Heart Attack, Plaque, and Coronary Artery Disease

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Myocardial infarction means “heart attack”. Myocardium is the name for the heart muscle. Infarction means the death of a muscle, tissue, or organ as a result of a blockage of the blood supply to it. Therefore a myocardial infarction is “the death of heart muscle tissue.”
The heart needs oxygen to survive. The coronary arteries deliver oxygenated blood to the heart muscle. When one or more of the coronary arteries blocks, the oxygen supply to the myocardium stops, and the part of the heart supplied by that particular artery dies. This is a myocardial infarction (death of heart muscle tissue).
Thrombosis is the formation of a clot or thrombus inside an artery which occludes the flow of blood.
A thrombus, or blood clot, is the final product of the blood coagulation step in hemostasis. A thrombus is physiologic in cases of injury (begins the normal healing process), but pathologic in case of thrombosis.
Formation of a thrombus will cause ischemia, meaning a decrease in the blood supply to a bodily organ, tissue, or part caused by constriction or occlusion of the blood vessels. Ischemia causes hypoxia, insufficient levels of oxygen in blood or tissue. Tissues starved of oxygen will suffer necrosis, the death of cells or tissues through injury or disease. Thus, as a result of a coronary thrombosis, ischemia will lead to hypoxia, which will cause necrosis of heart tissue, which is defined as an infarct.
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Normal Artery
The wall of a normal, health artery is lined with a layer of epithelial cells that are surrounded by smooth muscle.
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Damage to the Artery Wall

Damage to the lining of an artery causes inflammation and begins the process of plaque formation. The injury attracts white blood cells, which mature into macrophages, and makes the lining more permeable to LDL particles. Inside the artery wall, LDL is oxidized to form oxidized cholesterol.
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Plaque Formation
Inside the artery wall, macrophages fill up with oxidized LDL cholesterol and are transformed into foam cells. These cells get so full that they burst, depositing cholesterol. The accumulation of cholesterol and protein forms a plaque.
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Plaque Enlargement
As inflammation continues, plaque builds up, causing the artery to narrow and lose its elasticity. A cap of smooth muscle cells and fibrous proteins forms over the plaque, walling it off from the lumen of the...
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Plaque Rupture
If the inflammation continues, the fibrous cap covering the plaque degrades. If the cap ruptures or erodes, blood clots can rapidly form around it. The blood clots can completely block the artery at that spot or break loose and block an artery elsewhere.
Plaque

Plaque can build up in the lumen of the artery, thus narrowing the blood space and restricting flow.

Such plaques are often calcified, or hardened by the body. This causes increased rigidity and a thickening of the arterial wall in response to an increase in blood pressure, which furthers the arteriosclerosis.
Angina pectoris

Constricting chest pain, often radiating to the left shoulder and down the left arm, caused by an insufficient supply of blood to the heart. Coronary artery disease is a common cause of angina pectoris.
As these plaques grow, they tend to occlude the artery producing a “visible” area of stenosis within the arterial lumen. Therefore, they are typically detected by cardiac stress tests or an angiogram.

Stenosis - A constriction or narrowing of a duct or passage; a stricture.

Lumen Plaque Area of Stenosis

Cardiac stress test

Angiogram

Area of Stenosis
**Angiogram** – An x-ray of one or more blood vessels produced by angiography and used in diagnosing pathology in the cardiovascular system, such as arteriosclerosis.

Note the two separate areas of stenosis visible on the angiogram. These areas can be surgically “repaired” to prevent ischemia and possible major occlusion which could result in myocardial infarction.
The two most common surgical procedures used today are balloon angioplasty, often accompanied by stent placement, or coronary artery bypass.
Angioplasty with Stent

- A narrow balloon is inserted in the coronary artery
- The balloon is inflated to press the plaque against the arterial wall
- A stent can be inserted to hold the vessel open
- This opens the lumen and allows better blood supply
Angioplasty – a surgical technique for restoring normal blood flow through an artery narrowed or blocked by atherosclerosis, either by inserting a balloon into the narrowed section and inflating it or by using a laser beam.

First, angiography provides an angiogram which allows the area of stenosis to be located.
Before and after angioplasty
A broken heart is known medically as Takotsubo cardiomyopathy.
Coronary Artery Bypass Graft – open-heart surgery in which the rib cage is opened and a section of a blood vessel is grafted from the aorta to the coronary artery to bypass the blocked section of the coronary artery and improve the blood supply to the heart.

open-heart surgery - heart surgery in which the rib cage is spread open, the heart is stopped and blood is detoured through a heart-lung machine while a heart valve or coronary artery is surgically repaired.
Coronary Artery Bypass Graft Options

- Blockage in right coronary artery
- Saphenous vein used to bypass blockage
- Saphenous vein bypass
- Internal mammary artery bypass
- Radial artery bypass
- Sites of blockage
Before

Blocked coronary artery

After

Vein graft sewn in to bypass blockage
Plaques can also develop within the muscular wall of an artery, where it is called an **atheromatous plaque**.

**Atheromatous plaque** is defined as a buildup of fatty deposits, an **atheroma**, within the wall of an artery.
An insidiously dangerous form of plaque, called a **vulnerable (unstable) plaque**, is an atheromatous plaque which is particularly prone to producing sudden, major problems, such as a heart attack or stroke.

Generally an **atheroma** becomes vulnerable if it grows more rapidly and has a thin cover separating it from the bloodstream inside the arterial **lumen**. Tearing of the cover is called plaque rupture.
Because artery walls typically enlarge in response to enlarging vulnerable plaques, these plaques do not usually produce much **stenosis** of the artery **lumen**. Therefore, they are typically **not** detected by cardiac stress tests or an **angiogram**.
In many cases, a **vulnerable plaque** is one that has a thin fibrous cap and a large, soft lipid pool. These characteristics together with hemodynamic effects contribute to a high mechanical stress zone on the fibrous cap of the **atheroma**, making it prone to rupture.
Sudden rupture of a vulnerable plaque will lead to infarction, and if the rupture occurs in a coronary artery, this often leads to a more serious problem – **Sudden cardiac death** (SCD) which is the occurrence of a sudden and unexpected **cardiac arrest**.

- **Sudden cardiac death:**
  - affects up to 460,000 adult Americans every year.
  - most commonly affects men age 50 to 75 years.
  - is most likely the result of heart disease resulting from coronary artery disease (plaque deposits in the coronary arteries), but can be caused by other underlying conditions.
Such as:

- a myocardial infarction which leads to a serious arrhythmia and cardiac arrest.

- a spontaneous ventricular arrhythmia (electrical short-circuiting of the heart) such as ventricular fibrillation.

- trauma to the chest (cardiac concussion) and lead to a ventricular arrhythmia.
A **cardiac arrest**, or circulatory arrest, is the abrupt cessation of normal circulation of the blood due to a sudden failure of the heart to contract effectively during **systole**.

**Ventricular fibrillation** (VF or V-fib) constitutes the most common electrical mechanism in cardiac arrest, and is responsible for 65 to 80% of occurrences. Another 20-30% are caused by severe bradyarrhythmias.
Several of the risk factors discussed in class can contribute to or combine to produce high cholesterol or high lipid (triglyceride) counts in the blood:

- Poor diet
- Family history
- Lack of exercise
- Sleep deprivation
- Chronic stress

So what other factors can contribute to cardiovascular disease that may lead to other forms of “heart attack?”
Blood Pressure

The pressure (force) exerted by the blood on the inner walls of the arteries.

Blood pressure varies with the strength of the heartbeat, the **stroke volume** (volume of blood pumped with each systole – about 70 ml), and the elasticity of the blood vessels. Arterial blood pressure is usually measured by means of a **sphygmomanometer** (“blood pressure cuff”) and reported in millimeters of mercury as a fraction, with the numerator equal to the blood pressure during **systole** and the denominator equal to the blood pressure during **diastole**.
### Systole
The period during the normal beating of the heart in which the chambers of the heart, especially the ventricles, contract to force blood into the aorta and pulmonary artery.

### Diastole
The normal rhythmically occurring relaxation and dilatation of the heart chambers, especially the ventricles, during which they fill with blood.

Therefore, **Blood Pressure** = **systolic pressure** + **diastolic pressure**
Adult blood pressure is considered normal at 120/80 (where the first number is the systolic pressure and the second is the diastolic pressure).

**Hypertension**

Arterial disease in which chronic high blood pressure is the primary symptom. A person is considered hypertensive if one or both pressures are above the following:

- Systolic Pressure $> 140$
- Diastolic Pressure $> 90$
Hypotension

Abnormally or chronic low blood pressure. A person is considered hypotensive if one or both pressures are below the following:

Systolic Pressure < 90
Diastolic Pressure < 50

Hypotension, like bradycardia, is not necessarily a “bad” thing if it is physiological (in other words “normal” for that person). It is only a problem if it is a pathological condition (in other words caused by disease).
Prehypertension

A relatively new term used to refer to people who have blood pressures that constantly border on hypertensive. A person is considered pre-hypertensive if one or both pressures are chronically between the following:

Systolic Pressure = 130 – 139
Diastolic Pressure = 85 – 89