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DIAGNOSIS OF CORONARY ARTERY DISEASE BY MULTISLICE CT IN PATIENTS WITH ATYPICAL CHEST PAIN

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ABSTRACT

The MSCT scanners are equipped with multiple and thinner detector rows, and has a faster tube rotation speed creating two major advantages; high spatial resolution and short acquisition time that enable high-quality examinations. It is only with this immense increase in the data acquisition volume per unit time, that CT assessment of the coronary arteries has become possible. CT angiography has been the noninvasive detection and grading of coronary artery stenosis, assessment of coronary artery anomalies and follow up after coronary bypass surgery. Contraindications to CTCA include irregular heart beats (arrhythmias), contra-indications to iodinated contrast material including allergy, renal insufficiency and hyperthyroidism, contra-indications to radiation exposure; pregnancy, respiratory impairment and marked heart failure. Atypical angina is chest pain or discomfort that lacks one of the characteristics of typical angina. It can arise from a variety of etiologies including cardiac and non-cardiac causes. Cardiac chest pain may be caused by either coronary artery disease (CAD) or non-CAD related etiologies. The latter includes ischemic syndromes in the absence of as well as non-ischemic cardiac pain. MDCT plays an important role in the assessment of acute thoracic disease involving the great vessels such as pulmonary embolism and aortic dissection as well as non-cardiac causes of acute chest pain. CT based evaluation for significant coronary artery stenosis has been shown to decrease the number of unnecessary hospital admissions without reducing the rates of appropriate admissions by ruling out the absence of acute coronary syndrome.

INTRODUCTION

The coronary vessels are conductive vessels running through the epicardial surface of the heart, embedded in the adipose tissue, and showing short segments of mild penetration in the myocardial tissue. As indicated by its name (from the latin *corona*: crown), coronary artery are distributed over the heart as crown shaped network, showing anastomotic communications between its different branches, particularly at the level of the apex and base of the left ventricle (LV***) (Petit et al 1993).***

CT anatomy of the coronary arteries

Cardiac axis

The heart is studied in its oblique plane since the cardiac axis is not perpendicular to the MDCT device gantry. With this configuration, the ostia of the left coronary trunk and right coronary artery are localized at the same distance from the aortic valve when measured along the axis of the ascending aorta. However, on MDCT, these vessels typically are seen at different levels ***(Vogl TJ et al 2002).***

Left Coronary Artery

The left coronary trunk originates in the left aortic sinus and passes behind the pulmonary trunk. Normally, it has a horizontal course or a slightly caudo-cranial course. It courses for a variable distance before giving rise to the left anterior descending ***(LAD)*** artery and the left circumflex ***(LCX)*** branches ***(Vogl TJ et al 2002).***

The ***LAD*** artery initially passes behind the pulmonary trunk, after coursing between this vessel and the left atrial auricular to reach the interventricular septum ***(Fig 2).***When arteries are evaluated from the cardiac basis towards its apex, the anterior descending artery usually is the first coronary artery to be identified, followed by the left coronary trunk ***(Vogl TJ et al 2002).***

The major branches of the ***LAD*** artery are the ***diagonal*** and ***septal perforating*** arteries .The ***diagonal*** branches

course laterally and pre- dominantly supply the LV free wall. The ***septal*** branches course medially and supply the majority of the interventricular septum, as well as the atrioventricular (AV) bundle and proximal bundle branch ***(Fig 3) (Vogl TJ et al 2002).***

The ***LCx*** artery is the other major branch of the LCA. Immediately after arising from the left coronary trunk division, courses posteriorly to pass under the left atrial auricula and reach the left atrio-ventricular sulcus. A short segment of the circumflex artery is typically seen at the same level of the left coronary trunk division ***(Malouf JF et al 2005).***

The circumflex artery usually originates three marginal obtuse branches, sometimes referred to as lateral branches, the first of them being the greatest one ***(Fig 4).*** The ***LCx*** artery and its branches supply the LV free wall and a variable portion of the anterolateral papillary muscle. It variably gives rise to ***postero-lateral*** and posterior descending artery ***(PDA)*** branches supplying the diaphragmatic portion of the LV ***(Malouf JF et al 2005).***

In approximately 15% of patients, a third branch, the ramus intermedius ***(RI)*** branch arises at the division of the LCA, resulting in a trifurcation. When present the ***RI*** branch course laterally towards the LV free wall. Its course is similar to that of a diagonal branch of the LAD artery ***(Fig 5) (James P et al 2007).***

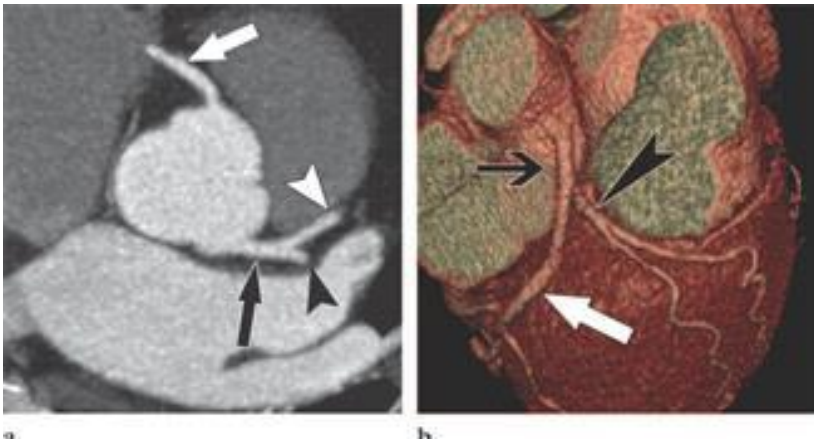


Figure 1. **(a) Axial MPR image displays the origin of the coronary arteries from the aorta. The LCA (black arrow) bifurcates into (LAD) artery (white arrowhead) and (LCx) artery (black arrowhead).White arrow indicates the right coronary artery (RCA). (b) VR image shows the LCA (black arrow) arising from the aorta and bifurcating into the proximal LCx artery (arrowhead) and the proximal LAD artery (white arrow)** ***(James P et al 2007).***

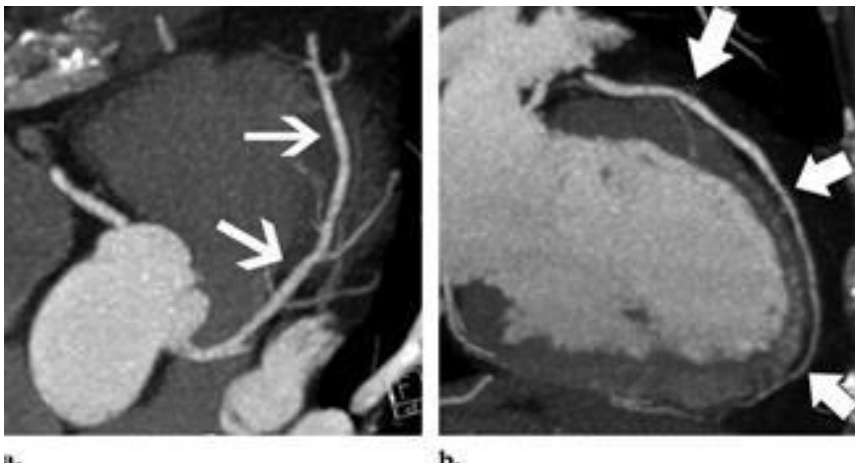


Figure 2. **Oblique axial (a) and vertical long-axis (b) MPR images show the normal LAD artery (arrows) coursing in the interventricular groove toward the LV apex** ***(James P et al 2007).***

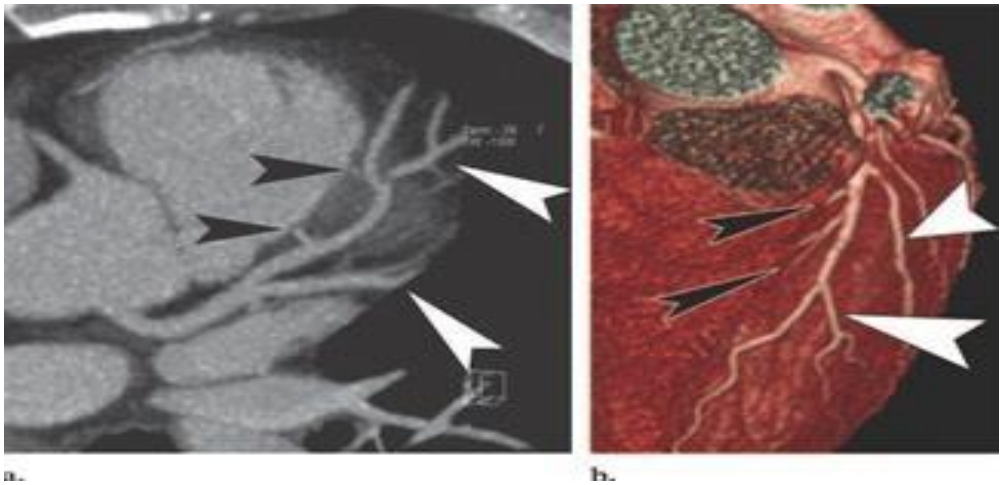


Figure 3.*Oblique axial MPR (a) and VR (b) images show the septal branches (black arrowheads) and diagonal branches (white arrow-heads) of the LAD artery. The septal branches quickly reach and penetrate the myocardium, whereas the diagonal branches course laterally to the LV free *(James P et al 2007).

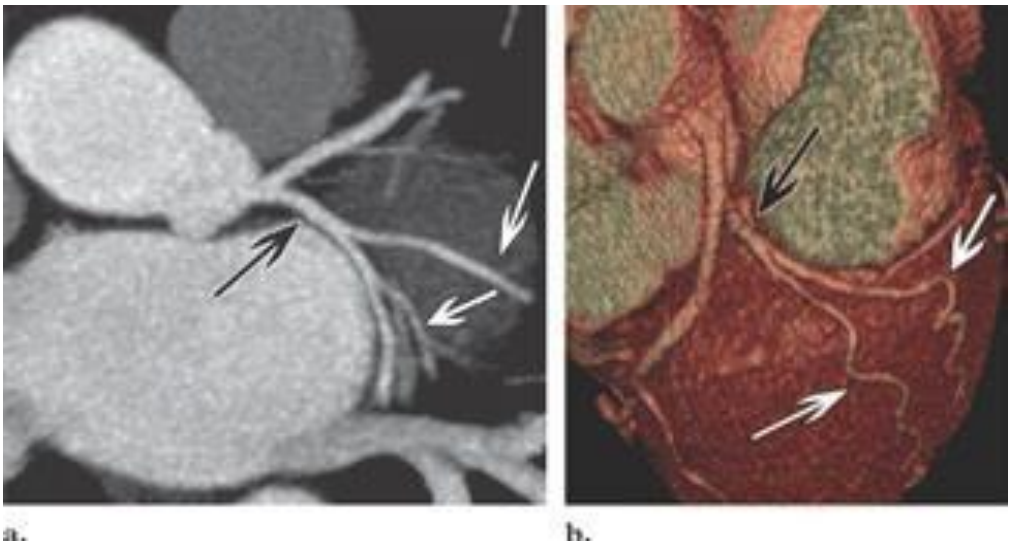


Figure 4*. Oblique axial MPR (a) and VR (b) images show the LCx artery (black arrow) and obtuse marginal branches (white arrows) *(James P et al 2007).

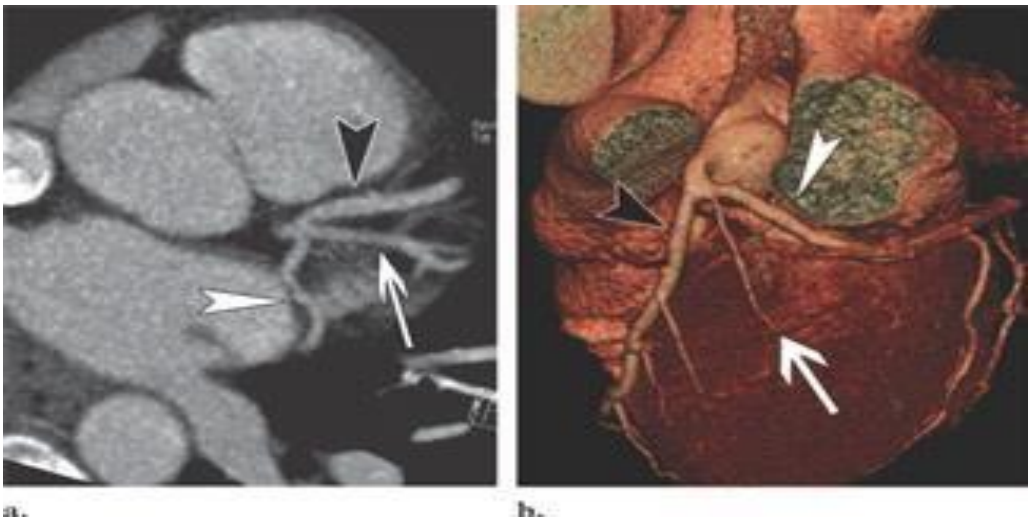


Figure 5.* (a) Oblique axial MPR image shows the RI branch (arrow) arising between the LAD artery (black arrowhead) and the LCx artery (white arrowhead), resulting in a trifurcation of the LCA. (b) VR image shows the RI branch (arrow) arising from the trifurcation. Black arrowhead indicates the LAD artery, white arrowhead indicates the LCx artery *(James P et al 2007).

Right Coronary Artery

The RCA normally arises from the right coronary sinus (CS) and courses in the right AV groove toward the crux of the heart (the point on the posterior surface of the heart where the AVgroove transects the line of the interventricular septum and interatrial septum, forming a cross).

It initially passes between the exit passage of the right ventricle and the right auricula and continues through the right atrioventricular sulcus. The initial portion of the right coronary artery (15–25 mm) follows in a horizontal course therefore is usually identified in longitudinal slices. The final portion of the proximal segment and the whole middle portion of the right coronary artery are transversally sliced during its course through the right atrioventricular sulcus. The distal portion of the right coronary artery originates after the marginal branch emergence and passes horizontally along the heart diaphragmatic surface where it can be identified in longitudinal slices ***(James P et al 2007).***

In approximately 50%–60% of patients, the first branch of the RCA is a ***conus*** artery. The conus artery can also arise directly from the aorta (30%–35% of patients)**.** The conus artery supplies the RV outflow tract (conus arteriosis) and forms the circle of Vieussens, an anastomosis with the LAD arterial circulation ***(James P et al 2007).***

In approximately 58% of patients, the ***sino-atrial-nodal*** artery, which is an atrial branch, distributed largely to the myocardium of both atria, mainly the right artery, arises from the RCA; in the remaining patients (42%), it arises from the LCx ***(James P et al 2007).***

The distal RCA divides into the posterior descending artery ***(PDA),*** and the posterior left ventricular branches. The PDA runs in the posterior inter-ventricular groove. If the LAD artery, which usually supplies the apex of the heart, is small, the PDA can extend around the apex to supply one-third of the anterior inter-ventricular septum. PDA is single in 70% of cases and is otherwise accompanied by parallel right coronary branches, to the right or left or on both sides of the sulcus ***(James P et al 2007)***

Congenital anomalies of the coronary arteries

Anomalies of the coronary arteries may be found incidentally in 0.3%–1% of healthy individuals. For several decades, premorbid diagnosis of coronary artery anomalies was made with angiography. However, it was recently reported that, identified consensually with multi–detector row CT, conventional angiographic findings alone allowed correct identification of the abnormalities in only 53% of cases.

Anomalies of origin

High takeoff
Multiple ostia
Single coronary artery
Anomalous origin of coronary artery from pulmonary artery* Origin of coronary artery or branch from opposite or noncoronary sinus and an anomalous (retroaortic, interarterial,* prepulmonic, septal [subpulmonic]) course.

-Anomalies of course

Myocardial bridging* Duplication of arteries

-Anomalies of termination

Coronary artery fistula*
Coronary arcade
Extracardiac termination.
*Hemodynamically significant anomalies

Case 1

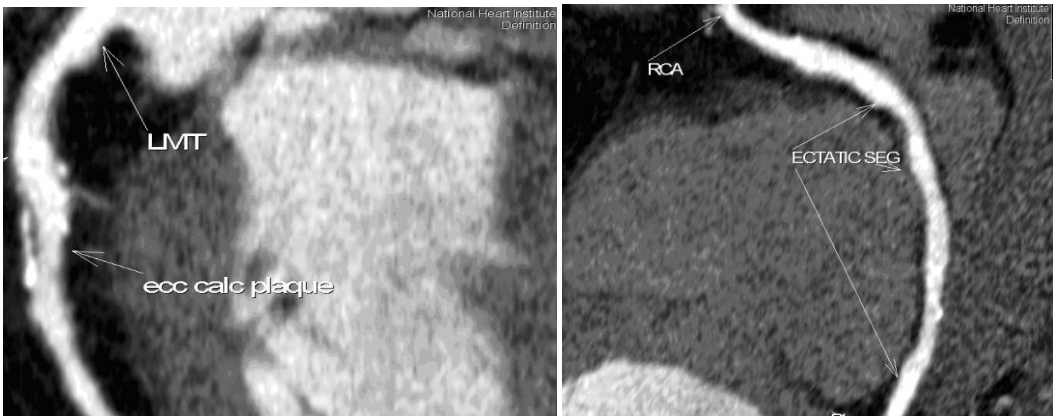
Male patient, 64 years old, hypertensive and diabetic with negative family history for CAD, presented for the last six months by dyspnea related to effort. In the last month, he developed chest pain (heaviness), not related to effort and not radiating. Resting ECG showed no ischemic changes. Troponin enzyme was negative. Multislice CT coronary angiography was requested to rule out significant coronary artery disease.

Non contrast ECG gated thin sections were carried through the coronary arteries to detected and calculate the coronary calcium score. IV injection of 80 ml of iodixanol 370 through an antecubital vein at a high flow rate (5.5 ml/sec.) followed by rapid acquisition of constructive ultra-thin sections (0.6 mm) through the heart to evaluate the coronary arteries. Retrospective reconstruction at 10 time points (30-80%) at 10% intervals throughout the cardiac cycle was performed. Multi-planar reformatted (MPR), maximal intensity projections (MIP) and volume rendering (VR) images at best diastole and best systole of the cardiac cycle with selective reconstruction of the improperly visualized coronary segments at different phases of the cardiac cycle were done.

CT coronary angiography revealed
Non obstructive CAD with ectasia.

- **LMT**: normal segment that bifurcates into LAD and LCX.
- **LAD**: Long artery that reaches and wraps around the apex. It gives a 2 diagonal branches. The proximal mid LAD show mild ectatic changes reaching 4.9 mm. The mid LAD shows an eccentric calcified plaque causing mild stenosis.
- **LCX**: Non dominant artery that gives 3 OM branches. The proximal LCX segment shows mild ectasia yet appear free of significant disease.
- **RCA**: Dominant artery that gives RV branches and ends by bifurcating into a long PDA and PL arteries. The RCA is an ectatic artery that reaches diameter of 5.3 mm at its proximal segment. The RCA and its branches also show mild diffuse atherosclerotic changes yet appear free of significant disease.

N.B Patent foramen ovale is noted



CT angiographic findings of case 1

Case 2

Female patient, 48 years old, hypertensive but not diabetic with negative family history for CAD, presented for the last two years by chest pain at rest. Resting ECG showed no ischemic changes. Troponin enzyme was negative Multislice CT coronary angiograhy was requested to rule out significant CAD.

Non contrast ECG gated thin sections were carried through the coronary arteries to detected and calculate the coronary calcium score. IV injection of 80 ml of iodixanol 370 through an antecubital vein at a high flow rate (5.5 ml/sec.) followed by rapid acquisition of constructive ultra-thin sections (0.6 mm) through the heart to evaluate the coronary arteries.

A dual source multi-detector CT coronary angiography (64 slices) is used with ECG-gated acquisitions through the heart during a single breath hold. Retrospective reconstruction at 10 time points (30- 80%) at 10% intervals throughout the cardiac cycle is performed. Multi- planar reformatted (MPR), maximal intensity projections (MIP) and volume rendering (VR) images at best diastole and best systole of the cardiac cycle with selective reconstruction of the improperly visualized coronary segments at different phases of the cardiac cycle were done.

CT coronary angiography revealed

Anomalous RCA that arise from left coronary sinus

Zero calcium score

- **LMT**: normal segment that bifurcates into LAD and LCX.
- **LAD**: Long artery that reaches and wraps around the apex. It gives 3 diagonal branches and many septal perforaters. It appear free of significant disease.
- **LCX**: Non dominant artery that gives a OM branches. It appear free of significant disease.
- **RCA**: A dominant artery that arises with a kink from the anterior aspect of the left coronary sinus of Valsalva. It runs a short course between the aorta and the right ventricular outflow tract (RVOT) to reach the right AV groove (Inter-arterial course). It supplies RV branches and ends at the crux of the heart by giving a PDA and PL branch. The RCA and its branches appear free of significant lesions.

CT angiographic findings of case 2

Case 3

Female patient, 48 years old, not hypertensive nor diabetic with positive family history for CAD, presented for the last 6 monthes by dyspnea and stitching chest pain not related to effort. Resting ECG showed no ischemic changes. Troponin enzyme was negative. Multislice CT coronary angiograhy was requested to rule out significant CAD.

Non contrast ECG gated thin sections were carried through the coronary arteries to detected and calculate the coronary calcium score. IV injection of 80 ml of iodixanol 370 through an antecubital vein at a high flow rate (5.5 ml/sec.) followed by rapid acquisition of constructive ultra-thin sections (0.6 mm) through the heart to evaluate the coronary arteries. A dual source multi-detector CT coronary angiography (64 slices) is used with ECG-gated acquisitions through the heart during a single breath hold. Retrospective reconstruction at 10 time points (30- 80%) at 10% intervals throughout the cardiac cycle is performed. Multi- planar reformatted (MPR), maximal intensity projections (MIP) and volume rendering (VR) images at best diastole and best systole of the cardiac cycle with selective reconstruction of the improperly visualized coronary segments at different phases of the cardiac cycle were done.

CT coronary angiography revealed
Normal coronary arteries with mediastinal mass

- Zero calcium score with normal CT angiographic appearance of the coronary arteries.
- A well defined large heterogeneously enhancing mass was noted occupying the left upper aspect of the anterior and middle mediastinum. It was seen mildly compressing the main pulmonary trunk and causing pericardial thickening in the adjacent area of the pericardium. Tiny flecks of calcification were noted within, with no areas of breaking down or bony invasion detected. The mass was diagnosed as a benign looking one most likely haemangioma.

CT angiographic findings of case 3

Case 4

Female patient, 40 years old, not hypertensive nor diabetic with negative family history for CAD, presented for the last year by recurrent attacks of non-radiating chest pain (compressive) which grew more frequent in the last month. Resting ECG showed no ischemic changes. Troponin enzyme was negative Multislice CT coronary angiograhy was requested to rule out significant CAD.

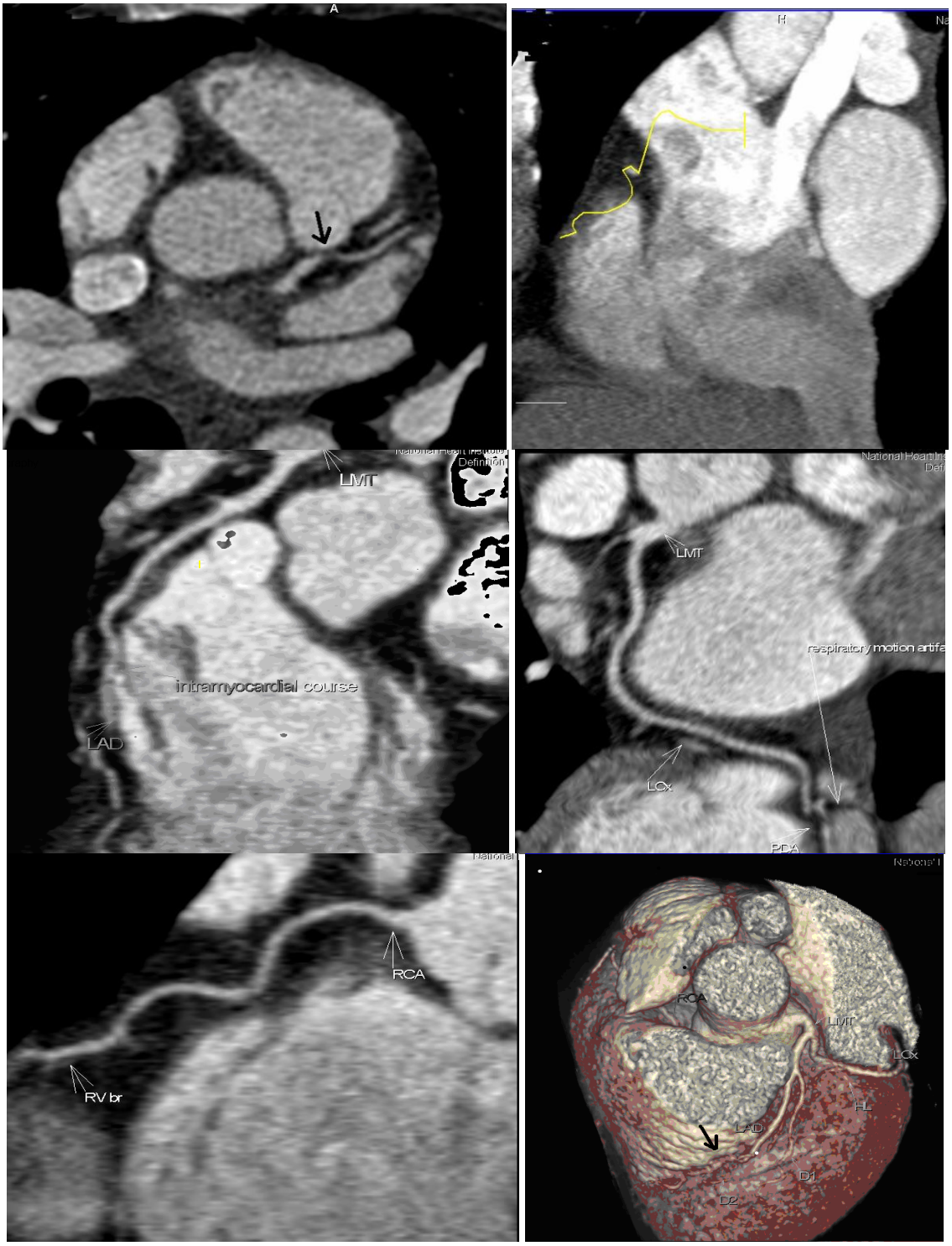
Non contrast ECG gated thin sections were carried through the coronary arteries to detected and calculate the coronary calcium score. IV injection of 80 ml of iodixanol 370 through an antecubital vein at a high flow rate (5.5 ml/sec.) followed by rapid acquisition of constructive ultra-thin sections (0.6 mm) through the heart to evaluate the coronary arteries. A dual source multi-detector CT coronary angiography (64 slices) is used with ECG-gated acquisitions through the heart during a single breath hold. Retrospective reconstruction at 10 time points (30- 80%) at 10% intervals throughout the cardiac cycle is performed. Multi- planar reformatted (MPR), maximal intensity projections (MIP) and volume rendering (VR) images at best diastole and best systole of the cardiac cycle with selective reconstruction of the improperly visualized coronary segments at different

phases of the cardiac cycle were done.

CT coronary angiography revealed: Intramyocardial bridging of mid LAD

Zero calcium score

- **LMT**: normal segment that bifurcates into LAD and LCX.
- **LAD**: Long artery that reaches and wraps around the apex. It gives diagonal branches and many septal perforaters. The mid LAD shows a short segment of a superficial intramyocardial course not leading to diameter reduction during systole (myocardial bridge). It appear free of significant disease.
- **LCX**: Dominant artery that supplies a HL branch, one OM (obtuse marginal) branch, a PL branch and ends at the crux by giving a PDA. It appear free of significant disease.
- **RCA**: Non-dominant small tortuous artery that supplies RV branch. The RCA appears free of significant disease.



CT angiographic findings of case 4

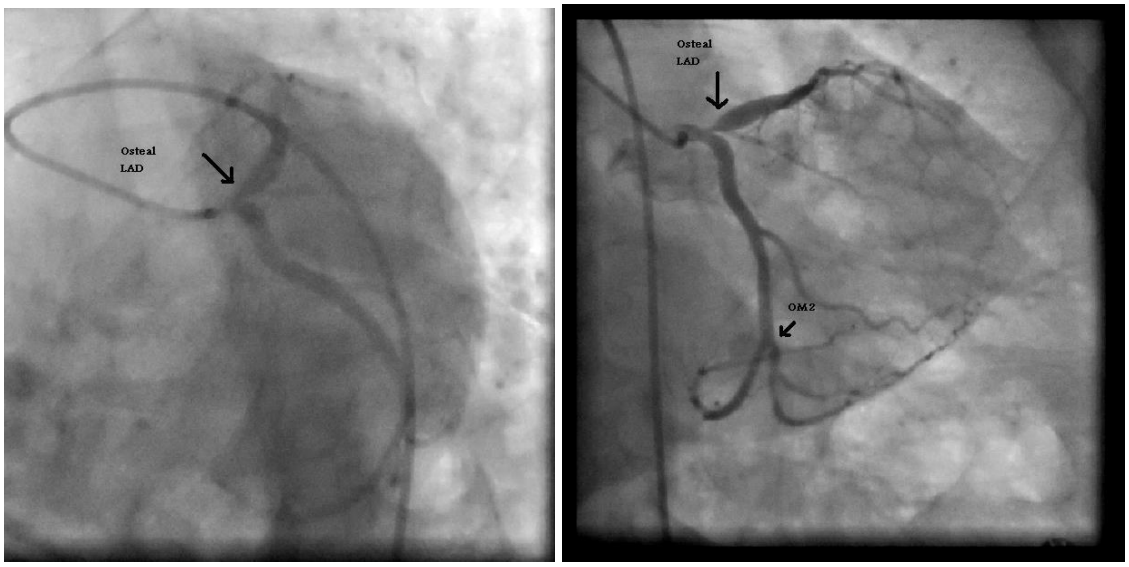
Case 5
A male patient, 39 years old, hypertensive, dyslipedemic and smoker since 10 years with positive family history for CAD, presented for the last 3 monthes by recurrent attacks of chest pain (heaviness) at rest. Resting ECG showed no ischemic changes but showed right bundle branch block. Tropnin test was negative. Multislice CT coronary angiograhy was requested to rule out significant CAD.

Non contrast ECG gated thin sections were carried through the coronary arteries to detected and calculate the coronary calcium score. IV injection of 80 ml of iodixanol 370 through an antecubital vein at a high flow rate (5.5 ml/sec.) followed by rapid acquisition of constructive ultra-thin sections (0.6 mm) through the heart to evaluate the coronary arteries. A dual source multi-detector CT coronary angiography (64 slices) is used with ECG-gated acquisitions through the heart during a single breath hold. Retrospective reconstruction at 10 time points (30- 80%) at 10% intervals throughout the cardiac cycle is performed. Multi- planar reformatted (MPR), maximal intensity projections (MIP) and volume rendering (VR) images at best diastole and best systole of the cardiac cycle with selective reconstruction of the improperly visualized coronary segments at different phases of the cardiac cycle were done.

CT coronary angiography revealed
Significant LAD stenotic lesion

- **LMT**: normal segment that bifurcates into LAD and LCX.
- **LAD**: Long artery that reaches and wraps around the apex. It shows a significantly stenotic osteal lesion. It gives diagonal branches and septal perforaters.
- **LCX**: Dominant artery that supplies, a HL branch and ends at the crux by giving a PDA. It appear free of significant disease.
- **RCA**: Non-dominant artery that supplies RV branch. The RCA appears free of significant disease.

The study was partially degraded as the patient had right bundle branch block causing some arrhythmia
The patient physician based on the MDCT results requested **CCA**, which was performed one week later. It revealed the same significantly stenotic LAD osteal lesion, in addition it also revealed another stenotic lesion at second OM which was not evaluated by MDCT coronary angiography.



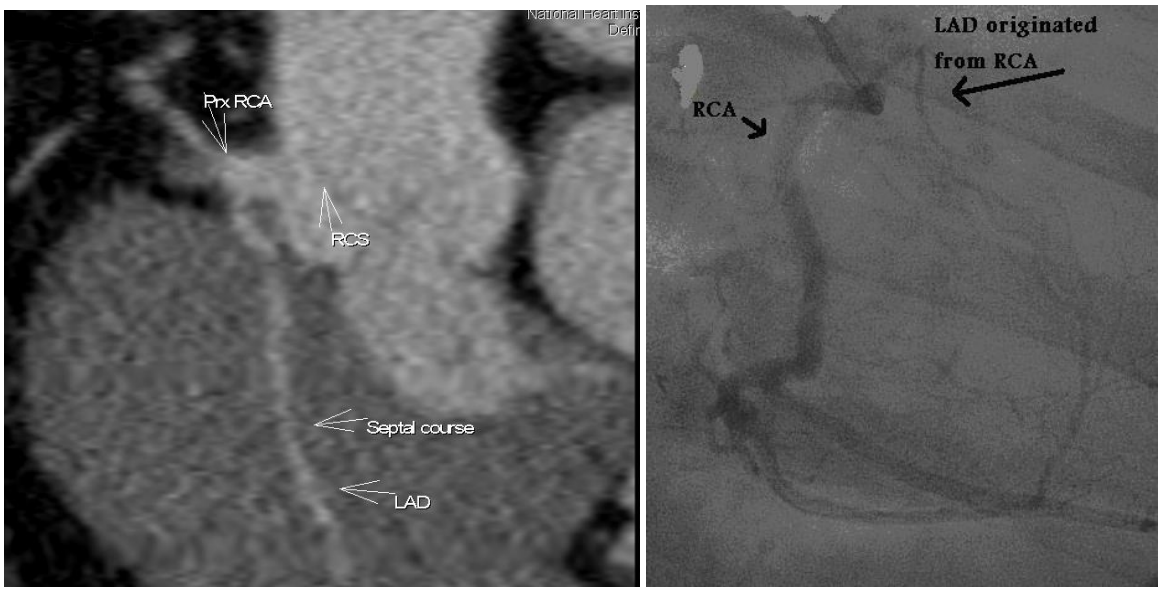
Comparable CT angiographic and conventional angiographic findings of case 5

Case 6
Female patient, 46 years old, dyslipedemic, diabetic with positive family history for CAD, presented for the 3 months by recurrent attacks of chest pain at rest. Resting ECG showed no ischemic changes. Troponin enzyme was negative CCA was performed to rule out significant CAD.

On **conventional coronary angiography**; there was failure to canulate the left coronary artery, even injection at the left coronary sinus didn't lead to opacification of the LMT. Selective injection at the right coronary artery led to opacification of a small artery (arising from proximal RCA), that has a short septal course. The RCA is a dominant artery that gives RV branches then ends by bifurcation into PDA and PL. MDCT coronary angiography was required to confirm the anomalous origin of the LAD.

Non contrast ECG gated thin sections were carried through the coronary arteries to detected and calculate the coronary calcium score. IV injection of 80 ml of iodixanol 370 through an antecubital vein at a high flow rate (5.5 ml/sec.) followed by rapid acquisition of constructive ultra-thin sections (0.6 mm) through the heart to evaluate the coronary arteries. A dual source multi-detector CT coronary angiography (64 slices) is used with ECG-gated acquisitions through the heart

during a single breath hold. Retrospective reconstruction at 10 time points (30- 80%) at 10% intervals throughout the cardiac cycle is performed. Multi- planar reformatted (MPR), maximal intensity projections (MIP) and volume rendering (VR) images at best diastole and best systole of the cardiac cycle with selective reconstruction.



Comparable CT angiographic and conventional angiographic findings of case 6

From the previous data, sensitivity, specificity, positive predictive value, negative predictive value & accuracy of MDCT coronary angiography was calculated compared to the gold standard CCA and were as follow; 98%, 97.7%, 90.5%, 99.5, 97.7% respectively.

Table: Comparison between positive findings of MDCT angiography and CCA among the studied cases.

MDCT	**CCA**	
	Negative (n= 220)	**Positive (n= 50)**
Negative (n=216)	215	1
Positive (n=54)	5	49

Table: Sensitivity, specificity, PPV, NPV, and accuracy of MDCT angiography in detection of significant CAD.

	Sensitivity	**Specificity**	**PPV**	**NPV**	**Accuracy**
MDCT angiography	49/50 (98%)	215/220 (97.7%)	49/54 (90.7%)	215/216 (99.5%)	264/270 (97.7%)

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