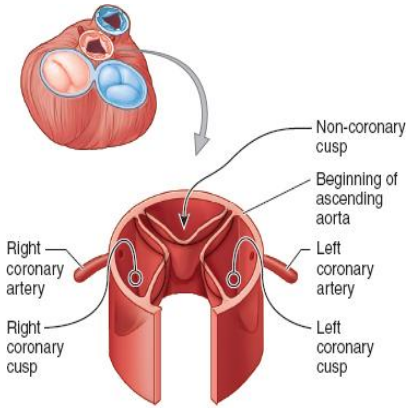


- Both arise from the coronary sinuses at the aortic root, just **superior to the aortic valve cusps**.
- They wrap with their branches around the outside of the heart to supply all cardiac muscle with blood.
- Coronary arteries deliver oxygenated blood to the cardiac muscle.

Coronary Sinus (Origin of coronary arteries)

Aortic valve has three cusps:

- Left coronary cusp (LCC).
- Right coronary cusp (RCC).
- Posterior non-coronary (NCC)cusp.



- There may be variations in the number, shape, & location of coronary ostia or origins of the coronary arteries, most of which are of **NO** clinical significance.

Female's slide only

Coronary Arteries Of The Heart

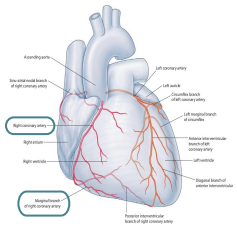
Coronary Circulation

Right coronary artery (RCA.)

- (RCA) is smaller than the(LCA).
- Arises from the **right coronary sinus**.
- Curves posteriorly & descends downward on the posterior surface of the heart.
- Terminates by anastomosing with the **left coronary artery**.
- Supplies blood to **the right atrium**, **the SA** (sinoatrial) & **AV** (atrioventricular) nodes, **right ventricle**, **bottom portion of both ventricles**, & **back of the septum.**

Main Branches of right coronary artery:

- Right posterior descending artery (RPD):
  Also called posterior interventricular artery.
- Right acute marginal artery(AM).

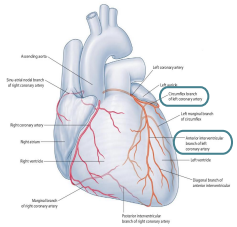


Lift coronary artery (LCA.)

- Also known as the **left main coronary artery** (LMCA).
- Larger than the right coronary artery.
- Arises from the **left coronary sinus**.
- Runs for 10-25 mm before bifurcating.
- Terminates by anastomosing with **the right coronary artery**.
- Supplies blood to the **left side of the heart muscle** (**left ventricle** & **left atrium**).

Main Branches of lift coronary artery

- Left anterior descending artery (LAD):
  Also called anterior interventricular artery.
- Circumflex artery (CX).



Main branches Right coronary Artery

Right posterior descending artery (RPD)

- Also called posterior **interventricular artery**.
- Curves posteriorly & descends downward on the posterior surface of the heart.

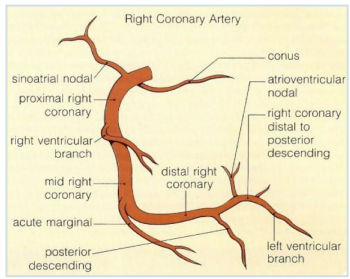
- Supplies blood to the right atrium, right ventricle, bottom portion of the left ventricle, & posterior 1/3 of the Interventricular (IV) septum.

- Branches into **AV nodal artery**, which supplies **the AV- node (in 60-90 % of hearts)** & the surrounding myocardium.

Right acute marginal artery (AM)

- Also called **anterior interventricular artery**.
- Runs down the right margin of the heart.

- Supplies blood to the right margin of the right ventricle, with minimal supply to the apex.



Smaller branches

A- Atrial branch: gives off
- SA nodal artery, which supplies the SA- node in 60%(~50-73%) of hearts & the surrounding myocardium.

B- Right conus arteriosus artery.
C- Right anterior ventricular artery.
D- Septal perforator (SP) artery.

Female's slide only

Main branches Left coronary Artery

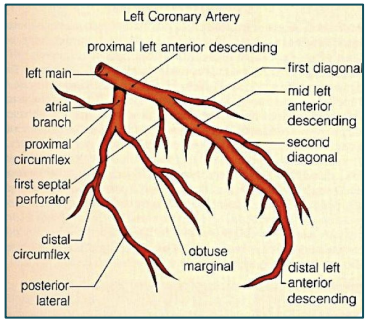
Left anterior descending artery (LAD)

Considered the most critical vessel in terms of myocardial blood supply.
It supplies **45-55% of the left ventricle** (the anterior & apical part of the heart):

1. The anterolateral of the left ventricle.
2. The apex of the heart.
3. The anterior 2/3 of the interventricular (IV) septum.
4. The front of the right ventricle.
5. The right & left bundle branches.

Further divides into:

-Diagonal arteries.
- Left conus arteriosus artery.
- Septal perforator (SP) artery.

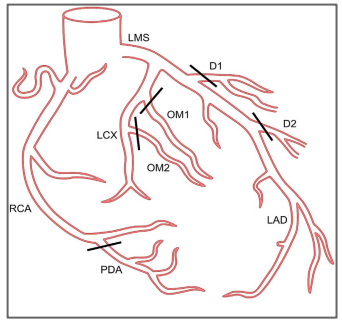


Circumflex artery (CX)

- **Encircles** the heart muscle.
- Supplies blood to the lateral & posterior surface of the heart: **left atrium**, & **the posterolateral of the left ventricle**.

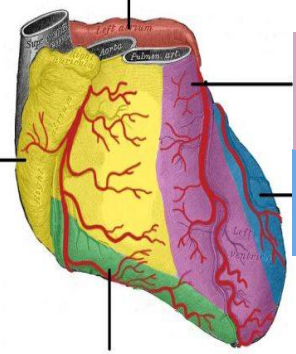
Further divides into:

- Left obtuse marginal (OM) artery, which supplies the left ventricle.
- 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.



The distributions of coronary arteries

Front view



Left circumflex artery
Supplies the left atrium and left ventricle

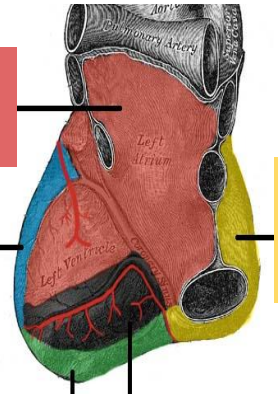
Left anterior descending artery
Supplies the right ventricle ,left ventricle and interventricular septum

Right Coronary artery
Supplies the right atrium and right ventricles

Left marginal artery
Supplies the left ventricle

Right marginal artery
Supplies the right ventricle and apex

Back view



Left circumflex artery
Supplies the left atrium and left ventricle

Right Coronary artery
Supplies the right atrium and right ventricles

Left marginal artery
Supplies the left ventricle

Posterior interventricular artery
Supplies the right ventricle ,left ventricle and interventricular septum

Right marginal artery
Supplies the right ventricle and apex

Female's slide only

Other circulations and drainages

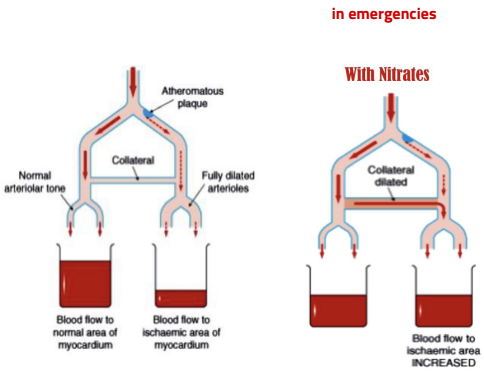
1- Anastomosis

Cardiac anastomosis: The two coronary arteries anastomose in the myocardium.
Extra cardiac anastomosis: the two coronary arteries anastomose with:

- Vasa vasorum of the aorta.
- Vasa vasorum of pulmonary arteries.
- Internal thoracic arteries.
- The bronchial arteries.
- Phrenic arteries.

2- Collateral Circulations:

Defintion. :Collateral circulation is a network of extra-cardiac channels formed of tiny blood vessels.
Under normal conditions it is **not open**, opens only in emergencies when the coronary arteries are blocked, as **(coronary artery disease):**
When the coronary arteries narrow to the point that blood flow to the heart muscle is limited, collateral vessels may enlarge & become active.
Benefits : 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.



Female's slide only

Other circulations and drainages

3-Venous Drainage Of The Heart:

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

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

Cardiac venous drainage occur through:
-Coronary sinus, which lies in the posterior part of the atrioventricular groove & is a continuation of the great cardiac vein.
Anterior (great), middle**,** & small cardiac veins.
Smallest cardiac veins (Venae Cordis Minimae).

4- Lymphatic Drainage Of The Heart:

Lymphatics of the heart accompany the two coronary arteries & form two trunks:
1-**The right trunk**, ends in the brachiocephalic node.
2-**The left trunk**, ends into the tracheo-bronchial lymph nodes at the bifurcation of the trachea.

Female's slide only

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.+SA node

There is 3 types

Left dominant
(in 8-10% of the population)

Right dominant

Co-dominant "Balanced"
(found in 7-10% of population)

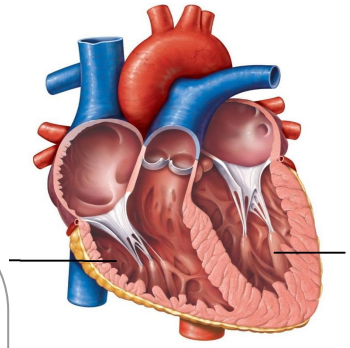
where the posterior inter ventricular artery is formed by both right coronary & Left CX arteries.

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.**

Blood flow to Heart during systole and diastole



In right ventricle

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. The pressure gradient between aorta & ventricles affects the CBF (fluids move from higher to lower)

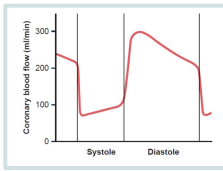
Pressure difference between the aorta & the right ventricle is greater **during systole (95 mmHg)** than during **diastole (80 mmHg)**, therefore more blood flow to right ventricle occurs during systole.

In left ventricle

During **systole**, coronary arteries are compressed & the blood flow to the left ventricle is reduced

Blood flow to the **subendocardial portion** of the **left ventricle** occurs only during diastole, & is **not** there during systole.

Therefore, subendocardial region of the left ventricle is prone to **ischemic damage** & it is the most common site of myocardial infarction.



ليس استخدمنا الـ aorta عشان نعرف ال coronary blood flow ؟
Because **coronary arteries** arise from **sinus of aorta**> same pressure
بمعنى كيف يمشي الدم في coronary إلى القلب؟ بنقيس ضغط الـ coronary ، طيب شلون نقيس ضغط الcoronary ؟ نقيس ضغط الـ aorta وبيطلع نفس الضغط لان ببساطه ال coronary طالع من الـ aorta

Pressure (mmHg) in:				Pressure difference (mmHg) between aorta and:	
	Aorta	Lt. Vent.	RT. Vent.	Lt. Vent.	Rt. Vent.
Systole	120	120	25	(120-120)= **0**	(120-95) = **95** So more blood flow in the RT during systole
Diastole	80	0-2	0-2	(80-0) = **80** So more blood flow in the LV during diastole	(80-0) = **80**

Coronary vascular resistance

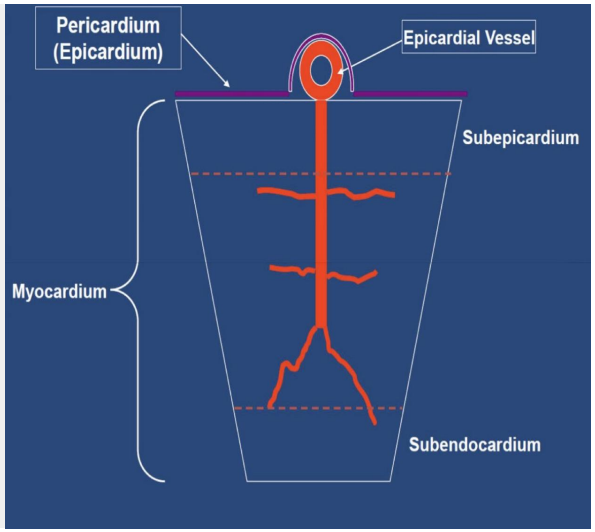
438

We recommend that you see the picture and explanation first.

Explanation:

We have said earlier that **during systole** there is a decline in Coronary blood flow (increase in coronary vascular resistance), this is because of the compression on the intramyocardial arteries by cardiac muscles. But the epicardial conductance vessels are not surrounded by muscles (no compression during systole).

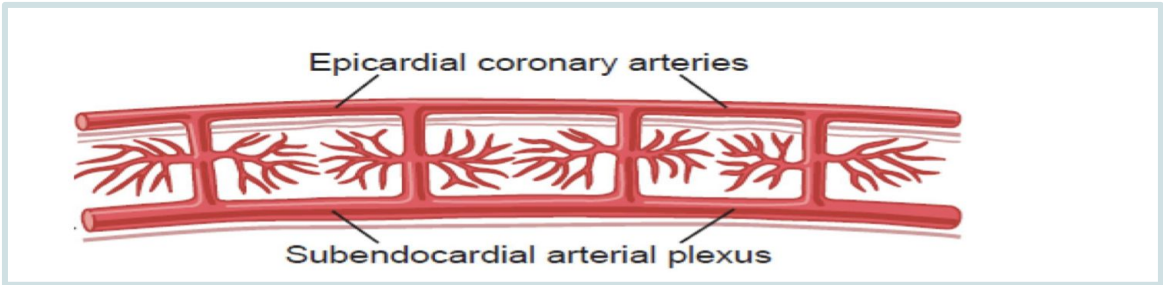
Therefore the vessels which are responsible of Coronary vascular resistance are the intramyocardial vessels not the epicardial vessels.



Epicardial conductance vessels: Contribute only to a **small percentage** of coronary vascular resistance.

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

- Blood flows to the subendocardial portion of left ventricle only during diastole, therefore this portion of left ventricle is prone to ischemic changes & is the most common site of myocardial infarction.
- However, the extra vessels of the subendocardial plexus normally compensate for this reduction .



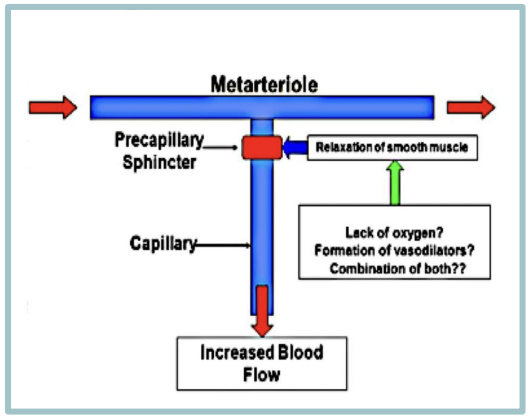
*Female's slide only

*Factors affecting coronary blood flow:

1-Pressure in the aorta
2-Chemical factors.
3-Neural factors.

Regulation of Coronary blood flow

01 Metabolic control **(chemical factors)**



02 Auto regulation

03 Endothelial Vascular tone

04 Extravascular compressive force

05 Neural control

Cont.Regulation of Coronary blood flow

01

Metabolic control
(chemical factors)

Local muscle **metabolism** is the primary controller:
- **Oxygen demand is a major factor in local coronary blood flow regulation.**

Coronary circulation is very sensitive to myocardial tissue oxygen tension.
Increased **oxygen demand** results in a lower tissue oxygen tension.
This causes **vasodilation** and increased **coronary blood flow** due to chemical factors like:
(increased O_2 demand results in a lower tissue O_2 tension)

1- ↑NO
2- ↑Prostaglandins
3 -Lack of O_2 , High conc. of CO_2.
4-↑Adenine nucleotides
5-↑Adenosine (which is formed from ATP during cardiac metabolic activity, causes **coronary vasodilatation**.)
6-↑Lactate
7-↑K+ and H+
8-NOTE: ↑Ca it does not increase CBF only affects HR and contractility

02

Auto regulation

-Ability of a vascular network to maintain **constant blood flow** over a range of arterial pressures.

-CBF shows considerable auto regulation.

-Auto regulation is an **independent** determinant of coronary blood flow

-The set point at which coronary blood flow is maintained depends on myocardial O_2 consumption.
The more the oxygen demand the more oxygen consumption the more CO_2 production

Note that
when tissue consumed more oxygen the oxygen tension would fall and the oxygen demand would increase when 1- oxygen demand is more - 2- oxygen tension is low - 3- oxygen consumption is more. That causes the chemical factors to be increase

Cont.Regulation of Coronary blood flow

03

Endothelial control of coronary Vascular tone control:

Damage to the endothelial which leads to:

1. ↓**NO and prostacyclin (vasodilators)** production.

2. ↑ **endothelin production,**
cell can lead to:
-Vasoconstriction -Vasospasm -Thrombosis

04

Extravascular compressive force:

Left ventricle	Right ventricle
• **Earlier systole:** initial flow reversal. • **Remainder of systole:** flow follows aortic pressure curve but at a much reduced pressure. • **Earlier diastole:** Abrupt pressure rise (80-90 % of of LV flow in earlier diastole). • **Remainder of diastole:** pressure decline slowly as aortic pressure decline	• lower pressure generated by right ventricle in systole. • No reversal blood flow during early systole. • Systolic constitutes a much greater proportion of of total blood flow

What is the most vulnerable portion of the heart during blood flow ?
It's the subendocardial of LV during early systole (Initial Flow Reversal.)

Cont.Regulation of Coronary blood flow

05 Neural control

Sympathetic

Coronary arteries have:
1-**Alpha Adrenergic receptors**
which mediate vasoconstriction (more epicardial)
2-**Beta Adrenergic receptors**
which mediate vasodilation (more in the intramuscular arteries "B2 with resistance Arteries")

▪ Neural control of the coronary circulation complements the above local effects
-Activation of sympathetic nerves innervating the coronary vasculature causes only transient vasoconstriction mediated by α-adrenoreceptors, This brief (and small) vasoconstrictor response is followed by vasodilation caused by enhanced production of vasodilator metabolites (active hyperemia or Metabolic demand) due to increased mechanical and metabolic activity of the heart resulting **from beta** -adrenoceptor activation of the myocardium
Therefore, **sympathetic activation** to the heart results in coronary vasodilation and increased coronary flow due to increased metabolic activity (increased heart rate,contractility) despite direct vasoconstrictor effects of sympathetic activation on the coronaries. This is termed "functional sympatholysis".

-Direct effects of nervous stimuli on the coronary vasculature.
-Sympathetic **greater** effects than parasympathetic.

Sympathetic : Continue..

Effect of Sympathetic Stimulation:

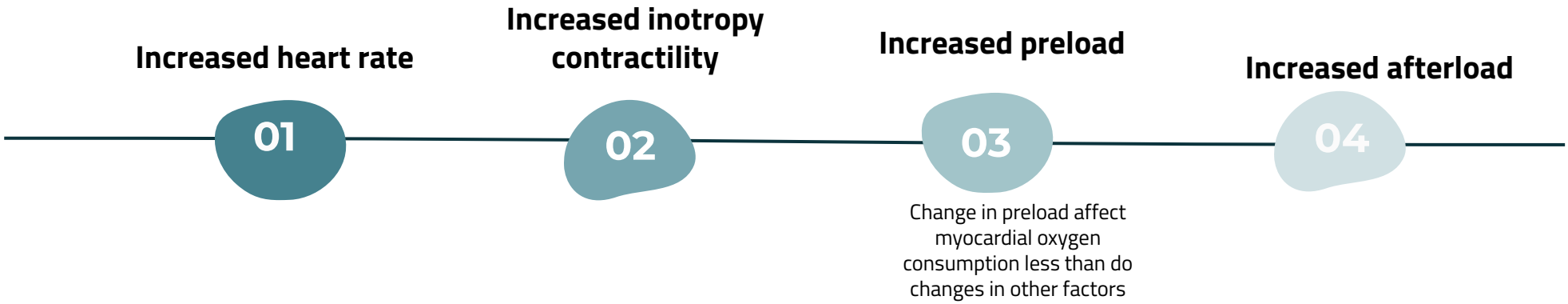
Direct	Indirect
Experimentally, injection of **noradrenaline** after **blocking** of the Beta adrenergic receptors in un anesthetized animals elicits coronary vasoconstriction	Sympathetic stimulation in intact body will lead to release of **adrenaline** & **noradrenaline** , increasing HR & force of contraction. However, coronaries will vasodilate due to the release of vasodilator metabolites. (Example: Athletes) despite direct vasoconstrictor effects of sympathetic activation on the coronaries. This is termed "**functional sympatholysis**." **Benefits of indirect effect of more adrenergic discharge:** when systemic BP decreases very low > Reflex increase of nor-adrenergic discharge > Increase CBF secondary to metabolic changes in the myocardium> In this way, circulation of the heart is **preserved** while the flow to other organs **compromised**.

Para-Sympathetic

Vagal stimulation (**Parasympathetic**) causes coronary **vasodilatation**. However, parasympathetic distribution is NOT great.
There is more sympathetic innervation of coronary vessels.
However, if parasympathetic activation of the heart results in a significant **decrease in myocardial oxygen demand** due to a **reduction in heart rate**, then intrinsic metabolic mechanisms will increase coronary vascular resistance by constricting the vessels.

Male's slide only

Factors increasing myocardial O_2 consumption



Diseases linked with coronary circulation

Angina

investigation
ECG might be normal, but does not exclude the condition.

Treatment for the attack
-if exercise-induced, **stop exercise**
-**glyceryl trinitrate** (0.5mg sublingual)

MI (Myocardial infarction)

investigation
-cardiac enzymes: CK-MB, AST, LDH, etc.
-ECG:deep Q wave, ST elevation, T inversion

clinical feature
Chest pain (even at rest & lasts for hours) with sudden onset, but can develop gradually.
Associated with: sweating, vomiting, hypotension.
Dr : ECG is important in diabetics patient because some of them may have Diabetic autonomic neuropathy and that would lead to painless MI

-When the normal portions of the ventricular muscle contract, the ischemic portion of the muscle, whether it is dead or simply nonfunctional, instead of contracting is forced outward by the pressure that develops inside the ventricle.

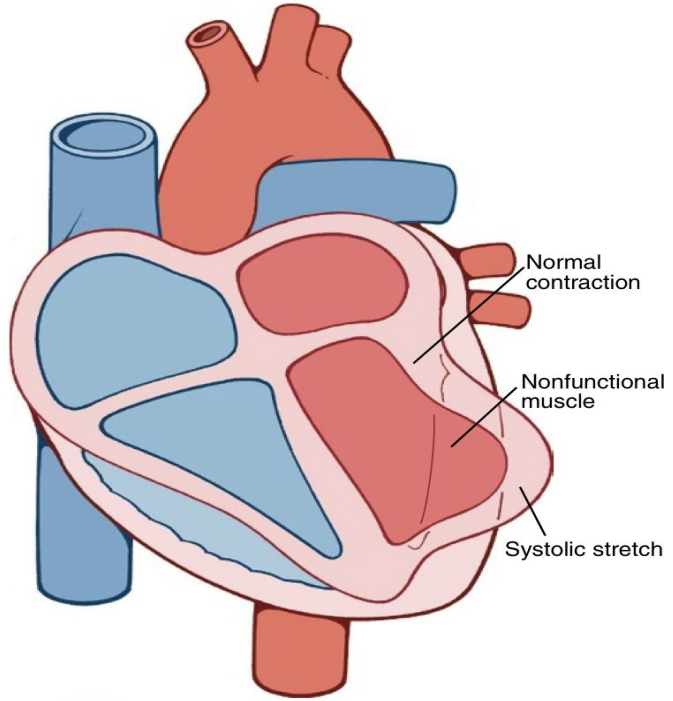


Figure 21-7 Systolic stretch in an area of ischemic cardiac muscle.

Extra: From Guyton:

Decreased Cardiac Output—Systolic Stretch and Cardiac Shock.

When some of the cardiac muscle fibers are not functioning and others are too weak to contract with great force, the overall pumping ability of the affected ventricle is proportionately depressed. Indeed, the overall pumping strength of the infarcted heart is often decreased more than one might expect because of a phenomenon called systolic stretch, shown in Figure 21-7. That is, when the normal portions of the ventricular muscle contract, the ischemic portion of the muscle, whether it is dead or simply nonfunctional, instead of contracting is forced outward by the pressure that develops inside the ventricle. Therefore, much of the pumping force of the ventricle is dissipated by bulging of the area of nonfunctional cardiac muscle.

When the heart becomes incapable of contracting with sufficient force to pump enough blood into the peripheral arterial tree, cardiac failure and death of peripheral tissues ensue as a result of peripheral ischemia. This condition is called coronary shock, cardiogenic shock, cardiac shock, or low cardiac output failure. Cardiac shock almost always occurs when more than 40 percent of the left ventricle is infarcted. And death occurs in over 70 percent of patients once they develop cardiac shock.

Quiz:

1-Which of the following statements about coronary blood flow is most accurate? (Guyton question)

A) Normal resting coronary blood flow is 500 ml/min
B) The majority of flow occurs during systole
C) During systole the percentage decrease in subendocardial flow is greater than the percentage
decrease in epicardial flow
D) Adenosine release will normally decrease coronary flow

2-Which of the following agents is usually the most important controller of coronary blood flow?

A) Adenosine
B) Ach
C) norepinephrine
D) ATP

3-"Ability of a vascular network to maintain constant blood flow over a range of arterial pressures" is:

A) Endothelial control
B) Extravascular compressive force
C) neural control
D) auto regulation

4-most of the population has ..... Dominant of coronary flow.

A)co-dominant
B) left dominant
C) middle dominant
D) right dominant

5-metabolic control is:

A) neural factora
B) physical factor
C) chemical factor
D) both (chemical and neural)

6- Right acute marginal artery supplies blood to..

A) the right margin of the right ventricle.
B) minimal supply to the apex.
C) the right atrium
D) A&B

7-Which statement of the following is correct ? the SA- node supplies by

A) around 20% of the heart by (CX) & 80% by (RPD)
B) around 40% of the heart by (CX) & 60% by (AM)
C) around 20% of the heart by (CX) & 80% by (AM)
D) around 40% of the heart by (CX) & 60% by (RPD)

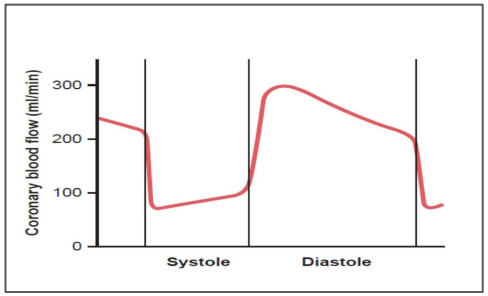
Answer Key: 1C- 2A - 3D - 4D - 5C
6D - 7B

Quiz:

1- in the following Graph:

A. describe what do you see

B. predict the changes in this graph during tachycardia and its effect in Coronary blood flow



2- List the chemical factors that can cause vasodilation

3- Enumerate the smaller branches of right coronary artery

4-Enumerate the main Branches of right coronary artery

1A:: the graph shows the difference in coronary blood flow during systole (reduced) and diastole (increased)

1B:there will be huge decrease in the periods of diastole, then the coronary blood flow will be reduced also (because most of the blood flow occurs during diastole)

A2: slide 16

A3: A- Atrial branch m B- Right conus arteriosus artery. , C- Right anterior ventricular artery. D- Septal perforator (SP) artery.

A4: RPD & AM

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