***Original Research Article***

# Normal and variant anatomy of CoronaryArteries:64-Slice MultiDetector Computed Tomography (MDCT) Coronary Angiographic Depiction in North Indian population


***Abstract-***

The aim of this study was to review the appearance of normal patterns of right and left coronary arteries their anatomic variants and anomalies and to assess their incidence in subjects of North India who underwent 64-slice Computed Tomographic Coronary Angiography (CT-CA) for suspected or known coronary artery disease (CAD).

This study was carried out in the Departments of Radiodiagnosis, KGMU, U.P, Lucknow, India. Fifty CT Coronary Angiograms of routine subjects of either sex and of different age groups coming to the department of Radiodiagnosis were evaluated prospectively to see the normal and variant anatomy of right and Left Coronary Arteries regarding their origin, length of main trunk and branching pattern.

The most common position of orifices of rca and lca was below the sinotubular junction (82%). Most common origin of rca was anterior aortic sinus and lca from Left Posterior Aortic Sinus (LPAS). The main branches of rca are sinoatrial nodal artery(78%),conus artery(86%),acute marginal branches,posterior descending artery(86%).The two main branches of LCA are Left Circumflex (LCX) artery and Left Anterior Descending (LAD) artery. This study revealed that the main trunk of LCA bifurcated into LCX artery and LAD artery in *68%* subjects. The artery was seen to be trifurcating in *30%* cases with the Ramus Intermedius (RI) being the third artery and tetrafurcated in 2% subjects.



***Keywords***- Coronary angiography (CA), Right coronary artery (RCA), Left coronary artery (LCA), Ramus intermedius (RI),Sinoatrial nodal artery(SANA), 64-Slice Multi-detector Computed Tomography (MDCT).

# I. INTRODUCTION

Cardiovascular diseases are the leading cause of mortality worldwide; responsible for one-third of all deaths [1]. The incidence of coronary artery disease is increasing today in developing countries as well, because of changing life style, urbanization, sedentary life style, hypertension, diabetes and increased type A personality [2,3]. With the ever increasing load of coronary heart disease, a detailed study of coronary arteries has been felt by the medical fraternity and it is of immense use to the cardiologists and interventional radiologists [4]. An in-depth knowledge of normal anatomy of coronary arteries, its variations and various anomalies of coronary circulation are of paramount importance in management of congenital and acquired heart diseases [5]. Coronary arteries show wide variations among different populations. These region based variations have not been dealt enough in the standard books [6].

Since decades Conventional Coronary Angiography (CCA) has been the technique of choice for visualizing coronary artery tree. Still there is a need for alternate methods to visualize the coronary arteries. CCA is invasive and has disadvantages in detecting coronary artery anomalies because of limited number of 2D projection images and absence of soft tissue information.In the past few years advances have been made in non-invasive cardiac imaging [7-9].

The 64-slice CT angiogram, introduced in 2005 is a one-stop shop, which provides detailed coronary anatomy and wall motion, calcium scoring, and plaque characterization [10]. MSCT is becoming an increasingly acknowledged means of visualizing coronary arteries. Coronary angiography (CA) has been considered as the gold standard for the quantification of coronary artery disease [11]. These days the use of CT coronary angiography is increasing in frequency as a non-invasive means of evaluating the coronary arteries. CT coronary angiography has helped radiologists to understand the variations and anomalies of the anatomy of the coronary arteries [12, 13]. This can be of immense help to the cardiologist for planning interventional procedures such as stenting, balloon dilatation and graft surgery in cases of calcification, plaque formation and stenosis.

Since decades the anatomy of coronary arteries has been studied in various populations by cadaveric dissection, corrosion casting techniques and different modes of angiography such as Magnetic Resonance Angiography (MRA), Computed Tomographic (CT) angiography etc. But no such study was

conducted in North Indian population to the best of our knowledge, so this endeavor was made to study the normal and variant anatomy of coronary arteries by 64 slice CT coronary angiography in North Indian population.

## II. MATERIALS AND METHODS

To study the anatomy of LCA, CT coronary angiograms of 50 subjects of both sex and different age groups [23 males (35-74 years), 27 females (35-73 years)] were analyzed.

### CT scan and reconstruction parameters

Coronary Angiography (CA) was performed on 64 Slice Multidetector Computed Tomographic (MDCT) scanner (BRILLIANSTMCT, Version 2.45.22042, manufactured by Philips) which is installed in the department of Radiodiagnosis, King George .Medical University (KGMU), Lucknow, Uttar Pradesh (U.P.), India. Retrospective Electrocardiographically (ECG) gated imaging was performed (scan protocol is given in Table1).

**Table - 1**

**Scan protocol of 64 slice CTCA**

| | |
|---|---|
| Slices/collimation | 64/0.625mm |
| Effective temporal resolution (with 180°algorithm) | 165 ms |
| Tube current | 800mAs |
| Pitch | 0.2 |
| Tube voltage | 120kV |
| Tube rotation time | 400ms |
| Section thickness | 0.9mm |
| Reconstruction Increment | 0.45mm |
| Field of view | 220mm |

| | |
|---|---|
| (FOV) | |
| ECG gating | Retrospective |
| Isotropic voxel resolution | 0.4× 0.4× 0.4 mm. |
| Scanning time | 10-12 seconds |

**Pre-procedure precautions**

 The subjects were enquired, to rule out the presence of any drug allergy, to avoid the occurrence of any untoward anaphylactic reaction during the procedure.

 Two days prior to the procedure the patients were advised to avoid the intake of fatty food.

 They were advised to drink only water just prior to the procedure.

 Blood urea and creatinine levels were evaluated.

**Procedure**

The subjects were laid supine. Their heart rate was stabilized with an oral dose of 50-100 mg Metoprolol one hour before the scan. If heart rate was not stabilized with an oral dose, then intravenous (IV) Metoprolol was given. Electrocardiogram (ECG) and pulse rate were monitored half an hour prior to the procedure. The subjects were counseled to reduce their anxiety.

The subjects were connected to a cardiac monitor. For venous access, an upper extremity vein (antecubital vein) and a 20-gauge intravenous canula was used. 80-85 ml of non-ionic contrast Iohexol (Omnipaque, GE, GE Healthcare Ireland, Cork)containing iodine concentration of 350 mgI/ml, injected with a

flow rate of 5.5ml/sec, followed by a 20 ml saline flush at a rate of 4ml/sec with a pressure injector (PSI-325). The scan timing was determined with automated bolus tracking technique by placing the region of interest over mid ascending aorta and setting the trigger threshold to 180 Hounsfield (Hu). The subjects were asked to lie still on the "scanning bed" for a period of 5-10 minutes. The instruction was given to the subjects to maintain an inspiratory breath hold during which CT data and ECG tracings were taken. CTCA was performed 5 seconds after aortic peak density. Scanning coverage was from the level of carina to the bottom of the heart. Raw spiral CT data of coronary arteries were reconstructed in various phases of cardiac cycle on a work station (Brilliance 64 version 4.5) to obtain images with the highest quality (without motion artefact).Reconstruction performed at 75% of R-R interval was found to be optimal for image analysis in most of the subjects. In some, if heart rate could not be stabilized properly, then reconstructions were performed at 45% of R-R interval. The images generated were reconstructed and viewed utilizing a separate workstation which enabled generation of the coronary arteries in the standard and in various other anatomical planes as and when required and were interpreted with the help of a cardiac radiologist. Subjects with previous bypass surgery and also those with suboptimal study due to breath hold artefacts were excluded.

All images were reviewed first in axial projection and then with post processing tools such as Multiplanar Reconstruction (MPR), Curved Planar Reformation (CPR), thin-slab Maximum Intensity Projection (MIP), and Volume-Rendering Technique (VRT) with transparent background display. MIPs were obtained using various thicknesses (5–30 mm). Volume-rendered images were also obtained using various orientations.

The length of main trunk of LCA was measured in straight MPR format from its orifice to its division into the Left Anterior Descending (LAD) and Left Circumflex (LCX) arteries in case of bifurcation and into LAD, LCX and Ramus Intermedius (RI) arteries in case of trifurcation

CTCA images of LCA were observed for: (1) Origin (2) Length of main trunk (3) Branching pattern

The origin of LCA was studied with relation to Sino-tubular (ST) junction.

The statistical analysis was performed by using software SPSS (Statistical Package for Social Sciences) version 15.0. The values were represented in Number (%) and Mean ± Standard Deviation (SD).

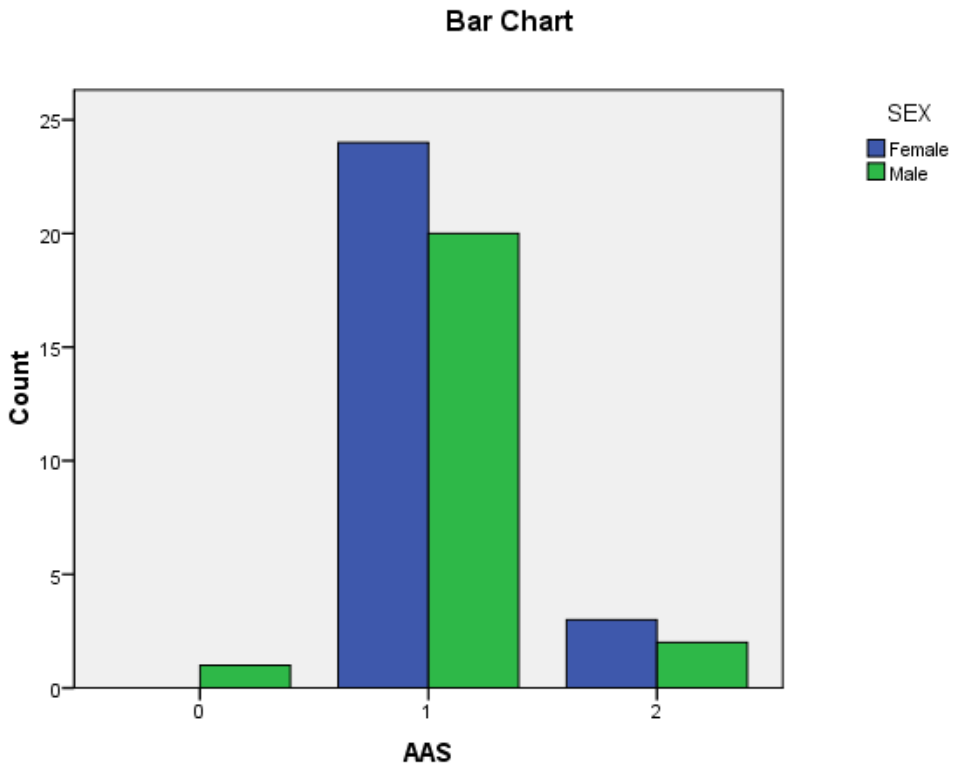
III. RESULTS

In the present study, the AAS showed absence of orifices (A0) in 1 case, who was male (100%). 44 cases [24 (54.5%) females and 20 (45.5%) males] had single orifice in the AAS **(A1).** 5 cases [3 (60%) females and 12 (40%) males] showed 2 orifices in the AAS (A2).LPAS showed single orifice (B1) in 49 cases [27 (55.1%) female & 22 (44.9%) males]. In 1 patient [1 (100%) male] two orifices (B2) were seen. No case was found to have lack in orifice in LPAS (B0). No case was found to have orifice in the RPAS (C).(Table 2).In 7 cases [4(57.1%) females and 3(49.9%) males] had an orifice of conus artery in the AAS in addition to the orifice of RCA (A2C)**.** In one case [1(100%) female] had an orifice of SANA in the AAS in addition to the orifice of RCA **(A2S)**. (Table 3)

**Table – 2. Incidence of variations in number of orifices in aortic sinuses according to gender**

| **Number of orifices** | **AAS** | | | **LPAS** | | | **RPAS** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **F (n%)** | **M (n%)** | **Total (n=50)** | **F (n%)** | **M (n%)** | **Total (n%)** | **F (n%)** | **M (n%)** | **Total (n%)** |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 27 | 23 | 50 |
| | .0% | 100.0 % | 100.0 % | 0.0% | 0.0% | 0.0% | 54.0 % | 46.0 % | 100.0 % |
| 2 | 24 | 20 | 44 | 27 | 22 | 49 | 0 | 0 | 0 |
| | 54.5 % | 45.5% | 100.0 % | 55.1 % | 44.9 % | 100.0 % | 0% | 0% | 0% |
| 3 | 3 | 2 | 5 | 0 | 1 | 1 | 0 | 0 | 0 |
| | 60.0 % | 40.0% | 100.0 % | 0% | 100 % | 100.0 % | 0% | 0% | 0% |
| | **$\chi^2$ =1.252; p=0.535** | | | **$\chi^2$ =1.198; p=0.274** | | | | | |

**Bar Diag. 1: Number of orifices in AAS according to Gender**




**Number of Orifices**

**Bar Diag. 2: Number of orifices in LPAS according to Gender**

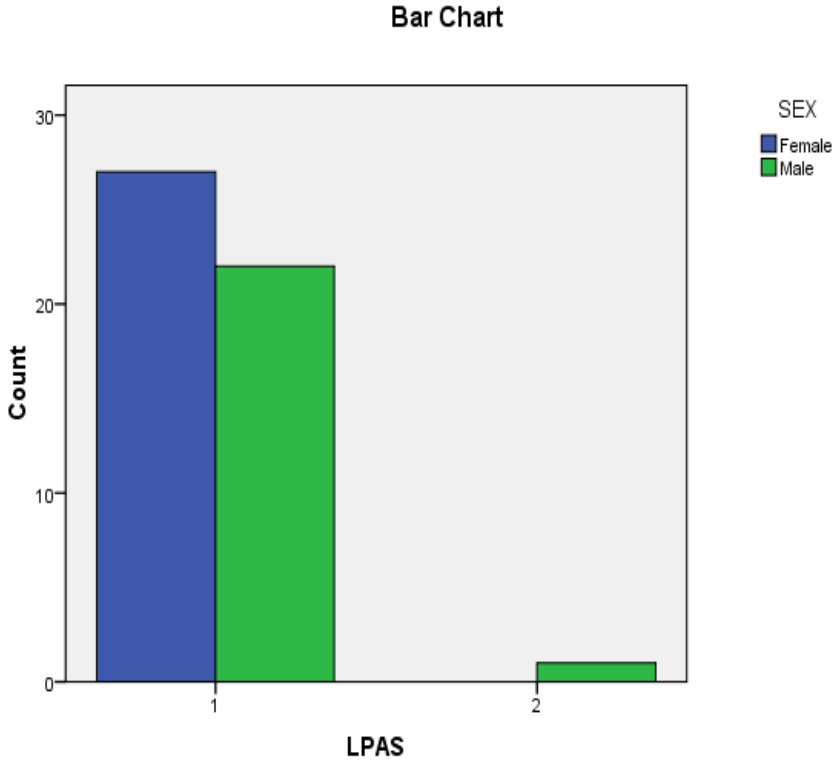


**Table – 3. Incidence of variations in number of orifices for different arteries in aortic sinuses**

| Group | Female (n%) | Male (n%) | Total (n%) | $\chi^2$ | 'p' |
|---|---|---|---|---|---|
| **A0** | 0 | 1 | 1 | 1.252 | 0.535 |
| | .0% | 100.0% | 100.0% | | |
| **A1** | 24 | 20 | 44 | | |
| | 54.5% | 45.5% | 100.0% | | |
| **A2** | 3 | 2 | 5 | | |
| | 60.0% | 40.0% | 100.0% | | |
| **B0** | 1 | 1 | 50 | 1.198 | 0.274 |
| | 100.0% | 100.0% | 100.0% | | |
| **B1** | 22 | 49 | 0 | | |
| | 44.9% | 100.0% | 0% | | |
| **B2** | 1 | 1 | 0 | | |
| | 100% | 100.0% | 0% | | |
| **C** | 0 | 0 | 0 | 0 | 0 |

***Figures in parentheses represent percentage***

A0 – No orifice in anterior aortic sinus (AAS).

A1 – Single orifice of RCA in AAS.

A2 – Two orifices in the AAS.

B0 – No orifice in the left posterior aortic sinus (LPAS).

B1 – Single orifice in the LPAS.

B2 – Two orifices in the LPAS one for the RCA other for the ICA.

C – Orifice was present in the right posterior aortic sinus (RPAS).

The position of the coronary orifices was observed in the frontal plane. The position of both orifices was compared among males and females.

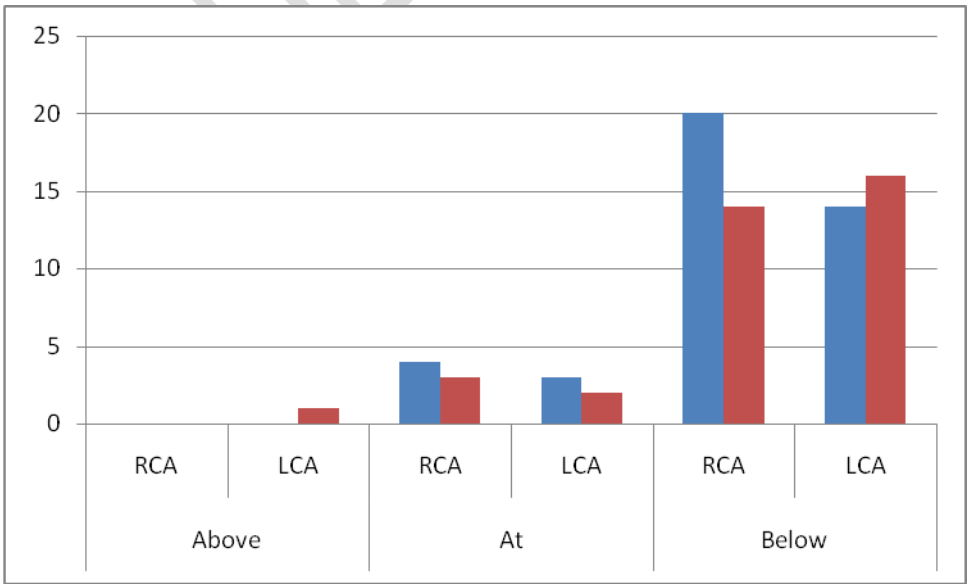
None of the case had orifice of RCA above the sinotubular junction. Sinotubular junction had origin of RCA in 9 cases [5(21.7%) males and 4(14.8%) females]. The orifice of RCA was positioned below the sinotubular junction in 41 cases [18(78.3%) males and 21(85.2%) females.

Orifice of LCA was present above sinotubular junction in only one subject who was a female. Sinotubular junction had origin of LCA in 8 cases [3(13%) males and 5(18.5%) females. The orifice of LCA was positioned below the level of sinotubular junction in 41 cases [20(87%) males and 21(77.8%) females. (Table-4)

**Table – 4. Gender wise distribution of position of coronary orifices with respect to the sinotubular junction**

| | **Position of coronary orifices with respect to ST junction** | | | | | |
|---|---|---|---|---|---|---|
| | **Above** | | **At** | | **Below** | |
| | **RCA** | **LCA** | **RCA** | **LCA** | **RCA** | **LCA** |
| Male (n=23) | 0 | 0 | 5 (21.73) | 3 (13.04) | 18 (78.26) | 20 (86.95) |
| Female (n=27) | 0 | 1 (3.7) | 4 (14.81) | 5 (18.51) | 23 (85.18) | 21 (77.77) |

**Bar Diag. 3 : Gender wise distribution of position of coronary orifices with respect to the sinotubular junction**



## IV. DISCUSSION & CONCLUSION

- The incidence of right dominance (86%), left dominance (12%) and co-dominance (2%) was more or less similar as compared to the incidence reported by others.
- The majority of hearts were right dominant and left dominant circulation was almost six times the co-dominant circulation.
- The incidence of left dominance was more in males (83.3%) as compared to the females (16.7%).
- The present study described the normal and variant anatomy of the orifices in the aortic sinuses. No orifices were observed in the right posterior aortic sinus.
- The number of orifices varied from 0-2 in the present series and multiple orifices were mostly seen in the anterior aortic sinus.
- The most common presentation of orifice in AAS was the presence of single orifice for right coronary artery.
- The most common presentation of orifice in LPAS was the presence of single orifice for left coronary artery.
- The incidence of double orifices was found to be more in AAS as compared to the LPAS.
- Most commonly the extra orifice in AAS was that of conus artery i.e. the third coronary artery.
- The prevalence and distribution of the TCA among North Indians resembles that described previously in some populations over the globe.
- In AAS additional orifice for SANA was seen only in females.
- The most common position of orifices of RCA and LCA was below the sinotubular junction (82%).
- The tendency of an orifice to be present at the sinotubular junction was more in case of RCA.
- The most common site of origin of RCA was anterior aortic sinus.

- The incidence of anomalous origin of RCA was more in males as compared to females.
- The length of RCA was slightly more in males as compare to females but this difference was not statistically significant.
- In most of the cases conus artery, SANA and PDA arose from RCA.
- In most of the cases single acute marginal branch was seen.
- The most common site of termination of RCA was at crux of the heart.
- The termination of RCA at the left border of the heart was not seen.
- In majority of cases LCA arose from LPAS.
- The incidence of "High take-off' of LCA was lower (3.7%) than the incidence (7%) as per the reports of previous studies.
- The length of main trunk of LCA were almost equal in males and females.
- The most common branching pattern of LCA was found to be bifurcation into LAD artery and LCX artery and there is no significant difference found in the branching pattern of LCA among males and females.
- The LAD artery originated from LCA in all the cases and no variation was found regarding the origin of LAD artery.
- The branching pattern of LAD artery was normal in all the cases. No other branch arose from the LAD artery in addition to its normal branches.
- Regarding the number of diagonal branches, the most common pattern was two diagonal branches.
- The difference in the number of males and females having 1 and 3 diagonal branches was statistically significant.
- Regarding the number of septal branches, the most common pattern was one septal branch..
- The difference in the number of septal branches between males and females was not statistically significant.
- The most common pattern of termination of LAD artery was Type 3 termination.

- No significant difference was found between males and females regarding the termination pattern of LAD artery.
- The LCX artery originated from LCA in all the cases and no variation was found regarding the origin of LCX artery.
- The incidence of origin of SANA from LCX artery was more in males (55.6%) as compared to the females (44.4%).
- Regarding the number of obtuse marginal branches, single and double obtuse marginal branches were found in equal number of cases.
- The incidence of origin of PDA from LCX artery in males (83.3%) was approximately five times the incidence found in females (16.7%).
- The most common site of termination of LCX artery was between obtuse marginal artery and crux of the heart.
- There is no significant difference in the dominance pattern of coronary circulation among males and females.
- Posterior descending artery most commonly terminated after traversing the upper 1/4$^{th}$ way of posterior interventricular groove.
- There is no significant difference in the termination pattern of PDA among males and females.
- Most commonly single sinoatriainodal artery was present.
- Double sinoatriainodal artery was found only in males.
- The most common site of origin of SANA was right coronary artery, second most common was LCX artery and least common was the anterior aortic sinus. .
- In our study, the origin of the SANA was mainly from the RCA (78%), then from LCX (18%) and from both RCA and LCX arteries (2%). However, more angiographic studies of coronary arteries in different races should be performed to provide conclusive data on the origin of the SANA.
- SANA arose from dominant artery in 66% cases.
- Most commonly single conus artery was present.
- The most common site of origin of conus artery was right coronary artery and second most common was anterior aortic sinus.

- ❖ Concerning the normal anatomical variations and the coronary artery anomalies, no significant difference was found between the males and females and this is similar to the results of Jamshid Shirani.
- ❖ An anomalous origin of the coronary anatomy must be present in the interpretations because of its importance for patients, cardiologists, and surgeons.

Congenital abnormalities of the coronary arteries are significant cause of chest pain and sudden cardiac death. The findings of present study will be beneficial in making a correct diagnosis and treat the patient accordingly. Variations in the origin, length and branching pattern of coronary arteries have anatomical, pathophysiological, diagnostic and therapeutic implications. A detailed knowledge of all these variations is crucial for the interpretation of coronary angiograms, implementation of stenting procedures and surgical revascularization of myocardium.

The findings of this study are of immense use for interventional cardiologists and radiologists during planning and performing any procedure on coronary arteries.



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