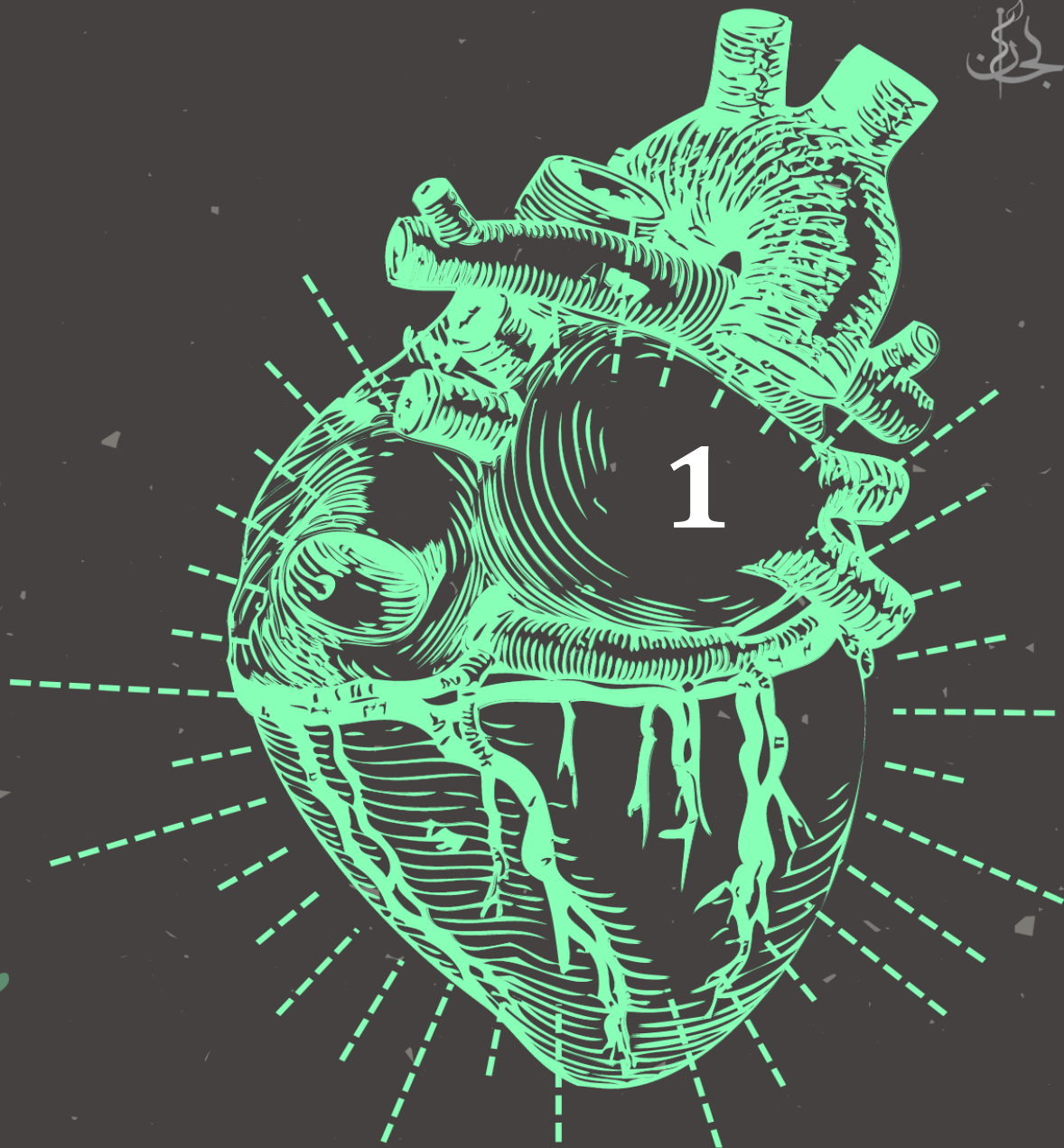


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# PBL: Adult Cardiac Surgery

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## History Of Cardiac Surgery

1. 1930's, **Claude Beck** - sought to increase myocardial blood flow indirectly with pericardial fat and abdominal omentum (new angiogenesis to the heart), it worked but not efficiently.
2. 1940's, **Arthur Vineberg** - Mobilization of **left internal mammary artery LIMA** (= left internal thoracic artery LITA, the same), with implantation of freely bleeding end into the **wall of the left ventricle** which improves heart blood supply without direct anastomoses. 1964, a follow-up study on 140 patients with 33% mortality rate and 85% relief from angina.
3. 1950's, **Mason Sones** - cine coronary arteriography.
4. 1962, **Mason Sones** - direct and reproducible catheterization of the coronary arteries.
5. 1962, **David C. Sabiston, Jr.**- Aortocoronary **saphenous vein** bypass.
6. 1964, **KOLOSOV**, anastomose **left internal mammary artery** with LAD in Russia.
7. May 6. 1953, **John H. Gibbon, Jr.**- invented the **Heart-lung machine** which is a cardiopulmonary bypass used to empty the heart during surgery (drawing the non-oxygenated blood from the right atrium, oxidizing it, and pumping it back into the ascending aorta), first use in ASD closure operation.

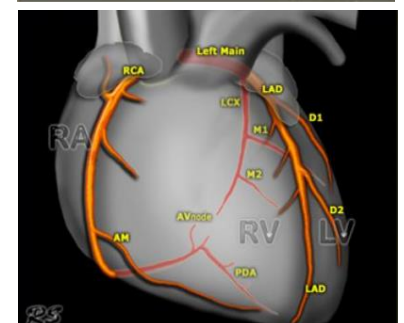
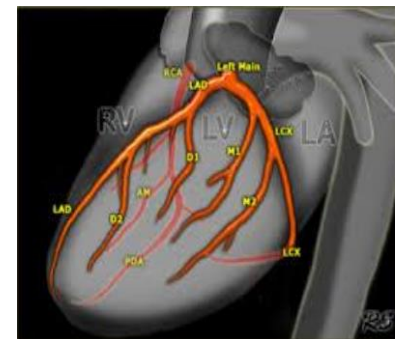
Early and widespread acceptance of **coronary bypass** as a surgical option was delayed. In the early 70th, Major randomized trials to prove the efficacy of **Coronary Artery Bypass Grafting** in improving the quality of life were done. Best known cooperative studies (1970-80s):

1. VA
2. Coronary Artery Surgery Study
3. European Coronary Surgery Study

## Anatomy of the coronary artery:

From the root of the aorta, three sinuses of Valsalva; one anterior, two right and left posterior.

- **Right coronary artery**, from the anterior coronary sinus of Valsalva.
- **Left main coronary artery**, from the left posterior coronary sinus of Valsalva, short artery that bifurcates a bit early into :
  - **Left anterior descending**, to the anterior wall of the heart in the anterior interventricular groove between right and left ventricles, above the interventricular septum, supplies anterior 2/3 of the interventricular septum.
  - **Circumflex**, on the left atrioventricular groove, supplies the posterolateral wall of the heart.



## Ischemic Heart Disease

It results from an imbalance between oxygen demand and supply.

In the normal situation, when there is an increase in oxygen demand, the **skeletal muscles** will increase the oxygen extraction from the blood, but that will not happen in the **cardiac muscles** because its oxygen extraction capacity is at maximum so, the blood flow in the coronary artery will increase.

In the case of the **coronary artery narrowing**, with the increase of oxygen demand, the **narrowing** will not allow increasing the blood flow and here the symptoms will show.

EXTRA, from physiology

oxygen extraction ratio in skeletal muscles at rest is 25% which increase during exercise up to 75% so skeletal muscles increase their O<sub>2</sub> requirement without increasing the blood flow while the oxygen extraction ratio in cardiac muscles at rest is already at a maximum of 75% so increase oxygen demand is met only by increasing blood flow.

## Etiology

1. **Atherosclerosis**; more than 90% of ischemic heart disease is related to atherosclerosis.
2. **Embolization**; rare.
3. **Coronary spasms**, especially in winter.
4. **Vasculitis** in connective tissue diseases.
5. **Ostial stenosis**.
6. **Severe LVH**; in the case of **aortic stenosis**, the left ventricle becomes very thick and contract vigorously which needs more blood supply, thus, the patient will have symptoms of angina with normal coronary arteries.
7. **Congenital anomalies of the coronary arteries**; one of the most common causes of **sudden cardiac death** in young people, e.g.
  - Anomalous origin of the LAD artery from the pulmonary artery.
  - right coronary from posterior sinuses.
  - Anomalous origin of circumflex from right coronary artery (the most common).

## Atherosclerosis & Acute Coronary Syndrome

Atherosclerosis is a **systemic** disease that affects coronary, carotid, aorta, abdominal aorta, peripheral arteries like femoral, superficial femoral, popliteal, and leg vessels in diabetic patients.

Usually, **Plaque** in the coronary artery will cause **progressive narrowing** (gradually get increase with time).

Sometimes, **sudden stress** or **sudden hypertensive crisis** led to **acute coronary syndrome** despite the narrowing being relatively small (about 20-30%). That's because with the sudden stress the plaque gets ulcerated, cracked, and ruptured, exposing subendothelial collagen → vWF binding → primary wave of platelet aggregation → thrombus formation, which will cause acute coronary syndrome (acute myocardial infarction or unstable angina).

## Risk Factors

### Uncontrollable

1. **Sex**; males are at higher risk than females, after the age of 50, the risk will be equal between both sex.
2. **Hereditary**, related to certain gens of lipids metabolism, succinyl-CoA metabolism, hyperlipidemia, and homocystinuria.
3. **Race**, Caucasians at highest risk, Africans at the lowest risk, Chinese and Japanese have no risk, however, with the new western lifestyle they develop some risk.
4. **Age**, Atherosclerosis is an aging process, so advances in age will affect a lot.

### Controllable

1. **High blood pressure**
2. **High blood cholesterol**
3. **Smoking**; number 1 in Jordan, especially in young people
4. **Physical activity**
5. **Obesity**
6. **Diabetes**
7. **Stress and anger**

## Diagnosis and Investigations

1. **History taking**, the description of the pain of angina is distinctive, (retrosternal chest pain, heaviness in nature associated with exercise, relief by rest, extending beyond the chest to the inner part of the left arm).  
Remember, sometimes the pain comes with rest→ unstable angina
2. **Physical examination**,
  - in acute attack; history of palpitations, tachycardia, sweaty patient.
  - In cardiogenic shock; sweaty, clammy, hypotensive, and cold-handed patient.
3. **ECG findings**; AMI
4. **cardiac enzymes**; AMI
5. **Chest x-ray**
6. **FBS**
7. **Serum lipids**
8. **TMT**
9. **Stress or pharmacologic stress myocardial perfusion studies**; for stable angina with infrequent pain, which is not easily diagnosed.
10. **Cardiac CT-Scan**; Can be used as an alternative to catheterization, especially in questionable patients (young age, vague non-typical chest pain, some risk factor). It is used to measure the calcium score in a coronary artery according to the calcium scoring system, we may need further investigation by catheterization.
11. **Cardiac MRI**
12. **Coronary angiography**; a catheter with dye is inserted in the radial or femoral artery and threaded through the blood vessels to the heart to check for blocked or narrowed coronary arteries.

**13. Precision Medicine/ Bioinformatics;** Nowadays, using the Patients clinical data + ECG + cardiac enzymes; the **computers** can reach a diagnosis of IHD, the diagnosis should be quick and precise, but we don't depend on the computer to make the final decision in our diagnosis, rather, the **clinical judgment** of the doctor is the most important.

## Treatment of coronary artery disease

1. **Nitrates;** to dilate the artery.
2. **Dual antiplatelet therapy,** e.g. Aspirin, Plavix, and acetyl-acetic acid.
3. **Beta-blockers;** decrease the cardiac cells' oxygen demand and decrease the force of contraction.
4. **Ca-channel blockers** (in coronary spasm)
5. **Treating the associated risk factors** (hypertension, diabetes, smoking, laziness)
6. **Treating the precipitating factor**
7. **Revascularization;** the final solution, to increase heart perfusion by new blood supply either surgical or interventional.

## Surgical interventions for coronary artery disease:

1. **Coronary Artery Bypass Grafting (CABG)**→ where we take a blood vessel from another part of the body and attach it to the coronary artery above and below the narrowed area or blockage, with emptying the heart from blood using a Heart-lung machine. *We will talk about it in this sheet*
2. **Off-Pump coronary artery bypass (OPCAB)**→ same as CABG but we don't empty the heart from blood, we do the surgery while the heart is beating, we use a stabilizer. [https://medlineplus.gov/ency/videos/mov/200058\\_eng.mp4](https://medlineplus.gov/ency/videos/mov/200058_eng.mp4)
3. **Percutaneous transluminal coronary angioplasty** → where a small balloon-tipped catheter is inserted into either the femoral or brachial artery and threaded up to the obstructing lesion in the coronary artery, rupture the plaque abruptly and placed a percutaneous stent. [https://medlineplus.gov/ency/videos/mov/200140\\_eng.mp4](https://medlineplus.gov/ency/videos/mov/200140_eng.mp4)

## Indications for Coronary Artery Bypass Grafting: (CABG):

- **Triple vessel disease** (three-vessel disease: RCA, circumflex, and LAD narrowing by atherosclerosis for example), when the narrowing exceeds 70% this means the narrowing impedes the flow→ Ventricle is not contracting well → ischemia or heart failure.
- **Left main coronary artery disease;** which gives an important branch "LAD" supplies main of the left ventricle and septum. Once the narrowing reaches 50%, we do revascularization.
- **Unstable angina** which failed the maximum medical treatment; two vessels disease with angina pain and the medication failed in the treatment.
- **Complications of PTCA;** when the surgeon blows up the balloon this may cause plaque rupture, thrombosis, rupture of the coronary artery, or dissection.
- **Life-threatening complications of acute massive MI** may result in **cardiogenic shock** either because of acute mitral regurgitation, ventricle septum defect, or acute pulmonary edema.



- **Anomalies of Coronary arteries**, e.g. Anomalous origin of Rt coronary artery from posterior aortic sinus compressed between the aorta and pulmonary trunk →we do reimplantation

## CABG Surgery Techniques

1. **Median sternotomy**; open the sternum in the middle with a saw, the size of the incision will be made depending on the physiology of the patient. A median incision is a classic conventional route that provides the best overall access to the heart, it allows almost all cardiac procedures. we can also do a portal incision in some surgeries. Then, open the **chest**, and the **pericardium**, we can see the right ventricle.
2. **Cardiopulmonary bypass** through a **Heart-lung machine**, where we take the blood from the right atrium and oxidize it and return it to the aorta using rt atrium cannula, aortic cannula.  
so, emptying the heart from blood but the heart still beating, and we cannot do surgery with an empty beating heart so?
3. **Cardioplegic arrest**; where we use **potassium-containing solution (Cardioplegia)** thus, temporarily arresting the heart so we can mobilize it. **Adenosine** and **Esmolol** are used to slow and even temporarily stop the heartbeat for short periods (around 20 seconds).
4. **Deep pericardial sutures** and the use of specialized instruments to prop the heart in a position that will allow the surgeon to access occluded arteries.
5. **Open the coronary artery** by a small slect 1 cm beyond the narrowing and anastomoses the graft with **prolene suture**, so new blood supply comes to the heart beyond the narrowing site. Arteries or veins can be harvested from the patient's chest wall, arm, and or leg.

### Conduit options in coronary artery bypass surgery:

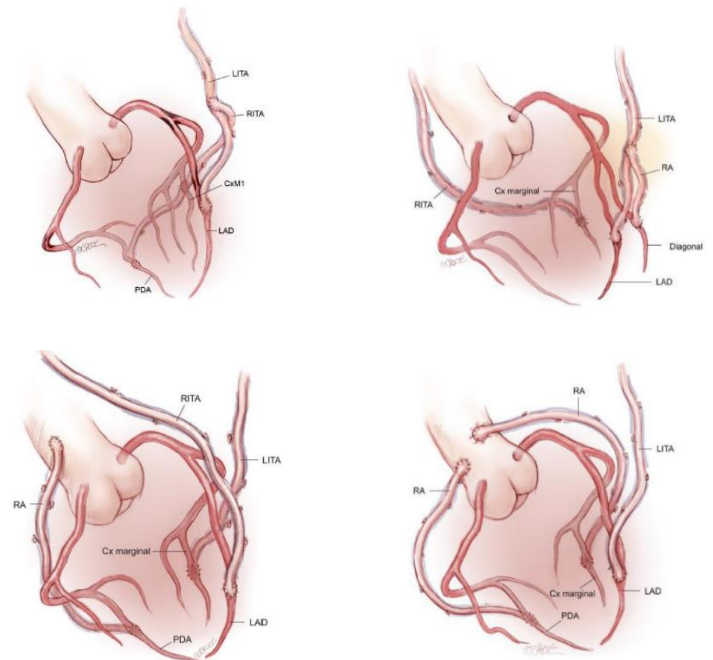
#### Arteries

1. Left internal mammary artery.
2. Right internal mammary artery
3. Radial artery
4. Right gastroepiploic artery

#### Veins

1. Great saphenous vein.
2. Short saphenous veins.
3. cephalic vein

We anastomose them in different shapes, and this should be arranged before starting the surgery: e.g.:



- Radial with RCA
- right mammary with LAD
- left mammary with circumflex
- right mammary with circumflex
- left mammary with LAD

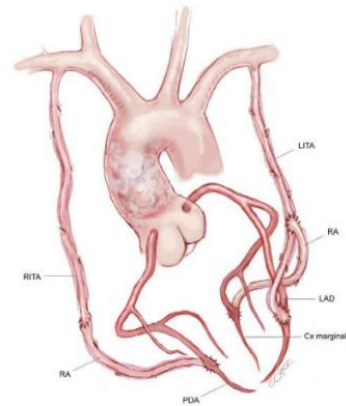
Mammary artery reversed saphenous vein, and radial artery is the most commonly used.

Now the question. What is the best graft? For sure, the **artery** is better than the vein for many reasons:

1. luminal **diameter** and wall thickness are almost the same.
2. **10 years patency rate**, for Mammary artery-LAD is about 95% while Saphenous vein is 55-60% so, almost half of them will close which means recurrent symptoms.  
**Note: patency** is the quality or state of being open or unobstructed, higher patency rate for a graft meaning better clinical outcomes.
3. When we anastomose a thin-walled Saphenous **vein** with the **aorta** (high systolic pressure), the vein **gets thicker** (new intima formation) and the new intima is sometimes not smooth as the artery which may cause narrowing later on.
4. the saphenous vein has **valves**, thus, narrowing might happen at the area of the valve.
5. **Artery** grafting fits with severe narrowing. More than 70% narrowing→ artery, 50% narrowing→vein.

### **This is the best configuration of CABG**

- right internal mammary with right coronary
- left internal mammary with LAD with a branch to circumflex (renal artery)
- and we keep the mammary arteries attached to their origins (subclavian)



Remember

**revascularization** is the final solution, if the coronary is not significantly narrow, we will not do the graft. If we do a graft when we don't need it, the competitive flow of the native coronary artery will happen, which will lead to a graft block.

## Complications of CABG

- 1. Mortality;** we have two scoring systems to measure the mortality rate by risk evaluation, it's lower than 2% for patients without complication.
  - STS PROM (Society of Thoracic Surgeons)
  - EURO SCORE II; detection of complication of mortality in CABG surgery according to the patient's risk factors (diabetes, RF, venous stroke, no cardiac output, HF, low ejection fraction, cardiogenic shock). Cardiogenic shock patient's mortality rate 30%-40%
- 2. Surgical Site Infections** (chest infection -sepsis); CABG surgery is a clean surgery, no contamination (not like GI and urinary tract surgeries)
- 3.** In postoperative MI, we do measure the flow in the new grafts intraoperatively, the grafted vessels close after the surgery immediately in 4%.
- 4. Stroke** (or cerebrovascular accident), happened because of:
  - patients with Carotid artery diseases.
  - the previous thrombosis, we use cannulas and clamps on the aorta thus, if there is atherosclerotic plaque it might rupture and cause a stroke.
  - during the surgery the blood pressure drop to 60 (hypoperfusion pressure), this also might lead to stroke (hypoperfusion injury).
  - left main coronary artery disease
  - old age
  - prolonged operation
- 5. Arrhythmias,** Atrial fibrillation is the most common.
- 6. Sternal dehiscence** at the site of sternotomy especially in smokers or with cough, so we use a stainless-steel wire to suture the sternum.
- 7. Systemic inflammatory response syndrome,** because of Cardiopulmonary bypass through Heart-lung machine.
- 8. Bleeding,** we give the patient large doses of unfractionated heparin, at the end of the surgery we reverse the heparin by protamine sulfate. In some cases, heparin remains in the subcutaneous tissue and causes bleeding.

You can check the figures in the [doctor's slides](#)

Sorry for errors if there was

Good luck