Introduction

Atherosclerosis and its cardiovascular complications remain the leading cause of death in modern societies. There is evolving evidence from basic and clinical research that some of these ubiquitous coronary hot-spots are suddenly activated and rupture, causing acute events, whereas others are associated with asymptomatic disease progression. ***(Schoenhagen, 2007)***

Disruption of an atherosclerotic plaque is responsible for at least two-thirds of acute coronary events. Ruptured plaques are histopathologically characterized by large plaque volumes and large necrotic cores that are covered by attenuated fibrous cap often inflamed with monocyte-macrophage infiltration. ***(Motoyama et al, 2007)***

The vessels are positively remodeled at the site of plaque disruption .In addition; small calcific concretions in fibrous caps have been shown contribute to plaque instability. Plaques vulnerable to rupture are termed thin cap fibroatheroma (TCFA) and show histopathological characteristics similar to disrupted plaques except that the fibrous caps are still intact. ***(Motoyama et al, 2007)***

The coronary arterial remodeling was defined as a change in the vessel diameter at the plaque site in comparison with the reference segment set proximal to the lesion in a normal-appearing vessel segment (reference segment). The remodeling index on MSCT is calculated and reported as positive remodeling when the diameter at the plaque site was at least 10% larger than the reference segment. ***(Motoyama et al, 2007)***

The plaque and necrotic core size are described as the most important determinants of the plaque vulnerability. Sparing of the lumen occurs because of a positive or outward remodeling of the vessel. Therefore, angiographic encroachment of the lumen often has been shown to be minimal, and angiographic luminal assessment does not correlate well with the incidence of acute coronary syndrome. In particular, lesions with hemorrhage, large necrotic cores, lipid core, macrophage inflammation, and calcification are more likely to show positive vascular remodeling. On the other hand, stable plaques show no expansive remodeling or rather arterial shrinkage. The expansive growth of vessel offers an easy target for structural imaging. ***(Motoyama et al, 2007)***

Plaque progression and regression are associated with arterial expansion (positive remodeling) and shrinkage (negative remodeling) respectively. Findings of several studies have shown that most acute coronary syndromes are initiated by sudden changes of mildly stenotic lesions, commonly found in positively remodeled arterial regions, rather than from progression of lesions already causing significant luminal narrowing. Therefore, it has been postulated that the identification of mildly stenotic but vulnerable atherosclerotic lesions could provide better markers of coronary risk than do measures of luminal stenosis. ***(Schoenhagen, 2007)***

AIM OF THE WORK

The aim of the current study is:

- To assess the role of multislice CT coronary angiography with its new applications such as reformatted images, and high resolution imaging, in detection and characterization of coronary atherosclerotic lesions and remodeling.

GROSS AND CT ANATOMY OF THE CORONARY ARTERIES

The heart is a hollow muscular organ of a somewhat conical form; supplied by two main coronary arteries and it lies between the lungs in the middle mediastinum and is enclosed in the pericardium.

THE CORONARY ARTERIES:

The human heart normally has two coronary arteries named after the location of their main branches in the coronary sulcus. The right and left coronary arteries arise from the ascending aorta in its anterior and left posterior sinuses respectively. No artery arises from the right posterior sinus, which called as the non coronary sinus. ***(William et al., 1995)***

Left Coronary Artery :

The left coronary artery is a large artery (Figure 1) with an approximate diameter of 5 mm at its origin that supplies an extensive portion of the walls of the left chambers of the heart, including most of the interventricular septal mass.

The Left main (LM) artery, a common initial segment of the left coronary artery, has variable length is embedded in adipose tissue, and courses between the main pulmonary artery and the left atrial appendage (Figure 2). Rarely (<1% of individuals), the LM is absent (Figure 3), with independent origins of its main branches from the left coronary sinus. In addition to its main ramification, the LM emits no other branches, except in those rare instances where the artery of the sinus node originates from it. At the level of the left atrioventricular groove, the LM gives two or three branches, namely the left anterior descending, the left circumflex artery and, occasionally, the intermediate artery. ***(Leta-Petracca, 2006)***

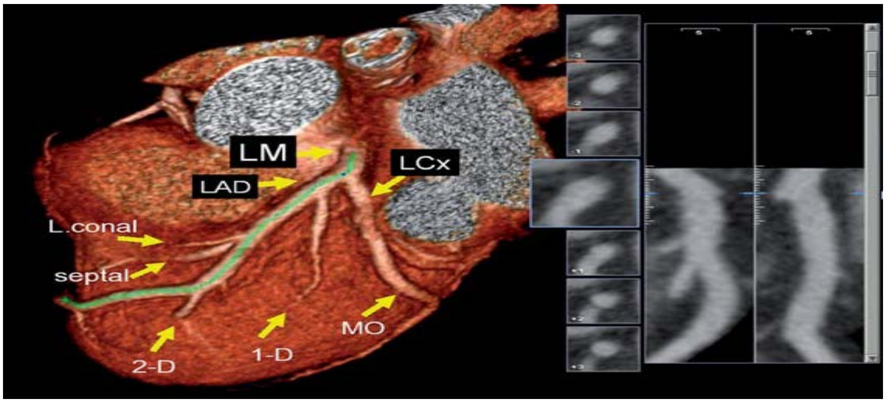

Figure 1: Left coronary artery with its branches, as seen on 3D (left) and a multiplanar construction (MPR) of its proximal segment (right). LAD: left anterior descending; L.Conal: left conal branch; LCx: left circumflex; LM:left main; MO: marginal obtuse branch of the LCx; Septal: first septal anterior branch of the LAD; 1D and 2D: first and second diagonal branches of the LAD. ***(Leta-Petracca, 2006)***

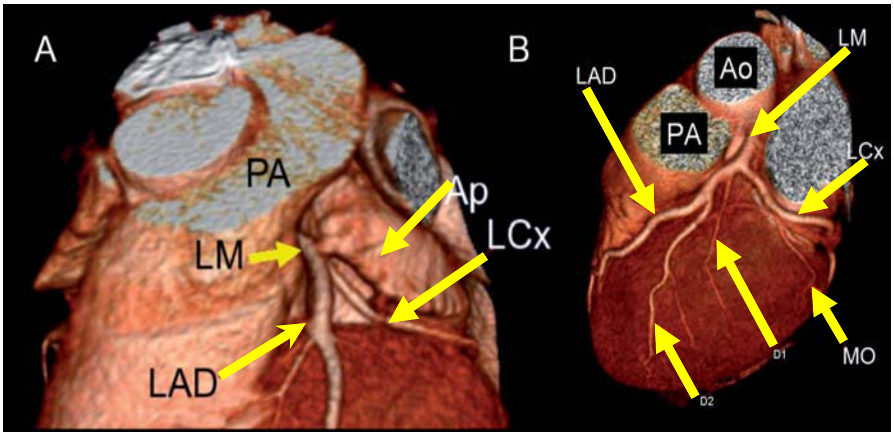

Figure 2: Anatomical relationships of the proximal segments of the main branches of the left coronary artery. Observe the course of the vessels below the left atrial appendage (Ap) in A, which is adequately displayed when the Ap is removed, in B. Ao: aorta; LAD: left anterior descending; LCx: circumflex artery; LM: left main; MO: marginal obtuse branch of the LCx; PA: pulmonary artery; 1D and 2D: first and second diagonal branches of the LAD. ***(Leta-Petracca, 2006)***

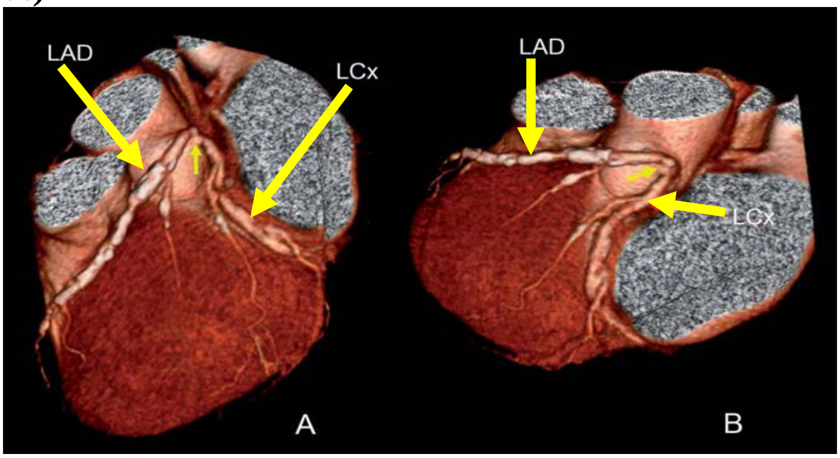

Figure 3 : Left oblique (A) and left lateral (B) views in a case of absent left main (LM) (yellow arrow), with an independent origin of the left anterior descending (LAD) and circumflex (LCx) arteries. Observe the extensive vessel wall calcification. ***(Leta-Petracca, 2006)***

Left anterior descending (LAD):

LAD coronary artery is a large vessel, 4– 5 mm in diameter at its proximal portion, that occupies the anterior interventricular groove, running in parallel with the great cardiac vein (Figure 4), with which it exhibits crossover points. It usually extends to the apical region of the left ventricle and, in two thirds of individuals; it reaches the distal (Figure 5) or even the middle portion of the posterior interventricular groove. In these cases, the LAD frequently shows anastomotic connections with the left posterior descending artery (PDA). ***(O'Brien et at., 2007)***

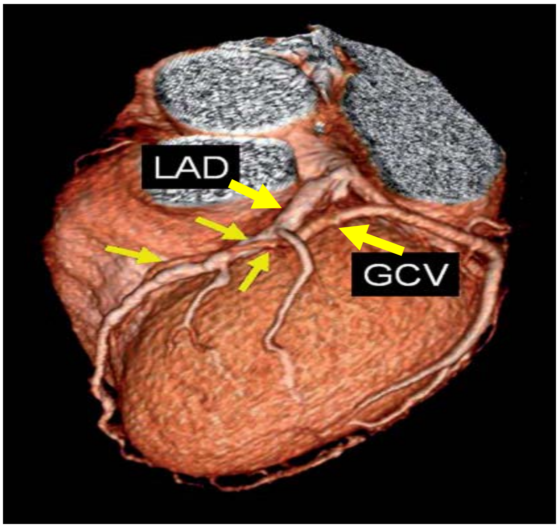

Figure 4: Relationship between the left anterior descending (LAD) and the great cardiac vein (GCV), showing vessel crossing at their middle course (yellow arrows). ***(Leta-Petracca, 2006)***

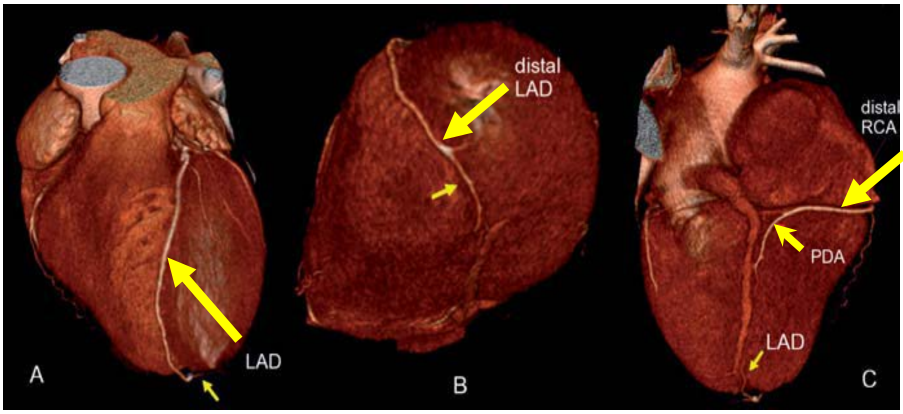

Figure 5: Recurrent course of the distal segment of the left anterior descending (LAD) artery reaching the interventricular posterior groove. A: anterior view; B: apical view; C: posterior view. PDA: posterior descending artery. ***(Leta-Petracca, 2006)***

The LAD gives some branches along its course:

– *Left conal artery* (Figure 1): with an origin in the proximal LAD, it communicates with the right conal artery, with which it constitutes the "arterial ring of Vieussens," along with the *vasa vasorum* of the aorta and pulmonary artery.

– *Right anterior ventricular branches*: usually irrelevant in number and diameter, as the right ventricle is almost exclusively irrigated through the right coronary artery.

– *Left anterior ventricular branches (diagonal arteries)* (Figure 6): Variable in number, these branches distribute diagonally over the anterior aspect of the left ventricle .The origin of the first diagonal artery (Figure 2) is used as the anatomical point dividing the middle and distal segments of the LAD. Frequently, one of these diagonal arteries is particularly large and follows a course parallel to the LAD (Figure 9), from which it can be distiguished by the lack of septal branches and the presence of secondary small diagonal branches. In cases where this diagonal artery reaches the obtuse margin of the heart, and from there, the posterior aspect of the left ventricle, it is known as posterolateral artery. The absence of diagonal arteries is extremely rare and, thus, when this is the case in coronary angiography, occlusion of some of these branches can be suspected.

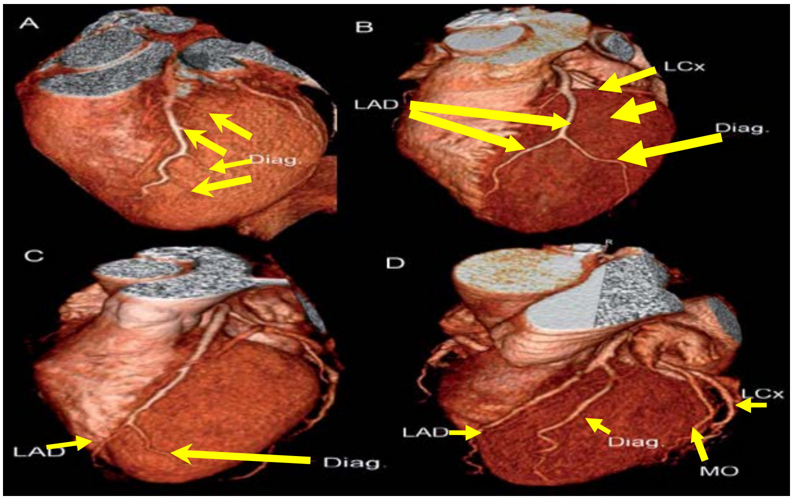

Figure 6: Normal anatomical variants of diagonal (Diag) branches. A: Multiple small brief branches; B: Single branch emerging from the middle left anterior descending (LAD); C: Single branch emerging from the distal LAD; D: Large vessel coursing parallel to the LAD; LCx: left circumflex; MO: marginal obtuse branch. ***(Leta-Petracca, 2006)***

– *Anterior septal branches*: variable in number, these branches arise orthogonally from the LAD and distribute into the anterior two thirds of the interventricular septum. The first septal branch is usually a well developed vessel , its origin being considered as the reference point dividing the proximal and middle portions of the LAD. ***(O'Brien et al., 2007)***

Left circumflex (LCx) artery:

LCx artery is also a large vessel, similar in diameter to the LAD, although more variable in terms of length and anatomical distribution. The proximal portion of the vessel lies beneath the left atrial appendage and, from there, its course follows the anterior aspect of the left atrioventricular groove, ending at the obtuse margin of the heart (Figure 7). In some cases, the vessel extends to the posterior aspect of the left atrioventricular groove, usually below the coronary venous sinus, ending proximally to the region of the *crux cordis*. Finally, in cases of anatomical dominance of the left coronary system; the LCx goes beyond this region and gives the PDA. ***(Standring et al., 2005)***

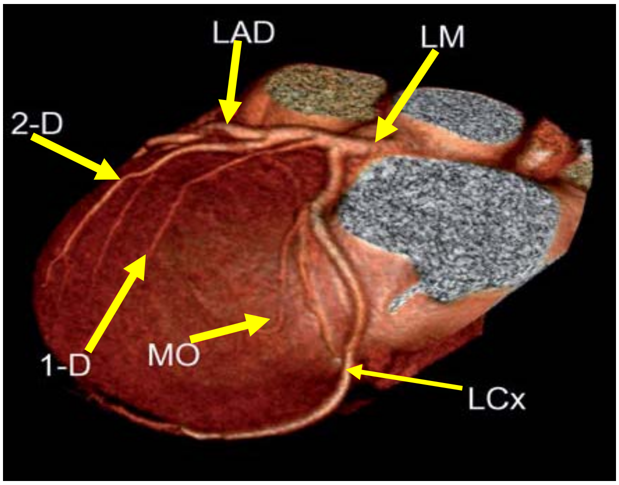

Figure 7: Left circumflex (LCx) artery ending at the (left) obtuse margin of the heart. LAD: left anterior descending; LM: left main; MO: marginal obtuse; 1D and 2D: first and second diagonal branch. ***(Leta-Petracca, 2006)***

LCx gives origin to different branches during its course:

– *Anterior or anterolateral ventricular branches (*Figure 8): when present, these small vessels arise proximally and course parallel to the first diagonal artery. When this artery is absent, it is substituted by these branches.
–*Sinusal or sinoatrial branch* (Figure 8): although usually arising from the right artery, the sinusal branch emerges from the proximal segment of the LCx in 30–35% of individuals, courses around the left atrium, and reaches the sinus node region at the superior vena cava drainage.

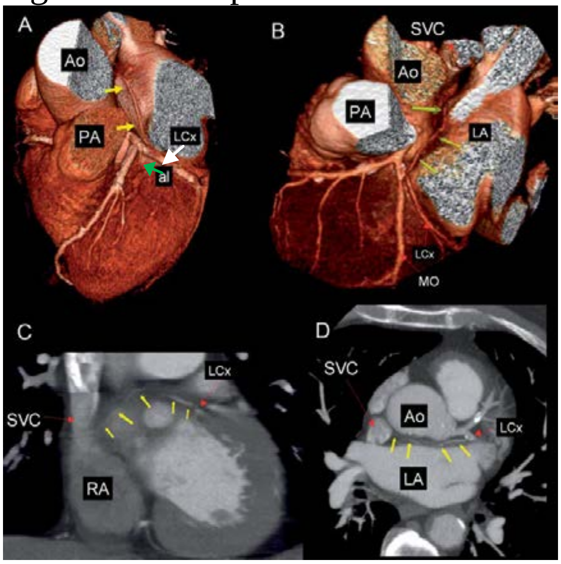

Figure 8: Left circumflex (LCx) artery. A: Anterior view showing an anterolateral (al) branch (green arrow) and a sinus branch (yellow arrows); B: Cranial view also displaying the sinus branch (yellow arrows); C: MPR on an oblique view with volume render, and; D: Axial slice with MIP, both showing the sinus branch of the LCx and its course towards the region of the superior vena cava (SVC); Ao: aorta; LA: left atrium; MO: marginal obtuse branch; PA: pulmonary artery; RA: right atrium. ***(Leta-Petracca, 2006)***

– *Atrial arteries:* these small vessels are usually located beneath the base of the left atrial appendage or at the posterior aspect of the left atrium.

– *Obtuse marginal branches* (Figure 9): usually one or two, their origin is used as a reference dividing the proximal and medial segments of the LCx. These branches are well-developed vessels emerging orthogonally from the LCx and coursing along the left margin of the heart until they reach the apex, where they can communicate with vessels from the LAD.

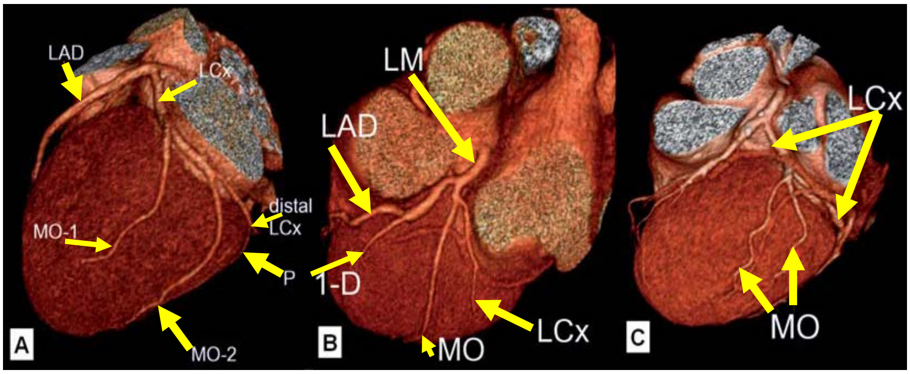

Figure 9 : Anatomy of marginal obtuse (MO) branches. A: Two MO branches are seen (1 and 2) and, also, a posterior branch irrigating the posterior aspect of the left ventricle; B: Occasionally, only a single MO branch is present which arises early from the left circumflex (LCx) and is frequently larger than the LCx itself; C: Bifurcated MO branch; LAD: left anterior descending; LM: left main; 1D: first diagonal. ***(Leta-Petracca, 2006)***

– *Posterior ventricular branches: although* the posterior wall of the left ventricle is mostly irrigated by branches from the right PDA, when this vessel is absent, a variable number of these posterior ventricular branches, together with a number of interventricular branches of the LCx are responsible for the blood supply to this region.

– *Atrioventricular nodal branch*: it arises from the LCx in up to 20% of subjects, particularly in cases of left dominance. ***(Standring et al., 2005)***

Right coronary artery (RCA):

The RCA supplies the blood flow for the right atria and ventricle and, when dominant, also for a variable extension of the posterior aspect of the left ventricle. The proximal segment of the RCA courses closely to the right atrial appendage and is then located on the anterior aspect of the right atrioventricular groove, where it is embedded in adipose tissue (Figure 10).

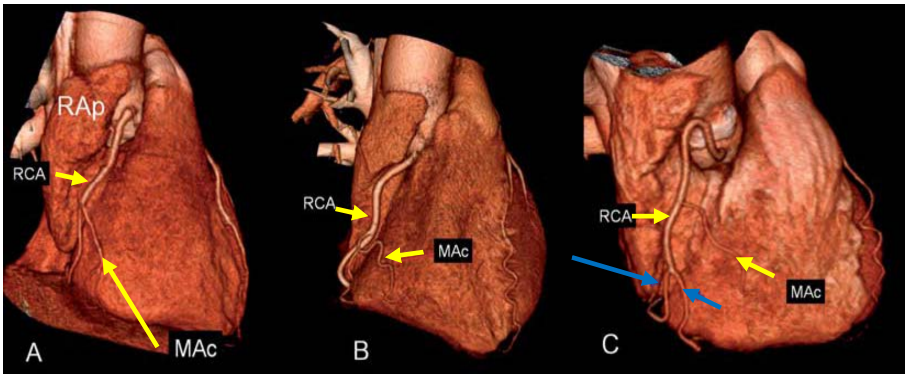

Figure 10: Anatomy of the right coronary artery (RCA). A: Proximal and middle segments of the vessel coursing in close relationship with the right atrial appendage (RAp) and giving origin to the marginal acute branch (MAc); B: Example of a tortuous MAc; C: Early bifurcation of the RCA at its middle segment (blue arrows). ***(Leta-Petracca, 2006)***

At its medial segment, the RCA rounds the right acute margin of the heart and through the posterior aspect of the right atrioventricular groove; it reaches the region of the *crux cordis*.(Figure 11).

There are variants of this anatomical distribution: in 10% of individuals the RCA ends at the level of the acute margin of the heart, or between this region and the *crux cordis*; in 60% the RCA extends beyond the *crux cordis* and reaches the inferior wall of the left ventricle where it shows connections with the distal LCx artery; finally, in 20% of subjects the vessel arrives to the left cardiac margin, irrigating the area corresponding to the LCx. ***(Leta-Petracca, 2006)***

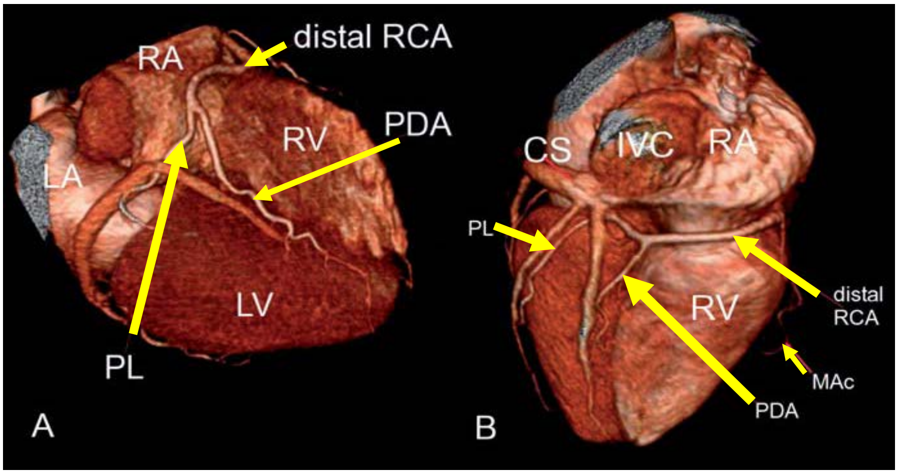

Figure 11: Anatomy of the distal right coronary artery (RCA). A: Bifurcation of the vessel near the region of the crux cordis into a posterior descending artery (PDA) and a posterolateral (PL) branch; B: Example of a long PL branch reaching the left margin of the heart; a marginal acute (MAc) artery is also seen over the right margin;CS: coronary sinus; IVC: inferior vena cava; LA: left atrium; LV: left ventricle; RA: right atrium; RV: right ventricle. **(*Lladó and Petracca, 2006)***

<u>The RCA gives different branches along its course:</u>

– ***Right conal branch***: usually a small vessel, but it may be occasionally large, supplying an extense portion of the right ventricle, in which case, the RCA appears less developed (Figure 17). The right and left conal branches are connected, constituting the “arterial ring of Vieussens.”

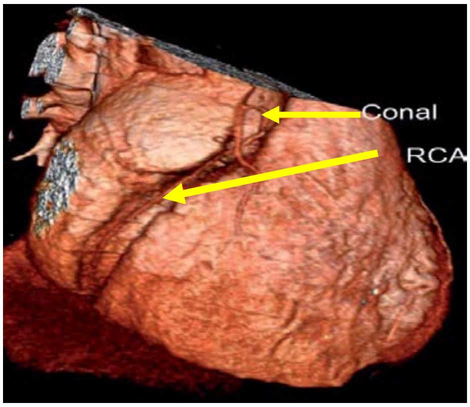

Figure 12: Right conal artery in a case with a relatively narrow right coronary artery (RCA). ***(Leta-Petracca, 2006)***

– ***Sinus node branch*** (Figure 13): this vessel originates from the RCA in more than 50% of individuals, usually arising from the most proximal portion of the RCA or, rarely, from its middle or even distal segment. The sinus node branch courses over the base of the right atrial appendage, ending at the drainage of the superior vena cava into the right atrium.

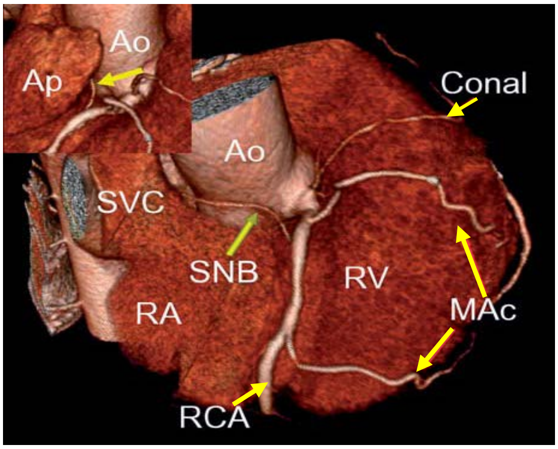

Figure 13: Sinus node branch (SNB) coursing close to the right atrial appendage (Ap) (see inset, at top left)and ending near the region of drainage of the superior vena cava (SVC). Ao: aorta; MAc: marginal acute branch; RA; right atrium; RV: right ventricle. ***(Leta-Petracca, 2006)***