Schematic view of the heart vessels

Sternocostal surface

Diaphragmatic surface
Normal Coronary Anatomy

The Latin term corona, or crown, aptly describes coronary arteries that supply cardiac parenchyma with nutrient blood flow. The sulcus which has shape like base of crown is called coronary sulcus and arteries lies in this sulcus are called coronary arteries. The two arteries as indicated by their name form an oblique inverted crown, Cardiac apex. There are two main coronary arteries, the left and right coronary arteries. The left main coronary artery divides into the left anterior descending artery (LAD) and the circumflex branch.

Why are the coronary arteries important?

Since coronary arteries deliver blood to the heart muscle, any coronary artery disorder or disease can have serious implications by reducing the flow of oxygen and nutrients to the heart, which may lead to a heart attack and possibly death. Atherosclerosis (a build-up of plaque in the inner lining of an artery causing it to narrow or become blocked) is the most common form of coronary artery disease.

The heart is supplied mostly by two coronary arteries right and left. Only the inner 75-100 micrometer of endothelial surface gets nutrition directly from the blood in cardiac chambers. Anatomically, coronary arteries are not end arteries because they anastomose with each other by their trunks, branches and subbranches mostly at the precapillary level. Functionally however they behave like end arteries. Since most of the anastomoses remains impervious. Anastomoses providing collateral circulation may become prominent in conditions like hypoxia and in CAD. An additional collateral circulation is pronounced by small branches from mediastinal, pericardial
and bronchial vessels. Anastomoses between right and left coronary arteries are abundant during fetal life but are much reduced by the end of the first year of life.

Each coronary artery is a vasavasorum of the ascending aorta because the heart is developed from the fusion of two primitive endothelial tubes which represent the ventral aortae. Coronary arteries (most often 2) are normally the only vessels arising immediately above the free margin of aortic valve from the ascending aorta. The level of coronary ostia are variable, they are usually at or above cuspal margins. The name and nature of a coronary artery or branch is defined by that vessel's distal vascularization pattern or territory, rather than by its origin. The right coronary artery (RCA) most commonly arises separately from an ostium just below the sinotubular junction of the right (right anterior) sinus of Valsalva. The left coronary artery arises from the left posterior aortic sinus of ascending aorta.

The main arteries and major branches are usually subepicardial but those in atrioventricular and interventricular grooves are often deeply sited and occasionally hidden by overlapping myocardium or embedded in it.

The caliber of coronary arteries ranges between 1.5 to 5.5 mm. The left exceeds the right in 60% of hearts, the right being larger in 17% and equal in 23%. The diameter of coronary arteries may increase up to thirteen years of age.

**RIGHT CORONARY ARTERY**

After originating from the anterior aortic sinus of ascending aorta, first artery passes forwards and to the right between the pulmonary trunk and right auricle; then it passes
downwards and to the right along the right part of the atrio-ventricular groove. It winds round the inferior border of heart, passes upwards and to the left along the posterior part of atrio-ventricular groove and reaches the crux of the heart. In 60% subjects the terminal part of RCA anastomoses with the circumflex branch of the LCA slightly to the left side of the crux: in 10% cases.

The RCA ends at the inferior border of the heart; in 10% it reaches the interval between the inferior border and the crux of the heart. In remaining 20% subjects the RCA traverses the entire posterior part of atrio-ventricular groove.

BRANCHES:

A) FROM THE FIRST SEGMENT:

1) Ventricular rami:

   a) Right conus artery: First branch of RCA and supplies infundibulum of the right ventricle;

      Sometimes it arises directly from the anterior aortic sinus. In such case it is called third coronary artery. Right conus artery anastomoses sometimes with the left conus artery, derived from the circumflex branch of LCA. The anastomotic necklace thus formed around the infundibulum is known as the ANNULUS OF VIEUSSENS.

   b) Right anterior ventricular rami: Three or four in number. Longest ventricular ramus is called right marginal artery.
2) **Atrial rami:**

They are arranged in three groups: anterior, lateral and posterior.

They supply myocardium of right atrium.

The Sinu Atrial Nodal artery belongs to atrial rami. In 65% cases it arises from initial segment of RCA and in 35% subjects from circumflex branch of LCA.

B) **FROM THE SECOND SEGMENT:**

1) **Right posterior ventricular rami:**

They supply diaphragmatic surface of right ventricle.

2) **Posterior interventricular branch:**

It arises from RCA near crux of heart as a single branch in 70% subjects and passes along the posterior interventricular groove close to the apex. It anastomoses with the anterior interventricular branch of LCA. In 10% individuals the posterior interventricular branch is derived as a continuation of LCA. On the basis of posterior interventricular branch, right and left coronary predominance is described. In 80% to 90% subjects the AV nodal artery is derived from the RCA, and in 10% to 20% cases from the LCA.

3) **Right posterior atrial rami**
LEFT CORONARY ARTERY

It is usually wider than RCA and supplies larger volume of the myocardium. The LCA arises from the left posterior aortic sinus of ascending aorta. The trunk of the artery passes behind the pulmonary trunk, and then appears forwards and to the left between the pulmonary trunk and left auricle, where it devides usually into two branches, anterior interventricular and circumflex. In 2% cases two branches arise separately from the left posterior aortic sinus. Only two terminal branches given by LCA.

1. ANTERIOR INTERVENTRICULAR BRANCH

It is the continuation of LCA, descends in the corresponding groove along the sterno-costal surface to the apex and after winding round the incisura apices cordis ends on the inferior surface by anastomosing with posterior interventricular branch of RCA.

Branches:

a) Anterior ventricular rami: One of the left ventricular rami is large and is known as the Diagonal artery. Sometimes it arises from the junction of the anterior interventricular and circumflex branches. In such condition the trunk of the LCA trifurcates. One of the right anterior ventricular rami form the left conus artery which supplies the infundibulam of right ventricle.

b) Septal rami
2. CIRCUMFLEX ARTERY

It passes along the left part of the atrio-ventricular groove, winds round the left border of heart and occupies the posterior part of the atrio-ventricular groove where it Anastomoses with the RCA.

Branches:

a) Atrial rami
b) Ventricular rami
c) SA nodal artery—In 35%
d) Left marginal artery
e) Posterior interventricular artery –In 10% to 20%
f) Kugel’s artery

The RCA courses in the right atrioventricular groove and provides nutrient branches to the right ventricular free wall, extending to the acute margin of the heart. The distal extent of the RCA varies and may extend posteriorly as far as the obtuse margin of the heart. In 90% of patients, the RCA supplies the posterior descending coronary artery branch at the crux of the heart, which supplies the atrioventricular (AV) node and the posterior aspect of the interventricular septum.

The first branch arising from the RCA is the conal or infundibular branch, which courses anteriorly to supply the muscular right ventricular outflow tract or infundibulum. The RCA supplies blood to the atria with a highly variable pattern of small branches. The sinus node artery arises from the proximal RCA in approximately 50% of patients. The left coronary artery (LCA) arises from the mid position of the left (left anterior) sinus of Valsalva (sinuses on either side of the point of aortic and
pulmonary commissural contact) just above the level of the free margin of the aortic valve leaflet and generally below the sinotubular junction.

The left coronary ostium is usually single, giving rise to a short, common LCA trunk that branches into the left anterior descending (LAD) and circumflex (Cx) arteries. The LAD courses in the anterior interventricular groove, giving rise to the anterior septal perforating branches as it extends toward the cardiac apex. Small branches may arise from the LAD and supply the anterior wall of the right ventricle. Diagonal branches arise from the LAD and course at downward angles to supply the anterolateral free wall of the left ventricle.

The Cx artery courses along the left AV groove, around the obtuse margin, and posteriorly toward the crux of the heart. The Cx artery reach the crux of the heart and supply the posterior descending coronary artery, the left coronary system would be termed dominant. This occurs in approximately 10% of patients. Atrial branches may arise from the Cx coronary artery and supply the sinus node in 40% of patients. Obtuse marginal branches arise from the Cx system to supply the posterolateral aspect of the left ventricle. In an estimated 70% of patients, a coronary branch (termed ramus medianus, intermedius, or intermediate branch) arises early off the left coronary system to supply an area between diagonal branches from the LAD and obtuse branches from the Cx systems.
Variability in coronary circulation

Despite the position of the heart within the chest and the position of the great arteries as they arise from the heart, aortic and pulmonary valves normally have a single point of contact, with commissural apposition at this point. Coronary arteries almost always arise normally from the "facing" sinuses of Valsalva on either side of this point of commissural contact. Coronary arteries do not normally arise from "nonfacing" or most distant sinus; however, variations in coronary anatomy are common. Variations that occur in less than 1% of the general population may be considered abnormal or anomalies.

Number and size of coronary ostia

Normally, an individual has two or, sometimes, three coronary ostia. Often, the conal branch of the RCA may arise separately from the right sinus. The Cx or LAD may, on occasion, arise directly from the aortic root. Coronary ostia are typically equal to, or larger than, the vessel they supply.

Positioning within sinuses

Coronary arteries arise more or less perpendicular to the aortic wall. Ostia are located in the middle of the sinus, just above the free leaflet margin of the aortic leaflet and below the sinotubular junction. Coronary arteries that arise ectopically usually course tangentially to the aortic wall or arise in close relationship to the commissure of the aortic valve.
Course of coronary arteries

The course of named coronary arteries is mostly epicardial, although the proximal LAD may have an intramural or subepicardial course in 5-25% of the general population. Branches of epicardial vessels generally proceed in a perpendicular course to supply myocardial arterioles and capillaries. This uniquely designed pattern of epicardial (reservoir) and intramyocardial (nutrient) supply optimizes blood flow to the heart.

Pathophysiology

The heart has a very limited capacity for anaerobic metabolism. The primary source of energy is oxidative metabolism of free fatty acids; therefore, the heart has a negligible ability to tolerate periods of ischemia, yet its capacity to extract oxygen is great (although relatively fixed), and limited degrees of hypoxemia are generally well tolerated. At rest, the oxygen requirement of the heart (8-10 mL/min/100 g) is much greater than of the skeletal muscle (0.115 mL/min/100 g). Exercise requires a 50% increase in oxygen demand primarily met by an increase in myocardial flow 3-4.5 times greater than baseline.

The pattern of coronary blood flow is unique. Epicardial coronary vessels serve as capacitance vessels, primarily filling during the period of diastole (as much as 85% of total flow), and intramural pressure and resistance to myocardial perfusion progressively increase from the outer to inner layers of the heart. Myocardial arterioles have tremendous vasodilatory reserve capacity and enable high flow and
low resistance in response to exercise. Recent investigations suggest that the coronary vascular tree has a dual mechanism of vasodilatation: larger proximal vessels by endothelium-derived nitric oxide and direct stimulation of smooth muscle cell alpha2-receptors by adenosine and other metabolites.

The left coronary ostium is usually single, giving rise to a short, common LCA trunk that branches into the left anterior descending (LAD) and circumflex (Cx) coronary arteries. The LAD courses in the anterior interventricular groove, giving rise to the anterior septal perforating branches as it extends toward the cardiac apex. Small branches may arise from the LAD and supply the anterior wall of the right ventricle. Diagonal branches arise from the LAD and course at downward angles to supply the anterolateral free wall of the left ventricle.

Coronary arteries are the vasa vasorum of the ascending aorta, because the heart is developed from the fusion of two primitive endothelial tubes, which represent the ventral aorta. The right coronary artery arises from the right coronary sinus (anterior aortic sinus) of the ascending aorta and the left coronary artery arises from the left posterior aortic sinus of the ascending aorta. Ostia of the coronary arteries are located in the center of the corresponding aortic sinuses. Malformations of the position of the ostia and origin of coronary arteries lead to high risk of sudden death. In some cases the coronary ostia are slit-like; during exertion, the coronary arteries get compressed between the aorta and pulmonary artery, this lead to lack of oxygenation and myocardial ischemia and may result in sudden death. Pathological examination of
coronary arteries in autopsies is essential for the explanation of the sudden death and for the improvement of the therapeutic procedures.

A coronary artery with an oblique origin, intramural (within the wall of the aorta) course, or positioning between the great arteries puts the coronary arteries at risk for compression and may significantly limit the reservoir capacity of the epicardial coronary system. Comparable pressure in larger vessels creates greater wall tension and is felt to cause compression of smaller vessels that are in continuity by the Laplace law (tension = pressure X radius).

Proximal areas of significant stenosis hamper the heart's capacity to respond to increased myocardial oxygen demands. The major regulators of coronary blood flow are as follows:

- Intramural pressure
- Aortic diastolic perfusion pressure
- Myocardial metabolic rate (in turn related to heart rate, inotropic state, and systolic arterial pressure)
- Autonomic nervous system control
- Endothelial function
- Blood viscosity in response to decreased myocardial oxygen supply

Myocardial ischemia is the primary manifestation of congenital or acquired coronary artery disease (CAD).
Coronary artery dominance

Base and diaphragmatic surface of heart.

The artery that supplies the posterior interventricular artery determines the coronary dominance.

- If the posterior interventricular artery is supplied by the **right coronary artery** (RCA), then the coronary circulation can be classified as "right-dominant".

- If the **posterior interventricular artery** is supplied by the **circumflex artery** (CX), a branch of the left artery, then the coronary circulation can be classified as "left-dominant".

- If the **posterior interventricular artery** (PIVA) is supplied by both the right coronary artery (RCA) and the circumflex artery, then the coronary circulation can be classified as "co-dominant".

Approximately 70% of the general population are right-dominant, 20% are co-dominant, and 10% are left-dominant.
Coronary flow

During contraction of the ventricular myocardium (systole), the subendocardial coronary vessels (the vessels that enter the myocardium) are compressed due to the high intraventricular pressures. However, the epicardial coronary vessels (the vessels that run along the outer surface of the heart) remain patent. Because of this, blood flow in the subendocardium stops. As a result most myocardial perfusion occurs during heart relaxation (diastole) when the subendocardial coronary vessels are patent and under low pressure. This contributes to the filling difficulties of the coronary arteries. Compression remains the same. Failure of oxygen delivery caused by a decrease in blood flow in front of increased oxygen demand of the heart results in tissue ischemia, a condition of oxygen debt. Brief ischemia is associated with intense chest pain, known as angina. Severe ischemia can cause the heart muscle to die of oxygen starvation, called a myocardial infarction. Chronic moderate ischemia causes contraction of the heart to weaken, known as myocardial hibernation.

In addition to metabolism, the coronary circulation possesses unique pharmacologic characteristics. Prominent among these is its reactivity to adrenergic stimulation. The majority of vasculature in the body constricts to norepinephrine, a sympathetic neurotransmitter the body uses to increase blood pressure. In the coronary circulation, norepinephrine elicits vasodilation, due to the predominance of beta-adrenergic receptors in the coronary circulation. Agonists of alpha-receptors, such as phenylephrine, elicit very little constriction in the coronary circulation.
Anastomoses

When two arteries of the coronary circulation join, dual blood flow to a certain area of the myocardium occurs. These junctions are called anastomoses. If one coronary artery is obstructed by an atheroma, the second artery is still able to supply oxygenated blood to the myocardium. However this can only occur if the atheroma progresses slowly, giving the anastomoses a chance to proliferate. Under the most common configuration of coronary arteries, there exist two anastomoses on the posterior side of the heart. More superiorly, there is an anastomosis between the circumflex artery and the right coronary artery. More inferiorly, there is an anastomosis between the anterior interventricular artery and the posterior interventricular artery (a branch of the right coronary artery).