Coronary Circulation: An Overview
Observations about Kugel's artery anatomy

“The heart has its reasons which reason knows not.”
Blaise Pascal (1623-1662)

French mathematician, physicist, inventor, writer and Catholic theologian.

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Coronary Circulation: An Overview

Coronary arteries supply oxygenated blood to the heart, and cardiac veins drain away the blood once it has been deoxygenated. Heart circulation is of major importance not only to its own tissues but to the entire body and even the level of consciousness of the brain from moment to moment. Interruptions of coronary circulation quickly cause myocardial infarctions, in which the heart muscle is damaged by oxygen starvation. Such interruptions are usually caused by coronary artery disease and sometimes by embolism from other causes like obstruction in blood flow through vessels. Coronary arteries supply blood to the myocardium and other cardiac components. Two coronary arteries originate from the left side of the heart at the root of the aorta, just after the aorta exits the LV. There are three aortic sinuses (dilations) in the wall of the aorta just superior to the aortic semilunar valve. Two of these, the left posterior aortic sinus and anterior aortic sinus, give rise to the LMCA and RCA, respectively. The third sinus, the right posterior aortic sinus, typically does not give rise to a vessel. Coronary vessel branches that remain on the surface of the artery and follow the sulci of the heart are called epicardial coronary arteries.(**Betts, J. Gordon (2013). Anatomy & physiology. pp. 787–846. ISBN 1938168135. Retrieved 11 August 2014.**)The LMCA distributes blood to the left side of the heart, the LA and LV , and the interventricular septum(IVS). The LCX arises from the LMCA and follows the coronary sulcus to the left. Eventually, it will fuse with the small branches of the RCA. The larger anterior interventricular artery, also known as the LAD, is the second major branch arising from the LMCA. It follows the anterior interventricular sulcus around the pulmonary trunk. Along the way it gives rise to numerous smaller branches that interconnect with the branches of the posterior interventricular artery(LPD), forming anastomoses. An anastomosis is an area where vessels unite to form interconnections that normally allow blood to circulate to a region even if there may be partial blockage in another branch. The anastomoses in the heart are very small. Therefore, this ability is somewhat restricted in the heart so a coronary artery blockage often results in MI death of the cells supplied by the particular vessel. The RCA proceeds along the coronary sulcus and distributes blood to the RA, portions of both ventricles, and the

conduction system. Normally, one or more marginal arteries arise from the RCA inferior to the RA. The marginal arteries supply blood to the superficial portions of the RV. On the posterior surface of the heart, the RCA gives rise to the posterior descending artery PAD,. It runs along the posterior portion of the interventricular sulcus toward the apex of the heart, giving rise to branches that supply the interventricular septum and portions of both ventricles. (**Betts, J. Gordon (2013). Anatomy & physiology. pp. 787–846. ISBN 1938168135. Retrieved 11 August 2014.**).

Anastomoses

There are some anastomoses between branches of the two coronary arteries. However the coronary arteries are functionally end arteries and so these meetings are referred to as potential anastomoses, which lack function, as opposed to true anastomoses like that in the palm of the hand. This is because blockage of one coronary artery generally results in death of the heart tissue due to lack of sufficient blood supply from the other branch. When two arteries or their branches join, the area of the myocardium receives dual blood supply. 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 are three areas of anastomoses. Small branches of the LAD branch of the left coronary join with branches of the PDA of the RCA in the interventricular sulcus(groove). More superiorly, there is an anastomosis between the LCX (a branch of the LMCA and the RCA in the atrioventricular groove. There is also an anastomosis between the septal branches of the two coronary arteries in the interventricular septum.

Variation

The left and RCA occasionally arise by a common trunk, or their number may be increased to three; the additional branch being the posterior coronary artery (which is smaller in size). In rare cases, a person will have the third coronary artery run around the root of the aorta.

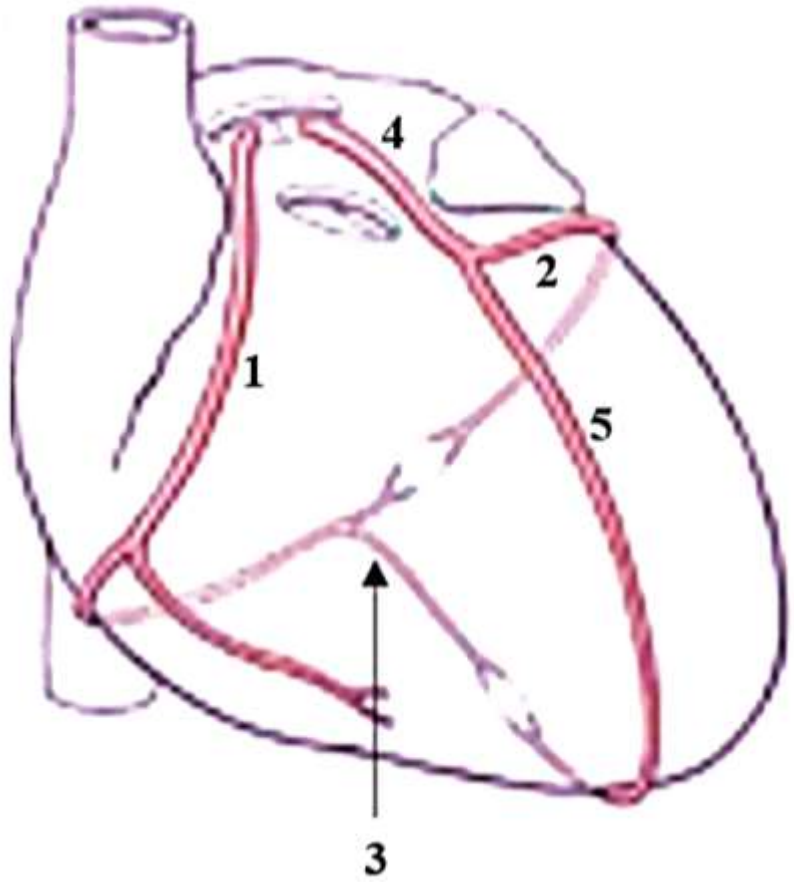
Occasionally, a coronary artery will exist as a double structure (i.e. there are two arteries, parallel to each other, where ordinarily there would be one).

Coronary Artery dominance

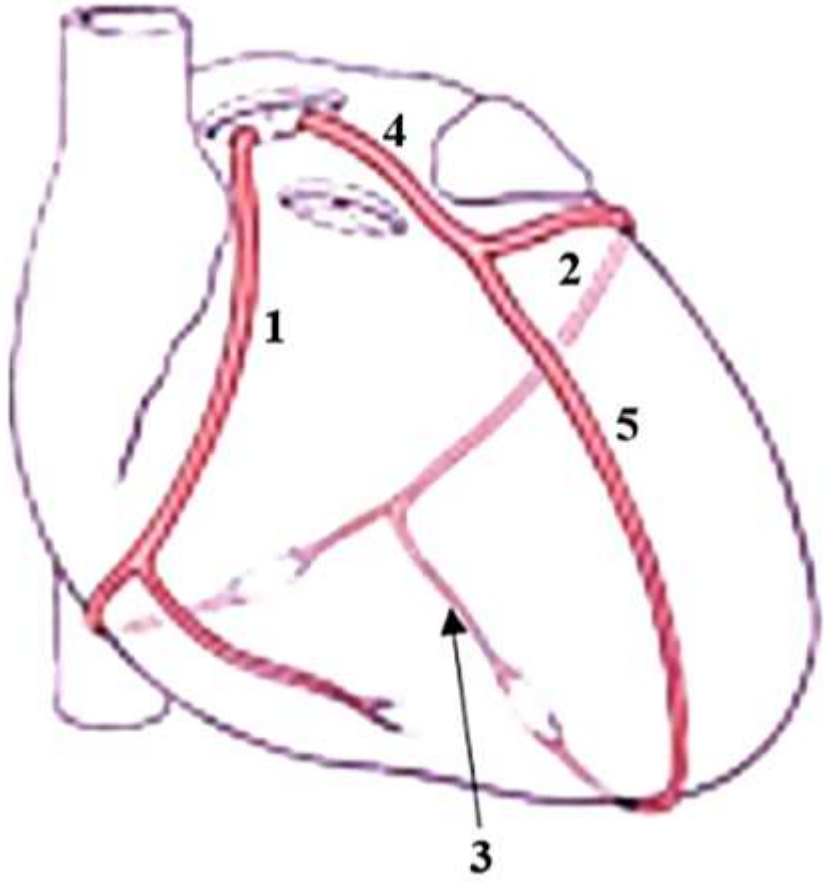
Coronary arterial dominance is defined by the vessel which gives rise to the posterior descending artery (PDA), which supplies the myocardium of the inferior 1/3rd of the interventricular septum. Most hearts (80-85%) are right dominant(RD) where the PDA is supplied by the RCA. The artery that supplies the posterior third of the interventricular septum – the PDA determines the coronary dominance.(**Gorlin R. Coronary anatomy. Major Prob Int Med 1976;11:40–58**.)(**Knaapen M, Koch AH, Koch C, et al. Prevalence of left and balanced coronary arterial dominance decreases with increasing age of patients at autopsy. A postmortem coronary angiograms study. Cardiovasc Pathol 2013;22:49–53**.) (**Fuster, V; Alexander RW; O'Rourke RA (2001). Hurst's The Heart (10th ed.). McGraw-Hill. p. 53. ISBN 0-07-135694-0**.). In conclusion coronary artery dominance is classified as LD, RD or CD depending on the origin of the posterior descending artery (PDA)

- ***If the PDA is supplied by the RCA, then the coronary circulation can be classified as "right-dominance"(RD).≈70% of cases;***
- ***If the PDA is supplied by the L(CX, a branch of the left artery, then the coronary circulation can be classified as "left-dominance"(LD). ≈20% of cases;***
- ***If the PDA is supplied by both the RCA and the LCX, then the coronary circulation can be classified as "co-dominant" or* "balanced coronary arterial dominance" or CD. *≈10% of cases. See figure in the next slide***.

I. Right dominance



II. Left dominance



I. If the posterior Descending Artery (PDA) is supplied by The Right Coronary Artery (RCA), then the coronary circulation can be classified as "right-dominance".

II. If the Posterior Descending Artery (PDA) is supplied by the Left Circumflex Artery (LCX) , then the coronary circulation can be classified as "right-dominance".

1. **Right Coronary Artery (RCA); 2. Left Circumflex Artery (LCX); 3. Posterior Descending Artery (PDA); 4. Left Main Coronary Artery; 5. Left Anterior Descending Artery** (**LAD**)

Impact of Right Coronary Dominance on Triple-Vessel Coronary Artery Disease

Recently, Peng L et al (**Liyuan Peng 1, Xincheng Guo 2, Ya Gao 3, Qi Guo 4, Jingjing Zhang 3, Bangjiang Fang 5, Bin Yan 1. Impact of Right Coronary Dominance on Triple-Vessel Coronary Artery Disease: A Cross-Sectional Study. Medicine (Baltimore) , 97 (32), e11685 Aug 2018 PMID: 30095625 PMCID: PMC6133631 DOI: 10.1097/MD.0000000000011685**) investigate the relationship between right coronary dominance and coronary angiographic characteristics in patients with or without significant coronary artery disease (CAD).

A total of 2225 patients undergoing coronary angiography between January 2011 and November 2014 were recruited in the study. Based on the coronary angiography results, patients were divided into the left dominance (LD) group, right dominance (RD) group, and co-dominance (CD) group. Multinomial logistic regression was applied to analyze the relationships between coronary dominance and triple-vessel CAD.

They found that patients with RD had a higher prevalence of triple-vessel CAD (36.6% vs 27.3%, $P = .008$) and significant stenosis in the RCA (40.5% vs 29.2%, $P = .001$). In addition, results of multinomial logistic regression analysis showed that RD was significantly associated with the triple-vessel disease (odds ratio 1.768, 95% confidence interval 1.057–2.956, $P = .030$).

In conclusion, RD positively correlated with triple-vessel CAD rather than LD or CD in patients. This result suggested that RD may serve as a risk factor for triple-vessel CAD and more effective measures should be taken in RD patients to prevent fatal cardiovascular events.

The papillary muscles of the Mammalians heart

The papillary muscles(PMs) are the involuntary muscles located in the ventricles of the mammalian heart. They are components of the The mitral valve apparatus. This apparatus has six components: 1) the left atrial wall, 2) the mitral annulus, 3) the mitral valve leaflets, 4) the chordae tendineae, 5) the papillary muscles, and 6) The left ventricular wall. This is a complex three–dimensional functional unit that is critical to unidirectional heart pump function. The last one are attach to the cusps of the atrioventricular valves (the mitral and the papillary muscles are the involuntary muscles which are present in the ventricles of the mammalian heart. They support the tricuspid valves and mitral valves. The contraction of the papillary muscles opens these values when the papillary muscles relax, the valves get closed. Chordae tendineae connects the papillary muscles to the valves. Chordae tendineae connects the papillary muscles to the tricuspid valves via the chordae tendineae and contract to prevent inversion or prolapse of these valves inside de atriums during the ventricular contraction) (**Moore KL, et al. 2007**). The PMs constitute about 10% of the total heart mass.

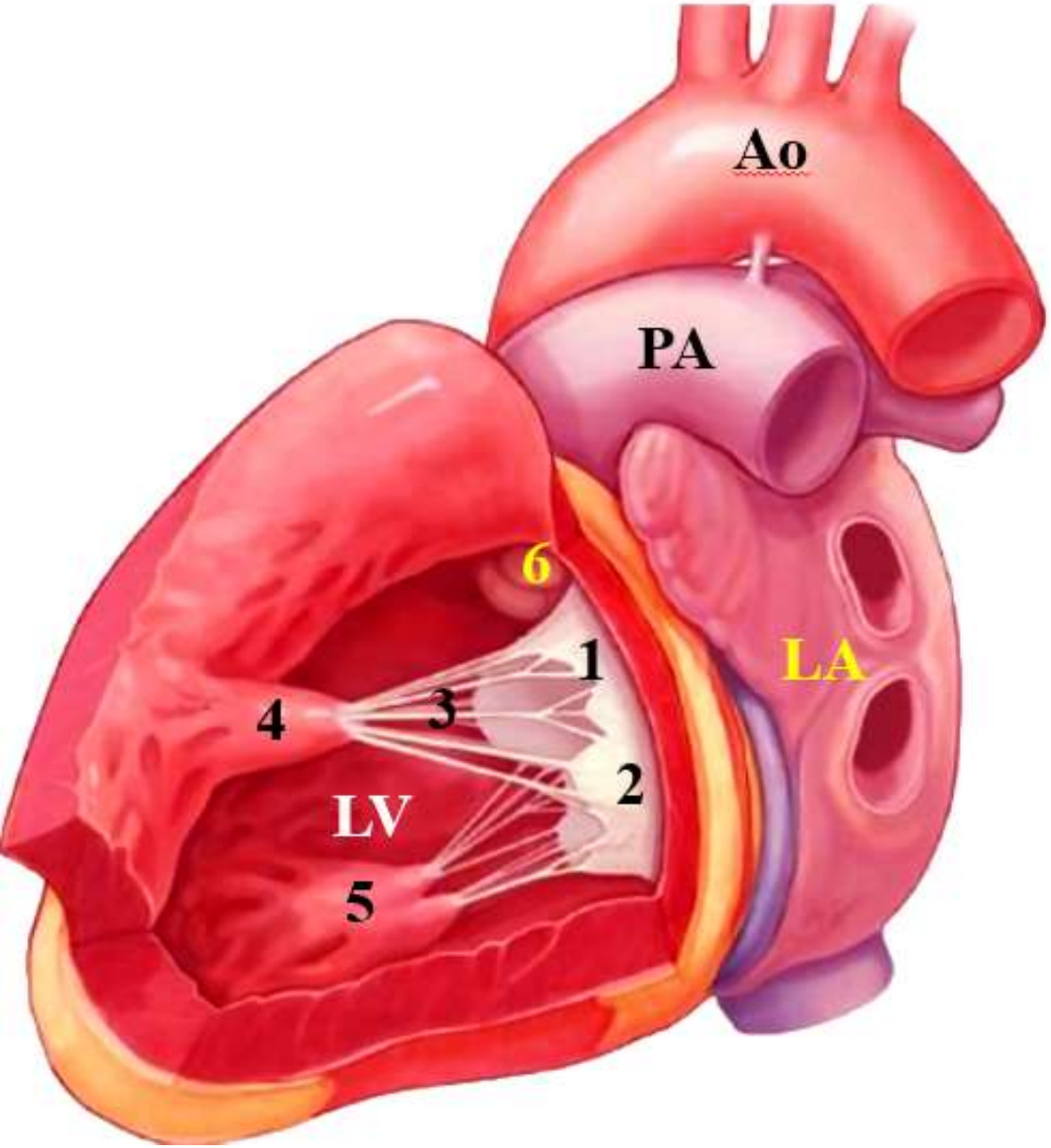
Structure

There are five total papillary muscles in the heart; three in the right ventricle and two in the left. The anterior, posterior, and septal papillary muscles of the RV each attach via chordae tendineae to the tricuspid valve. There are typically two papillary muscles arising from the area between the apical and middle thirds of the LV free wall. The anterolateral papillary muscle is often composed of one body or head, whereas the posteromedial papillary muscle may have two or more heads. Each papillary muscle provides chordae to both leaflets, and the axial relationship of the chordae prevents chordal abrasion or dyssynchrony. The attachment of the papillary muscles to the lateral wall of the LV indicates that the ventricle is also an important part of the mitral valve complex. Any change in ventricular geometry that affects papillary muscle position can change the axial relationship of the chordae and leaflets, resulting in valve dysfunction

Supply to papillary muscles

The papillary muscles attach the mitral valve (the valve between the LA and the LV) and the tricuspid valve (the valve between the RA and the RV) to the wall of the heart. The **papillary muscles** are **muscles** located in the ventricles of the heart. They attach to the cusps of the atrioventricular valves via the chordae tendineae and contract to prevent inversion or prolapse of these valves on systole. If the papillary muscles are not functioning properly, the mitral valve may leak during contraction of the LV . This causes some of the blood to travel "in reverse", from the LV to the LA , instead of forward to the aorta and the rest of the body. This leaking of blood to the LA is known as mitral regurgitation. Similarly, the leaking of blood from the RV through the tricuspid valve and into the RA can also occur, and this is described as tricuspid insufficiency or tricuspid regurgitation. The anterolateral papillary muscle more frequently receives two blood supplies: LAD artery and the LCX.(**Voci P, Bilotta F, CarettaQ, Mercanti C, Marino B (1995). "Papillary muscle perfusion pattern. A hypothesis for ischemic papillary muscle dysfunction". Circulation. 91 (6): 1714–8. doi:10.1161/01.cir.91.6.1714. PMID 7882478**.) It is therefore more frequently resistant to coronary ischemia. On the other hand, the posteromedial papillary muscle is usually supplied only by the PDA. This makes the posteromedial papillary muscle significantly more susceptible to ischemia. The clinical significance of this is that a MI involving the PDA is more likely to cause mitral regurgitation.

Components of the Mitral Valve Apparatus



Ao: Aorta; PA: Pulmonary Artery; LA: Left Atrium; 6: Aortic valve.

The mitral valve apparatus is a complex three–dimensional functional unit that is critical to unidirectional heart pump function. The main mitral valve apparatus components are:

1) ***Anterior leaflet of mitral valve***
2) ***Posterior leaflet of mitral valve***
3) ***Chordae tendineae***
4) ***Anterolateral papillary muscle***
5) ***Posterolateral papillary muscle***
6) ***Aortic valve***

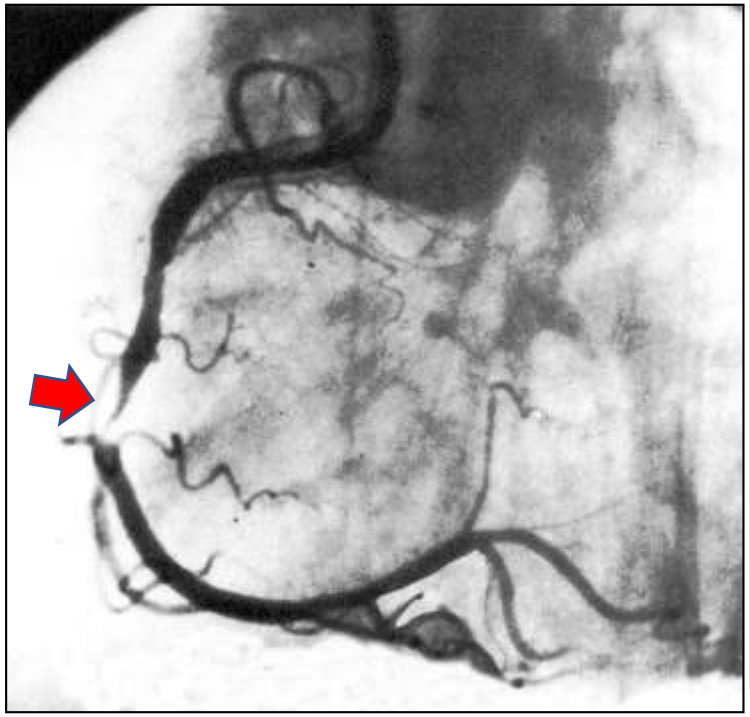
Ao) Aorta

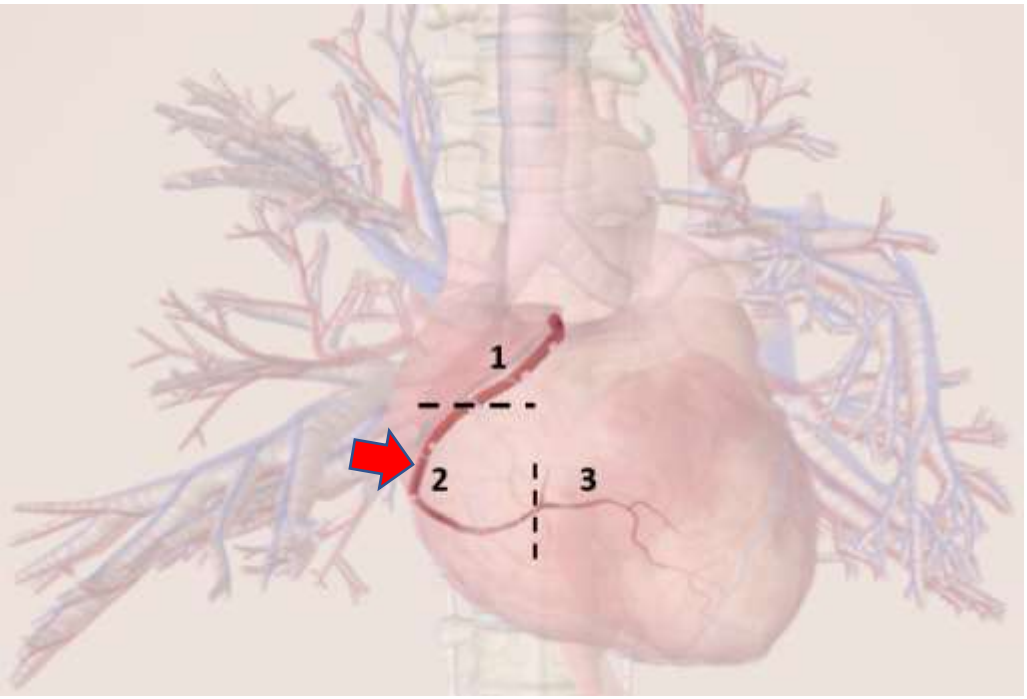
LA) Left atrium

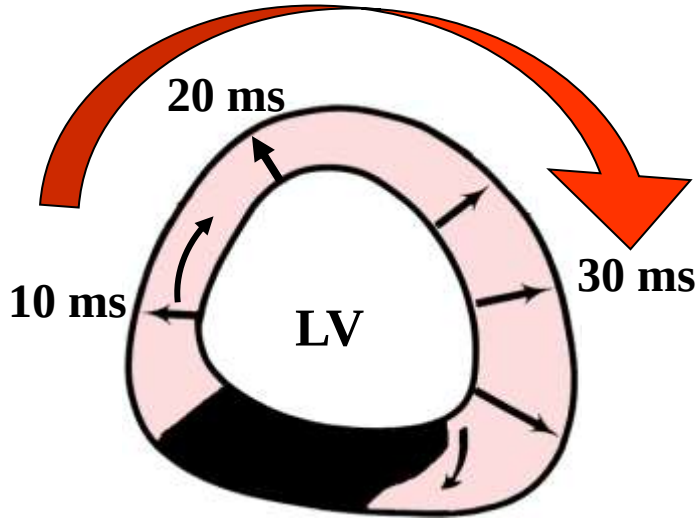
LV) Left ventricle

PA) Pulmonary artery

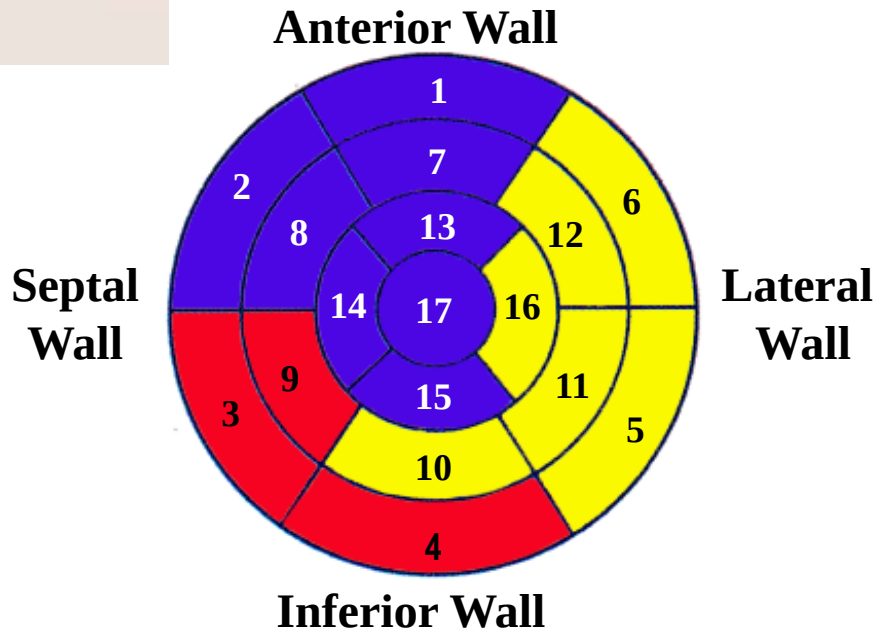
Example of total obstruction in middle part of Right Coronary Artery (RCA): R-2







Bulls eye (apical short axis)



Posterior Descending (RCA or LCx)

Main Coronary Arteries The coronary tree

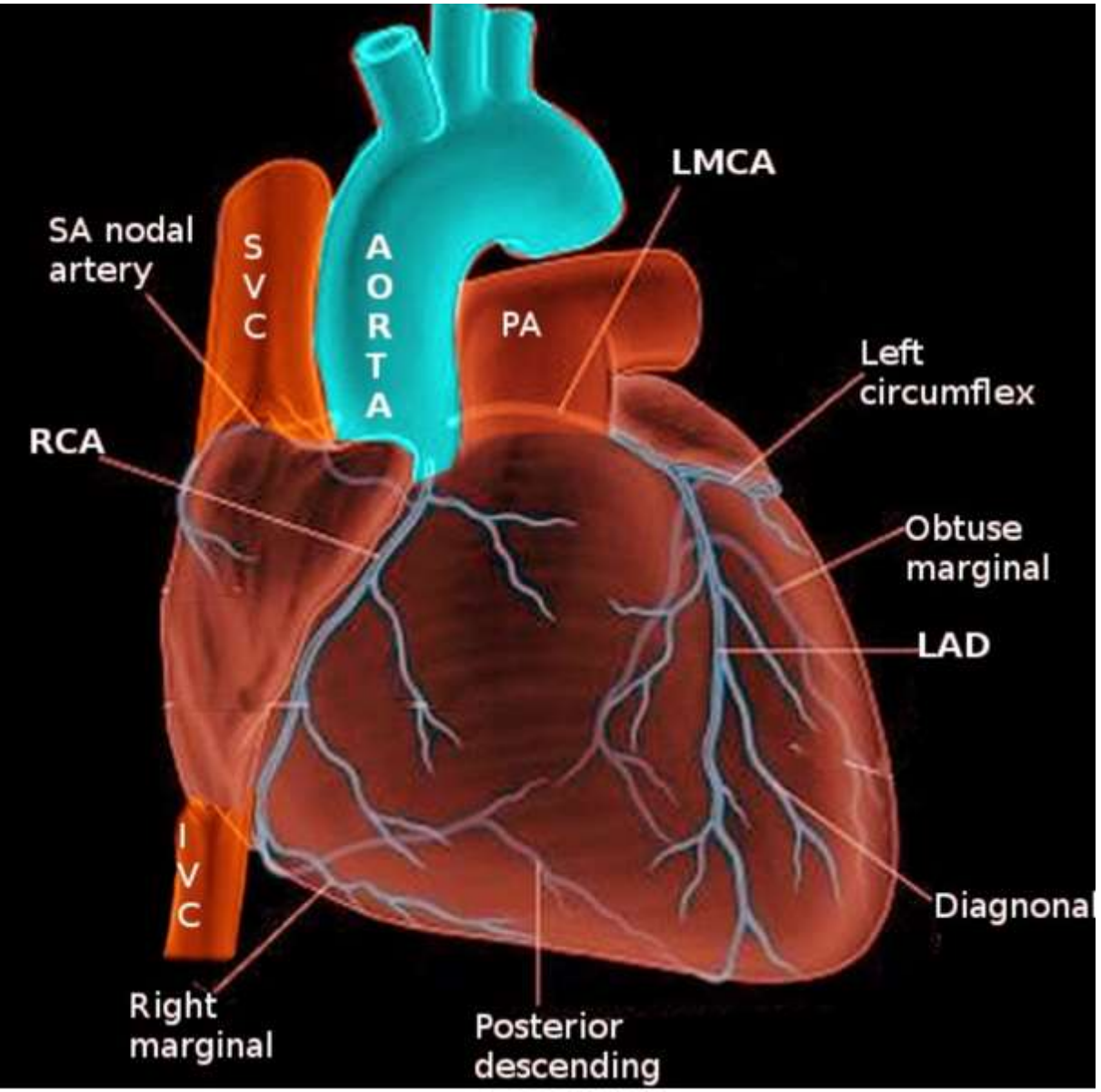
I. ***Left Main Coronary Artery, Left Main, the left main stem coronary artery (LMCA/LCA), the Left Mai Trunk, the Left Main Stem coronary artery (abbreviated LMS):*** The LMCA runs from its origin in the aorta to its bifurcation into:
   - The left anterior descending(LAD)
   - Left circumflex artery (LCX).
     I. *Obtuse marginal artery #1 (OM1) Obtuse marginal artery #2 (OM2)*
     II. *Posterior descending artery (PDA. Only in 10% of the cases(Left dominance)*

II. ***Left Anterior Descending Artery (LAD):***
   I. *Diagonal arteries:*
      1 - Dg1 or first diagonal;
      2 - Dg2 Diagonal artery 2 - or second diagonal
   II. *Anterior Septal Perforator Branches:*
      I. ***S_1**: First Septal Perforator branch;*
      II. ***S_2**: Second Septal Perforator and*
      III. ***S_3**: Third Septal Perforator branch*

III. Right Coronary Artery (RCA):

1. *The conus (arteriosus) artery which runs to the right ventricular outflow tract*
2. *The atrial branch which gives off the SA nodal artery (in ~ 60 % of hearts), which runs along the anterior RA to the SVC, encircling it before reaching the SA node*
3. *Atrioventricular nodal branch*
4. *Right marginal branch/artery; of is a large marginal branch which follows the acute margin of the heart and supplies blood to both surfaces of the RV.*
5. *Posterior descending artery (PDA); It is typically a branch of the RCA (70%, right dominance).*
6. *Posterolateral artery #1 (PL#1) and*
7. *Posterolateral artery #2 (PL#2)*

The Coronary tree



Left Main Coronary Artery(LMCA): the LMCA branches into the circumflex and LAD In about 15% of people, the LMCA gives rise to both of the interventricular arteries. The LMCA supplies blood to the left side of the heart.

Right Coronary Artery (RCA): The RCA supplies blood to the right side of the heart. The RCA gives rise to the sinoatrial nodal branch of the RCA IN 60% of cases, PDA branch of the RCA, and the marginal branch. supplies blood to the RA, RV, SA node, AV node and helps supply blood to the septum. The atrioventricular nodal artery supplies the AV node and comes of the RCA.

Left Anterior Descending (LAD) Supply blood to the LA and LV. The LAD supplies blood to the front and the left side of the heart, ventricular septum and the greater portion of the anterior portion of the LV.

Left Circumflex (LCX): Supply blood to the LA and the basal-lateral aspect of the LV. The LCx supplies blood to the lateral wall of the LV and sometimes to the basal inferior aspect of the heart when there is left heart dominance.

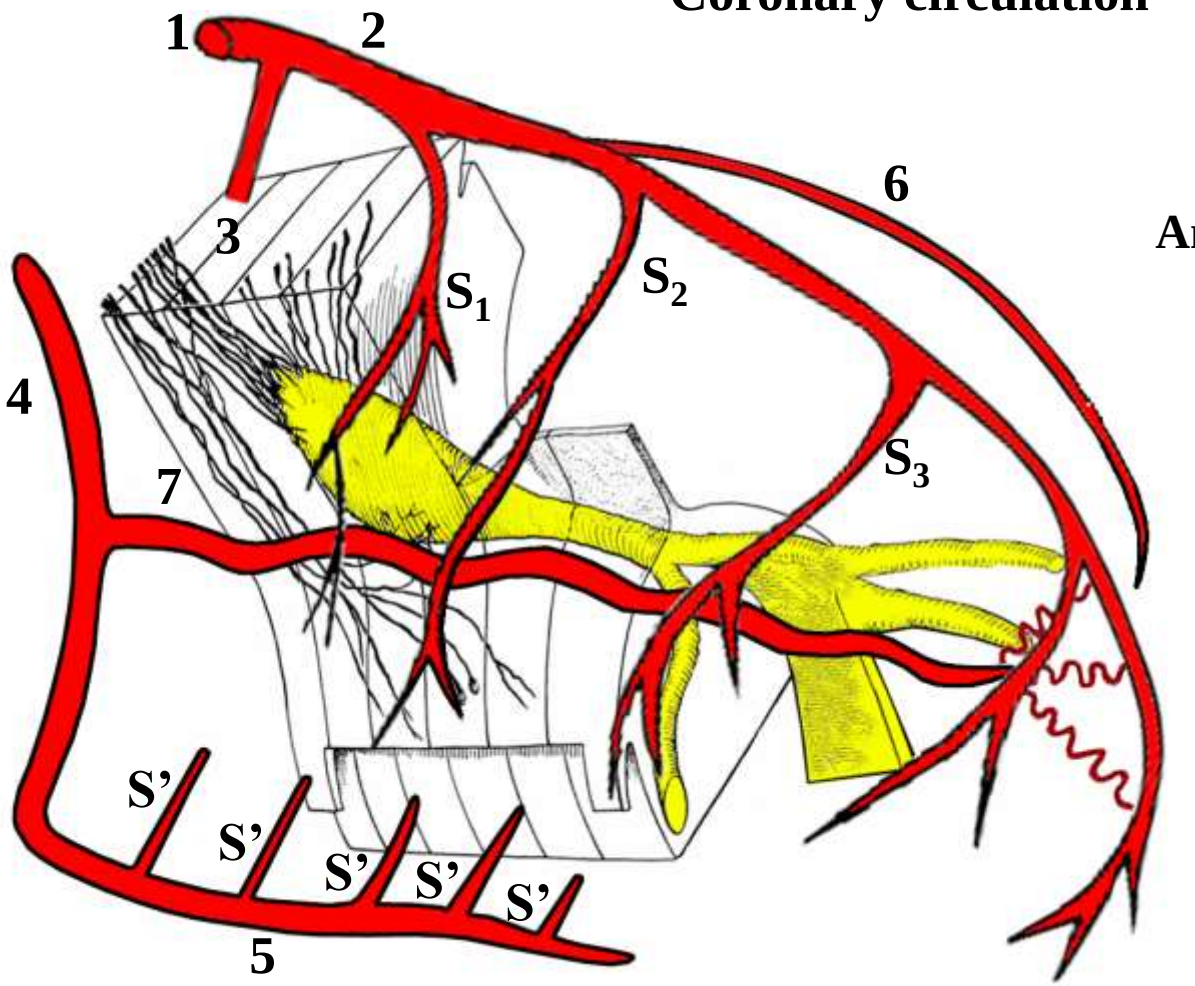
Acute marginal Artery or marginal branch of the RCA: provides blood supply to the lateral portion of the RV.

Posterior Descendam Artery (PDA): supplies blood to the inferior aspect of the septum.

Obtuse Marginal: the obtuse marginal branches supply the inferior wall directly.

Right Marginal of RCA or right marginal artery) is a large marginal branch which follows the acute margin of the heart and supplies blood to both surfaces of the right ventricle.

Coronary circulation

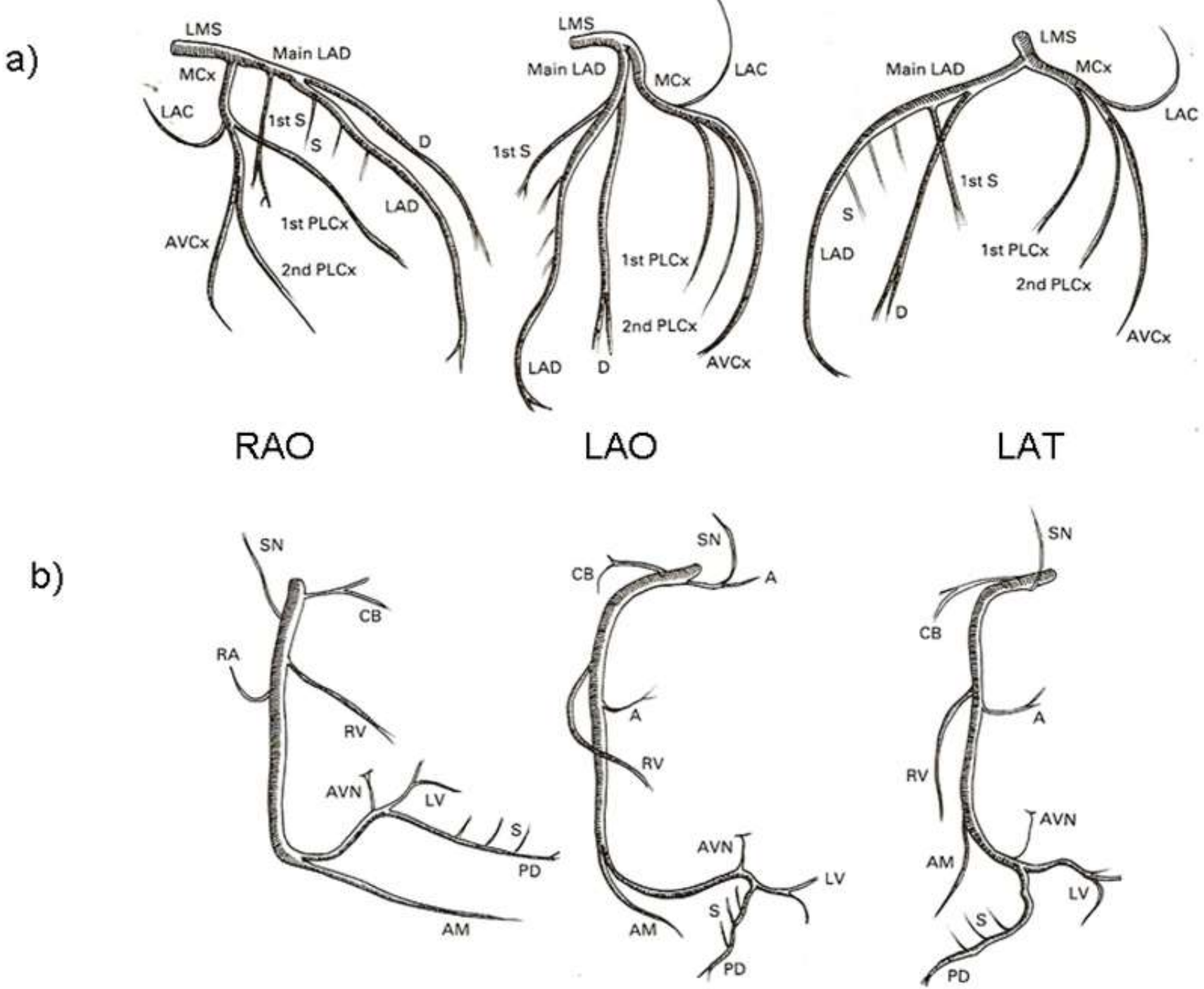


Anterior Septal Perforator Branches

S_1: First Septal Perforator branch
S_2: Second Septal Perforator
S_3: Third Septal Perforator

S': Posterior Septal Perforators

1. Left Main Coronary Artery (**LMCA)**
2. Left Anterior Descending Artery (**LAD)**
3. Left Circumflex Coronary Artery (**LCX)**
4. Right Coronary Artery (**RCA)**
5. Posterior Descending Artery (**PDA**). In this case is supplied by the RCA, then the coronary circulation can be classified as "right-dominance“
6. First Diagonal (**Dg**)
7. Acute Marginal (**A. Mg)**

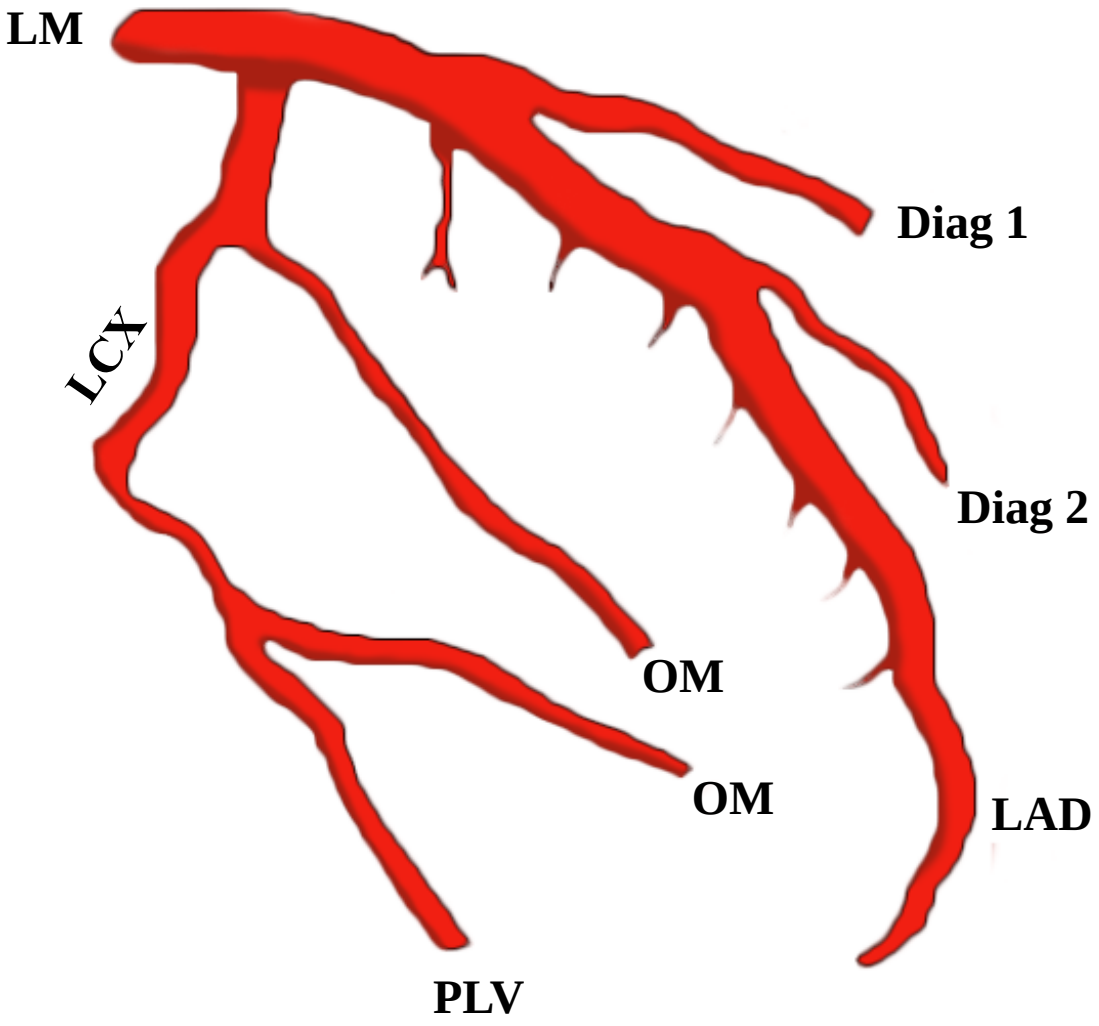


Coronary artery anatomy. a) Left coronary artery and b) Right coronary artery. A, atrial branch; AM, acute marginal artery; AVCx, atrioventricular groove branch of circumflex; AVN, atrioventricular node artery; CB, conus branch; D, diagonal branch of LAD; LAC, left atrial circumflex; LAD, left anterior descending; LAO 30° left anterior oblique projection; LAT, left lateral projection; LMS, left main stem; LV, left ventricular branches; MCx, main circumflex; PD, posterior descending; PLCx, posterior circumflex branch (obtuse marginal); RA, right atrial branch; RAO, 30° right anterior oblique projection; RV, right ventricular branch;

S, septal perforating arteries;

SN, sinus node artery.

The left Coronary Artery tree



The American Heart Association divides the LMCA: left main coronary artery, LM: left main artery, 8. LAD: left anterior descending artery, 9 Diag 1: 1st diagonal branch, Diag 2: 2nd diagonal branch, LCX: left circumflex artery, OM: obtuse marginal branch

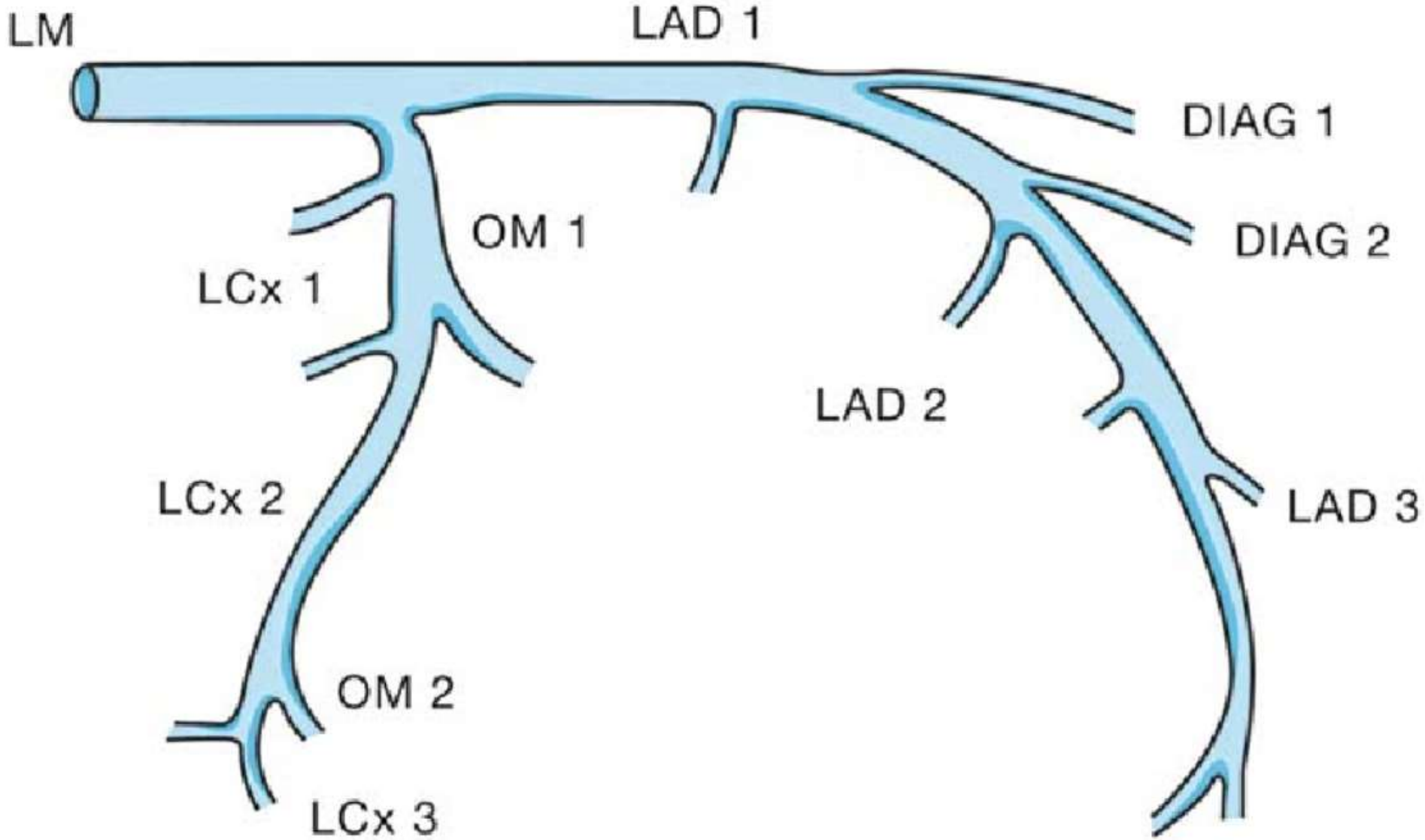


Fig. Left coronary artery in caudal right anterior oblique (RAO) view. LM Left main artery, LAD left anterior descending artery (segments 1–3), DIAG 1 1st diagonal branch, DIAG 2 2nd diagonal branch, LCX left circumflex artery (segments 1–3), OM 1 1st obtuse marginal branch, OM 2 2nd obtuse marginal branch

Right Coronary Artery (RCA)

The RCA is an artery originating above the right cusp of the aortic valve, at the right aortic sinus in the heart. It travels down the right coronary sulcus, towards the crux of the heart. It branches into the PDA and the right marginal artery. Although rare, several anomalous courses of the RCA have been described including origin from the left aortic sinus (**Angelini, P. (15 July 2014). "Novel Imaging of Coronary Artery Anomalies to Assess Their Prevalence, the Causes of Clinical Symptoms, and the Risk of Sudden Cardiac Death". Circulation: Cardiovascular Imaging. 7 (4): 747–754. doi:10.1161/CIRCIMAGING.113.000278**). At the origin of the RCA is the conus artery. In addition, to supplying blood to the RV, the RCA supplies 25% to 35% of the LV. In 85% of patients (Right Dominant), the RCA gives off the PDA. In the other 15% of cases (Left Dominant), the PDA is given off by the LCX. The PDA supplies the inferior wall, ventricular septum, and the posteromedial papillary muscle. The RCA also supplies the SA nodal artery in 60% of people. The other 40% of the time, the SA nodal artery is supplied by the LCX. The RCA emerges from the aorta into the AV groove. It descends through the groove, then curves posteriorly, and makes a bend at the crux of the heart and continues downward in the posterior interventricular sulcus. Within millimeters after emerging from the aorta, the RCA gives off two branches: 1) the conus (arteriosus) artery which runs to the right ventricular outflow tract, and 2) the atrial branch which gives off the SA nodal artery (in ~ 50-73% of hearts), which runs along the anterior RA to the SVC , encircling it before reaching the SA node. The RCA continues in the AV groove and gives off a variable number of branches to the RA and RV. The most prominent of these is the **right marginal branch** which runs down the right margin of the heart supplying this part of the RV. As the right coronary curves posteriorly and descends downward on the posterior surface of the heart, it gives off two to three branches. **The AV nodal artery** which branches from the RCA at the crux of the heart and passes anteriorly along the base of the atrial septum to supply the AV node (in 50-60 % of hearts), proximal parts of the bundles branches of His, and the parts of the posterior interventricular septum that surround the bundle branches.

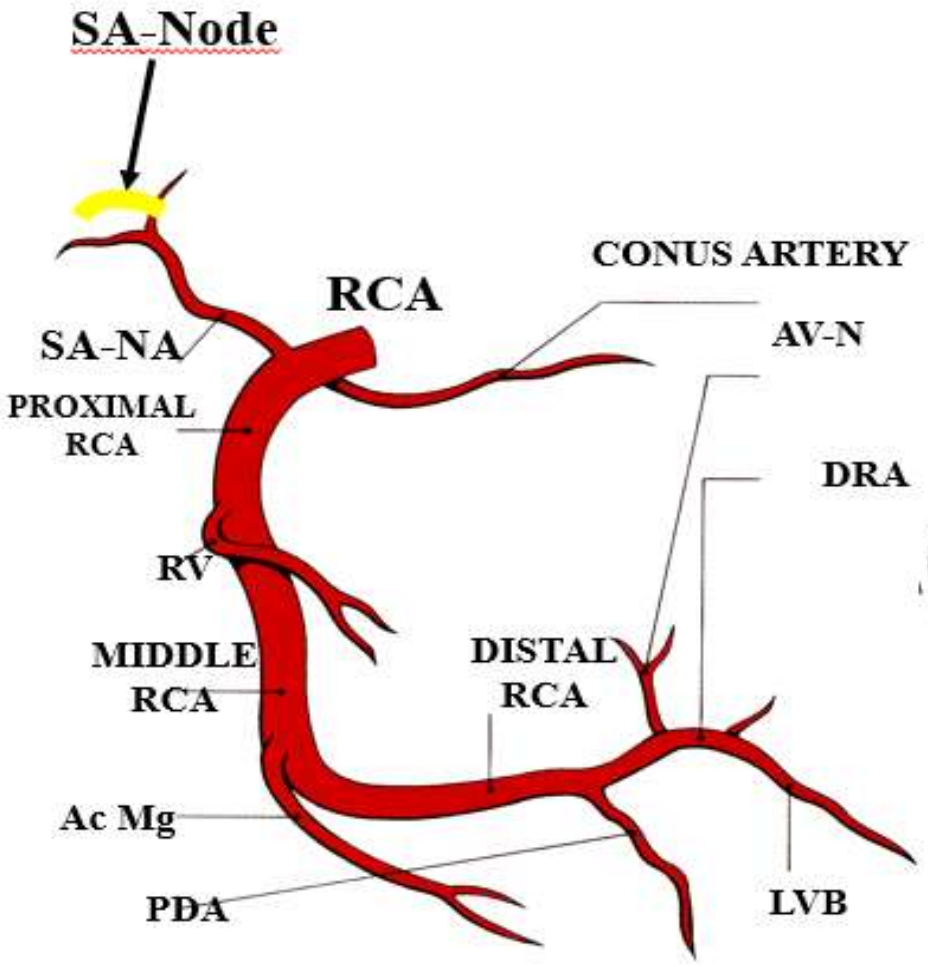
1. ***The conus (arteriosus) artery*** *which runs to the right ventricular outflow tract*, At the origin of the RCA is the conus artery. It ramus is only present in about 45 % of the human hearts, and which provides collateral blood flow to the heart when the LAD artery is occluded. (**Wynn GJ, Noronha B, Burgess MI (2008). "Functional significance of the conus artery as a collateral to an occluded left anterior descending artery demonstrated by stress echocardiography". International Journal of Cardiology. 140 (1): e14–5. doi:10.1016/j.ijcard.2008.11.039. PMID 19108914**.)(**Schlesinger MJ, Zoll PM, Wessler S (1949). "The conus artery: a third coronary artery". American Heart Journal. 38 (6): 823–38. doi:10.1016/0002-8703(49)90884-4. PMID 15395916**.)
2. ***The atrial branch*** *which gives off the* ***SA node/nodal artery*** *(in ~ 60 % of hearts), which runs along the anterior RA to the SVC, encircling it before reaching the SA node*. This is the second branch of the RCA (the first one is the conus artery) and in 38% of cases from the LCX and from both arteries in 3%.(**Kyriakidis MK, Kourouklis CB, Papaioannou JT, Christakos SG, Spanos GP, Avgoustakis DG. Sinus node coronary arteries studied with angiography. Am J Cardiol. 1983 Mar 1;51:749-750.**) The sinoatrial nodal artery is an artery of the heart which supplies the SA-Node, the natural pacemaker of the heart, and arises from the RCA in around 60% of cases. In about 40% of cases, the sinoatrial artery is a branch of the LCX.(**Pejković B, Krajnc I, Anderhuber F, Kosutić D (July 2008). "Anatomical aspects of the arterial blood supply to the sinoatrial and atrioventricular nodes of the human heart". Journal of International Medical Research. 36 (4): 691–8. doi:10.1177/147323000803600410. PMID 18652764**.) In less than 1% of cases, the artery has an anomalous origin directly from the coronary sinus, descending aorta, or distal RCA. In > 50% of cases, the artery actually courses close to the superior posterior aspect of the interatrial septum. (**Click RL, Holmes DR Jr, Vliestra RE et al. Anomalous coronary arteries: Location, degree of atherosclerosis and effect on survival-A report from the coronary artery surgery study. J Am Coll Cardiol 1989; 13:531-537**.).The origin of the Sinoatrial node artery is not related to coronary artery dominance, which means the side (right or left) that provides the circulation to the back of the

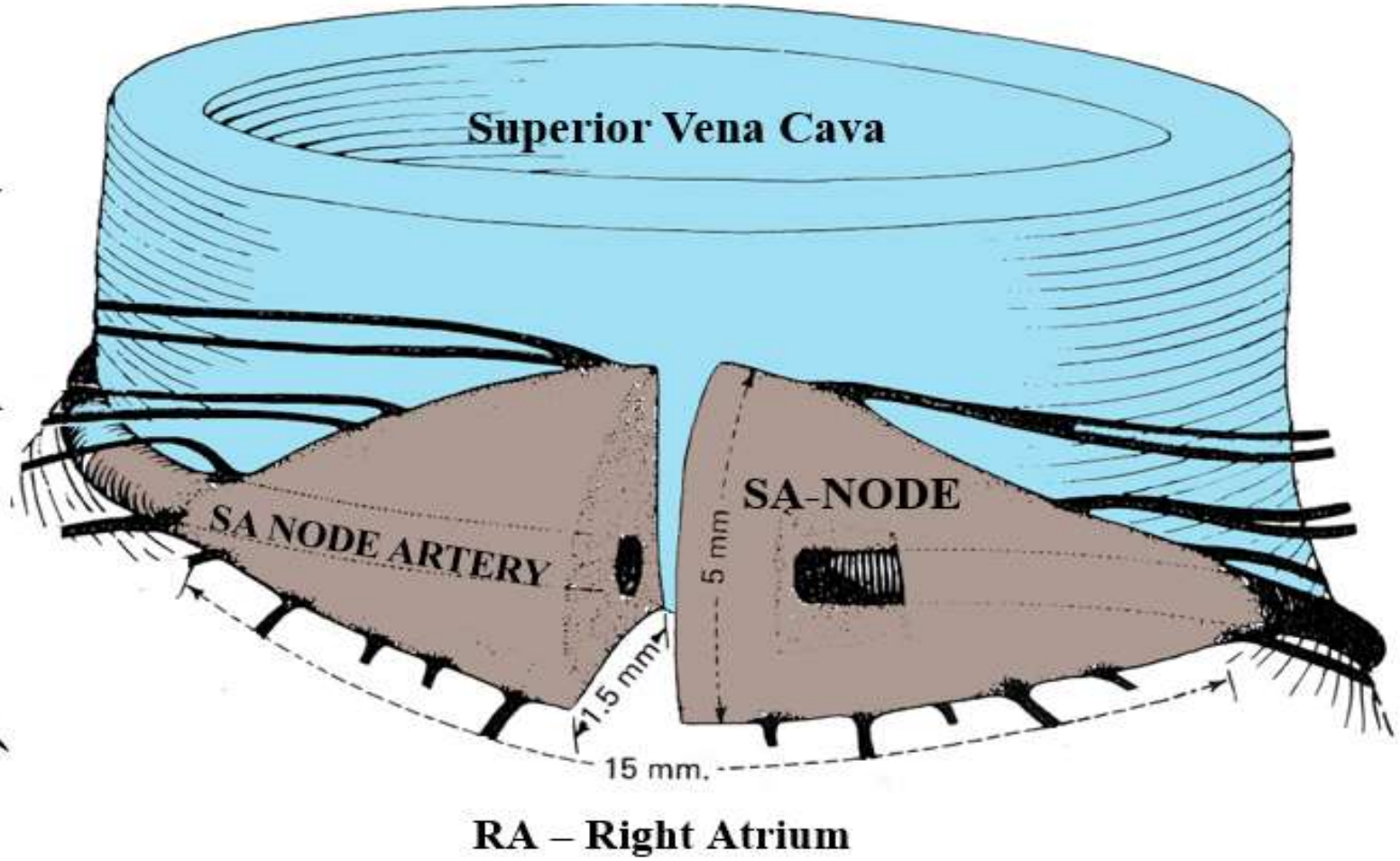
heart. In contrast, the AV nodal branch, that is the artery that brings blood to the AV-Node, depends on coronary artery dominance. The SA-Node surrounds the sinoatrial artery, which can run centrally (in 70% of individuals) or off center within the node.(**Sanchez-Quintana D, Anderson RH, Cabrera JA, et al. The terminal crest: morphological features relevant to electrophysiology. Heart 2002;88: 406–411**.) A left S-shaped sinoatrial node artery, originating from the proximal LCX artery, has been described as a common variant in ≈10% of cases.(**Saremi F, Channual S, Abolhoda A et al. MDCT of the S-shaped sinoatrial node artery. Am J Roentgenol 2008; 190:1569-1575**.) This artery is larger than normal and supplies a good part of the LA, but also right sided structures like part of the SA-Node and the AV nodal areas. In this variant, the artery courses in the sulcus between the left superior pulmonary vein and the left atrial appendage where it could be susceptible to injury during catheter or surgical ablation.

3. ***Atrioventricular nodal branch:*** The atrioventricular nodal branch is a cardiac artery that is crucial because it feeds the AV-Node. In over 80% of hearts it arises as a distal branch from the RCA near the crux of the heart. In ≈ 18% the AV-Node instead receives blood from the LCX. In ≈ 2% of cases, the vascular supply to the AV-Node arises from both the RCA and the LCX (**Sow ML, Ndoye JM, Lo EA. The artery of the atrioventricular node: an anatomic study based on 38 injection-dissections. Surg Radiol Anat 1996;18:183–187**)
4. ***Right marginal branch/artery****; of is a large marginal branch which follows the acute margin of the heart and supplies blood to both surfaces of the RV.*
4. ***Posterior descending artery (PDA); It is typically a branch of the RCA (70%, right dominance).***
5. ***Posterolateral artery #1 (PL#1) and***
6. ***Posterolateral artery #2 (PL#2)***

Blood supply of SA-Node

In the majority of individuals (≈ 59% of cases), the SA-Node receives blood from a SA node artery. This is the second branch of the RCA (the first one is the conus artery) and in 38% of cases from the LCX and from both arteries in 3% in remain.





Summary of the Right Coronary Artery - Basic Anatomy

- **Origin**
  Right aortic sinus (lower origin than Left Coronary Artery
- **Course**
  Down right AV groove toward crux of the heart, gives off PDA (85%) from which septal branches arise, continues in LAV groove giving off posterior LV branches (posterolateral). PDA may originate more proximally, bifurcate early of be small with part of "its territory" supplied by an acute marginal branch.
- **Supplies**
  25% to 35% if the Left ventricle.

Right Coronary Artery - Other Branches

- **Conus Artery**
  Usually very proximal (≈50% have a separate origin) –courses anteriorly and upward over the RVOT toward the LAD. May be an important source of collaterals.
- **SA Node Artery**
  (≈69%) usually 2nd branch of RCA-courses obliquely backward through upper portion of atrial septum and anteromedial wall of the RA-supplies SAN, usually RA and sometimes LA.
- **Right ventricular (Acute Marginal Branches)**
  Arise form mid RCA; supply anterior RV; may be a collateral source
- **AV Nodal Artery**
  Arise at or near crux; supplies AV node.
- **PDA**

  Supplies inferior wall, ventricular septum, and posteromedial papillary muscle

Right Coronary Artery: Optimal View

- **LAO (30°) Cranial 30°) LAO** refers to rotating the camera to the patient's left (catheter and spine will be on the right side of the image),

  Particularly this projection is indicate for distal bifurcation (AP Cranial may be better)

- **RAO:** to the patient's right (catheter and spine on the left side of the image). Angulation describes the position of the image intensifier in the short axis of the patient.

  Main shaft; cranial enhances distal vessels and very proximal; caudal may help with shepherd´s crook

- **Lateral**

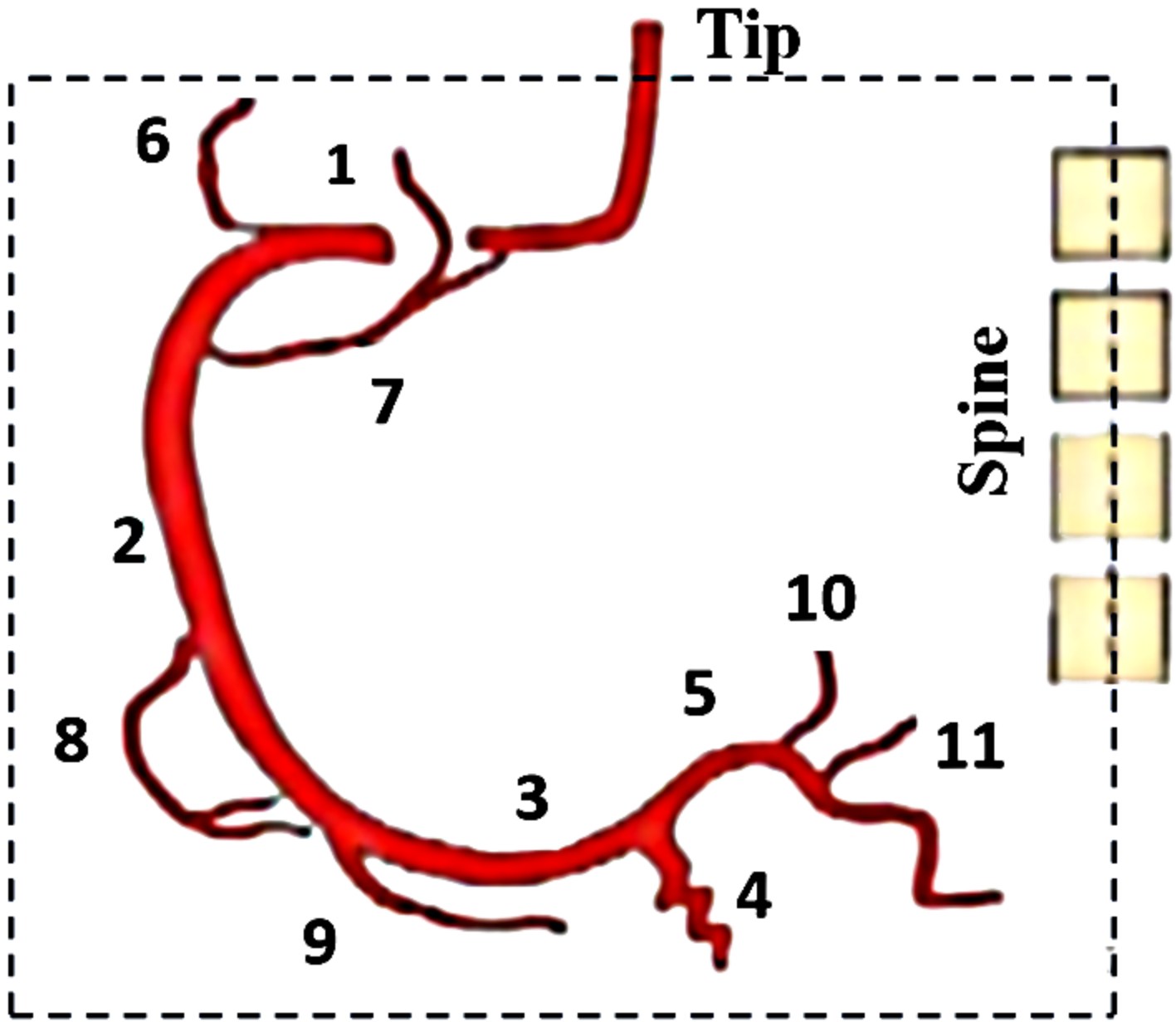
  Bifurcations with RV branches-distal bifurcation, particularly with cranial.

Standard Angiographic Views

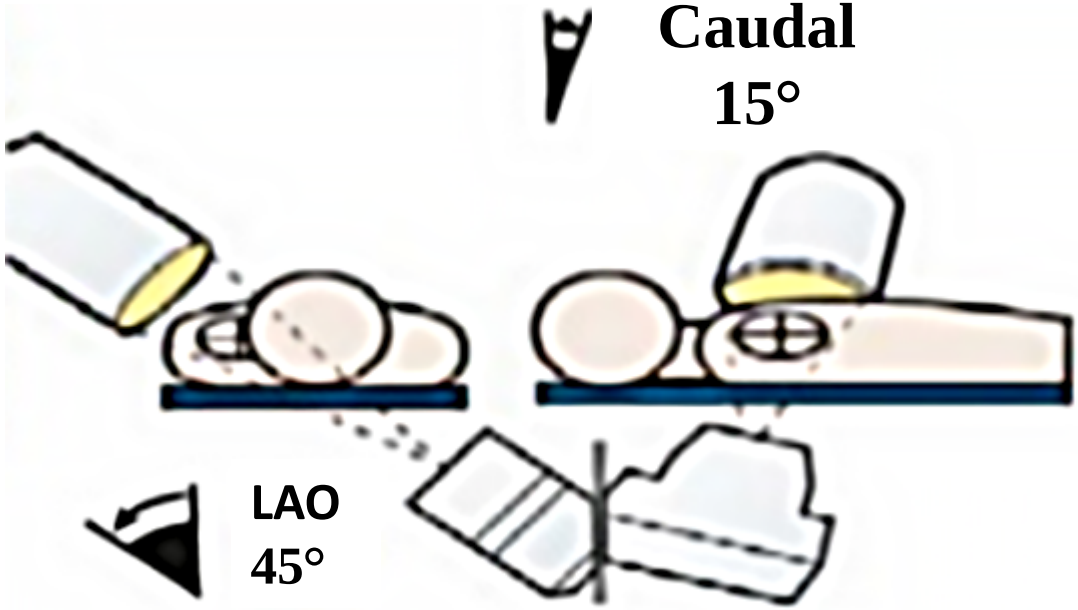
- **LAO 30 30° LAO**
  - Best for visualizing ostial and proximal RCA
- **RAO**
  - Best for visualizing mid RCA and PDA
- **PA Cranial: PA and 30° cranial**
  - Best for visualizing distal RCA bifurcation and the PDA

Left Anterior Oblique Projection at 45° combined with a caudal angulation of 15°

This projection allows the whole study of the RCA and especially, clearly defines the region of the crux cordis

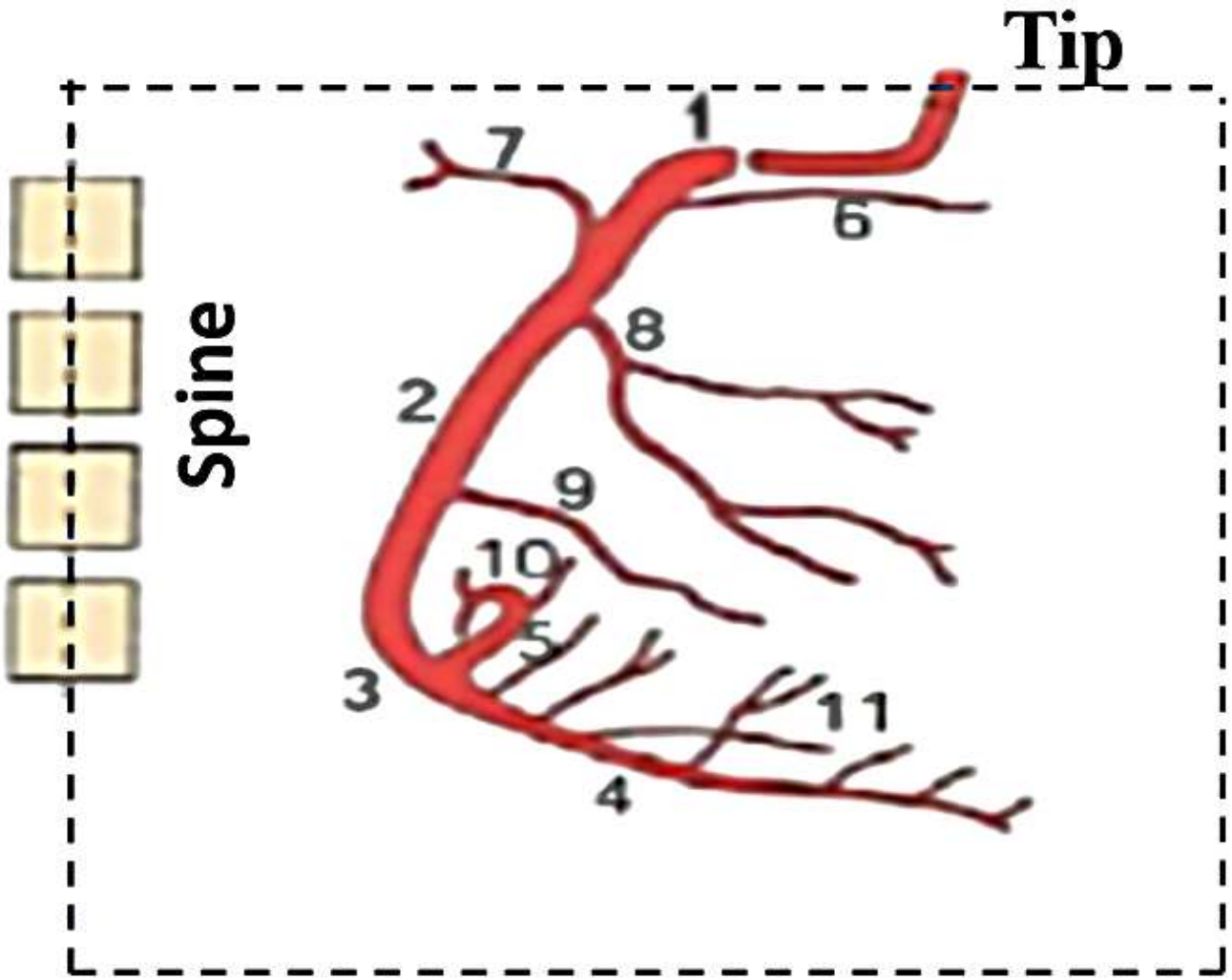


1. First (horizontal) segment of the RCA
2. Second(vertical) segment of the RCA
3. Third(horizontal) segment of the RCA
4. Posterior interventricular
5. Retro ventricular artery
6. Conus branch
7. Artery of the SAN
8. Right ventricular artery
9. Right marginal artery
10. Artery of the AV-Node
11. Diaphragmatic artery

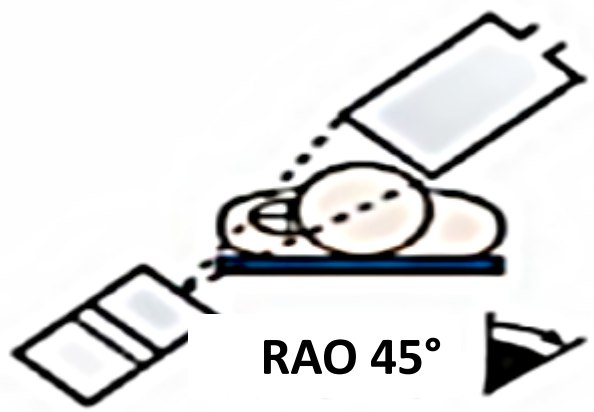


Right Anterior Oblique (RAO) Projection at 45°

The RAO projection at 45° permits the survey of the second(vertical) segment of the RCA, the posterior interventricular artery and the collateral branches(right ventricular and right marginal arteries) On the other hand, the first segment and third segment as well MAs the retro ventricular artery are not clearly defined. This projection also allows the visualization of the retrograde re opacification of the distal part of LAD proximally occluded.

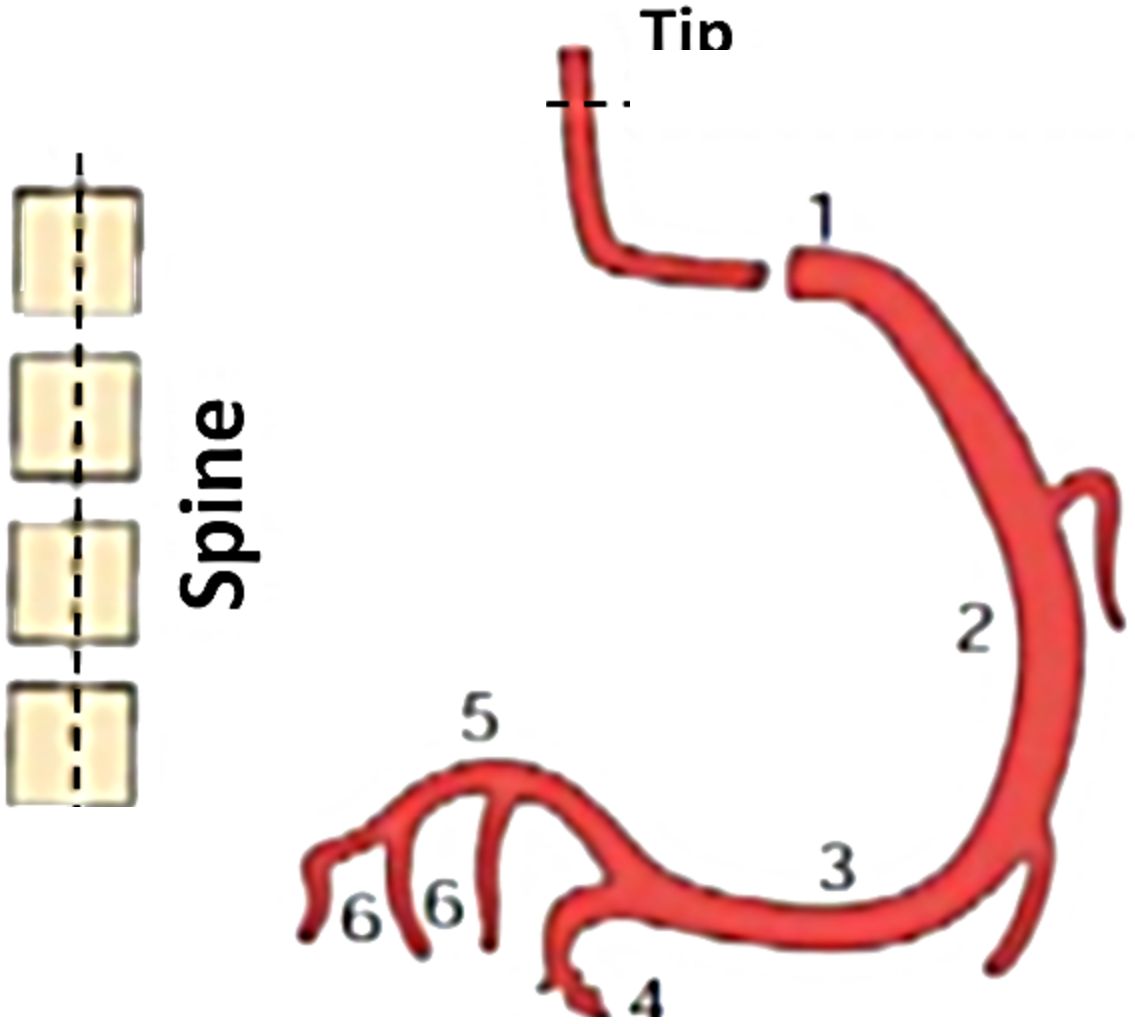


1. First (horizontal) segment
2. Second (vertical) segment of the RCA
3. Third (horizontal segment of the RCA
4. PDA
5. Retro ventricular artery
6. Conus branch
7. Artery of the SAN
8. Right ventricular artery
9. Right Marginal Artery
10. Artery of the AV Node
11. Inferior Septal Arteries

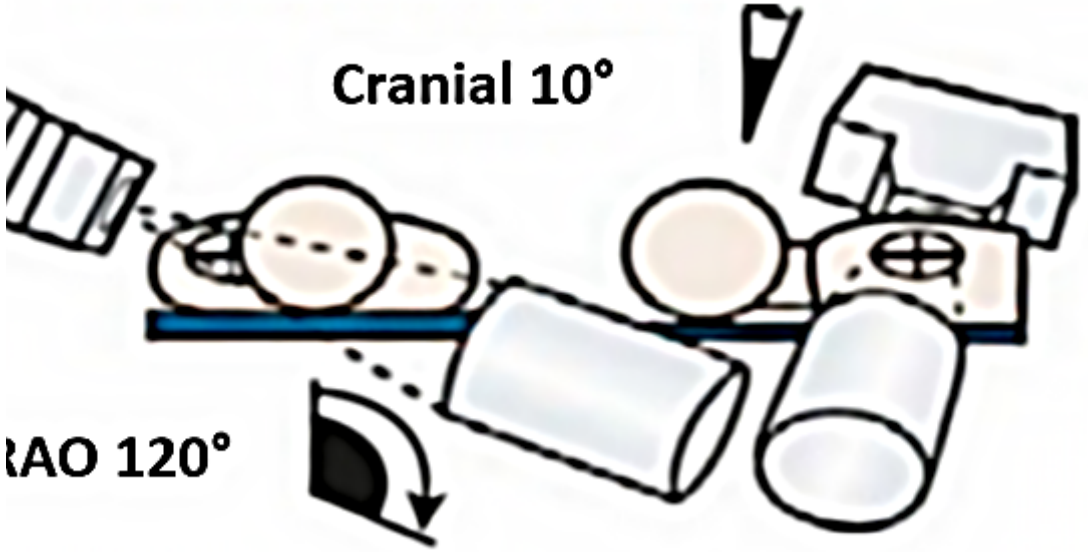


Right anterior oblique projection 120° combined with a cranial angulation of 10°

This projection is very useful for studying the third horizontal segment, the crux cordis, and the retro ventricular artery and its branches.

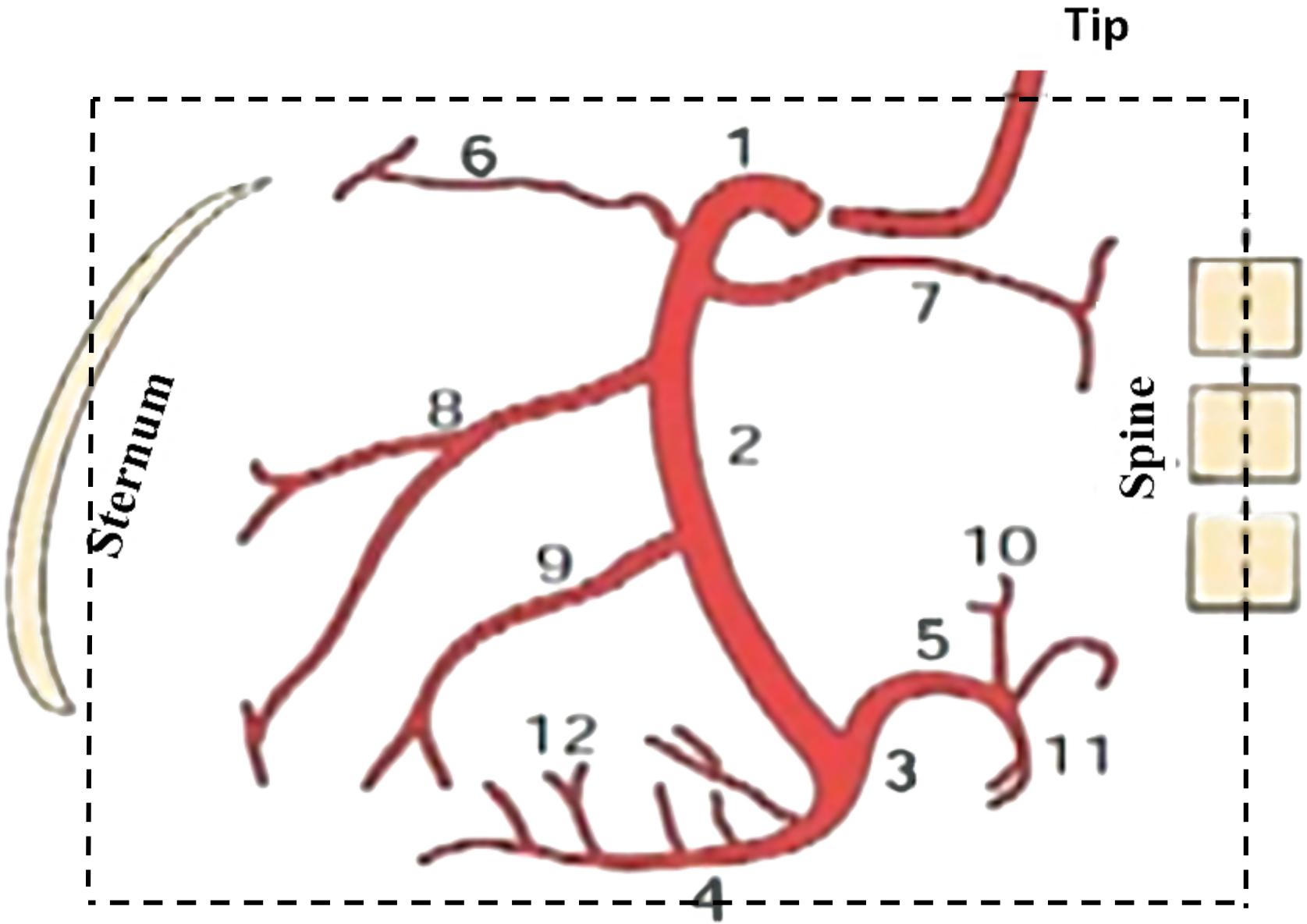


1. First (horizontal segment of the RCA
2. Second (vertical) segment of the RCA
3. Third (horizontal) segment of the RCA
4. Posterior interventricular artery
5. Retro ventricular artery
6. Diaphragmatic artery

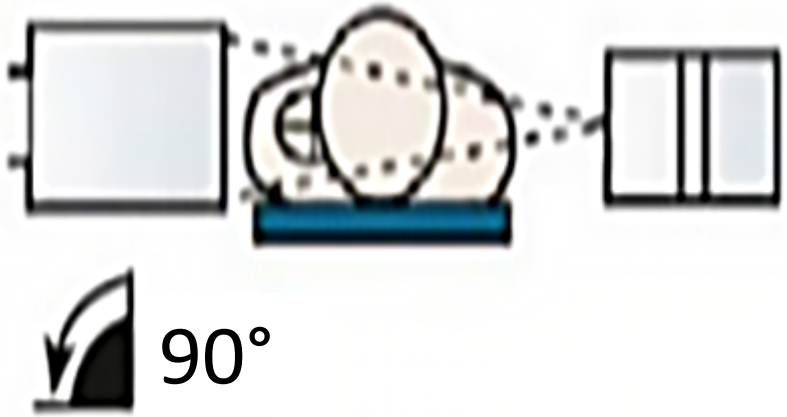


Left Lateral Projection

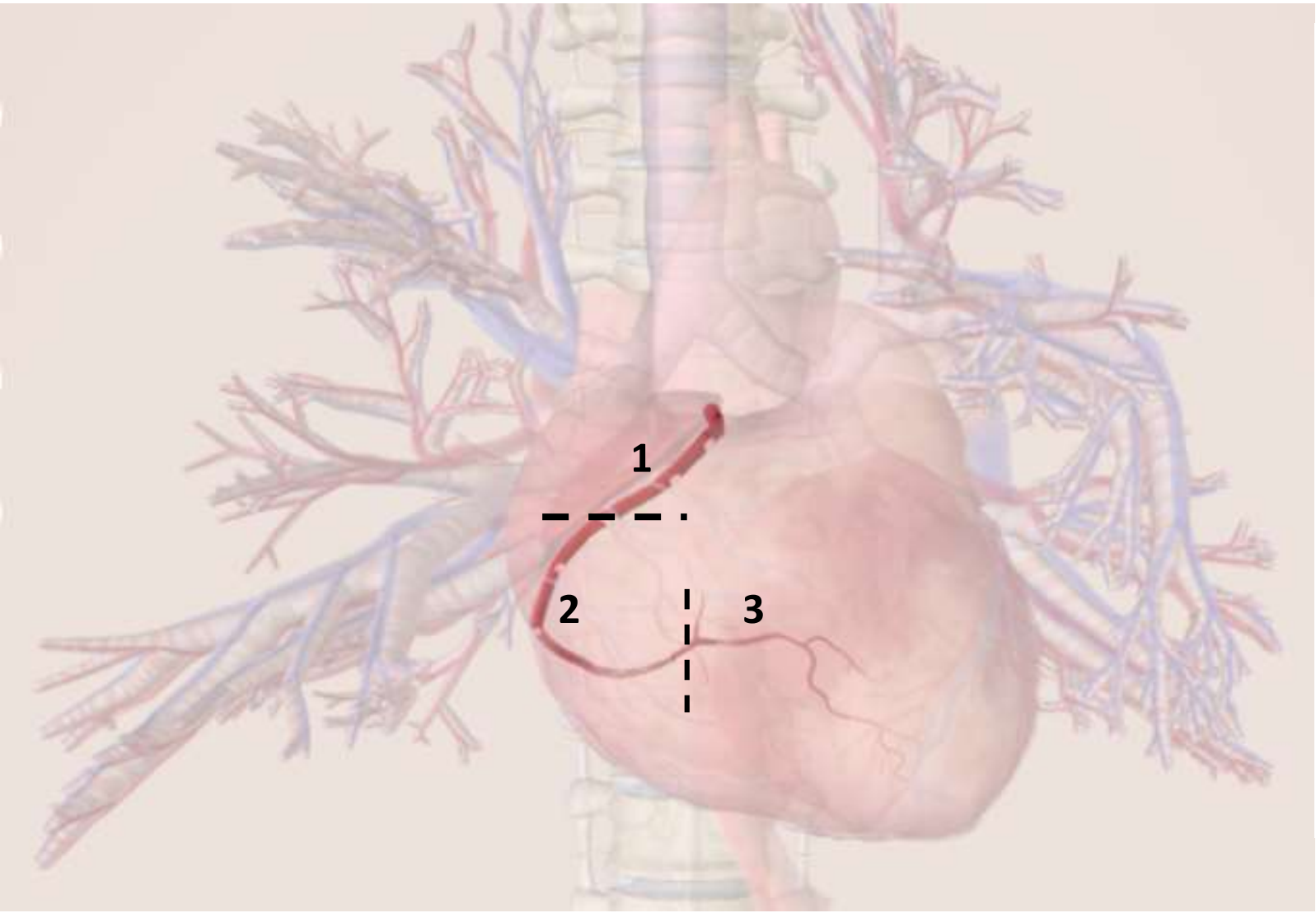
This projection permits the study of the second (vertical) segment of the RCA and the collateral branches (conus branch RV artery, right marginal artery

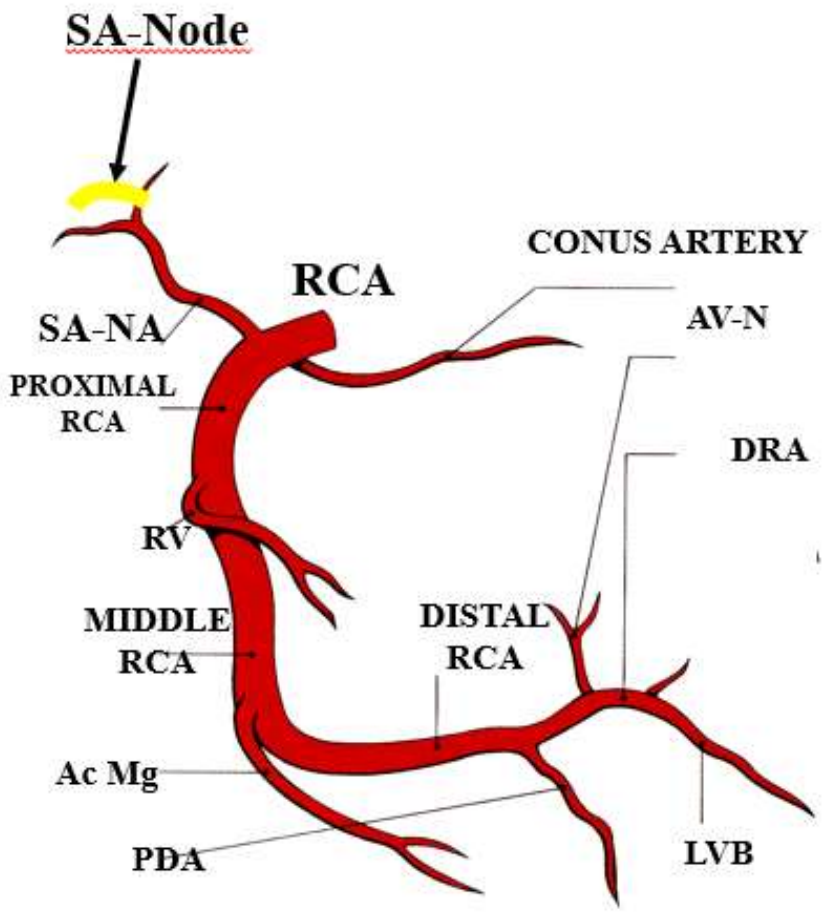


1. First horizontal segment of the RCA
2. Second(vertical) segment of the RCA
3. Third (horizontal) segment of the RCA
4. Posterior interventricular artery
5. Retro-ventricular artery
6. Conus branch]Artery of the sinus node
7. Right ventricular artery
8. Right marginal artery
9. Inferior septal arteries



Right Coronary Artery (RCA): Proximal, Middle and Distal parts

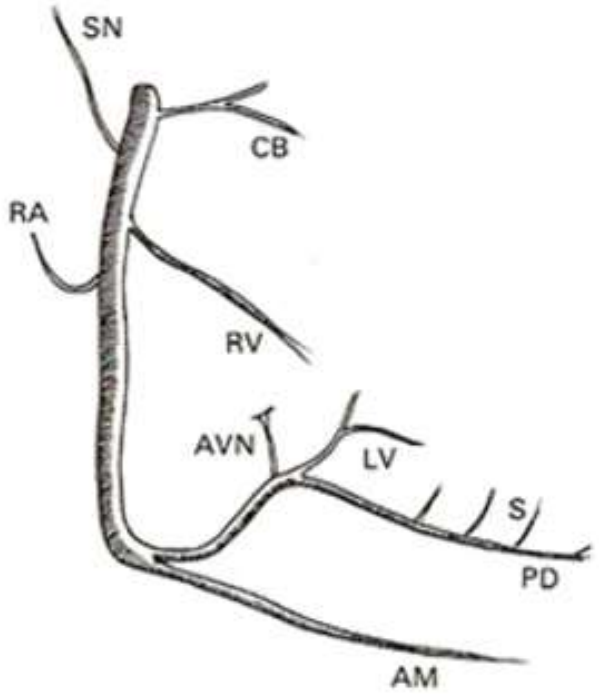


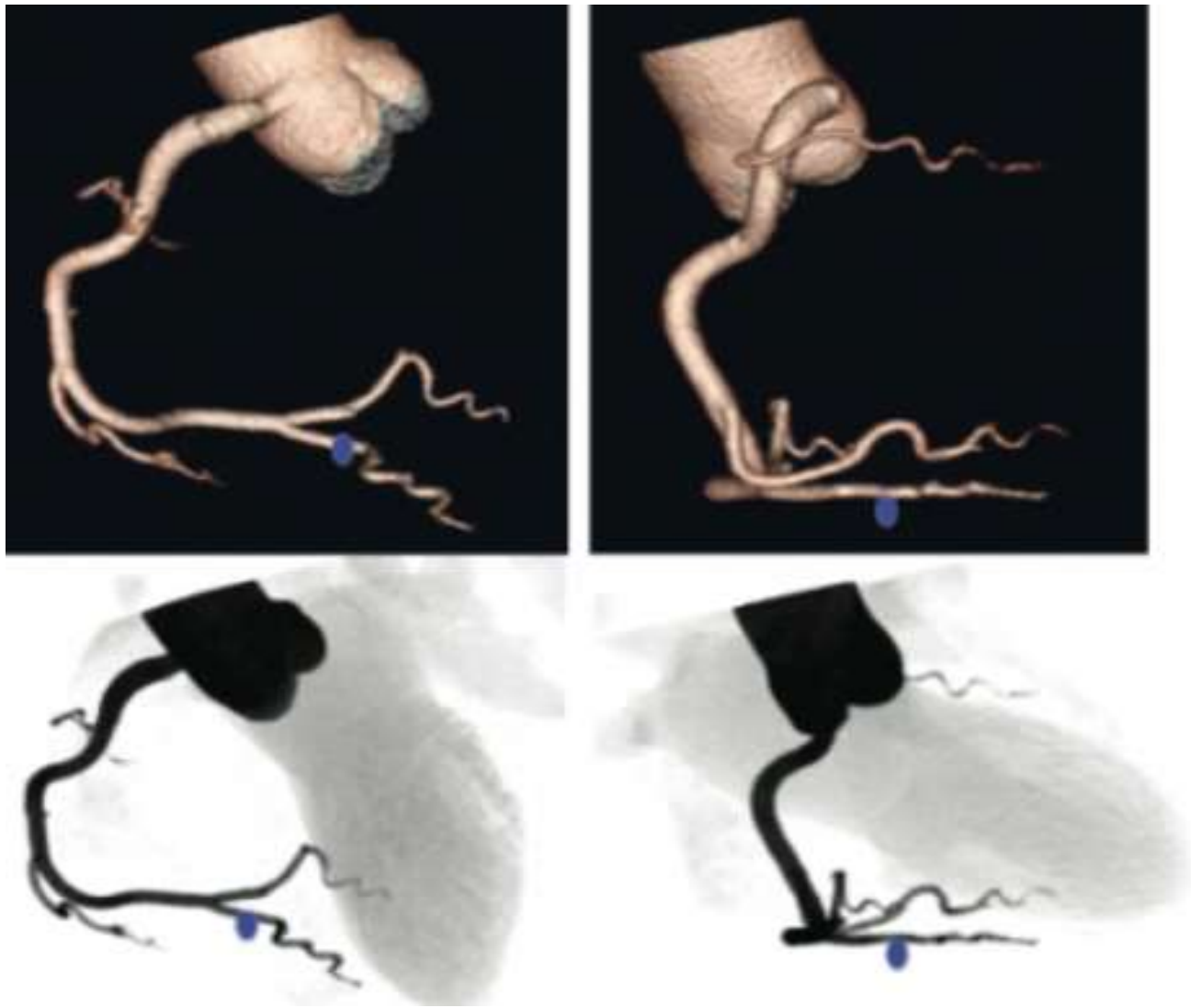


1, Proximal part of RCA: R-1 segment; 2. Middle part of RCA: R-2 segment; 3, Distal part of RCA: R-3 segment .

Coronary Angiography Right Coronary Artery RCA

RAO Right Anterior Oblique

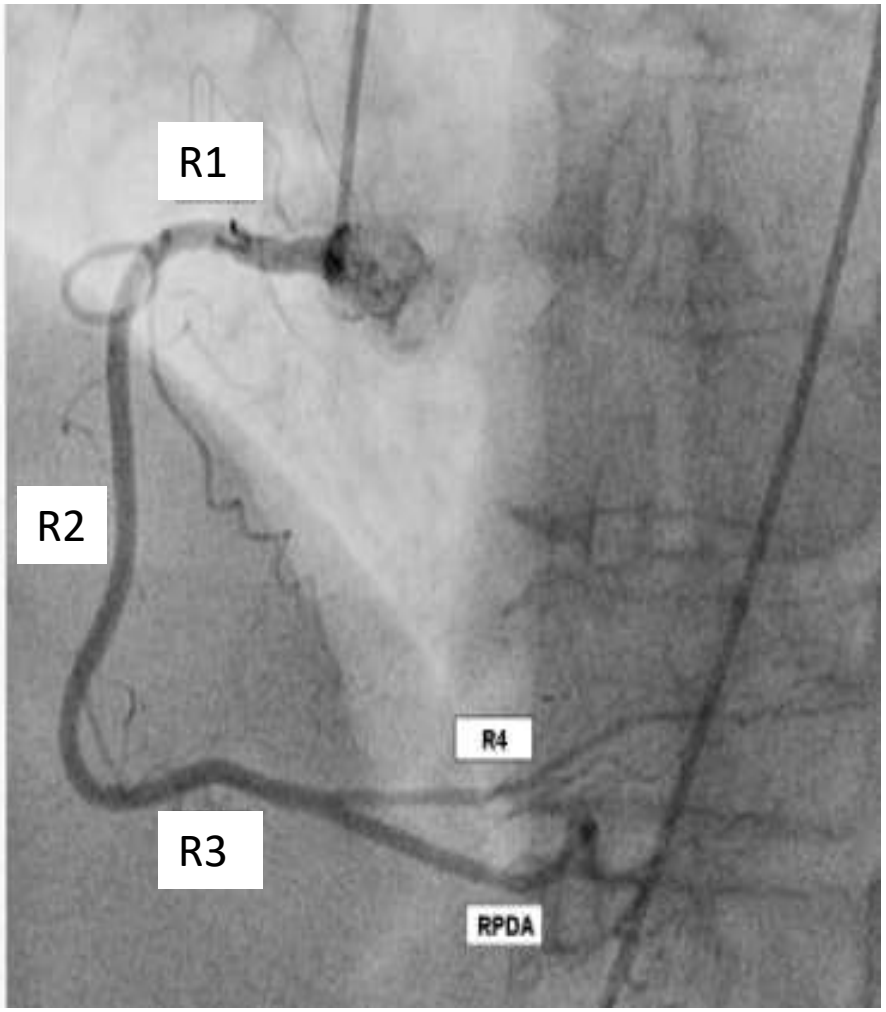


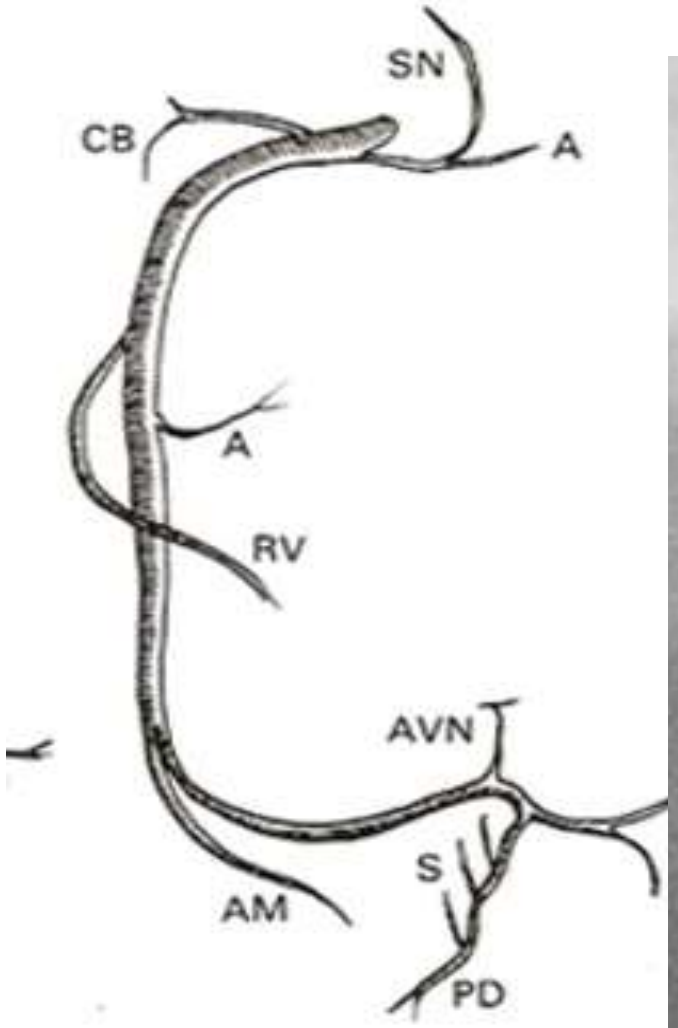


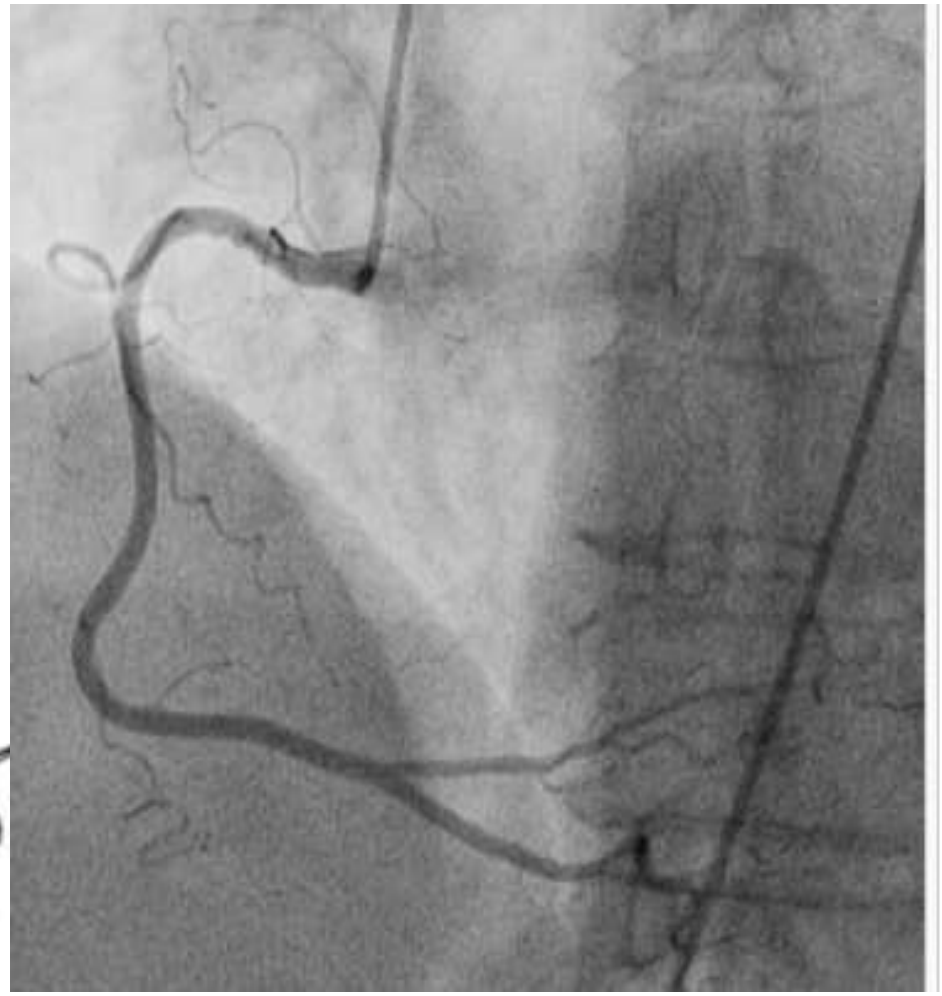
CTA reconstruction of the RCA in the left anterior oblique (LAO) view, cranial(left) and right anterior oblique(RAO) (no cranial or caudal(right) angulations. The lower drawing are salutations of the images that are seen on contrast angiography

LAO

The Proximal RCA (R1 segment) including the ostium is best visualized in the 30° LAO view with no cranial or caudal angulation.

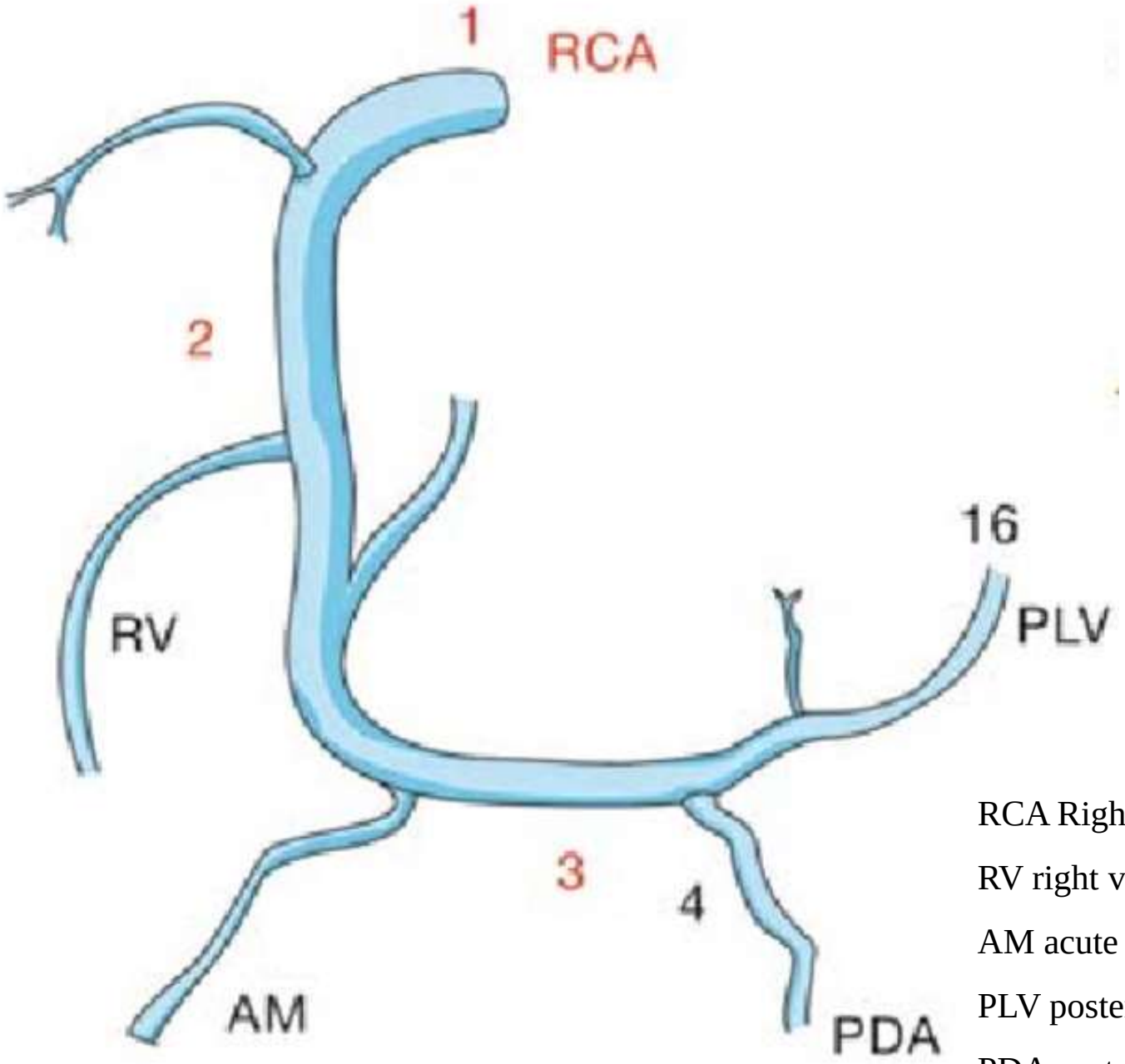


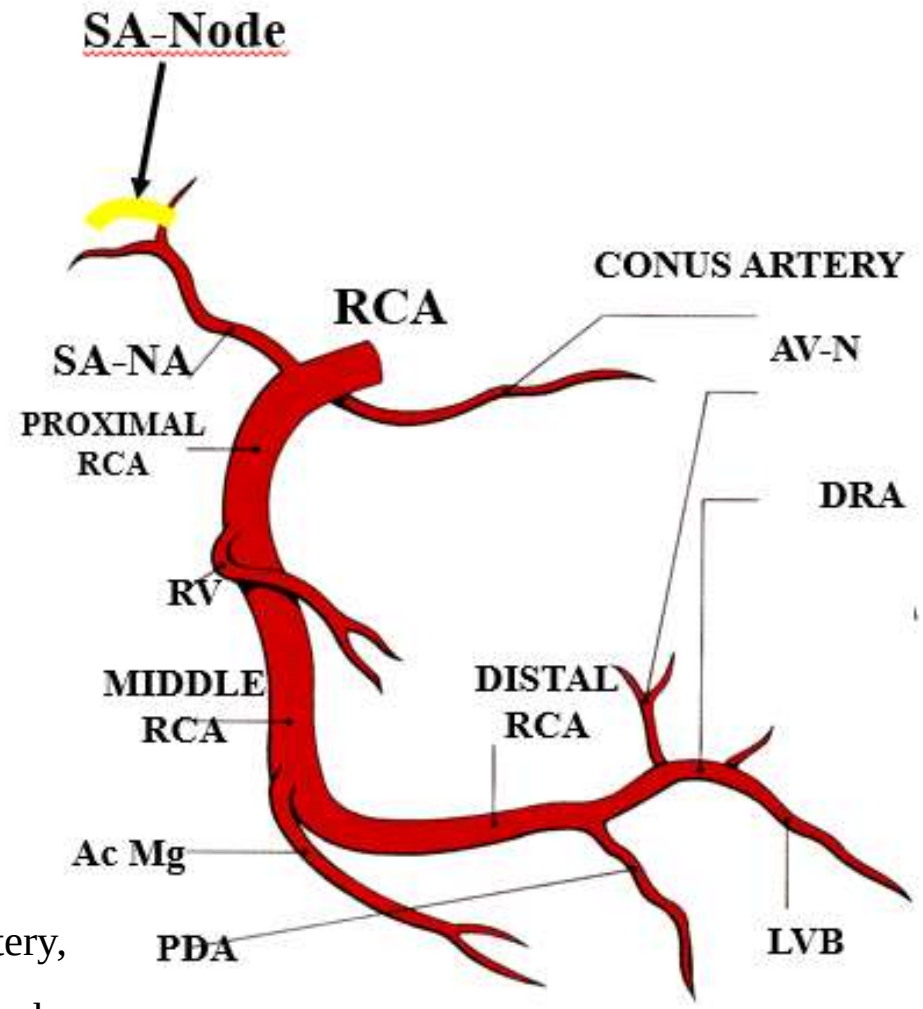




R1: Proximal part of RCA: **R2:** Middle part of RCA; **R3:** Distal part of RCA.

The American Heart Association division of the Coronary tree





RCA Right coronary artery,

RV right ventricular branch,

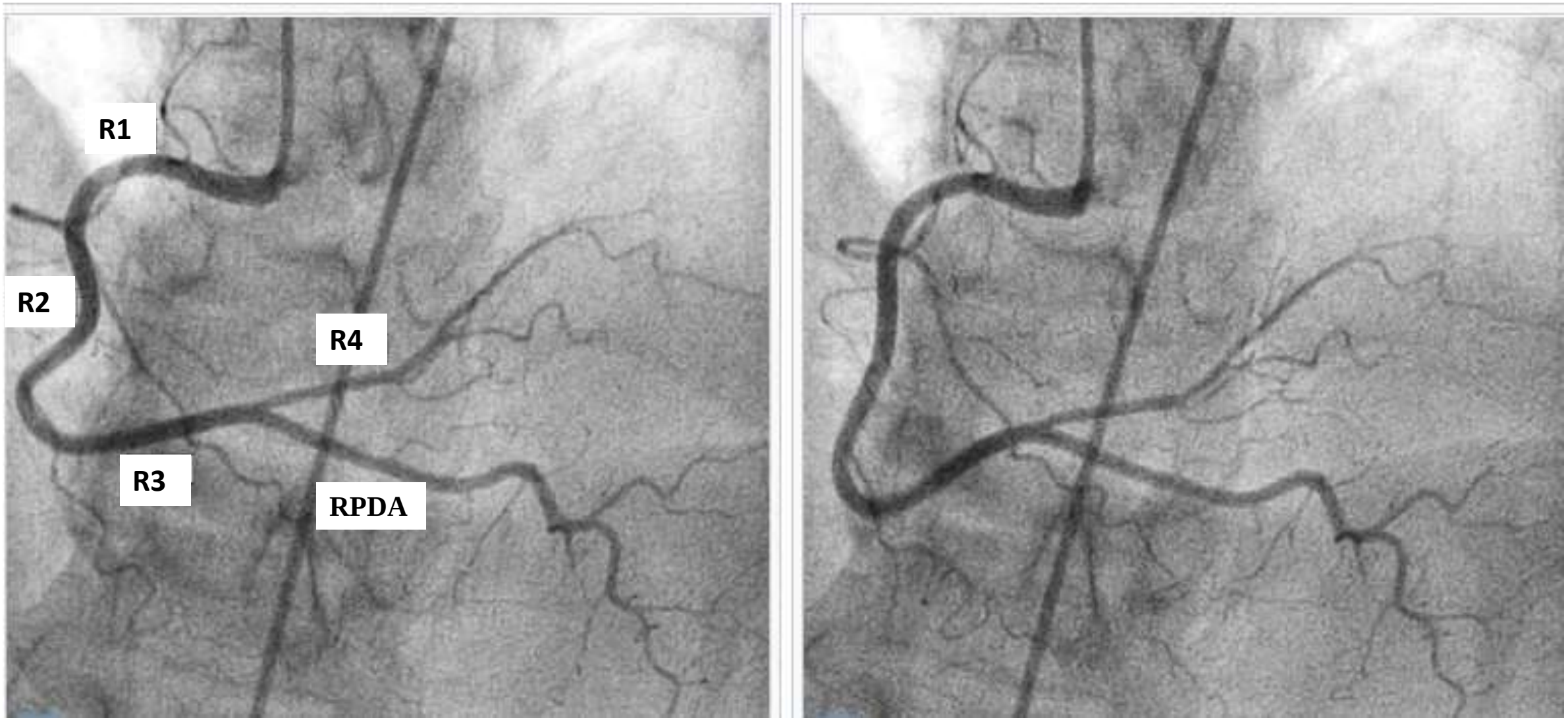
AM acute marginal branch,

PLV posterolateral ventricular branch,

PDA posterior descending artery,

Bifurcation of the RCA

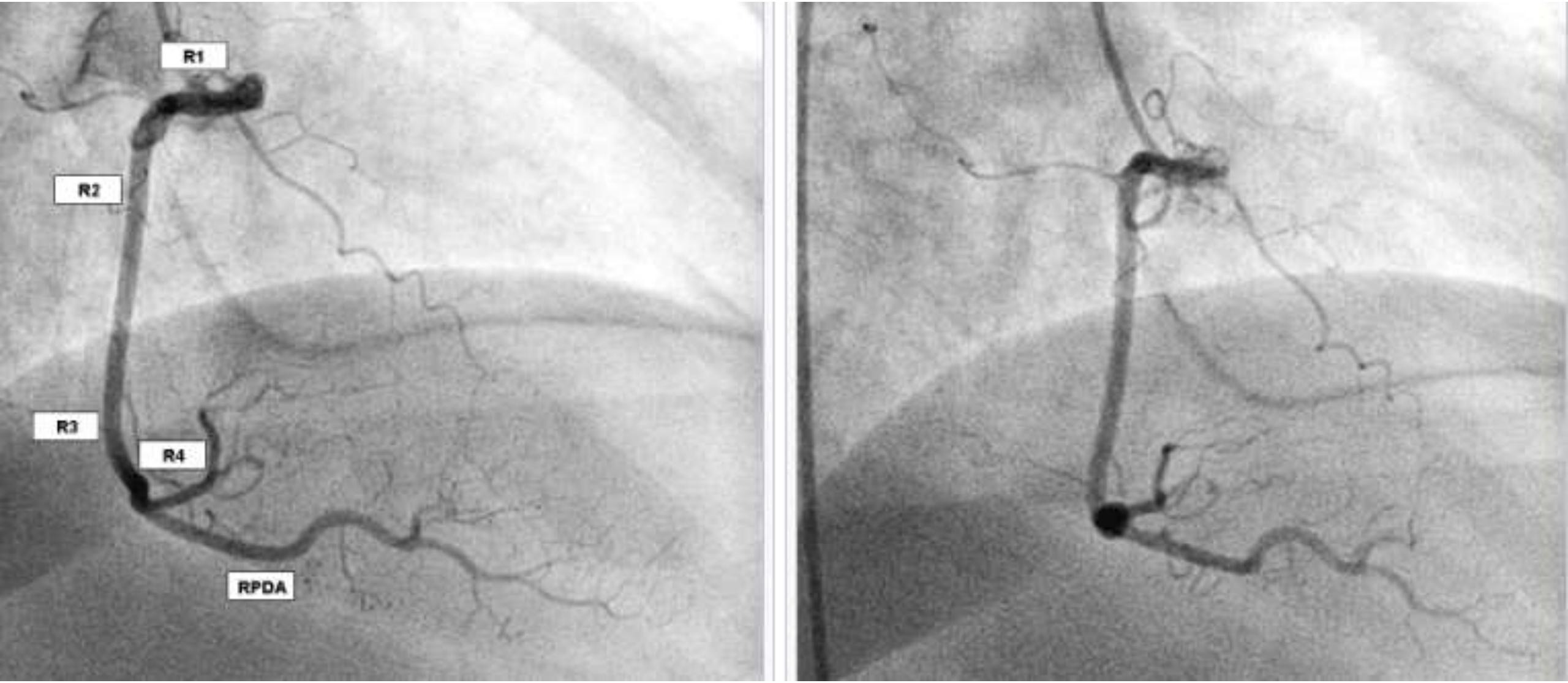
The camera is cranial to 15° - 20° and the LAO angulation is minimized to 5° - 10°. This view optimizes the bifurcation of the distal RCA where the right posterolateral artery and the posterior descending artery divide and branch from the distal RCA. The patient should take a deep breath and hold it during the injection to optimize the view.



R1 = Proximal RCA; **R2 =** Middle RCA**; R3** = Distal RCA; **RPDA =** Right posterior descending artery.

Mid RCA

The middle RCA (R2 segment) is best visualized in the 30° RAO straight view.

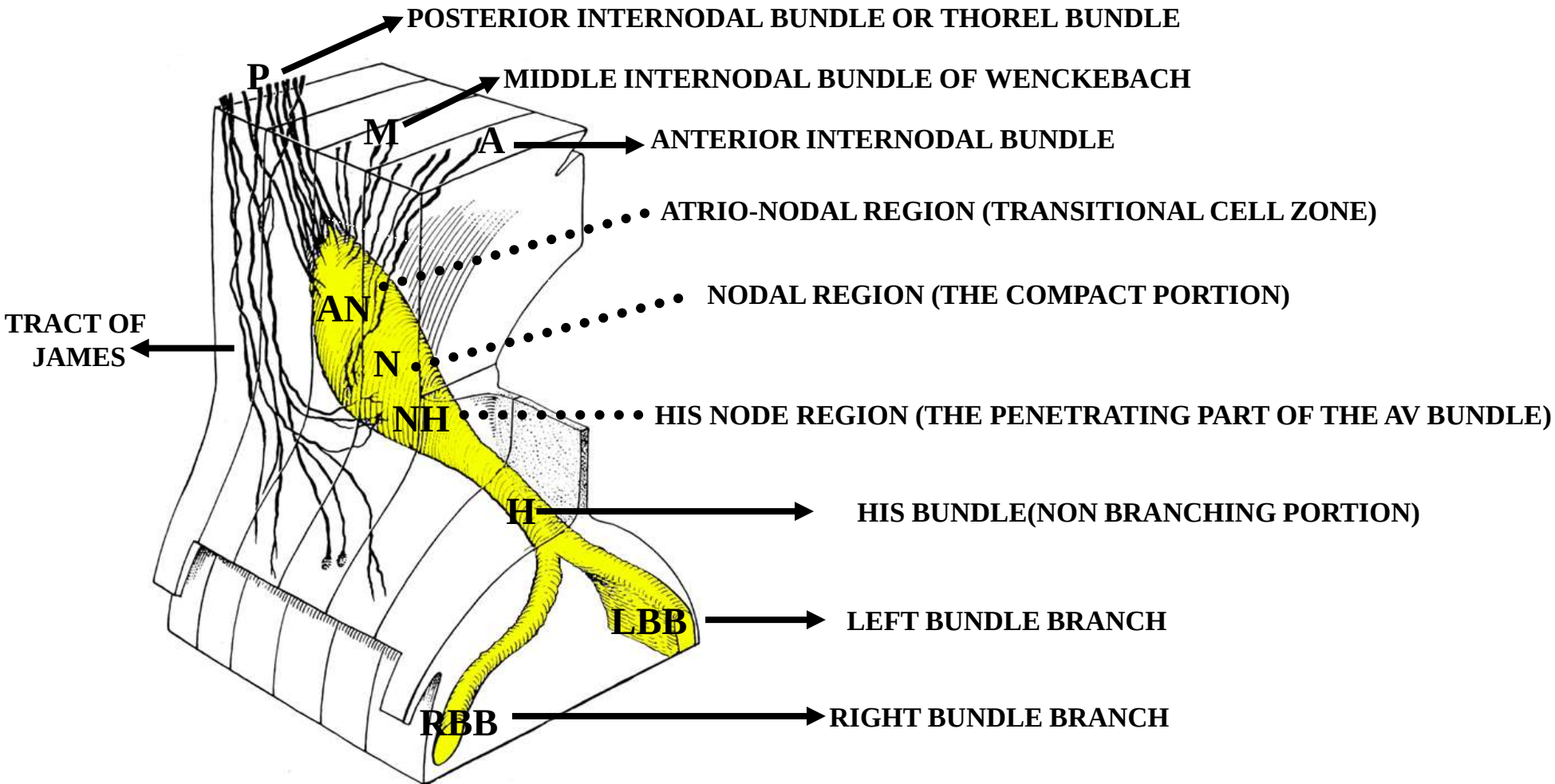


R1 = Proximal RCA; R2 = Middle RCA; R3 = Distal RCA; RPDA = Right posterior descending artery.

The junctional or atrioventricular area

The AV junction can be divided into 3 regions as follows:

1. Transitional cell zone = AN: Atrionodal Region
2. Compact AV node = N: Nodal Region
3. Penetrating portion of the AV bundle = NH
4. Penetrating portion of His bundle = H



BLOOD SUPPLY OF THE COMPACT AV NODE

In 85% of cases AV node receives its blood supply from the RCA. In the remaining 13% by the **LCX** and in 2% by both arteries[1].

The AV node becomes the AV His bundle at the point where the overall axis for conduction penetrates into the central fibrous body[2].

BLOOD SUPPLY OF THE HIS BUNDLE

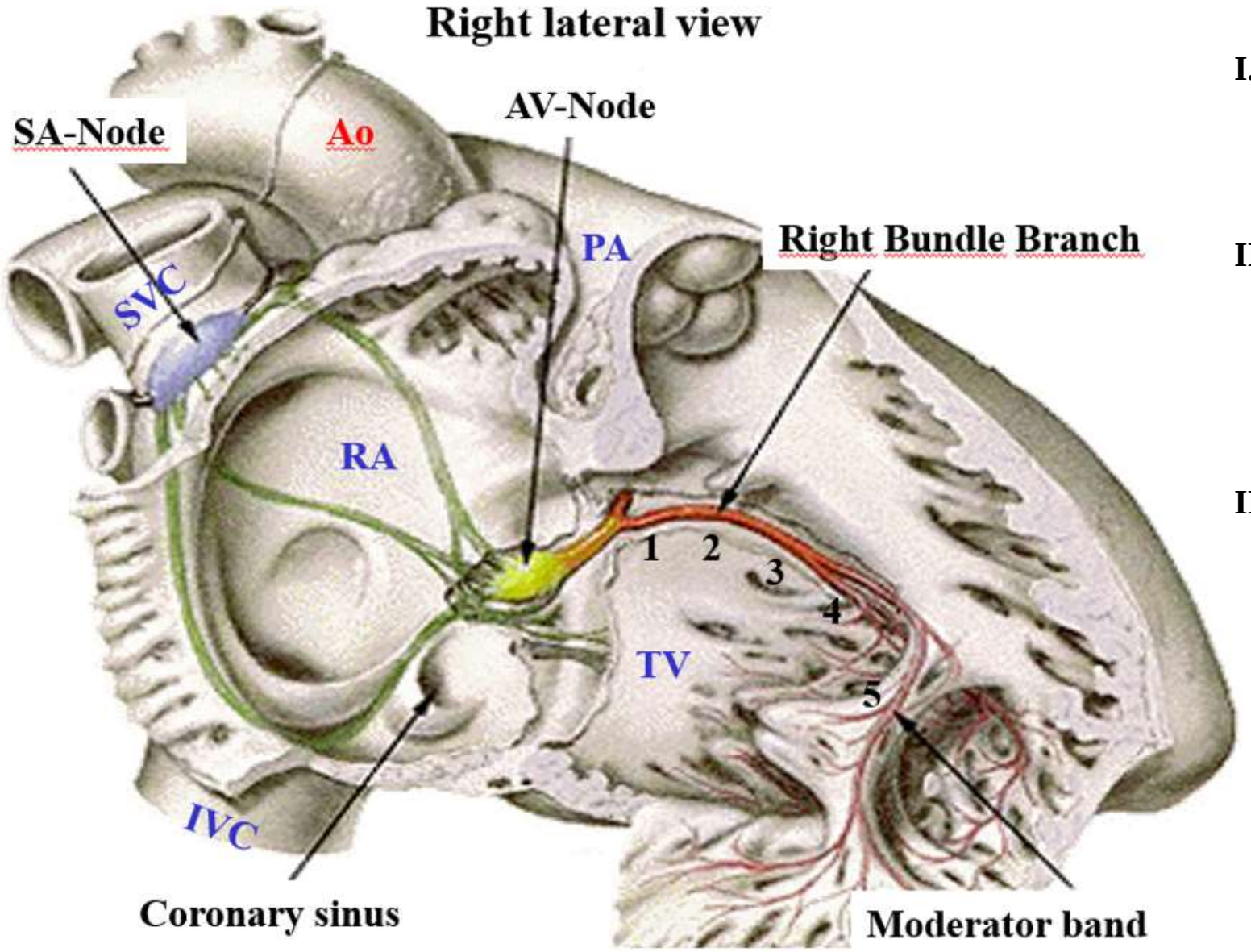
This structure has double blood supply: from branches of the LAD and PDA[3].

- **BLOOD SUPPLY OF THE LEFT BUNDLE BRANCH (LBB)** branches of the PDA (90% of the RCA): AV node artery: ramus septi fibrosi, ramus septi ventriculorum superior and ramus cristae.
- Branches of LAD: Ramus limbi sinistri (equivalent to ramus limbi dextri of the LDA). Consequently, the blood supply to the LBB is dual: RCA atrioventricular branch (90% of hearts) and septal perforator branches of the LAD (10% of hearts) https://www.pharmacology2000.com/Cardio/Cardio_risk/adult_cardiac_procedures/anatomy4.htm

)

1. **Hadziselimović H. Vascularization of the conducting system in the human heart. Acta Anat (Basel). 1978;102:105-110.**
2. **Anderson RH, Ho SY, Becker AE. Anatomy of the human atrioventricular junctions revisited. Anat Rec. 2000 Sep 1;260:81-91.**
3. **Lumg G, Singletary HP. Blood Supply to the Atrioventricular Node and Bundle of His: A Comparative Study in Pig, Dog, and Man Am J Pathol. 1962 Jul;41:65-75.**

Right Bundle Branch on right septum surface of right ventricle



I. **Proximal portion: 1+2** is irrigated by the AV node artery of the RCA and the first septal perforator artery (S_1) of the LAD.

II. **Middle portion: 3** is irrigated by: Posterior Septal perforators of the PDA and the second septal perforator artery(S_2) of the LAD and Kugel's artery, branch of the LCX.

III. **Middle and distal portion: 4** are irrigated by the "Ramus limbi dextri", branch of the S_2 of the LAD.

Blood supply of the Right Bundle Branch (RBB)

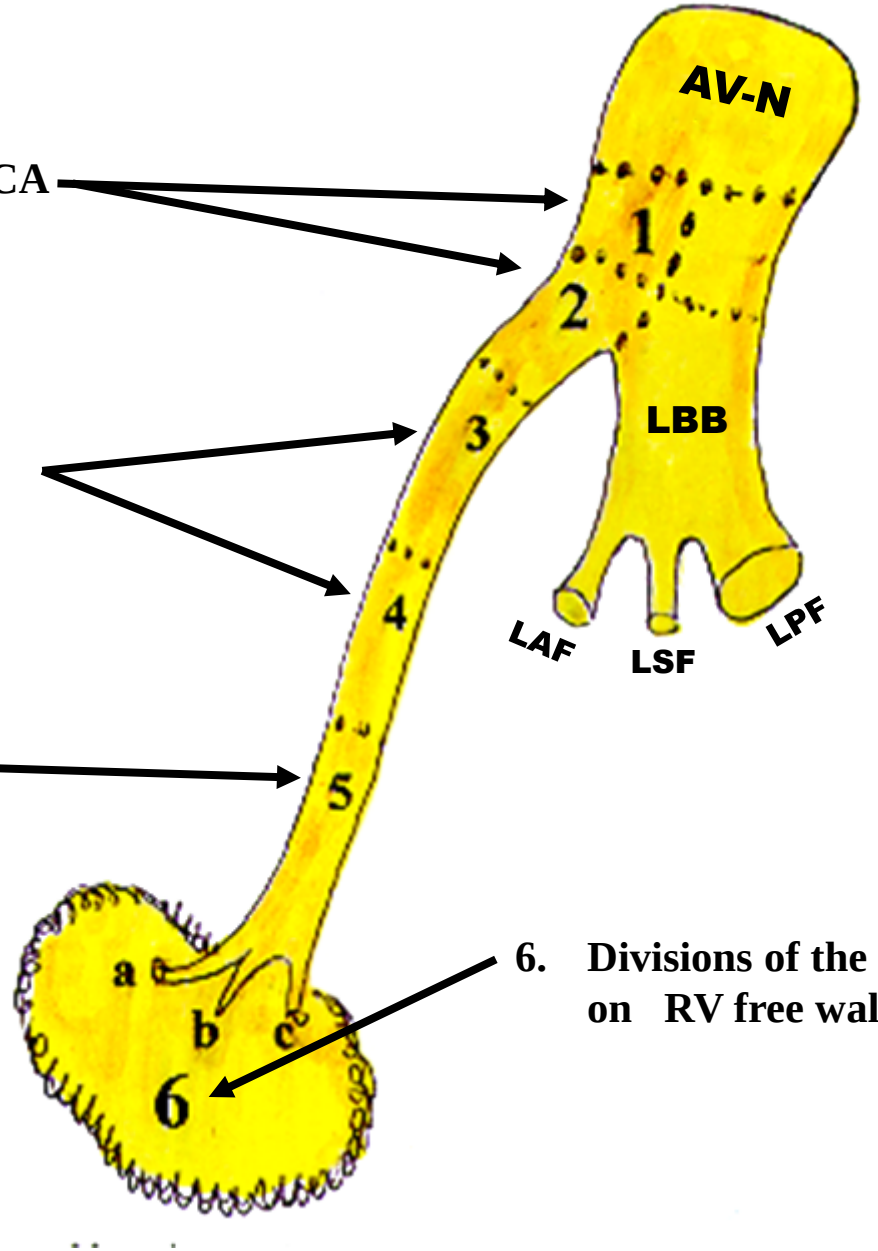
Septal RBB

PROXIMAL PORTION is irrigated by the AV node artery of the RCA and the first septal perforator artery (S_1) of the LAD.

MIDDLE PORTION is irrigated by:

- **Posterior Septal perforators of the PDA**
- **Second septal perforator artery(S_2) of the LAD**
- **Kugel's artery, branch of the LCX.**

MIDDLE AND DISTAL PORTION: are irrigated by the "Ramus limbi dextri", branch of the S_2 of the LAD.



6. Divisions of the RBB on RV free wall

1) His Right Penetrating Portion.
2) His Right Branching Portion
3) Proximal or membranous of RBB
4) Middle, intramyocardial or mimetic
5) Inferior, distal, moderator Band (MB) or septomarginal trabécula (**Latin**: trabecula septomarginalis): It is a muscular band of heart tissue

found in the RV of the base of the anterior papillary muscle of the tricuspid valve to the ventricular septum. The MB is an important structure because it carries part of the RBB of the AV bundle of the conduction system of the heart to the anterior papillary muscle of the tricuspid valve. This shortcut across the chamber of the ventricle seems to facilitate conduction time, allowing coordinated contraction of the anterior papillary muscle. From its attachments it was thought to prevent overdistension of the ventricle, and was named the "moderator band". It was first described by Leonardo da Vinci in his exploration of human anatomy. The moderator band is often used by radiologists and obstetricians to more easily identify the RV in prenatal ultrasound. The MB is a consistent structure in the morphologic RV and can be helpful as a landmark in situations where the ventricles may be ambiguous (i.e. in some forms of congenital heart disease).The term "septomarginal" is descriptive since the muscle extends from the interventricular septum to the margin of the RV, contacting/joining the base of the anterior papillary muscle. The MB does not attach to the tricuspid valve, but acts as part of the electrical conduction pathway of the heart (final portion of the septal RBB).

Irrigation of the Right ventricle

The different segments of the right ventricular chamber are irrigated in this way:

1. **RV free wall:** RCA truncus, except the anterior edge;
2. **RV lateral wall:** acute marginal branch (Ac.Mg), the right marginal branch or ramus marginalis dexter, The right marginal branch of right coronary artery (or right marginal artery) is a large marginal branch which follows the cardiac acute margin and supplies blood to both surfaces of the right ventricle and the apex.
3. **RV anterior surface:** right ventricular branch of the RCA;
4. **RCA cone branch:** part of the septum;
5. **Posterior descending artery(PAD) :** (in 86% of the cases, RCA branch): RV posterior wall. In 14% of the cases, the PD is the branch of the Cx.

Note: in a small percentage of cases, the branches of the anterior descending artery (ADA) irrigate part of the RV. This happens with prolonged ADA, called type IV ADA, which surround the tip.

Blood Supply of the Left Fascicles of Left Bundle Branch

1. **Left Anterior Fascicle (LAF)** Is supplied either by septal branches of the LAD or by the AV nodal artery
2. **Left Posterior Fascicle (LPF):** The proximal part of LPF is supplied by the artery to the AV Node and, at times, by septal branches of the LAD artery. The distal portion has a dual blood supply from both anterior (S) and posterior (S`) Septal Perforator Arteries.
3. **Left Septal Fascicle (LSF):** It is supplied exclusively by septal branches of the LAD. Critical lesions of the LAD before the first septal perforator, constitute the main cause of LSFB in the first world.

RESPONSIBLE SYSTEM	LAF	LPF	LSF
Branches of the LAD	40 %	10 %	100 %
Double irrigation (LAD & RCA)	50 %	40 %	0 %
RCA branches	10 %	50 %	0 %

Summary of Left Main Coronary Artery

- **Origin**

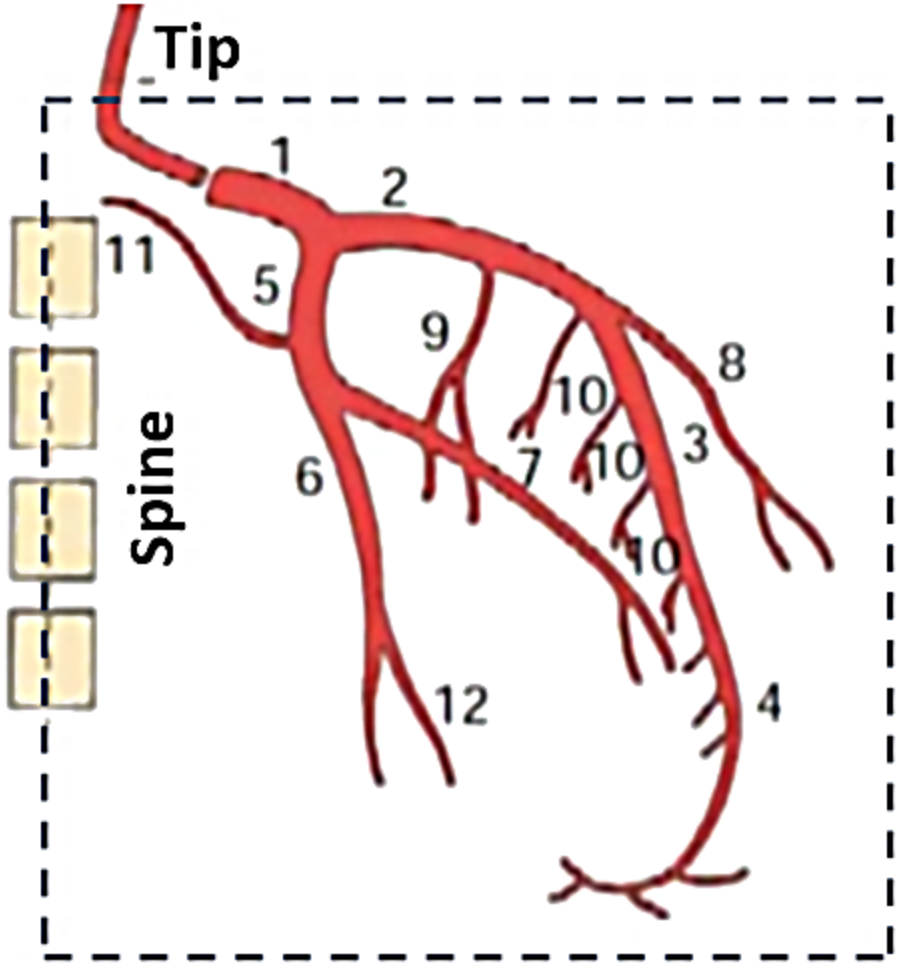
  Upper portion pf left aortic sinus just below the sinotubular ridge. Typically 0-10mm in length. Rarely no LMCA(separate origins).

- **Optimal Views**

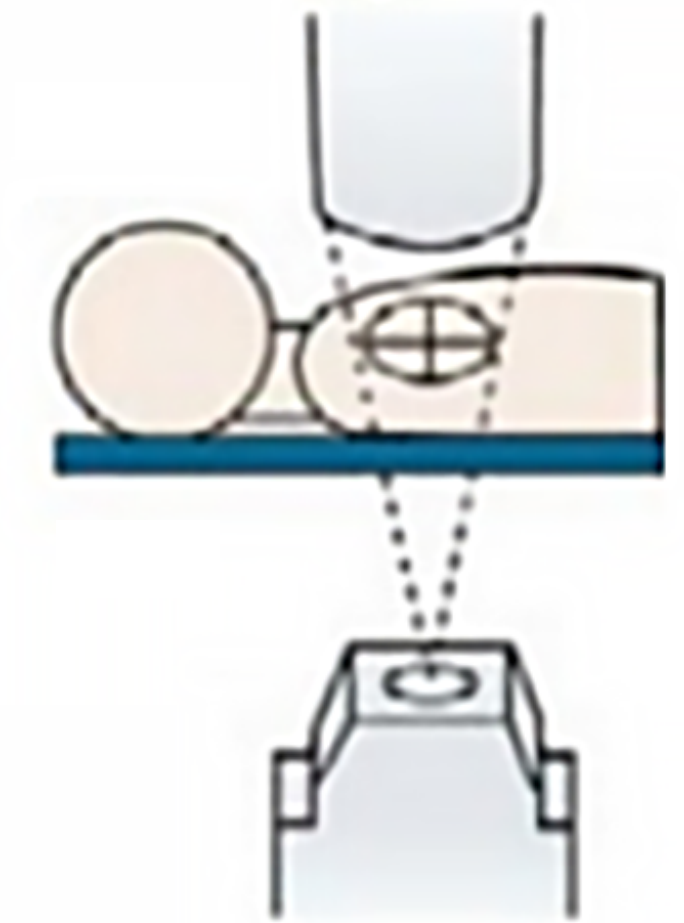
  LAO caudal and cranial; AP-caudal, cranial or flat.

A-P PROJECTION

The A-P projection allows a good visualization of the LMCA

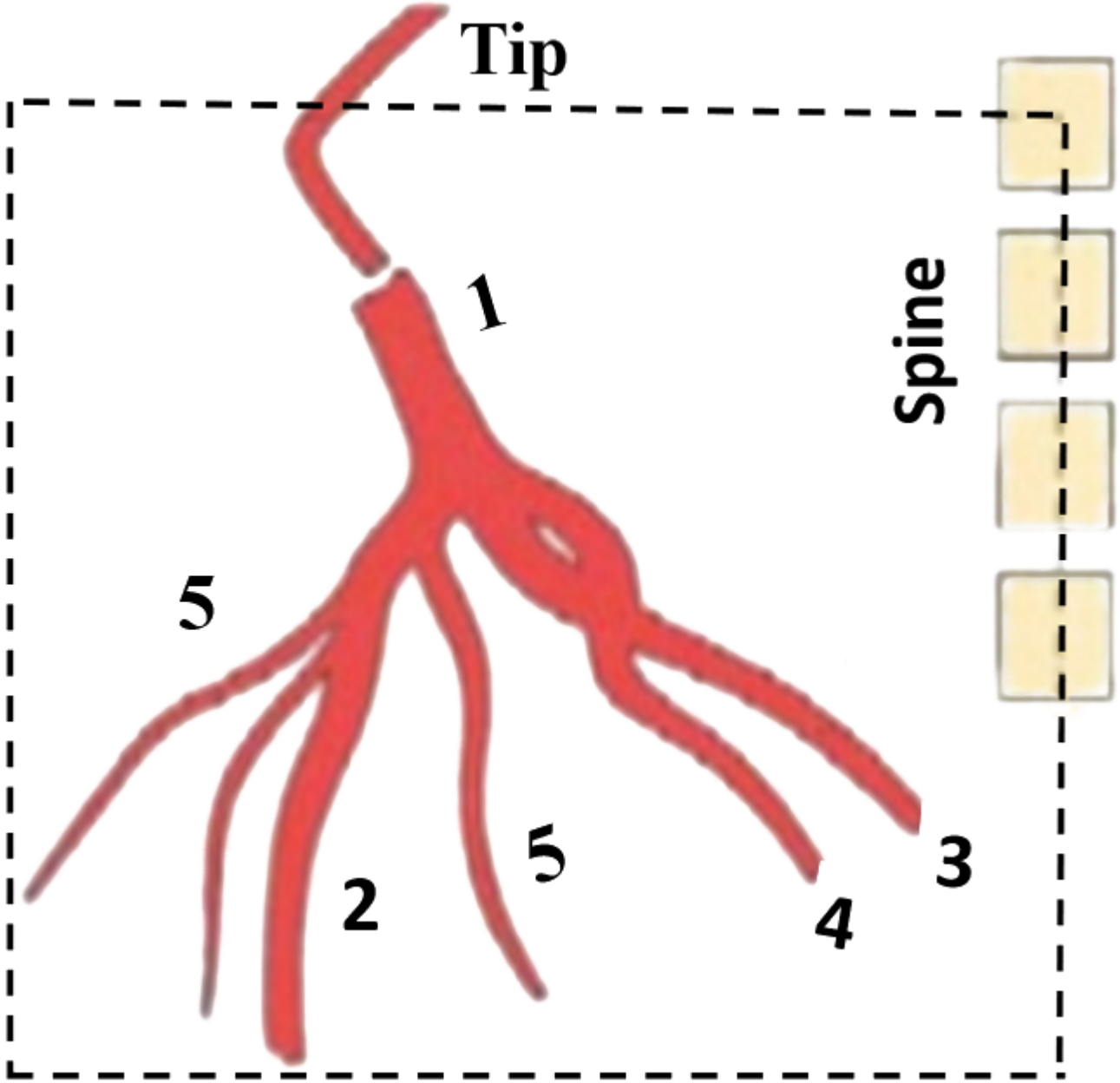


1. LMCA
2. Proximal part of LAD
3. Distal part of LAD
4. Proximal LCX
5. Distal LCX
6. Left Obtuse Marginal Artery
7. First Diagonal Artery
8. First Septal Perforator Branch
9. Septal arteries
10. Auricular branch of LCX
11. Obtuse Marginal Artery n° 2

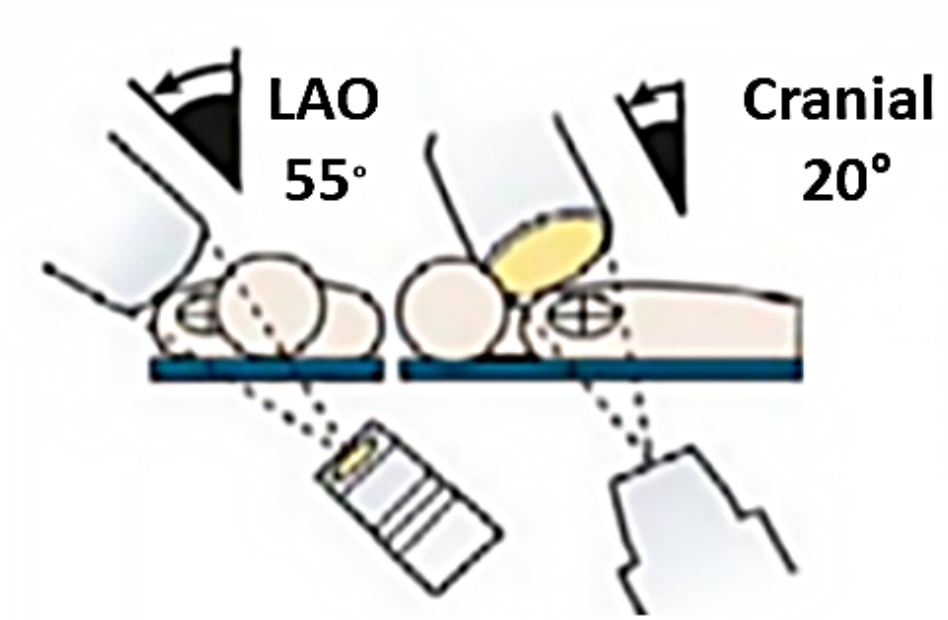


Left Anterior Oblique Projection at 55/60° combined with a Cranial angulation of 20°

The cranial angulation of 20°combined with the LAO projection at 55/60° is especially useful to study the LMCA



1. **LMCA**
2. **Middle part of the LAD**
3. **Proximal LCX**
4. **Obtuse Marginal Artery**
5. **Septal perforator branches**



Left Anterior Descending Artery

- **Course**

  Down the anterior interventricular groove-usually reaches apex. In 22% of cases does not reach apex.

- **Branches**

  Septal and diagonals-supply lateral wall of LV, anterolateral papillary muscle; 37% have median ramus(courses like 1st diagonal).

- **LAD**

  Supplies anterolateral, apex and septum:≈45% -55% of the left ventricle.

The left anterior descending artery (LAD) is the largest coronary artery runs anterior to the interventricular septum in the anterior interventricular groove, extending from the base of the heart to the apex. The LAD gives two sets of branches.

Structure

It passes at first behind the pulmonary artery and then comes forward between that vessel and the left atrium to reach the anterior interventricular sulcus, along which it descends to the notch of cardiac apex. Although rare, multiple anomalous courses of the LAD have been described. These include the origin of the artery from the right aortic sinus. In 78% of cases, it reaches the apex of the heart.

Branches

The LAD gives off two types of branches: septals and diagonals. Septals originate from the LAD at 90° to the surface of the heart, perforating and supplying the anterior $^{2}/_{3}$ of the interventricular septum. Diagonals run along the surface of the heart and supply the lateral wall of the left ventricle and the anterolateral papillary muscle.

Function

The artery supplies the anterolateral myocardium, apex, and interventricular septum. The LAD typically supplies 45-55% of the left ventricle (LV) and is therefore considered the most critical vessel in terms of myocardial blood supply.

Left: Critical stenosis (95%) of the proximal LAD in a patient with Wellens' Warning.

Right: The same patient after reperfusion.

Further information: Wellens' sign

Widow maker is an alternative name for the anterior interventricular branch of the LAD. (***Topol, Eric J.; Califf, Robert M. (2007). Textbook of Cardiovascular Medicine. Lippincott Williams & Wilkins. p. 283. ISBN 9780781770125. Retrieved 6 November 2014. The most worrisome type is the proximal left anterior descending artery*** The name widow maker may also apply to the LMCA (**Barbara J. Aehlert; Robert Vroman (2011). "22". Paramedic Practice Today: Above and Beyond (1st ed.). Jones & Bartlett Publishers. p. 819. ISBN 978-0-323-08535-9. Retrieved 2 March 2015**.) or severe occlusions to that artery.(**Richard Beebe; Jeff Myers (11 December 2009). "34". Professional Paramedic, Volume I: Foundations of Paramedic Care. Cengage Learning. p. 764. ISBN 1-4283-2345-7. Retrieved 2 March 2015**)(**Carlos S Restrepo; Dianna M. E. Bardo (1 January 2011). Cardiac Imaging. Thieme. p. 188. ISBN 978-1-60406-186-4. Retrieved 2 March 2015**.) This term is used because the LMCA and/or the LAD supply blood to large areas of the heart. This means that if these arteries are abruptly and completely occluded it will cause a massive MI that will likely lead to sudden death. The blockage that kills is made up of platelets streaming to the site of a ruptured cholesterol plaque. Even a small amount of plaque in this area can (for a variety of poorly understood reasons) rupture and cause death; bypassing chronic blockages or trying to open them up with angioplasty does not prevent heart attack but it can restore blood flow in case of a sudden blockage or heart attack and if performed within a rapid time period can minimize the damage done. An example of the devastating results of a complete occlusion of the LAD artery was the sudden death of former NBC News Washington Bureau Chief Tim Russert,(**Morgan, David (June 13, 2008). "TV newsman Tim Russert dies of heart attack". Reuters. Archived from the original on June 24, 2008. Retrieved June 13, 2008**) as well as the near-death of film director Kevin Smith (https://www.livescience.com/61863-kevin-smith-widow-maker-heart-attack.html).

From the minute a widow maker heart attack hits, survival time ranges from minutes to several hours. Rapidly progressing symptoms should signal the need for immediate attention. Symptoms of initial onset may include nausea, shortness of breath, pain in the head, jaw, arms or chest, numbness in fingers, often of a novel but imprecise sensation which builds with irregular heart beat. Early symptoms may be mistaken for food poisoning, flu or general malaise until they intensify. A widow maker cannot kill instantly but induces cardiac arrest which may do so within 10 to 20 minutes of no circulation. A victim with no pulse or breath is still alive, living off oxygen stored in the blood and may be able to be rescued if treatment is begun promptly within this window.(**Kearl, Mary (June 2009). "Surviving a Widow-Maker Heart Attack". AOL Health. Retrieved June 22, 2009**.)

Left Circunflex (LCX)

It follows the left part of the coronary sulcus, running first to the left and then to the right, reaching nearly as far as the posterior longitudinal sulcus. There have been multiple anomalies described, for example the LCX having an aberrant course from the RCA.(**PAGE, H. L.; ENGEL, H. J.; CAMPBELL, W. B.; THOMAS, C. S. (1 October 1974). "Anomalous Origin of the Left Circumflex Coronary Artery: Recognition, Angiographic Demonstration and Clinical Significance". Circulation. 50 (4): 768–773. doi:10.1161/01.CIR.50.4.768**)

Branches

The LCX curves to the left around the heart within the coronary sulcus, giving rise to one or more left marginal arteries also called obtuse marginal branches (OM1 and OM2) as it curves toward the posterior surface of the heart. It helps form the posterior LV branch or posterolateral artery. The left marginal artery of the heart is a branch of the circumflex artery. It originates as the latter passes around the left border of the heart in the interventricular groove. The left marginal artery passes obliquely down the left border towards the apex of the heart. Its fine branches supply the LV. The LCX ends at the point where it joins to form to the LPD in 15% of all cases, which lies in the posterior interventricular sulcus. In the other 85% of all cases the LPD comes out of the RCA. When the LCX supplies the LPD in those 15% of cases, it is known as a left dominant circulation.

Structures supplied

The LCX supplies the basal-lateral LV and the anterolateral papillary muscle. It also supplies the sinoatrial nodal artery in 38% of people.

It supplies 15-25% of the LV in right-dominant systems. If the coronary anatomy is left-dominant, the LCX supplies 40-50% of the LV.

LCX Summary

- **Origin:**

  from distal LMCA

- **Course**

  Down distal left AV groove

- **Branches**

  Obtuse marginal

  Posterolateral-supply basal lateral LV, anterolateral papillary muscle.

  SA-Node 38%

- **Supplies**

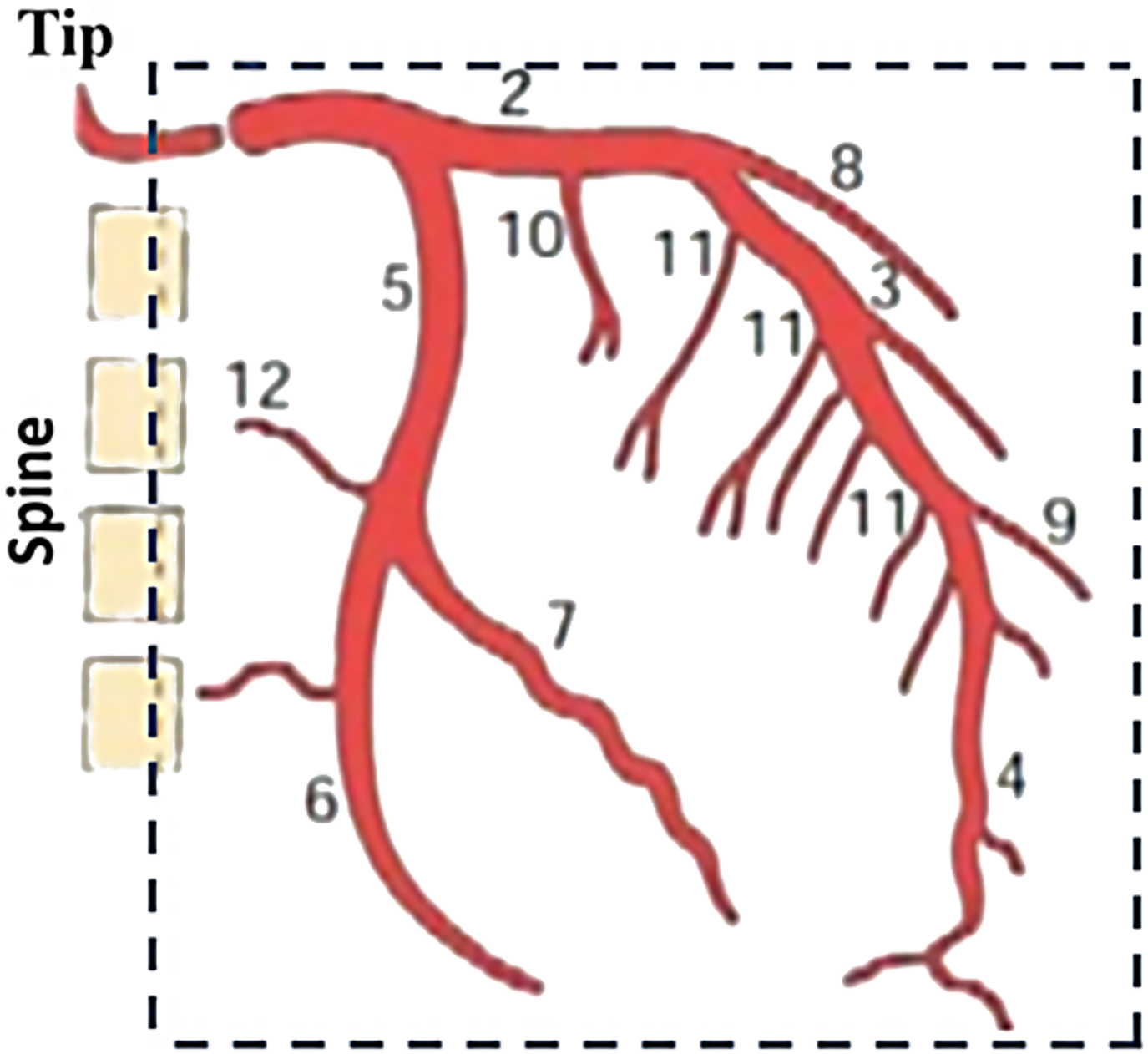
  15%-25% of LV, unless dominant(supplies 40-50% of LV

- **Coronary Angiography**

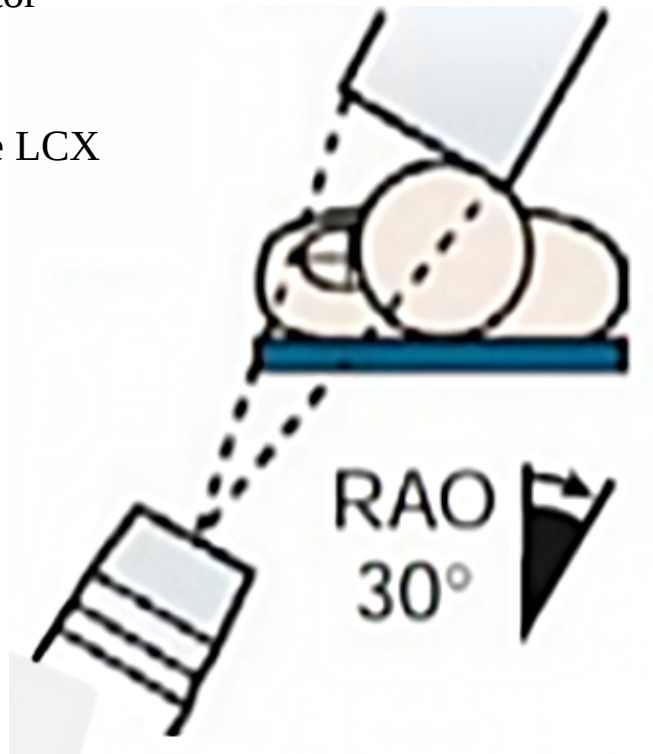
  Left lateral view best visualizing proximal LCX

  Right Anterior Oblique projection 30° (RAO 30°): The RAP projection at 30° permits the entire circumflex system to be studied, as well as the first centimeters of tle anterior interventricular artery (see next slide)

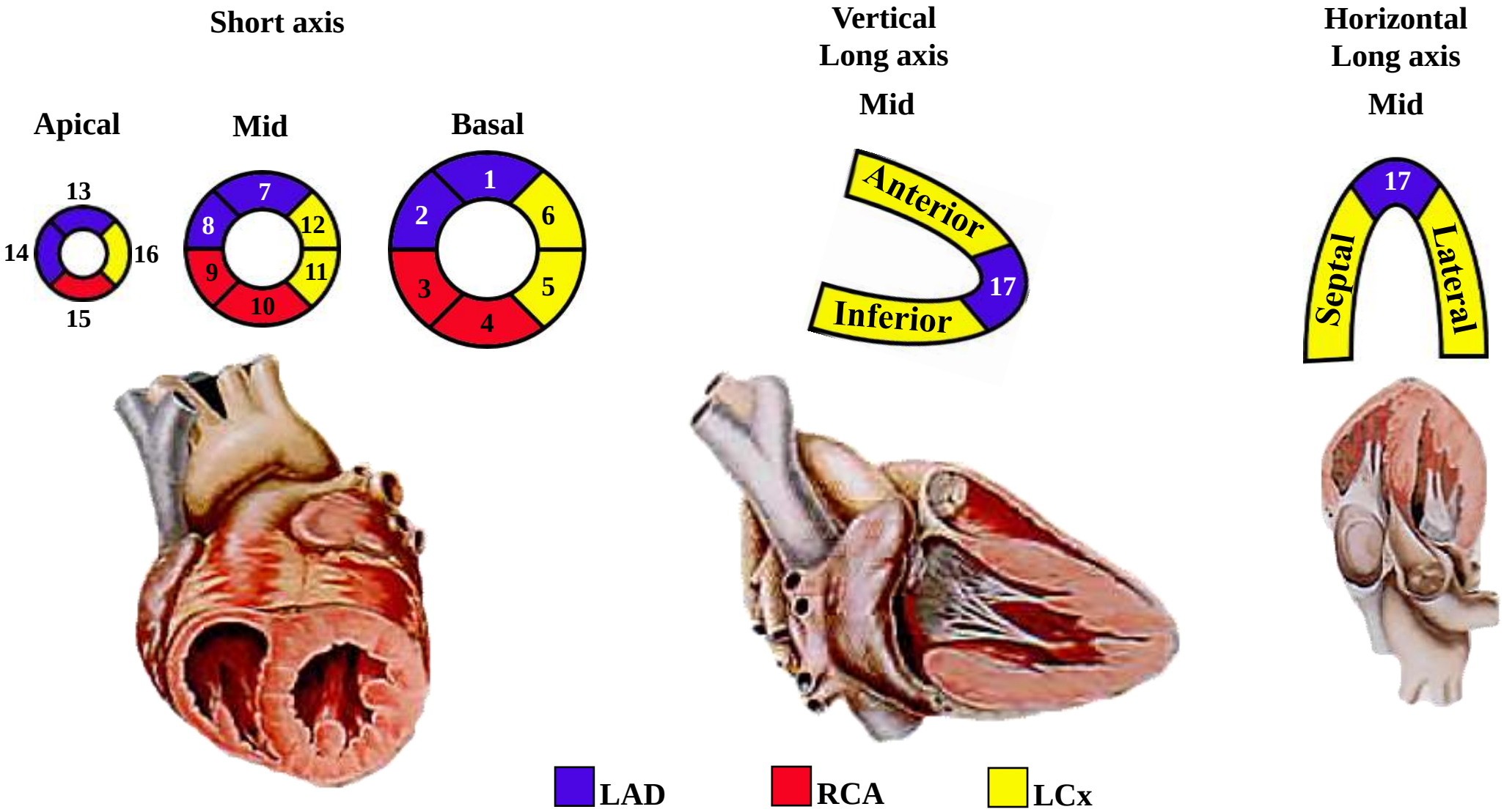
Right Anterior Oblique projection 30° (RAO 30°)



1. LMCA
2. Proximal part of LAD
3. Mid part of LAD
4. Distal parte of LAD
5. Proximal LCX
6. Distal LCX
7. Obtuse Marginal Artery
8. First diagonal artery
9. Second diagonal artery
10. First septal perforator artery
11. Septal arteries
12. Atrial branch of the LCX

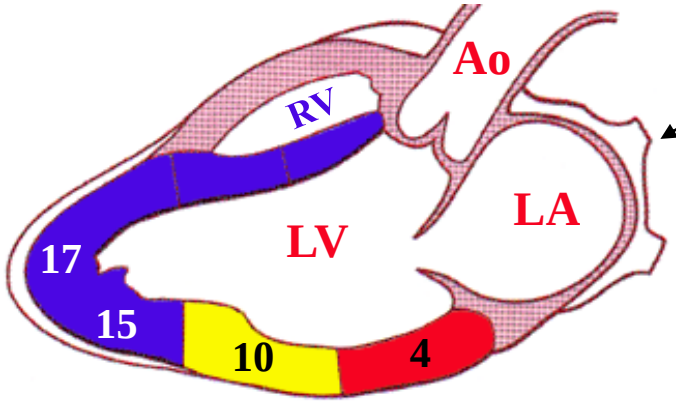


Coronary artery territories

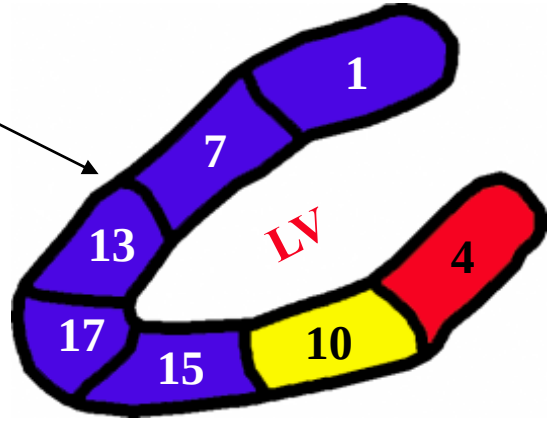


Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, Laskey WK, Pennell DJ, Rumberger JA, Ryan T, Verani MS; American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart. A statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation. 2002 Jan 29;105(4):539-42.

Left Ventricle myocardial segmentation, standard standard 17-segment model, and vascular territories

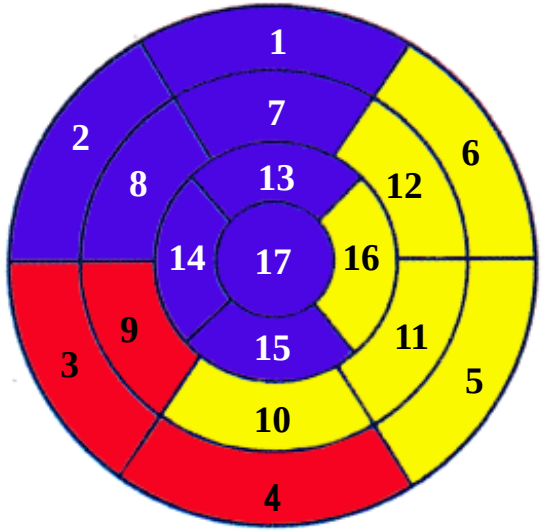


Longitudinal paraesternal



Bulls eye (apical short axis)

Anterior Wall

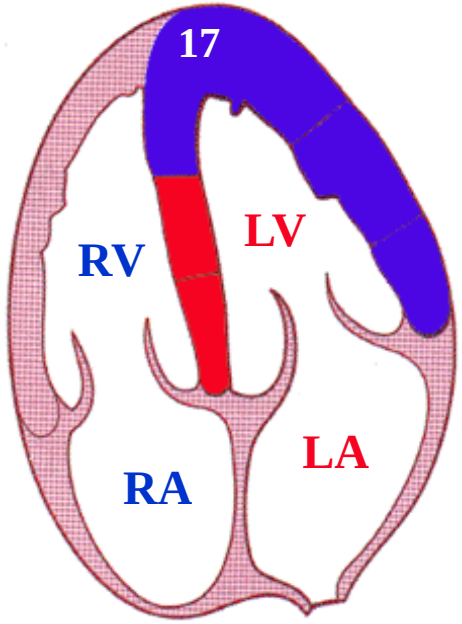


Septal Wall

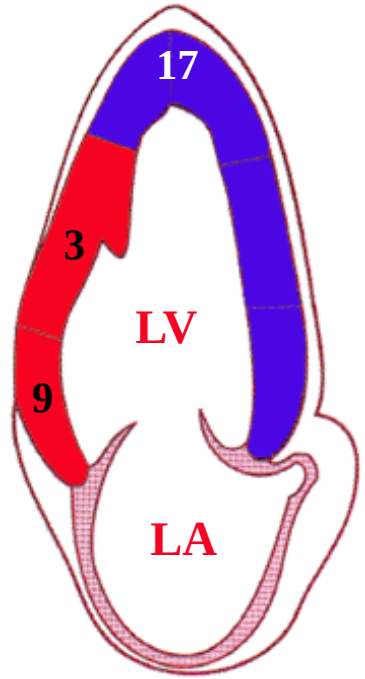
Lateral Wall

Inferior Wall

Apical four chambers



Apical two chambers



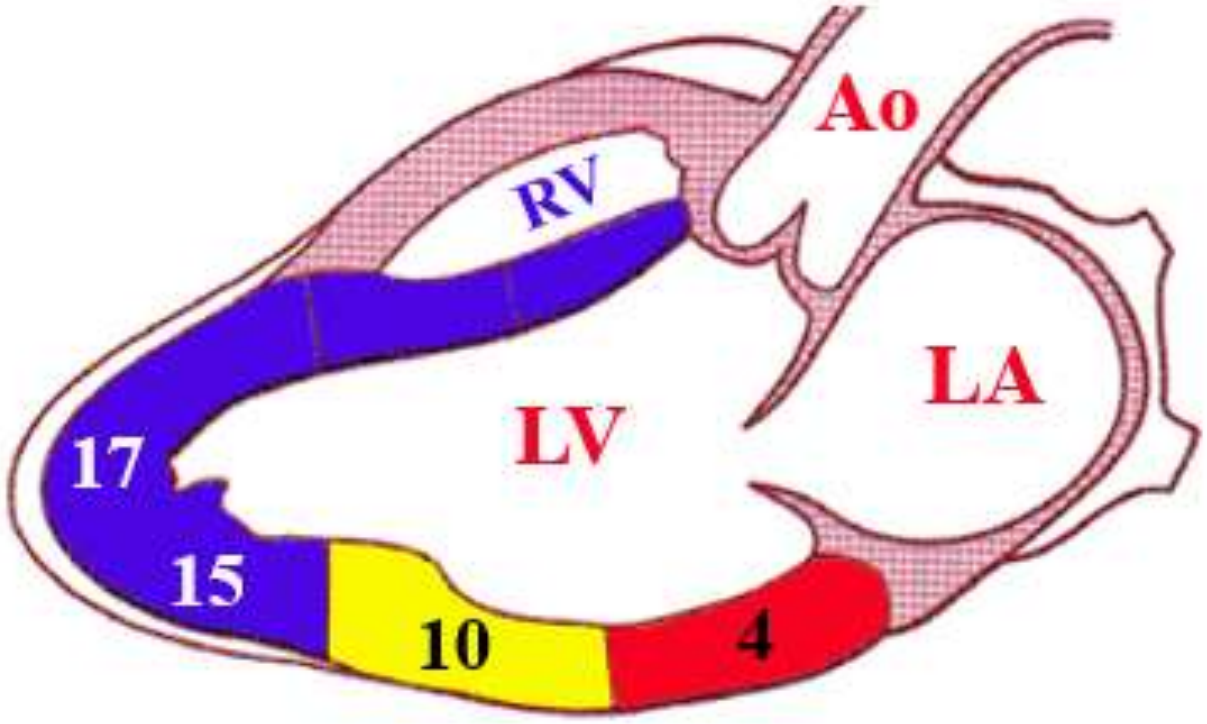
Left Anterior Descending (LAD)

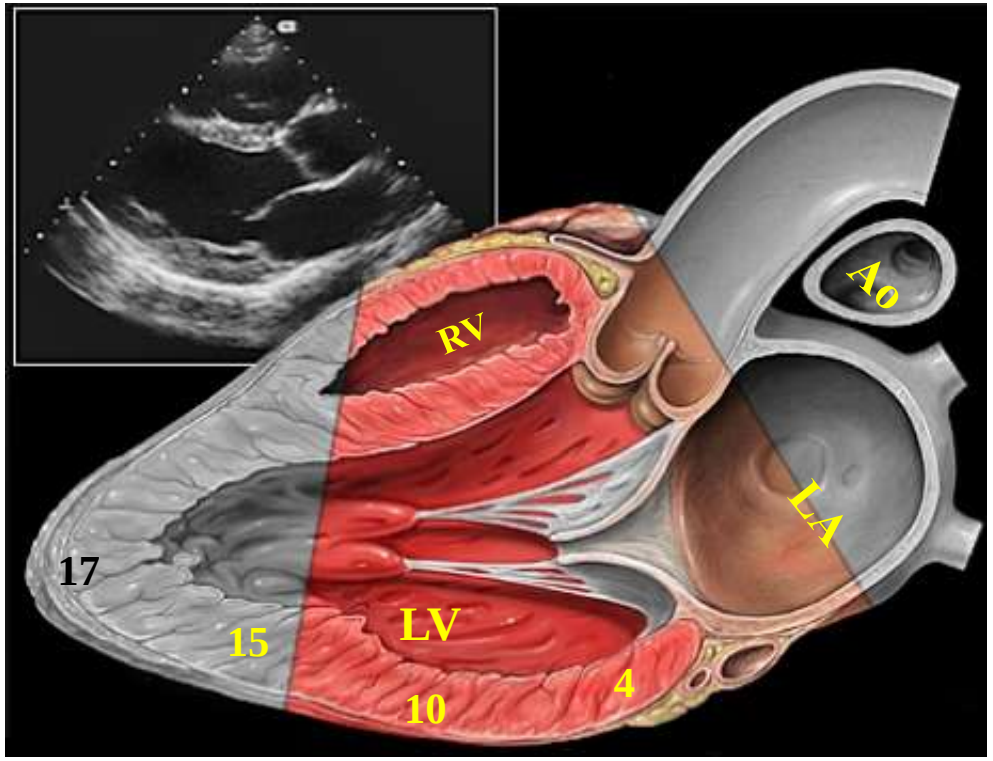
Left Circunflex (LCx)

Posterior Descending (RCA or LCx)

The apex is analyzed separately, usually from a vertical long-axis slice.

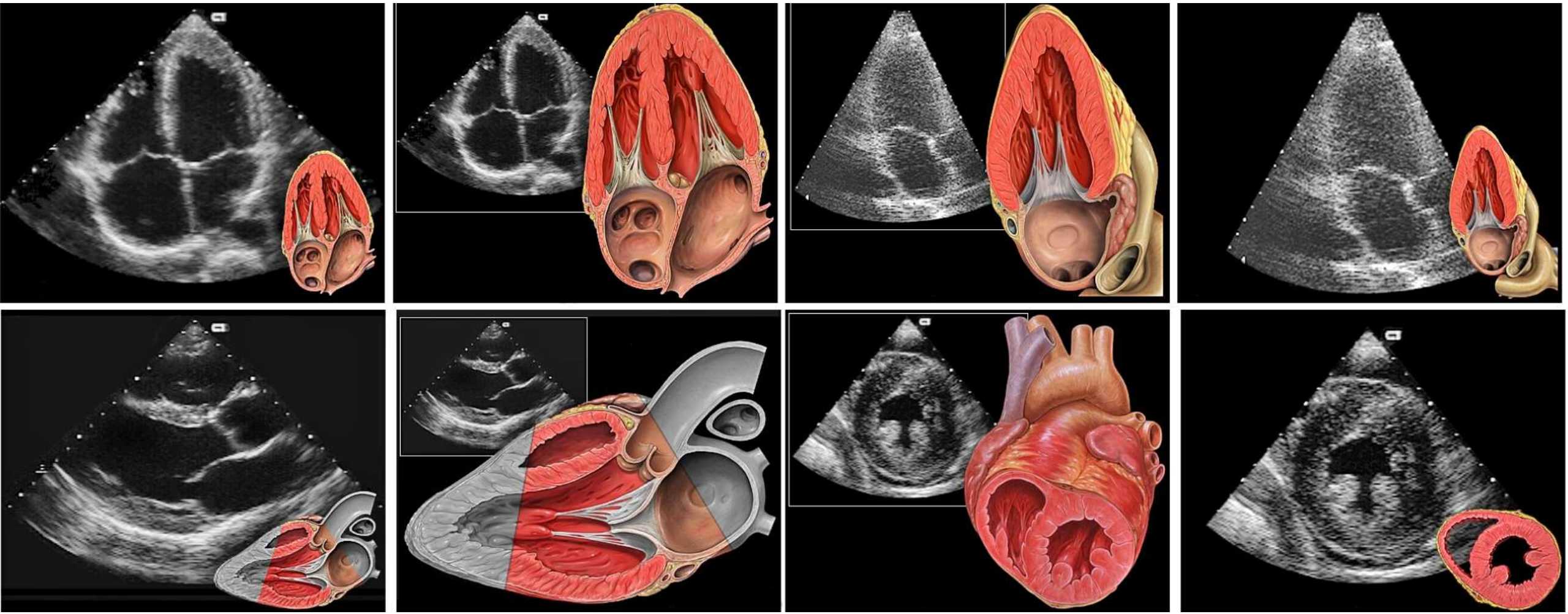
Parasternal long axis (PLAX)





This view is obtained to the left of the sternum and views the heart in its long axis. In this view, the mitral valve, aortic valve, right ventricular outflow tract, base of the LV , and the LA can be visible. Angulation in this view can bring the right ventricular inflow tract and tricuspid valve into view, and angulation the opposite way can bring the pulmonary valve into view. In this view, it is possible to appreciate the long-axis cross section of the mitral and aortic valves. The classic "hockey stick" shape of rheumatic mitral stenosis can be appreciated in this view. However, the angle of the probe with these valves can lead to under-appreciation of valve dysfunction. The parasternal long view of the pulmonary valve is the only view of the posterior leaflet.

Structures visible: Anterior septal and inferior lateral walls of the LV; LA; Mitral valve in long-axis with chordae; Aortic valve in long-axis; Tricuspid valve in long-axis (angulated) and RVIT; Pulmonary valve in long-axis (angulated) and right ventricular; outflow tract; Measurements in this view can be used to quantify the heart:; Left ventricular size and wall thickness; Left atrial linear dimension (as opposed to area); Left ventricular outflow tract diameter (used to calculate aortic valve area by the continuity equation); Aortic annulus, sinus of Valsalva, and aortic root sizes. Color doppler of all four valves; Spectral doppler of tricuspid and pulmonary valves



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Kugel's artery anatomy

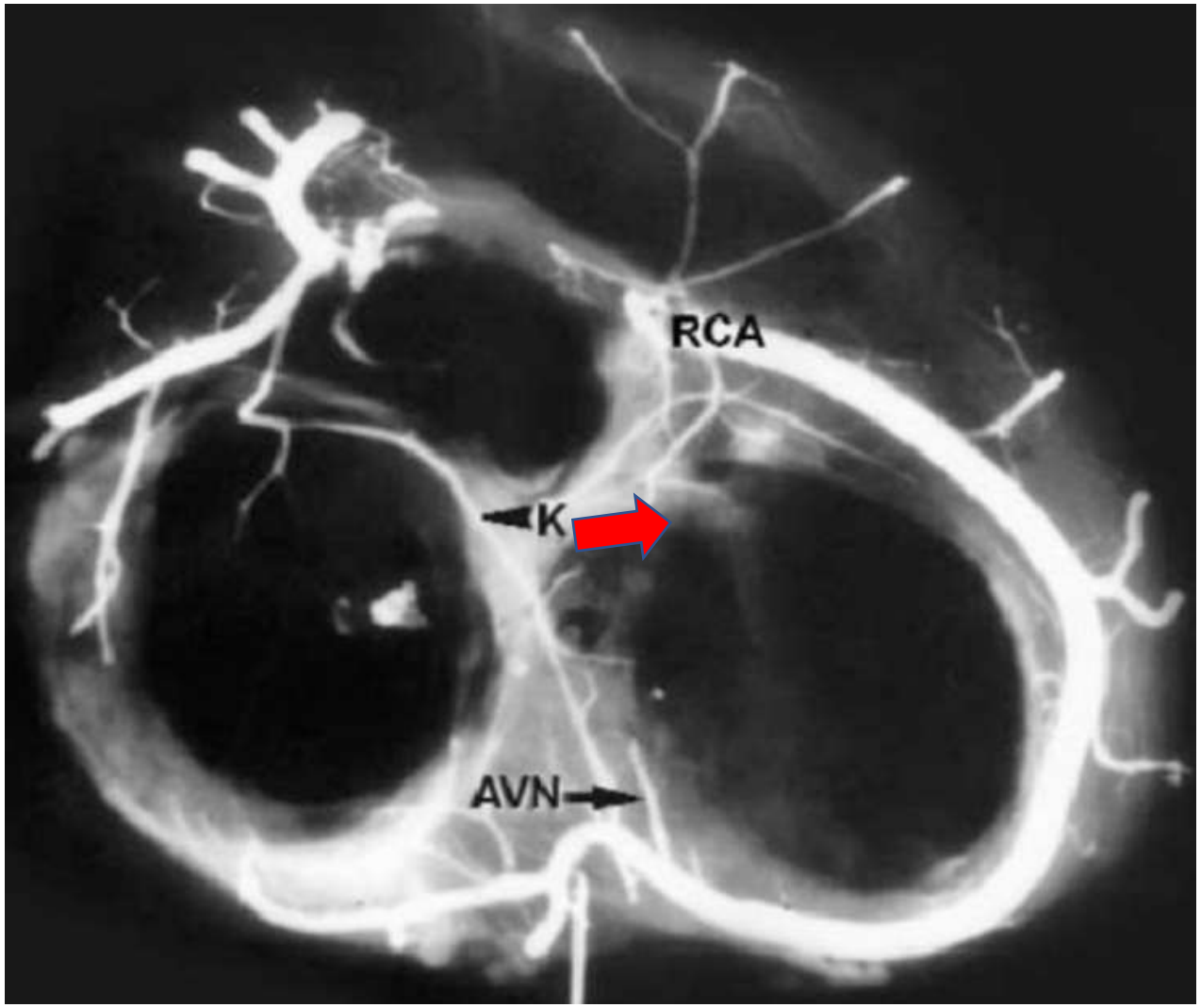
Kugel (**Kugel MA. Anatomical studies on the coronary arteries and their branches. I. Arteria anastomotica auricularis magna. Am Heart J 1927;3:260–70**.) described an atrial artery that arose from the proximal LCx or from its branches, coursed through the lower part of the interatrial septum, and in most of his cases (66%) anastomosed directly or through its branches with the distal RCA. In the rest of his cases, the same artery formed anastomoses with the proximal RCA (26%) or with branches from the anterior portion of the LCx and RCA and the posterior portion of the LCx (8%). He called this artery "arteria anastomotica auricularis magna" because of its large caliber, the apparent importance of its anastomotic role, and its consistent occurrence at this site. James (**James TN. Anatomy of the coronary arteries. New York: Paul B Hoeber; 1961. p. 132–4**.) and McAlpin (**McAlpin WA. Heart and coronary arteries: an anatomical atlas for clinical diagnosis, radiological investigation, and surgical treatment. New York: Springer-Verlag; 1975. p. 151**.) did not accept the existence of such an artery in their anatomical studies. Instead, they described small atrial branches that arose from either the LCx or the RCA, or even from both arteries, and connected with one another or with other small atrial branches from the surrounding area, then coursed posteriorly to the base of the interatrial septum and anastomosed with the AVN artery. Although these authors described an anastomotic network without accepting the existence of an artery, they applied the term "Kugel's artery" to this network. Moreover, they did not indicate the frequency of the network. On the other hand, angiographic studies have shown the existence in the same area of a large atrial artery that arises from the RCA or the LCx, or through the SN artery, and anastomoses with the AVN artery in various percentages (3.6%, 4.5%, and 6%) of cases. These authors, however, emphasize that this artery was found only in cases of severe atherosclerosis of the large coronary arteries. In the literature mentioned, Kugel's artery was not simple to demonstrate postmortem, and was extremely difficult to see in coronary arteriograms in vivo. Nerantzis et al, using a large series of specimens and a new technique, attempts to resolve the confusion in the literature regarding the existence of Kugel's artery, its origin, its ending,

and its relationship to the AVN artery. It also attempts to give details regarding whether an anastomotic network of small atrial arteries exists in the same area and what its relation to Kugel's artery and the AVN artery might be. These new anatomical findings may become useful to physicians who engage in diagnostic and therapeutic procedures that involve this area of the heart (**Nerantzis CE1, Marianou SK, Koulouris SN, Agapitos EB, Papaioannou JA, Vlahos LJ. Kugel's artery: an anatomical and angiographic study using a new technique. Tex Heart Inst J. 2004;31(3):**267-70). Professor Gustavo Abuin et al, From Buenos Aires described 2 vascular conduits that have never before been objectively shown to supply the conduction system. Twenty human hearts from subjects aged between 15 and 65 years--with and without coronary artery disease--were dissected after anterograde and retrograde injection with latex butaclor E-650 by means of a technique developed by the authors. In 40% of these hearts, Kugel's artery was found to supply the atrioventricular node. The right descending superior artery supplied the AVN in 70% of the hearts dissected. These findings may be of major significance both in clinical cardiology and in cardiovascular surgery (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC325521/pdf/thij00021-0033.pdf). We succeeded in using a new technique to find, and then describe in detail, vascular courses in the lower part of the interatrial septum. In all of our cases, we observed anastomotic networks of various sizes. In addition, in 6 of the 100 hearts, we found a Kugel's artery in the same area. Nerantzis et al. described as a Kugel's artery an atrial artery that connected directly or through the Sinus node artery the proximal part of the LCx or the RCA with the distal part of the vessel where it crossed the crux. This artery is long and wide, and suitably fulfills the 4 initial descriptive terms given by Kugel: “arteria anastomotica auricularis magna.” Also Soto et al. and Smith et al. (**Soto B, Jochem W, Karp RB, Barcia A. Angiographic anatomy of the Kugel's artery. Am J Roengenol Radium Ther Nucl Med 1973;119:503–7**; **Smith C, Amplatz K. Angiographic demonstration of Kugel's artery (arteria anastomotica auricularis magna). Radiology 1973;106:113–8**) have not accepted the term “artery” because they found small atrial branches, but not a vessel so large in diameter as an artery in the lower part of the interatrial septum. It is strange, however, that they used the term Kugel's artery, despite the

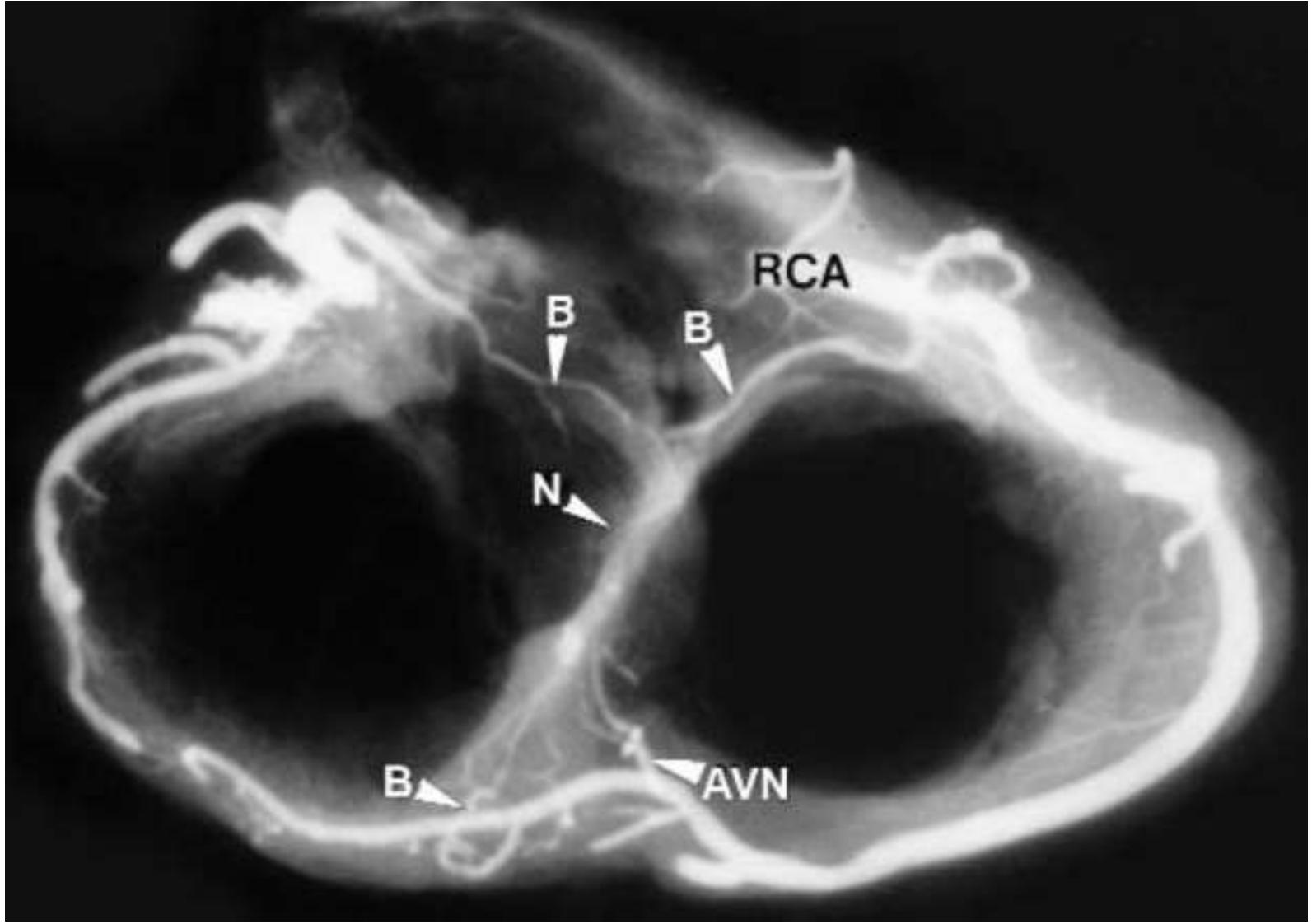
fact that they described only an anastomotic network in this area. Nerantzis et al. found only 6 Kugel's arteries out of 100 normal hearts (6%). Similar percentages ranging between 3.6% and 6%, albeit in patients with severe atherosclerotic heart disease, have been reported in the literature, in 3 coronary angiographic studies (**Grollman JH Jr, Heger L. Angiographic anatomy of the left Kugel's artery. Cathet Cardiovasc Diagn 1978;4:127–33; Levin DC. Pathways and functional significance of the coronary collateral circulation. Circulation 1974;50:831–7; Soto B, Jochem W, Karp RB, Barcia A. Angiographic anatomy of the Kugel's artery. Am J Roengenol Radium Ther Nucl Med 1973;119:503–7**). On the other hand, in anatomical studies, the percentage ranged between 40% and 66%. These increased percentages probably included cases with a large anastomotic network. It is hard to explain why other authors did not report any percentages in their studies. Kugel's arteries originated from the LCx in 3 hearts and from the RCA in the other 3 (via the sinus node artery in 1 of these last). Nerantzis results, in accordance with previous publications, clearly demonstrate that this artery does not have a standard point of origin. In their 6 hearts, Kugel's artery was connected directly with the distal artery after it crossed the crux, keeping a course independent from the AVN artery. The same finding has been described BY Thompson (**Thompson AJ, Froelicher VF. Kugel's artery as a major collateral channel in severe coronary disease. Aerosp Med 1974; 45(11):1276–80**). Kugel reported that in some cases his artery connected directly with the distal RCA , while in all other cases it connected via the AVN artery. Most of the authors who have reported finding Kugel's artery in their anatomical and angiographic studies have mentioned its indirect connection with the artery that crosses the crux, always through the AVN by Soto and Smith. Kugel's artery is difficult to demonstrate in postmortem angiography, and it is also difficult to see in vivo, in the usual coronary arteriographic projections. However, with Nerantzis technique, they succeeded in demonstrating clearly for the 1st time this artery in postmortem angiograms. Nerantzis also believe that Kugel's artery will be easy to demonstrate in vivo if the right oblique projection is used for the right arteriogram and the left lateral projection for the left arteriogram. In both projections, a cephalad angle will often help to bring the artery into the middle of the projection, parallel to the AVN

artery, thereby avoiding overlap with the vessels in the atrioventricular groove. The anastomotic network was found in all 100 hearts, connecting indirectly the proximal and distal parts of the large coronary arteries—via the AVN artery in 66 cases and, in the rest, via small branches from the artery that crossed the crux. This type of connection via the AVN artery has been described in most of the studies. The sinus node artery or its branches contributed to the formation of this network, an observation that has been mentioned. Nerantzis et al. observed the participation of the right superior descending artery, but they did not describe this in detail because of the small number of cases in which it was found. They believe that our technique will render satisfactory the postmortem angiographic demonstration of the network in normal hearts, but in vivo arteriographic demonstration of the network, unlike that of Kugel's artery, will remain very difficult due to the small size of the vessels. In other studies, all these inter- and intracoronary anastomoses tended to be larger in hearts with stenotic lesions of the major epicardial coronary arteries. Since both Kugel's artery and the anastomotic network originate from the beginning of the coronary trunks, they have to be taken into consideration in many surgical procedures involving the aortic root. Moreover, interventional cardiologists who perform procedures involving the lower part of the interatrial septum, such as radiofrequency ablation and biventricular pacemaker insertion, should be aware of the potential risk of damaging these important anastomotic branches.

In conclusion, following the observations of Nerantzis et al an anastomotic network of small atrial branches courses through the lower part of the interatrial septum and in all cases indirectly connects the proximal to the distal ends of the larger coronary arteries, while Kugel's artery, in 6% of the cases, provides a direct arterial anastomosis in the same area. The knowledge from these findings is important for anatomists, cardiologists, and cardiac surgeons Figures of slides 56 and 57.



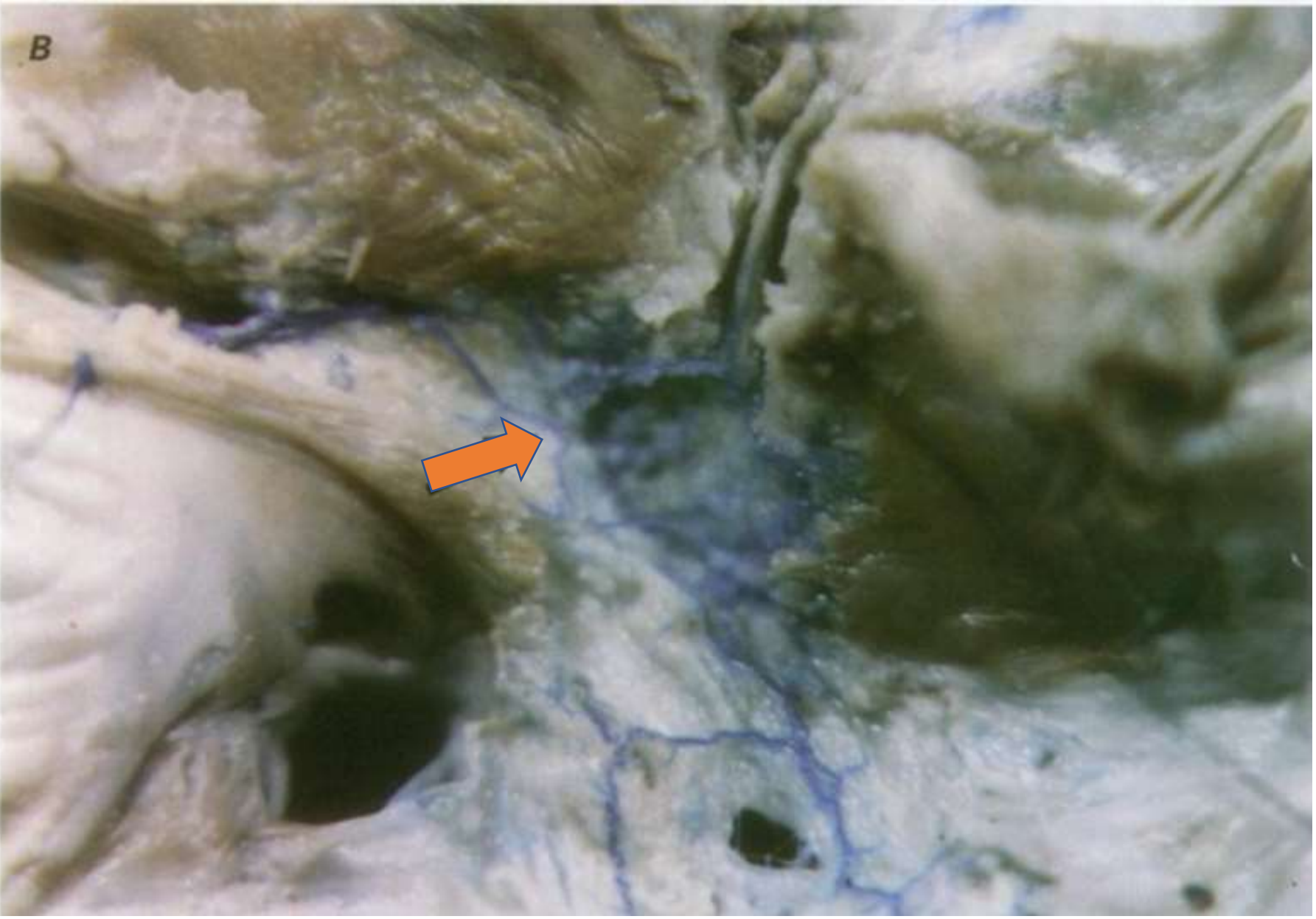
Superior view of the middle part of a normal right dominant heart containing the arteries and their branches that course through the atrioventricular groove and the lower portion of the interatrial septum. The arteriogram shows that Kugel's artery (K red arrow) directly connects the proximal left circumflex artery with the distal right coronary artery (RCA) near the crux (inter coronary connection). Kugel's artery distributes branches throughout its course. The independent atrioventricular node (AVN) artery can also be seen. Furthermore, atrial branches forming an anastomotic network are shown.



Superior view of the middle part of a normal right dominant heart containing the arteries and their branches that course through the atrioventricular groove and the lower portion of the interatrial septum. The arteriogram shows that atrial branches (B) originating from the proximal left circumflex artery and the RCA connect and form an anastomotic network (N). It also shows the contribution of the atrioventricular node (AVN) artery to the network. Note that the atrial branches shown The authors magnified this figure to better demonstrate the network and also because the absence of Kugel's artery makes them larger.

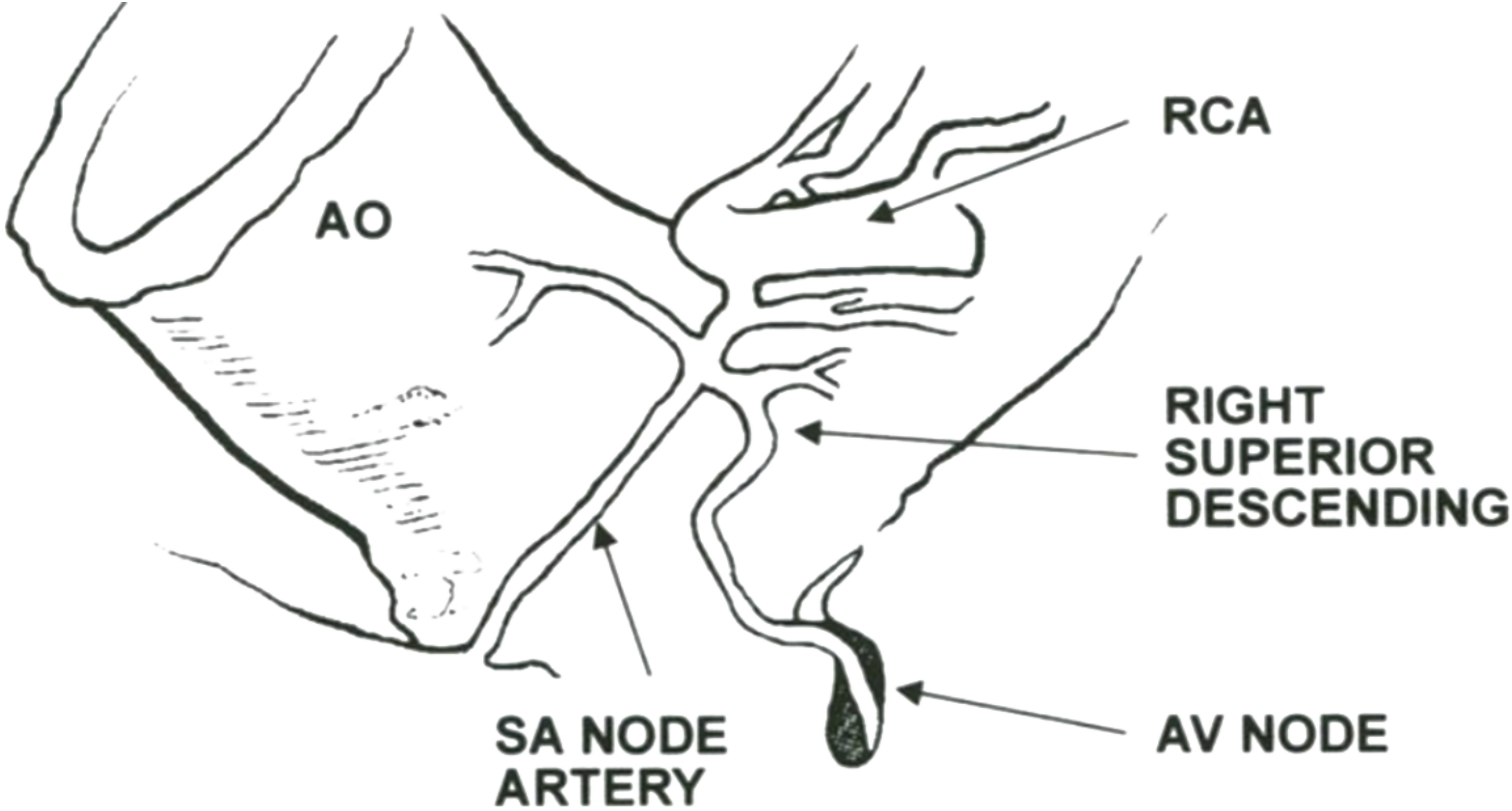
Professor Gustavo Abuin
Kugel's artery
Universidad de Buenos Aires | UBA · Department of Anatomy
Figures 1, 2 and 3 Gustavo Abuin currently works at the Department of Anatomy, University of Buenos Aires. Gustavo does research in Cardiothoracic Surgery.

Kugel's artery. A) Anastomosis between right and left coronary trunks.



Atrial branch supplying the atrioventricular node (arrow).

The anatomy of the heart's conduction system and of its blood supply have been research topics for many years. However, several proposals have never been demonstrated. Professor Gustavo Abuin et al, described 2 vascular conduits that have never before been objectively shown to supply the conduction system. Twenty human hearts from subjects aged between 15 and 65 years--with and without coronary artery disease--were dissected after anterograde and retrograde injection with latex butaclor E-650 by means of a technique developed by the authors. In 40% of these hearts, Kugel's artery was found to supply the atrioventricular node. The right descending superior artery supplied the atrioventricular node in 70% of the hearts dissected. These findings may be of major significance both in clinical cardiology and in cardiovascular surgery.



The right superior descending artery has an important role in RCA supplying the atrioventricular node (arrow).