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# Depiction of Normal and Variant Anatomy of Coronary Artery 64 Slice Multi Detector Computed Tomography (MDCT) Coronary Angiography among North Indian Population

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

The aim of the study was to access and review the appearance of normal pattern of left and right coronary artery and their anatomic variants and to assess the incidence of anatomic variants in subject of North Indian population who underwent 64 slice Computed Tomographic coronary Angiography (CT-CA) for suspected or known of coronary artery disease (CAD) This study was carried out in the Departments of Radiodiagnosis, KGMU, U.P, Lucknow, India. Total One hundred and 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

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variant anatomy of right and Left Coronary Arteries regarding their origin, length of main trunk and branching pattern and the result in term of incidence was evaluated. Most common origin of Right coronary artery (RCA) and left coronary artery (LCA) was from left posterior erotic sinus and RCA from interior erotic sinus the main branch of RCA 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). Most common origin of Right coronary artery (RCA) was anterior aortic sinus and left coronary artery (LCA) from Left Posterior Aortic Sinus (LPAS). The main branches of Right coronary artery (RCA) are sinoatrial nodal artery (78%), conus artery (86%), acute marginal branches, posterior descending artery (86%). The two main branches of the left coronary artery (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 most common position of orifices of Right coronary artery (RCA) and left coronary artery (LCA) was below the Sino tubular junction (82%). 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); Left Coronary Artery (LCA); Right Coronary Artery (RCA); Ramus Intermedius (RI); Sinoatrial Nodal Artery (SANA); 64-Slice Multi-Detector Computed Tomography (MDCT).*

## 1. INTRODUCTION

Cardiovascular diseases were the leading cause of mortality and morbidity worldwide; responsible for one-third of all deaths. In developing countries, the incidence of coronary artery disease is increasing today because of changing lifestyle, urbanization, sedentary lifestyle, hypertension, diabetes and increased type A personality. 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. 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. Coronary arteries show wide variations among different populations. These region-based variations have not been dealt with enough in the standard books.

For visualizing coronary artery trees Conventional Coronary Angiography (CCA) has been the technique of choice for many decades. 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 the limited number of 2D projection images and absence of soft tissue information. In the past few year's advances have been made in non-invasive cardiac imaging.

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. MSCT is becoming an increasingly acknowledged means of visualizing coronary arteries. For the quantification of coronary artery disease Coronary angiography (CA) has been considered as the gold standard. 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 anatomy, variations and anomalies of the anatomy of the coronary arteries. This can be of immense help to the cardiologist all over the world for planning interventional procedures such as stenting, balloon dilatation and graft surgery in cases of calcification, plaque formation and stenosis.

Through cadaveric dissection the anatomy of coronary arteries has been studied in various populations since decades. Corrosion casting techniques and different modes of angiography such as Magnetic Resonance Angiography (MRA), Computed Tomographic (CT) angiography were methods to study the normal and variant anatomy of coronary arteries. Among North Indian population to the best of our knowledge no such study was conducted, so this endeavour was made to study the normal and variant anatomy of coronary arteries by 64 slice CT coronary angiography in North Indian population and a total of one hundred and fifty cases were taken into consideration.

## 2. LITERATURE OF REVIEW

An extensive search of literature from the year 1956 to 2011 revealed that various methods were adopted for detection of variations in the arterial supply of the heart. An effort has been attempted to classify the assembled literature on the basis of studies done on living and dead subjects.

A brief survey of studies conducted on cadaveric hearts along with studies performed by catheter angiography, transoesophageal echocardiography, magnetic resonance angiography (MRA) & computed tomographic angiography (CTA) have been incorporated.

### 2.1 Autopsy/Cadaveric Studies

#### (A) Variations in Coronary Ostia

- R Virmani et al. (1984) examined "41 patients at autopsy who were victims of sudden death. 22 patients (mean age 46) had no significant anatomic cause of death compared with 19 patients who died of known causes (control group). Of the 22 patients p, 13 (59%) had acute angle takeoff of the coronary artery and 9 (41%) had ostial valve-like ridges. Of the 19 control subjects, 4 (21%) had acute angle take off and only 2 (11%) had an ostial valve-like ridge".
- Carla Frescura et al. (1998), studied "coronary arteries in 1200 postmortem cases of congenital heart disease in which an isolated anomalous origin of coronary arteries was observed in 27 specimens (2.2%). Stenosis of coronary ostia was present in 4 specimens".
- Kalpana R. (2005), studied "100 specimens of human hearts by manual dissection of coronary arteries in which 90% of ostia of right coronary artery (RCA) and 80% of ostia of left coronary artery (LCA) were below the Sinotubular Junction (STJ). In one specimen, a separate ostium apart from ostium of RCA was present in right aortic sinus for an anomalous artery".

#### (B) Variations in Right Coronary Artery (RCA)

Coronary arteries were studied in 1200 postmortem cases of CHD by Carla Frescura et al. in 1998 in which an isolated anomalous origin of coronary arteries was observed in 27 specimens (2.2%). Right coronary artery (RCA) originated from right sinus in 4 specimens & from left sinus in 7 specimens, high takeoff of RCA was present in 3 specimens, in 43% cases of right coronary artery originated from left aortic sinus, the final outcome was sudden death.

- Kalpana R. (2005), studied "100 specimens of human hearts by manual dissection of coronary arteries in which both proximal and distal segments of the right coronary artery were present in 89%. Dissected hearts of 50 adult Turkish cadavers were studied by Fazliogullari Z et al. in 2010. Right coronary artery (RCA) arose from the right aortic sinus and had an average diameter of 3.32±0.79 mm".
- Luis Ernesto Ballesteros et al. (2011), studied "RCA in 221 fresh hearts by RCA ostium canalization with polyester synthetic resin. The Caliber of RCA proximal segment and at the level of acute angle of the heart was 3.42±0.66 mm and 2.9±0.50 mm, respectively. It ended between crux and left margin in 75.6% of specimens. Posterior interventricular artery (PIA) reached the inferior third, or the apex, or the anterior interventricular sulcus in 149 (67.4%) cases".

#### (a) Variations in Conus Artery

100 specimens of the human heart were studied by Kalpana R. (2005). The third coronary artery was present in 24% specimens.

- Fazliogullari Z et al. (2010) studied "Hearts dissected from 50 Turkish cadavers. The conus branch from the right coronary artery in 32% of hearts and from the right aortic sinus in 68% of hearts".

#### (b) Variations in Sino-Atrial Nodal Artery (SANA)

- C Nerantzis and D Avgoustakis (1980), studied "coronary vessels in 300 human hearts by X-ray films in 240 cases & by corrosion casting technique in 60 cases & found sinus node artery (SNA) arose from RCA in 185 cases (62%), from left circumflex (LCX) artery in 111 cases (37%) and from both coronary arteries in 4 cases (1%). Out of 111 cases in which SNA arose from LCX, an S-shaped sinus node artery (SSNA) was found in 24 (21.5%) cases i.e., 8% of all the hearts. The SSNA

constituted a branch of LCX artery in 15 cases, the upper part of a divided LCX artery in 6 cases, and the main continuation of this artery in 3 cases, I t was larger than the normal SNA".

- Luis Ernesto Ballesteros et al. (2011), studied "RCA in 221 fresh hearts by RCA ostium canalization with polyester synthetic resin. Sinoatrial node artery (SNA) originated from RCA in 134 (60.6%) cases, in 77 (34.9%) cases from circumflex artery (CxA) and from both in 10 (4.5%) cases".

**(C) Variations in Left Main Coronary Artery (LMCA)**

- Carla Frescura et al. (1998), studied "coronary arteries in 1200 postmortem cases of congenital heart disease in which an isolated anomalous origin of coronary arteries was observed in 27 specimens (2.2%). Left coronary artery (LCA) originated from pulmonary trunk in 5 specimens, from left sinus in 7 specimens, from right sinus in 4 specimens & from posterior sinus in 1 specimen. In all cases of LCA originated from the right aortic sinus, the final outcome was sudden death & it occurred in 40% cases of LCA originating from the pulmonary trunk".
- Kalpana R. (2005), studied "100 specimens of human hearts by manual dissection of coronary arteries in which left coronary artery (LCA) showed bifurcation in 47%, trifurcation in 40%, Quadrifurcation in 11%, pentafurcation in 1% and only one branch in 1%".
- Fazliogullari Z et al., (2010), dissected "the hearts of 50 adult Turkish cadavers. The left coronary artery (LCA) arose from the aortic sinus and had an average diameter of 4.44±1.79 mm. LCA showed bifurcation in 23 (46%) hearts, trifurcation in 22 (44%) hearts and quadrifurcation in 5 (10%) hearts. The median artery was identified in 27 hearts, with a mean diameter of 2.00 mm".

**(a) Variations in Left Circumflex (LCX Artery**

- Carla Frescura et al. (1998), studied "coronary arteries in 1200 postmortem cases of congenital heart disease in which an isolated anomalous origin of coronary arteries was observed in 27 specimens (2.2%). Left circumflex branch originated from the right aortic sinus or from the very proximal part or right coronary artery in 3 specimens".

**(D) Variations in Coronary Dominance**

- C Nerantzis and D Avgoustakis (1980), studied "coronary vessels in 300 human hearts by X-ray films in 240 cases & by corrosion casting technique in 60 cases. 266 cases were right dominant type, 28 were left dominant type and 6 were balanced type".
- Kalpana R. (2005), studied "100 specimens of human hearts by manual dissection of coronary arteries. There was right dominance in 89% and left dominance in 11% of the specimens studied".
- Fazliogullari Z et al. (2010), dissected "the hearts of 50 adult Turkish cadavers. Right dominance was observed in 42%, left dominance in 14%, and equal dominance in 44% of hearts".

**(E) Other Findings**

- Ralph W. Alexander and George C. Griffith (1956) found "54 cases with anomalies involving the coronary artery circulation among 18,950 autopsies during a 10-year period, from 1940 to 1949".

## 2.2 Catheter Angiographic Studies

**(A) Variations in Coronary Ostia**

- Engel H. J. et al. (1975), studied "coronary angiograms of 4250 patients. In 51 (1.2%) patients, one or more major elements of the coronary arterial system had ectopic origin from sinuses of Valsalva. The majority of variations involved the left coronary artery & majority of ectopic Ostia were located in the right sinus of Valsalva".
- Chaitman BR et al. (1976), reviewed "coronary angiograms of 3750 patients & found 31 patients with anomalous coronary artery origin. In 17 patients LCX arose from the right sinus of Valsalva & ran posterior to aorta".
- Attila Kardos et al. (1998), analysed "angiographic data of 7,694 patients. Congenital coronary anomalies (CCA) were found in 103 patients. The incidence

of ectopic coronary origin from the opposite aortic sinus was 1.9%".

- Harikrishnan S et al. (2002), "retrospectively reviewed 7400 coronary angiograms excluded patients with congenital heart diseases, coronary artery fistulae and patients with separate origin of the conus artery. They found 34 cases (0.46%) with coronary anomalies. In 1 patient all three coronary arteries originating separately from right sinus".

**(B) Variations in Right Coronary Artery (RCA)**

- Chaitman BR et al. (1976), reviewed "coronary angiograms of 3750 patients & found 31 patients with anomalous coronary artery origin. In 7 patients RCA arose from the left sinus of Valsalva & ran anterior to aorta".
- Charles E. Wilkins et al. (1988), reviewed "coronary angiography records of 10,672 patients and identified major coronary artery anomalies in 94 patients. RCA arose from the left aortic sinus in 30 patients, beginning anteriorly to the LMCA and coursing anteriorly between aorta and pulmonary trunk. 1 patient had RCA to the right atrial fistula. 2 patients had fistulas between both RCA and LCA and the left ventricle".
- Topaz O et al. (1992), studied "coronary angiograms of 13010 adults. 80 (0.61%) had anomalous coronary arteries. The RCA was the most common anomalous vessel. In 35 patients RCA arose from left aortic sinus, in 14 patients RCA arose from posterior sinus, and in 1 patient RCA arose from left coronary artery".
- Kaku B et al. (1996), reviewed "56 patients with anomalous origin of the coronary arteries. Anomalous origin of RCA from the left sinus of Valsalva was seen most frequently (78.6%)".
- Ayalp R, Mavi A, et al. (2002), retrospectively "analysed angiographic data of 5253 consecutive adult patients. In 2 patients, RCA arose from the left coronary sinus of Valsalva with a separate orifice for RCA and LCA and in 3 patients RCA arose from above the left coronary sinus of Valsalva. In these 5 patients, RCA coursed between aorta and pulmonary artery".
- Harikrishnan S et al. (2002), "retrospectively reviewed 7400 coronary angiograms excluded patients with congenital heart diseases, coronary artery fistulae and patients with separate origin of the conus artery and found 34 cases (0.46%) with coronary anomalies. In 7 patients RCA arose from left coronary sinus (20.6%). 1 patient had a double right coronary artery".
- Pallavi Solanki et al. (2010), studied "angiographic data of 2,120 patients. 23 (1.1%) patients had ectopic right coronary arteries (RCAs). Of these, 15 (65%) originated from the anterior third of the right sinus, while 8 (35%) originated from the anterior half of the left sinus".

**(C) Variations in Left Main Coronary Artery (LMCA)**

- Chaitman BR et al. (1976), reviewed "coronary angiograms of 3750 patients & found 31 patients with anomalous coronary artery origin. In 7 patients LCA arose from right sinus of Valsalva or RCA".
- Charles E. Wilkins et al. (1988), reviewed "coronary angiography records of 10,672 patients and identified major coronary artery anomalies in 94 patients. LCA originated from the right aortic sinus in 3 patients, Initial course of LCA in these 3 patients was between the aorta and pulmonary artery. In 3 patients LCA originated from main pulmonary arteries and all these 3 were observed to have dominant RCA and well-developed collateral vessels with retrograde flow to their main pulmonary arteries via LCA".
- Topaz O et al. (1992), studied "coronary angiograms of 13010 adults. 80 (0.61%) had anomalous coronary arteries. 1 patient had an anomalous LMCA".
- Harikrishnan S et al. (2002), "retrospectively reviewed 7400 coronary angiograms excluded patients with congenital heart diseases, coronary artery fistulae and patients with separate origin of the conus artery. They found 34 cases (0.46%) with coronary anomalies. In 1 patient LMCA arose from the right sinus".

**(a) Variations of Left Circumflex (LCX) Artery**

- Charles E. Wilkins et al. (1988), reviewed "coronary angiography records of 10,672 patients and identified major coronary artery anomalies in 94 patients. LCX arose

from the right aortic sinus or from the 1st portion of RCA in 28 patients and it was the most common anomaly found. In all cases, the initial course of LCX was posterior to the aorta. 1 patient had 2 fistulas between LCX and main pulmonary artery. 2 patients had a LCX to right atrial fistula".

- Leroy F et al. (1992), analysed "angiographic features of 30 patients with an anomalous origin of the left circumflex coronary artery. Left circumflex arose from the right anterior sinus of Valsalva with a separate orifice in 37% patients, from a common orifice with RCA in 23% patients and arose from a proximal segment of RCA in 40% patients. 5 patients (17%) had a significant stenosis of the anomalous left circumflex coronary artery".
- Topaz O et al. (1992), studied "coronary angiograms of 13010 adults. 80 (0.61%) had anomalous coronary arteries. 22 (27%) patients had anomalous LCX".
- Attila Kardos et al. (1998), analysed "angiographic data of 7,694 patients. Congenital coronary anomalies (CCA) were found in 103 patients. The incidence was the highest for the separate origin of LCX artery from the left sinus of Valsalva. Incidence of origin of LCX artery from RCA was 8.7% and from right sinus of Valsalva was 18.4%".
- Harikrishnan S et al. (2002), "retrospectively reviewed 7400 coronary angiograms excluded patients with congenital heart diseases, coronary artery fistulae and patients with separate origin of the conus artery and found 34 cases (0.46%) with coronary anomalies. 12 patients had separate origins of LAD artery and LCX artery and this was the most common anomaly (35.3%). In 6 patients LCX artery arose from the right sinus (20%)".
- Ayfer Mavi et al. (1998), analysed "coronary angiographic data of 10,042 adult patients. 27 (0.3%) patients had anomalous origin of LCX artery. The LCX artery arose from the left coronary sinus of Valsalva in 15 (55.5%) patients, from right coronary sinus of Valsalva in 7 (25.9%) patients, and from proximal part of RCA in 8 (29.6%) patients".

**(b) Variations of Left Anterior Descending (LAD) Artery**

- Charles E. Wilkins et al. (1988), reviewed "coronary angiography records of 10,672 patients and identified major coronary artery anomalies in 94 patients. LAD originated from the right aortic sinus in 2 patients and the initial course of this LAD was anterior to the right ventricular outflow tract. In 4 patients, the LAD arose from the pulmonary trunk. 2 patients had multiple small fistulas between the LAD and left ventricle".
- Topaz O et al. (1992), studied "coronary angiograms of 13010 adults. 80 (0.61%) had anomalous coronary arteries. 9 (11%) patients had anomalous LAD artery. 1 patient had an anomalous septal perforator artery".
- Harikrishnan S et al. (2002), retrospectively "reviewed 7400 coronary angiograms excluded patients with congenital heart diseases, coronary artery fistulae and patients with separate origin of the conus artery. They found 34 cases (0.46%) with coronary anomalies. 12 patients had separate origins of LAD artery and LCX artery and this was the most common anomaly (35.3%). In 1 patient, the LAD artery arose from the right coronary sinus".

**(D) Presence of Single Coronary Artery**

- Charles E. Wilkins et al. (1988), reviewed "coronary angiography records of 10,672 patients and identified major coronary artery anomalies in 94 patients. Single coronary artery was observed in 7 patients. In 4 of these patients, the initial portion of the single coronary artery followed the path of a normal LCA but continued posteriorly in the atrioventricular groove to the area of the heart normally supplied by the RCA, in 1 patient single coronary artery arose from right coronary sinus, with a single large trunk traversing between the aorta and pulmonary artery to areas normally supplied by LCX and LAD. In the remaining 2 patients, the single coronary artery arose from the right coronary sinus and trifurcated with the LCX passing posteriorly and the LAD passing anteriorly to the pulmonary artery or between the great vessels".

- Desmet W et al. (1992), searched "coronary angiographic reports of 50,000 consecutive adult patients for diagnosis of single coronary artery. They reviewed all concerned films and retrieved 33% cases of single coronary artery with an incidence of 0.066%".
- Attila Kardos et al. (1998), analysed "angiographic data of 7,694 patients. Congenital coronary anomalies (CCA) were found in 103 patients. The incidence of single coronary arteries was 3.88%".
- Harikrishnan S et al. (2002), "retrospectively reviewed 7400 coronary angiograms excluded patients with congenital heart diseases, coronary artery fistulae and patients with separate origin of the conus artery and found 34 cases (0.46%) with coronary anomalies. Single coronary artery was seen in 3 cases (8.8%)".

## 2.3 Transesophageal Echocardiographic Studies

### (A) Variations in Right Coronary Artery (RCA)

- Francis Fernandes et al. (1993), "studied 9 patients by transoesophageal echocardiography with colour flow Doppler. 2 patients had origin of RCA from left aortic sinus".

### (B) Variations in Left Coronary Artery (LCA)

- Francis Fernandes et al. (1993), "studied 9 patients by transoesophageal echocardiography with colour flow Doppler. In 4 patients, LCA originated from the right sinus of Valsalva and runs between the aorta and pulmonary artery. 1 patient had the origin of the left main coronary artery from the pulmonary artery".

### (a) Variations in Left Circumflex (LCX) Artery

- Francis Fernandes et al. (1993), "studied 9 patients by transoesophageal echocardiography with colour flow Doppler. 1 patient had origin of circumflex artery from right sinus".

### (b) Variations in Left Anterior Descending (LAD) Artery

- Francis Fernandes et al. (1993), "studied 9 patients by transoesophageal echocardiography with colour flow Doppler. 1 patient had the origin of LAD from the right sinus".

## 2.4 Magnetic Resonance Angiography (Mra) Studies

### (A) Variations in Right Coronary Artery (RCA)

- Michael V. McConnell et al. (1995), reviewed "magnetic resonance coronary angiographic (MRCA) data of 16 patients with anomalous aortic origins of the coronary arteries. RCA originated from the left aortic sinus in 4 patients. In 1 patient RCA was anteriorly displaced".

### (B) Variations in Left Main Coronary Artery

- Michael V. McConnell et al. (1995), reviewed "magnetic resonance coronary angiographic (MRCA) data of 16 patients with anomalous aortic origins of the coronary arteries. In 3 patients LCA originated from the right sinus".

### (a) Variations in Left Circumflex (LCX) Artery

- Michael V. McConnell et al. (1995), reviewed "magnetic resonance coronary angiographic (MRCA) data of 16 patients with anomalous aortic origins of the coronary arteries. In 16 patients LCX was right-sided and in 2 patients LCX originated separately from the left sinus".

### (b) Variations in Left Anterior Descending (LAD) Artery

- Michael V. McConnell et al. (1995), reviewed "magnetic resonance coronary angiographic (MRCA) data of 16 patients with anomalous aortic origins of the coronary arteries. In 2 patients LAD originated from the left sinus".

## 2.5 Computed Tomographic Angiography (Cta) Studies

### (A) Variations in Coronary Ostia

- Pinar Kosar et al. (2009), retrospectively reviewed "the computed tomographic appearance of coronary artery anatomic

variants and anomalies in 700 patients. Anomalous origin of the coronary artery from the opposite sinus was observed in 1% of cases".

**(B) Variations in Right Coronary Artery (RCA)**

- Schmitt R et al. (2005), examined "1758 individuals with ECG-gated 4-and 16-row MDCT and found 44 patients with anomalies of the coronaries. 28 patients showed origin and course anomalies of the central coronary segments. In these 28 patients, 11 patients had malignant RCA which courses between aortic root and pulmonary trunk".
- Jaydip Datta et al. (2005), retrospectively evaluated "18 patients with anomalous coronary arteries. In 4 patients, right coronary artery originated from the left sinus".
- Duran C et al. (2006), reviewed "MDCT coronary angiography data of 725 patients. The right coronary artery was absent in 1 patient (0.13%), ectopic origin of RCA from the left anterior descending (LAD) artery was seen in 1 patient".
- G.J.R. ten Kate et al. (2008), visualized "64-slice computed tomography angiography data of 1000 patients. RCA arose from the left sinus in 5 patients and its course was interarterial".
- Pinar Kosar et al. (2009), retrospectively reviewed "the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients. High takeoff of RCA was observed in 0.1%".
- Lee Bae Young et al. (2009), retrospectively reviewed "25 ECG-gated MDCT cases of 24 patients with anomalous origin of RCA from left coronary sinus with an interarterial course. The orifice was the narrowest portion of RCA in 16/25 cases and interarterial course was the narrowest portion in 6 cases. 3 cases revealed the same diameter between orifice and interarterial course. The location of the orifice was not correlated with the diameters of anomalous RCA. Takeoff angles were correlated with the relative narrowing of the orifice of anomalous RCA and the relative narrowing of the interarterial course. Only 1 patient showed significant luminal narrowing (>50% stenosis), and this patient showed a minimal takeoff angle and a persistent symptom".
- Franz von Ziegler et al. (2009), analysed "datasets of 748 consecutive symptomatic patients. 17/748 patients (2.3%) showed coronary artery anomalies (CAA) of origin and further vessel course. 1 patient had high anterior origin of right coronary artery, 7 patients had origin of right coronary artery from left anterior sinus with separate ostium, 1 patient had right coronary artery arising from left anterior sinus having a common ostium with left main coronary artery".

**(a) Variations in Conus Branch**

- Pinar Kosar et al. (2009), retrospectively reviewed "the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients. Conus artery with a separate ostium in the right sinus of Valsalva were observed in 22%, and two conus arteries originating with separate ostia were visualized in 0.2%".

**(c) Variations in Sino-Atrial Nodal Artery (SANA)**

- Pinar Kosar et al. (2009), retrospectively reviewed "the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients. The sinus node artery (SNA) originated from the right coronary artery (RCA) in 79%, from left circumflex (LCX) artery in 20%, and from left main coronary artery (LMCA) in 0.4%. SNA originated from the right sinus of Valsalva with a separate ostium in 0.4%".

**(C) Variations of Left Coronary Artery (LCA)**

- Schmitt R et al. (2005), examined "1758 individuals with ECG-gated 4-and 16-row MDCT and found 44 patients with anomalies of the coronaries. 28 patients showed origin and course anomalies of the central coronary segments. In these 28 patients, 2 patients had malignant LMCA which courses between aortic root and pulmonary trunk".
- Jaydip Datta et al. (2005), retrospectively evaluated "18 patients with anomalous coronary arteries. In 13 patients LCA originated from the right cusp and in 1

patient LCA originated from noncoronary cusp".

- Duran C et al. (2006), reviewed "MDCT coronary angiography data of 725 patients. Left main coronary artery was absent in 4 patients (0.52%), ectopic origin of the left main coronary artery from the right sinus of Valsalva was seen in 1 patient (0.13%)".
- Cademartiri F et al. (2008), reviewed "543 patients who underwent 64-slice computed tomographic coronary angiography (CT-CA) for suspected or known coronary artery disease. The left main coronary artery had a mean length of 112±55 mm. The intermediate branch was present in the 21.9%. A variable number of diagonals (one, 25%; two, 49.7%; more than two, 24% none, 1.3%) and marginals (one, 35.2%, two 46.2%; more than two, 18%; one, 0.6%) were visualized".
- G.J.R. ten Kate et al. (2008), visualized and reviewed "64-slice dual source computed tomography angiography data of 1000 patients. LCA arose from the right sinus in 2 patients and its course was retroaortic. In 1 case LCA arose from pulmonary artery".
- Pinar Kosar et al. (2009), retrospectively reviewed the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients LMCA was absent in 0.4%. High takeoff of LMCA was observed in 0.7%. Ramus intermedius was present in 31%.
- Franz von Ziegler et al. (2009), analysed datasets of 748 consecutive symptomatic patients. 17/748 patients (2.3%) showed coronary artery anomalies (CAA) of origin and further vessel course. 1 patient had a high anterior origin of the left coronary artery.
- Kevin N. Christensen et al. (2010), analysed 105 cardiac dual-source computed tomography images. Average LMCA length was 9.9±4.15 (range 2-21 mm). Average angle of bifurcation between LCX and AIVA was 69.30±33.30 (range 140 – 2000). The most frequent division of LMCA was a bifurcation into LCX and anterior interventricular artery (AIVA). Trifurcation was seen in 20/105 cases (19.0%). Average cross-sectional area of LMCA at its bifurcation was 12.4±4.4 mm2 (range 2.3 – 25.9 mm2).

**(a) Variations in Left Circumflex (LCX) Artery**

- Duran C et al. (2006), reviewed MDCT coronary angiography data of 725 patients. Ectopic origin of the left circumflex artery from right sinus of Valsalva was seen in 3 patients (0.39%) and ectopic origin of left circumflex artery from RCA was seen in 2 patients (0.26%).
- Cademartiri F et al. (2008), reviewed 543 patients who underwent 64-slice computed tomographic coronary angiography (CT-CA) for suspected or known coronary artery disease. There was 1 marginal in 35.2%, 2 marginals in 46.2%, >2 marginals in 18% and no marginal in 0.6%.
- G.J.R. ten Kate et al. (2008), and reviewed 64-slice computed tomography angiography data of 1000 patients. LCX artery arose from the right sinus in 1 patient and its course was retro-aortic.
- Pinar Kosar et al. (2009), retrospectively reviewed the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients. LCX was absent in 0.1%.
- Franz von Ziegler et al. (2009), analysed datasets of 748 consecutive symptomatic patients. In 7 patients LCX arose from the right anterior sinus (RAS).
- Kevin N. Christensen et al. (2010), analysed 105 cardiac dual-source computed tomography images. Average cross-sectional area of LCX at the point of LMCA bifurcation was 7.4±3.5 mm2 (range 1.2-23 mm2).

**(b) Variations in Left Anterior Descending (LAD) Artery**

- Duran C et al. (2006), reviewed MDCT coronary angiography data of 725 patients. Double LAD and ectopic origin of LAD from RCA was seen in 1 patient (0.13%).
- Pinar Kosar et al. (2009), retrospectively reviewed the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients. Diagonals were absent in 0.1%.
- Franz von Ziegler et al. (2009), analysed datasets of 748 consecutive symptomatic patients. In 7 patients LCX arose from the right anterior sinus (RAS).
- Kevin N. Christensen et al. (2010), analysed 105 cardiac dual-source

computed tomography images. Average cross-sectional area of AIVA at the point of LMCA bifurcation was 8.5±3.5 mm2 (range 1.3-25.9 mm2).

**(D) Presence of Single Coronary Artery**

- Jaydip Datta et al. (2005), retrospectively evaluated 18 patients with anomalous coronary arteries. One patient had a single coronary artery arising from the right cusp.
- Franz von Ziegler et al. (2009), analysed datasets of 748 consecutive symptomatic patients. 1 patient had a single coronary artery arising from right anterior sinus (RAS).

**(E) Variations in Coronary Dominance**

- Cademartiri F et al. (2008), reviewed images of computed tomographic coronary angiography of 543 patients. There was right dominance in 86.6%, left dominance in 9.2% and balanced in 4.2%.
- Eren et al. (2008), reviewed MD (16 detector) CT coronary angiography data of 325 patients. Coronary circulation was right dominant in 227 (70%) patients, left dominant in 40 (12.5%) patients and balanced in 58 (17.5%) patients. Dominance of right circulation was detected in 150 of 217 (69%) men and in 77 of 108 (71%) women; dominance of left circulation was found in 26 of 217 (12%) men and in 14 of 108 (13%) women; balanced circulation was found in 41 of 217 (19%) men and in 17 of 108 (16%) women.
- G.J.R. ten Kate et al. (2008), visualized and reviewed 64-slice computed tomography angiography data of 1000 patients evaluated between 1 April 2006 and 25 January 2008. Right dominance was present in 851 (85.1%) patients, left dominance in 88 (8.8%) and balanced in 61 (6.1%).
- Pinar Kosar et al. (2009), retrospectively reviewed the computed tomographic appearance of coronary artery anatomic variants and anomalies in 700 patients in which the coronary artery system was right dominant in 76%, left dominant in 9.1% and co-dominant in 14.8%.
- Kevin N. Christensen et al. (2010), analysed 105 cardiac dual-source computed tomography images. Right dominance was seen in 85.7%, left dominance in 9.5% and codominance 4.8%.

**(E) Other Findings**

- Jaydip Datta et al. (2005), retrospectively evaluated 18 patients with anomalous coronary arteries. In one patient, a left coronary artery-to-vein fistula was observed.
- Duran C et al. (2006), reviewed MDCT coronary angiography data of 725 patients. The anomalous anatomical origin and course of the coronary arteries was found in 42 patients with an incidence of 5.79% and myocardial bridging was present in 29 patients (4%).
- Eren et al. (2008), reviewed MD (16 detector) CT coronary angiography data of 325 patients. Coronary artery variations were found in 34 patients (10.4%). Both the number and the rate of coronary artery variations were significantly higher among the patients with left artery dominance.

G.J.R. ten Kate et al. (2008), visualized and reviewed 64-slice dual source computed tomography angiography data of 1000 patients. In 1 patient aorto-atrial fistula was present.

## 3. MATERIALS AND METHODS

To study appearance of normal pattern of left and right coronary artery and their anatomic variants and to assess the incidence of anatomic variants in subject of North Indian population the CT coronary angiograms of 50 subjects of both sex and different age groups [23 males (35-74 years), 27 females (35-73 years)] were analysed.

### 3.1 CT SCAN and Reconstruction Parameters

On 64 Slice Multidetector Computed Tomographic (MDCT) scanner (BRILLIANSTMCT, Version 2.45.22042, manufactured by Philips) Coronary Angiography of 150 patients were performed in the department of Radiodiagnosis, King George Medical University (KGMU), Lucknow, Uttar Pradesh (U.P.), India. Retrospective Electrocardiographically (ECG) gated imaging was performed on a total of 50 patients (scan protocol is given in Table1).

**Table 1. Scan protocol of 64 slice Multidetector Computed Tomographic (MDCT) Coronary Angiography**

| | | |
|---|---|---|
| • | Slice collision | 64/0.625mm |
| • | Effective Temporal Resolution | 165ms |
| • | Tube current | 800mAs |
| • | Pitch | 0.2 |
| • | Tube rotation time | 400ms |
| • | Tube voltage | 120kV |
| • | Section thickness | 0.9mm |
| • | Reconstruction Increment | 0.45mm |
| • | Scanning time | 10-12 seconds |
| • | Isotropic voxel resolution | 0.4×0.4×0.4mm |
| • | ECG gating | Retrospective |
| • | Field view | 220mm |

## 3.2 Preprocedural Precautions

- To rule out the presence of any drug allergy, to avoid the occurrence of any untoward anaphylactic reaction during the procedure in subject were required.
- The patients were advised to avoid the intake of fatty food two days prior to the procedure.
- Advised to drink only water just prior to the procedure.
- Blood urea and creatinine levels were evaluated and should be within normal limits.

## 3.3 Procedure

To start the procedure the subjects were laid supine and were counselled to reduce their anxiety. One hour before the scan heart rate was stabilized with an oral dose of Metoprolol 50-100 mg. Intravenous (IV) Metoprolol was given if heart rate was not stabilized with oral dose of Metoprolol. Half an hour prior to the procedure Electrocardiogram (ECG) and pulse rate were monitored.

An upper extremity vein (antecubital vein) and a 20-gauge intravenous cannula was used for venous access. Following venous access subjects were connected to a cardiac monitor for visualization of heart rate. 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 and 80-85 ml in quantity, followed by a 20 ml saline flush at a rate of 4 ml/sec with a pressure injector (PSI-325). With automated bolus tracking technique, the scan timing was determined by placing the region of interest over mid ascending aorta and setting the trigger threshold to 180 Hounsfield (Hu). On the “scanning bed” for a period of 5-10 minutes the subjects were advised to lie still. The subjects were given instructions to maintain an inspiratory breath hold during which CT data and ECG tracings were taken. Computed tomography coronary angiography (CTCA) was performed 5 seconds after aortic peak density. From the level of carina to the bottom of the heart scanning coverage was done.

On a workstation (Brilliance 64 version 4.5) raw spiral CT data of coronary arteries were reconstructed in various phases of cardiac cycle to obtain images with the highest quality (without motion artefact). For optimal image analysis most of the subject’s reconstruction was performed at 75% of R-R interval. The reconstructions were performed at 45% of the R-R interval in some subject whose heart rate could not be stabilized properly. 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.

Images received were reviewed first in axial projection and then again 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. Volume-rendered images were also obtained using various orientations and MIPs were obtained using various thickness (5-30mm).

In straight MPR format the length of main trunk of Left coronary artery (LCA) was measured (Fig. 4) from its orifice to its division into the Left Anterior Descending (LAD) and Left Circumflex (LCX) arteries in case of bifurcation and into LCX, LAD and Ramus Intermedius (RI) arteries in case of trifurcation

Computed tomography of coronary artery (CTCA) images of LCA were observed under following headings- (1) Origin (2) Length of main trunk (3) Branching pattern

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

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

## 4. 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 a lack of 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 | | | | | |

**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 |

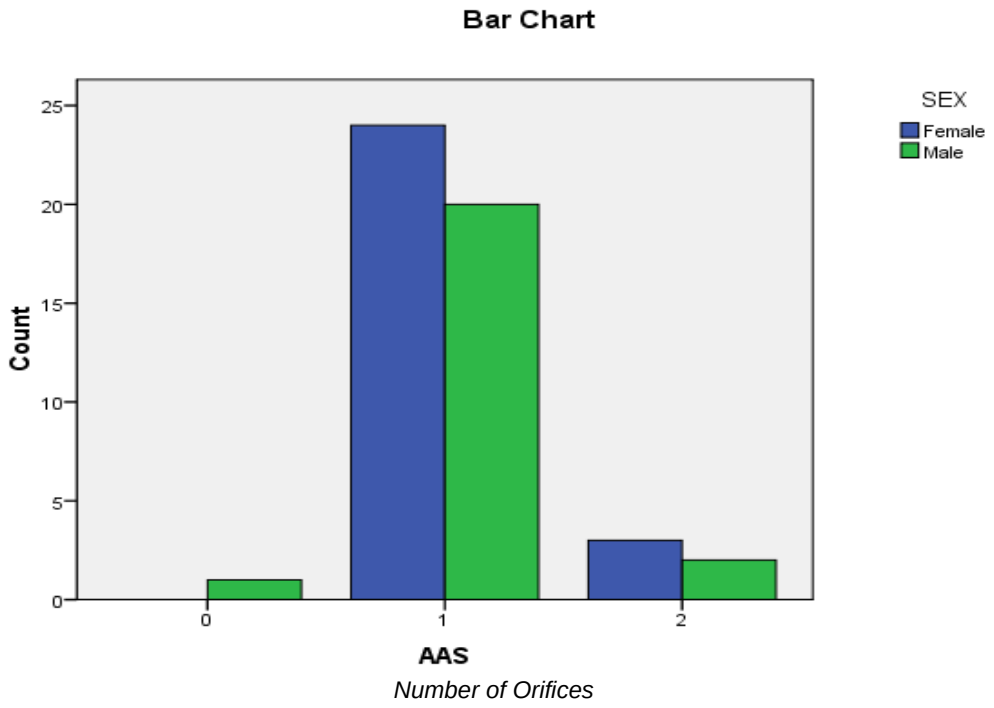



**Fig. 1. Number of orifices in AAS according to gender**

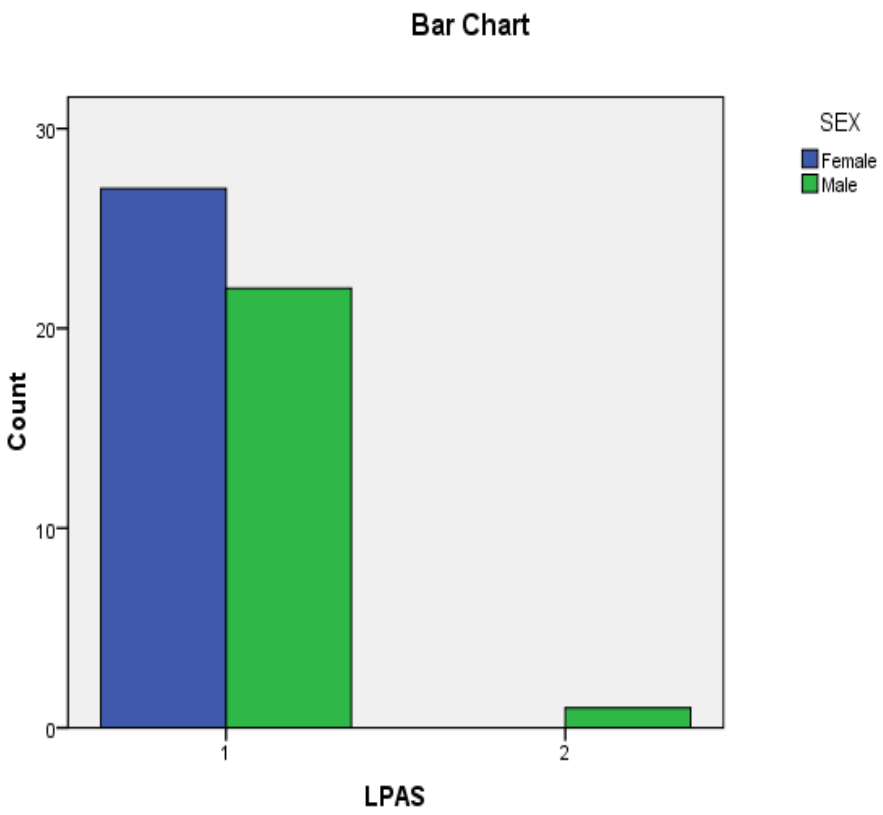



**Fig. 2. Number of orifices in left posterior aortic sinus (LPAS) according to gender**

### 4.1 Figures in Parentheses Represent Percentage

A0 – No orifice in left posterior aortic sinus (LPAS). (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).

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

None of the cases had orifice of RCA above the Sinotubular junction. Sinotubular junction had the 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 the 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)

## 5. DISCUSSION

The incidence of right dominance of coronary artery (86%), left dominance (12%) and codominance (2%) was more or less similar as compared to the incidence reported by others. [1,2,3].

**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) |

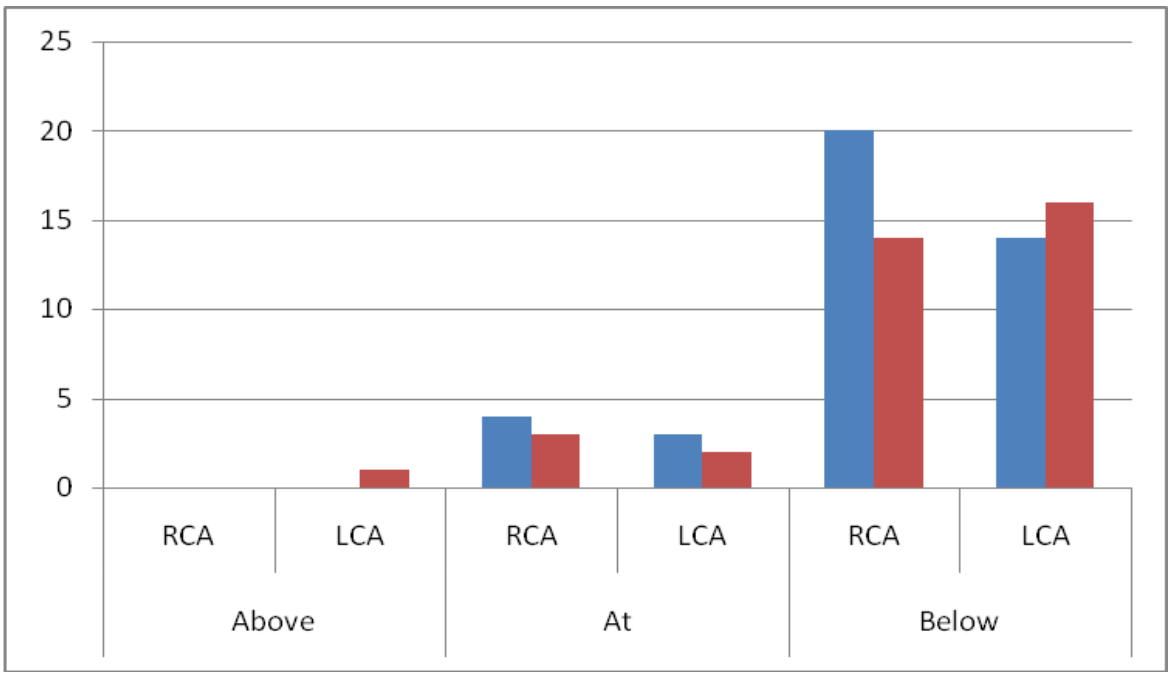



**Fig. 3. Gender wise distribution of position of coronary orifices with respect to the sinotubular junction**

- In the majority of subjects there were right dominant and left dominant circulation was almost six times the co-dominant circulation. [4,5,6]
- In males the right dominance was more (83.3%) as compared to the females (16.7%). [4,5]
- Present study described the normal and variant anatomy of the orifices in the aortic sinuses among the North Indian population. No orifices were observed in the right posterior aortic sinus. [6,7,8]
- Multiple orifices were mostly seen in the Anterior aortic sinus and the number of orifices varied from 0-2 in the present study.[9]
- Most common presentation of orifice in Anterior aortic sinus (AAS) was the presence of a single orifice for the right coronary artery.
- Most common presentation of orifice in Left posterior aortic sinus (LPAS) was the presence of a single orifice for the 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 the conus artery, the third coronary artery. [11,12,13]
- 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%). [10,11]
- The tendency of an orifice to be present at the sinotubular junction was more in case of RCA. [12,13,14,15]
- The most common site of origin of Right coronary artery (RCA) was anterior aortic sinus.
- In males as compared to females the incidence of anomalous origin of RCA was more. [15,16,17]
- The length of RCA was slightly more in males as compared to females but this difference was not statistically significant. [16,17]
- In most of the cases conus artery, SANA and PDA arose from RCA.
- In most of the cases a single acute marginal branch was seen. [17,18]
- The most common site of termination of RCA was at the 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. [17,18,19]
- The incidence of "High take-off' of LCA was lower (3.7%) than the incidence (7%) as per the reports of previous studies. [19,20]
- The length of the main trunk of LCA was 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 the LAD artery.
- The branching pattern of the LAD artery was normal in all 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 the LAD artery was Type 3 termination.
- No significant difference was found between males and females regarding the termination pattern of LAD arteries.
- 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 females (44.4%).
- Regarding the number of obtuse marginal branches, single and double obtuse marginal branches were found in equal numbers 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 the 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 the dominant artery in 66% cases.
- Most commonly a single conus artery was present.
- The most common site of origin of the conus artery was the 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.

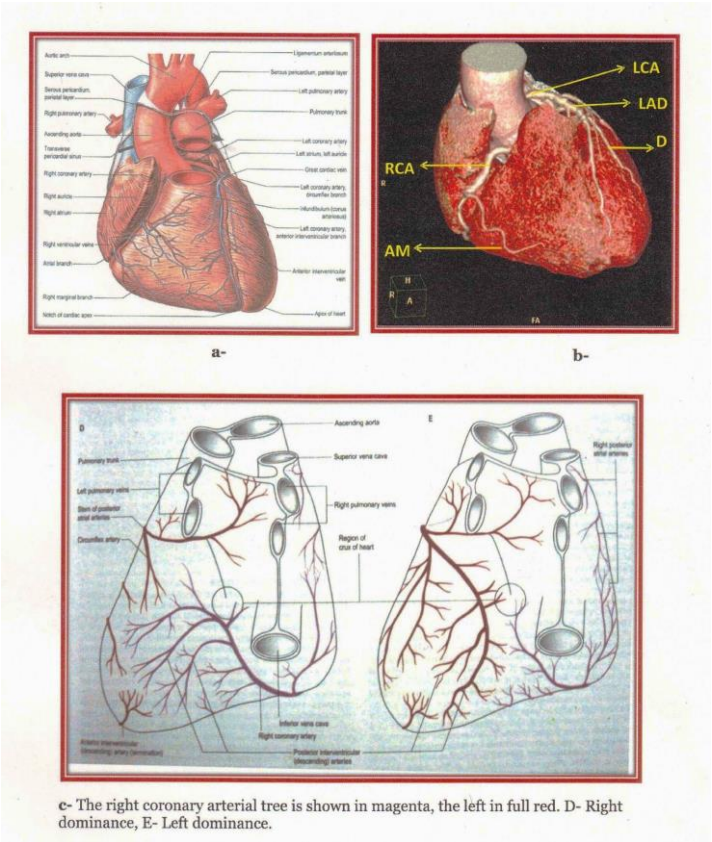
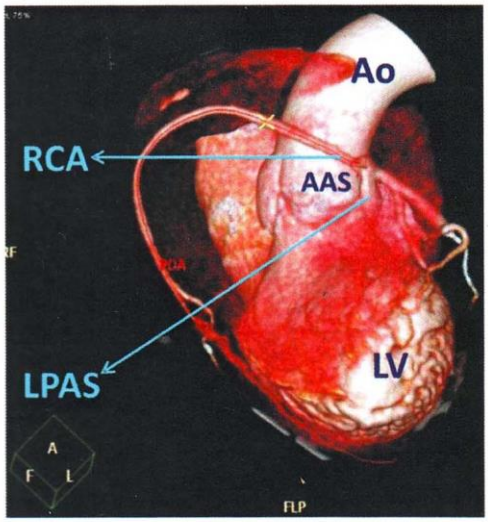
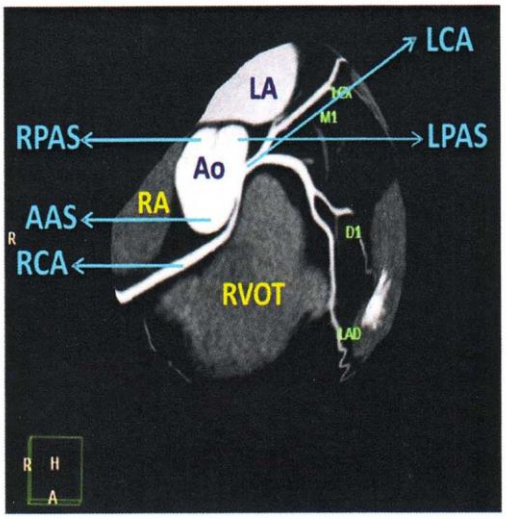


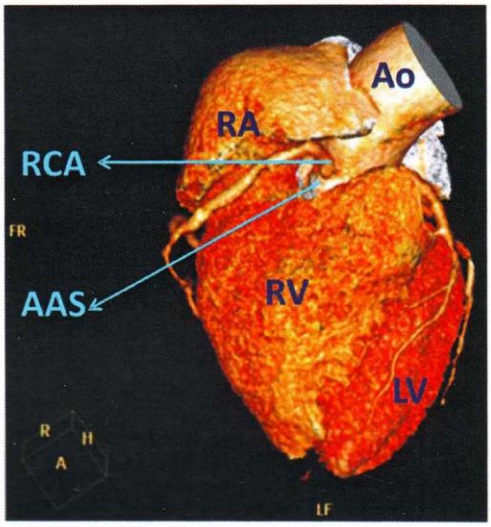

**Fig. 4. The beart and great vessels: a- anterior view with corresponding 3D reconstructions from multislice CT seanning (b) and c- posteroinferior views showing coronary arteries and their branches RCA- right coronary artery, AM-acute marginai branch of RCA,LCA- left coronary, LAD left anterior descending artery, D- diagonal branch of LAD (Main figures gray's 2008)**



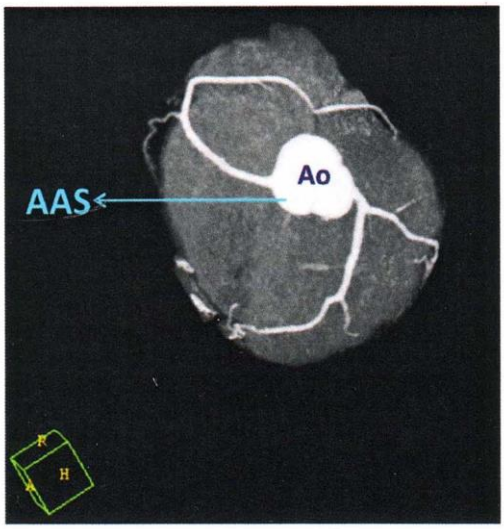

**a-** 3D VR image showing no orifice in AAS **(A0).**




**b-** CPR image showing no orifice in AAS **(A0).**

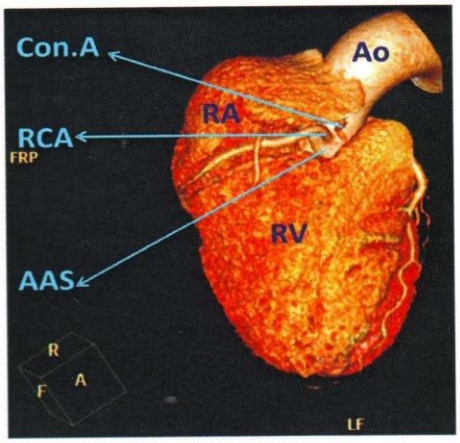



**c-** 3DVR image showing single orifice of RCA in AAS **(A1)**

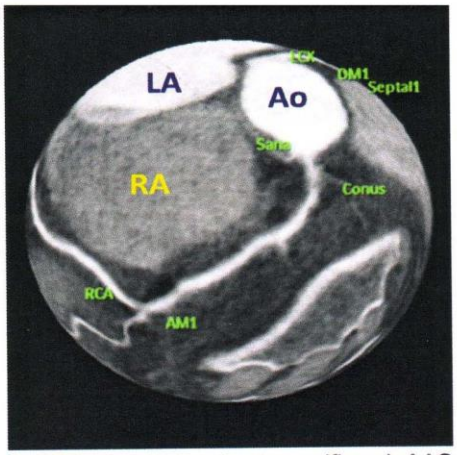



**d-** 3D VR image showing single orifice of RCA in AAS **(A1).**

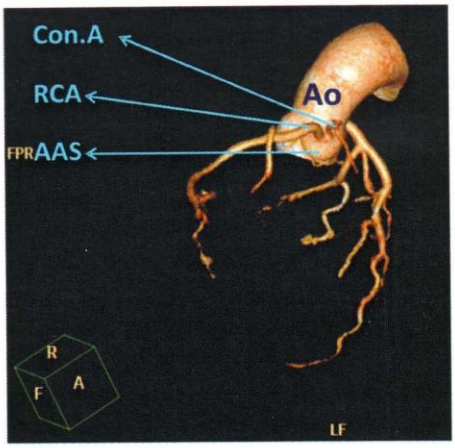
**Fig. 5. MDCTA images of the heart showing variations in the number of orifices in AAS. AO- aorta, AAS- anterior aortic sinus, LPAS- left posterior aortic sinus, RA- right atrium, RV- right ventricle, LA- left atrium, LV- left ventricle, RCA- right coronary artery, LCA- left coronary artery, AVOT- right ventricular outflow tract, RPAS- right posterior aortic sinus, Con.A- conus artery**



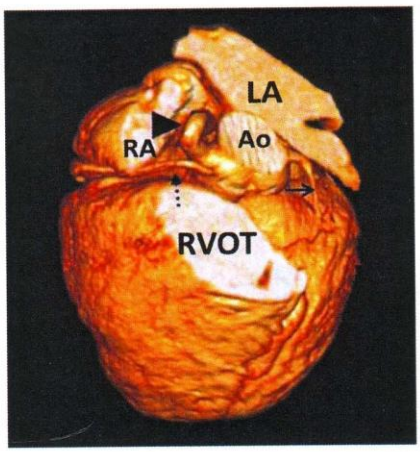

**a-** 3D VR image showing two orifices in AAS, one for conus artery, other for RCA **(A2C)**



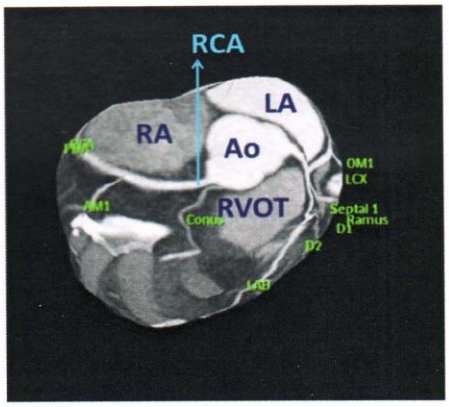

**d-** CPR image showing two orifices inAAS, one for SANA, other for RCA **(A2S).**



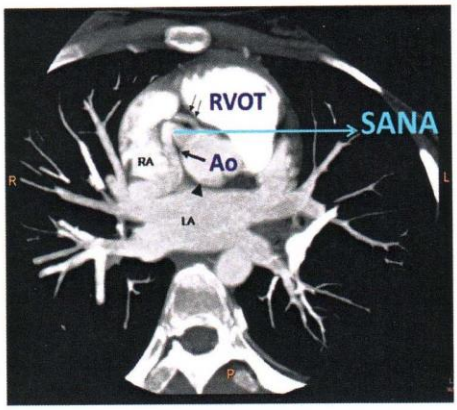

**b-** 3D contrast vessel tracking tree VR image showing two orifices in AAS one for conus artery, other for RCA **(A2C).**




**e-** 3D VR image showing two orifices in AAS, one for SANA, other for RCA **(A2S)**.RCA (*dotted arrow),anomalous* SANA (*arrowhead)*

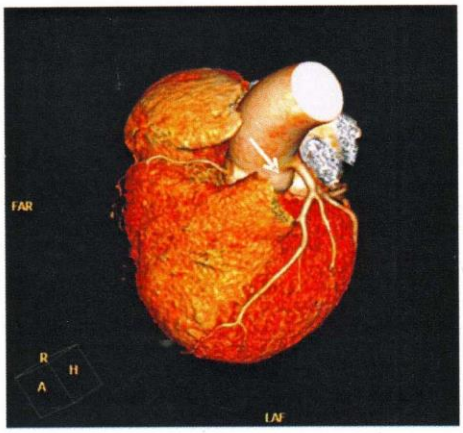



**c-** 3D VR image showing two orifices in AAS one for conus artery, other for RCA **(A2C).**

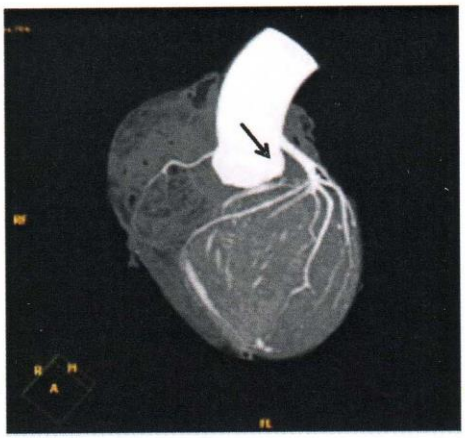



**f-** Axial MIP image showing two orifices in AAS, one for SANA, other for RCA **(A2S)**.RCA (*double arrow*).

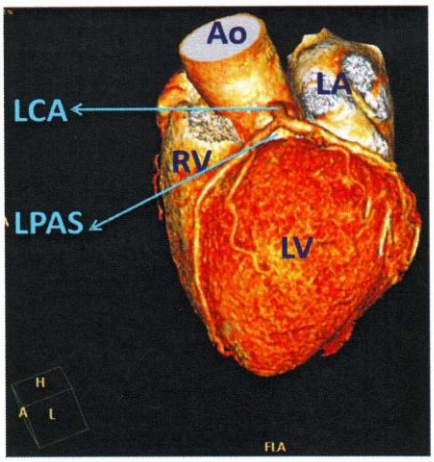
**Fig. 6. MDCTA image of the heart showimg variations in the number of orifices in anterior aortic sinus. Ao- acrta, AAS- anterior acrtic sinus, LV- left ventricle,RCA- right coronary artery, LCA- left coronary artery, RVOT- right ventricular cutflow tract, RPAS- right postericr acrtic sinus, Con-A conus artery, SANA- sinoatrial nodal artery**



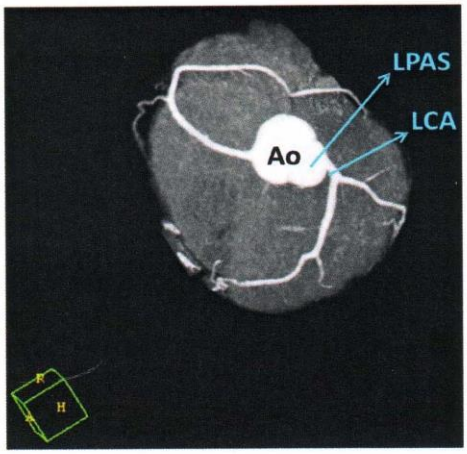
**a-** 3DVR image showing lack of orifice in left posterior aortic sinus **(B0).** LPAS (*arrow*)



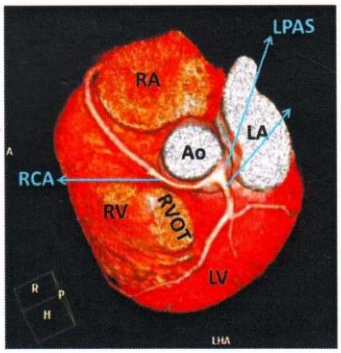
**b-** 3DVR image (cardiac outline protocol) showing lack of orifice in LPAS **(B0).** LPAS (*arrow*)



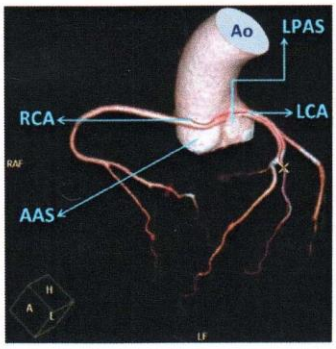

**c-** 3DVR image showing single orifice of LCA in LPAS **(B1)**



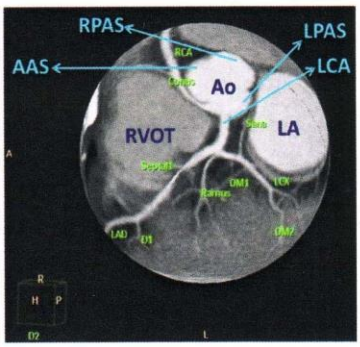

**d-** 3D VR image (cardiac outline protocol ) showing single orifice of LCA in LPAS **(B1)**




**e-** 3D VR image showing two orifices in LPAS, one for LCA and other for RCA **(B2).**




**f-** 3D contrast vessel tracking tree VR image showing two orifices in LPAS one for LCA, other for RCA **(B2).**




**g-** CT Globe image showing two orifices in LPAS one for LCA, other for RCA **(B2).**

**Fig. 7. MDCTA images of the heart showing variations in the number of orifices in left posterior aortic sinu, AO- aota, AAS- anterior acrium, LPAS- left posterior acrtic sinus, RPAS- right posterior acrtic sinus, RA- right atrium, RV- right ventricle, LA- left atrium, LV- left ventricle, RCA- right coronary artery, LCA- left coronary artery, RVOT- right ventricular outflow tract**

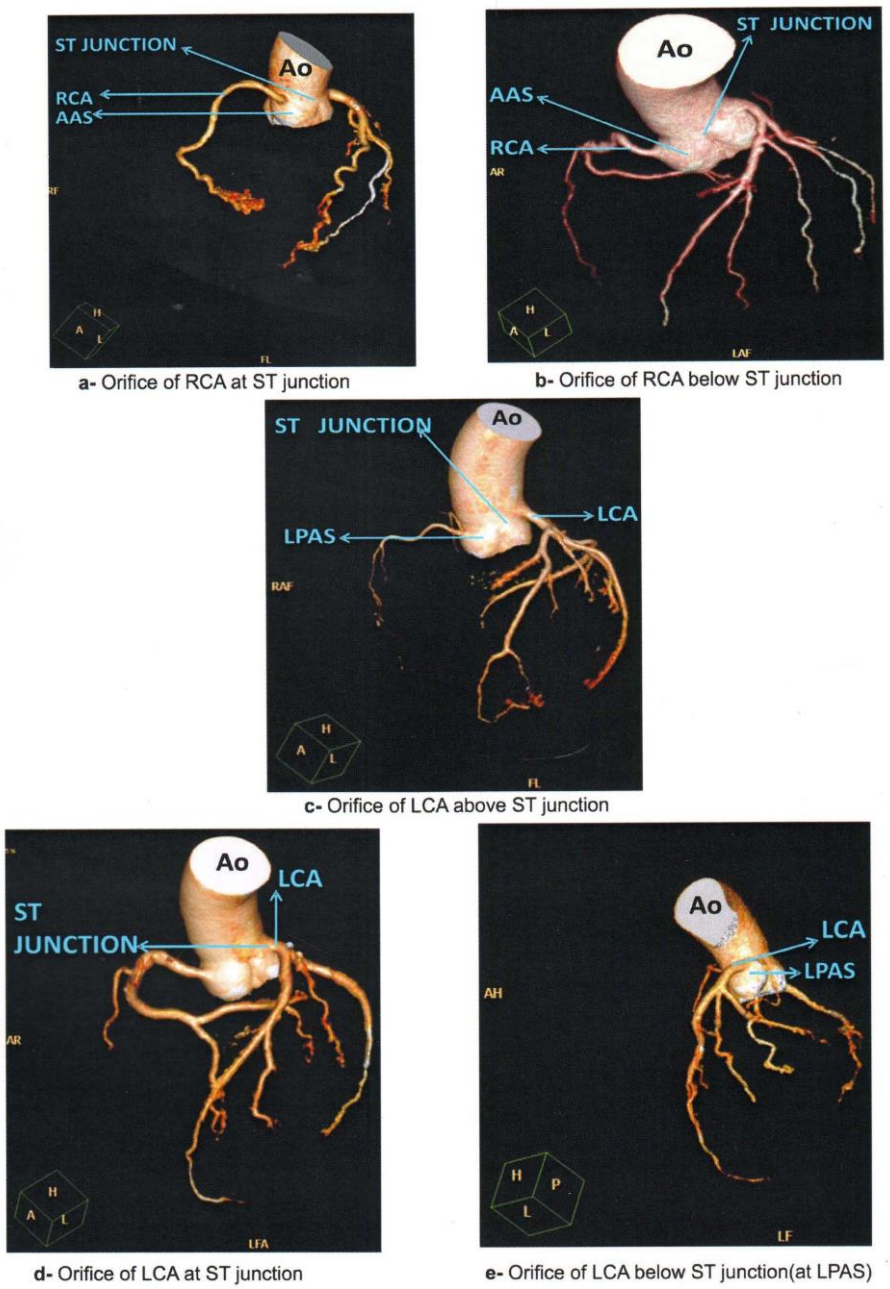



**Fig. 8. MDCTA images of the heart. 3D contrast vessel tracking tree VR protocol showing locations of coronary orifices. Ao- acrta, AAS anterior aortic sinus, LPAS- left posterior aortic sinus, RCA- right coronary artery, LCA- left coronary artery, ST- junction sinctubular junction**

## 6. CONCLUSIONS

Congenital abnormalities of the coronary arteries are of great significance as they are associated with chest pain and sudden cardiac death. For correct diagnosis and treatment of the patient the finding of the present study is of utmost significance. Variations in the origin, length and branching pattern of coronary arteries in this study have anatomical, pathophysiological, diagnostic and therapeutic implications and help as a guide to cardiologists in many ways. For interpretation of coronary angiogram, implementation of stenting procedures and surgical revascularization of myocardium a detailed knowledge of all these variations is crucial.

For interventional cardiologists and radiologists during planning and performing any procedure

on coronary arteries the finding of this study is of immense use.

## CONSENT AND ETHICAL APPROVAL

It is not applicable.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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