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Frequency and Clinical Significance of Conus Artery and Its Variant Third Coronary Artery (TCA) in North Indian Population:A 64-Slice CT Angiographic Study

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Abstract- In most of the cases two coronary arteries supply oxygenated blood to the heart, the right coronary artery (RCA) and the left coronary artery (LCA). One of the important branches of RCA is the conus artery (CA) which supplies the infundibulum of the right ventricle or pulmonary conus.

In the present studyComputed Tomographic (CT)coronary angiograms of 50 subjects of north Indian population were analyzed prospectively to see the pattern of origin and number of conus artery. One of the most important variant of origin of conus artery is the *third coronary artery*(TCA). The incidence of TCA was also assessed.

All the subjects were undergone multidetector CT coronary angiography in the department of RadiodiagnosisKGMU, U.P, Lucknow.

One conus artery was seen in *47* (*94%*) subjects. Out of these 47 subjects, conus artery arose from theRCA in *38 (76%)* cases and from the anterior aortic sinus (AAS) of ascending aorta in*9* (*18%*) cases**.** In these 9 cases, conus artery acts as *third coronary artery*. In some cases RCA and conus artery have separate orifice in the AASand some cases have common orifice for RCA and conus artery.Two conus arteries were observed in *1* (2%) case. In this case one artery arose from AAS(*third coronary artery)*and second from RCA. In 2 (4%) cases conus artery was not visualized. In this way*third coronary artery*was seen in *10 (20%)* cases.

The *third coronary artery* represents a significant path of collateral coronary circulation as it often anastomoses with left anteriordescending (LAD) branch of LCA.

Index Terms- Computed Tomography (CT), Conus Artery (CA), Coronary Angiogram, Third Coronary Artery (TCA).

I. INTRODUCTION

An in-depth knowledge of the anatomy of coronary arteries is a pre-requisite for a detailed understanding of the coronary artery disease (CAD) and for planning of cardiovascular surgery. In most of the cases the heart is supplied by two coronary arteries right and left. Sometimes *third coronary artery* is present. Normally the conus artery is a branch of RCA. According to *Schlesinger*TCA isthe conus artery arising directly from the anterior aortic sinus (AAS) [21]. This *third coronary artery* may be a boon for the person having it.This artery when present may help in the establishment of partial identity of an individual, if ante mortem records of coronary angiograms are available [4].

Occurrence and distribution of *third coronary artery* is important for accurate understanding of coronary angiograms, assessment of severity and effect of coronary insufficiency and appropriate preparation for timely revascularization of ischemic myocardium.

Usually the conus artery is the first right ventricular branch of the RCA which originates from the *first part of RCA* (extending from origin to the junction of right and inferior borders of the heart).The conus artery supplies the pulmonary conus or outflow portion of the right ventricle. Several authors had suggested that conus artery is a collateral arterial channel between the right and left coronary arteries.

This study was done with an aim to assess the variations in the origin and number of conus artery and the frequency of *third coronary artery* in North Indian population. The findings of this study would be of great significance in the interpretation of coronary angiograms and for surgical revascularization of ischemic myocardium.

This was a prospective study in which 64-slice computed tomographic (CT) coronary angiograms of 50 subjects were visualized. *Third coronary artery* was seen in *10 (20%)* subjects. The *third coronary artery* plays a significant role in collateral circulation of the heart because it anastomoses with a branch of left anterior descending (LAD) artery. The results of this study provide an extensive knowledge of the origin of conus artery which is required for the diagnostic and therapeutic interventional procedures done on coronary arteries.

II. MATERIAL AND METHODS

CT coronary angiograms of 50 subjects of both sex and different age groups [32 males (14-75 years), 18 females (12-70 years); mean age 51.36 ± 14.07 years, age range 12-75 years] were analyzed.

Scan protocoland image reconstruction

Coronary Angiography (CA) was performed in all subjects using a 64-Slice Multidetector Computed Tomographic (MDCT) scanner (BRILLIANS^{TM}CT, Version 2.45.22042, Philips) installed in the department of Radiodiagnosis, King George Medical University (KGMU), Lucknow, Uttar Pradesh (U.P.), India. Retrospective Electrocardiographically (ECG) gated imaging was performed.

The scan field extended from the carina to the diaphragm. The imaging parameters were: **slices/detector collimation** of 64×0.625 mm, **effective temporal resolution** (with 180°algorithm) of 165 ms, **tube voltage** of 120 kV, **tube current** of 800 mA, **gantry rotation time** was 400 ms, **pitch** of 0.2, **slice thickness** of 0.90 mm and 0.45mm**reconstruction interval**, **Field of view** (FOV) was 220mm, **Isotropic voxel resolution**of0.4×0.4×0.4 mm. A single inspiratory breath-hold of approximately10-12 seconds **(scanning time)** completed the examination.

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.
- The subjects were advised to avoid the intake of fatty food two days prior to the procedure.
- 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. Computed Tomographic Coronary Angiography (CTCA) was performed 5 seconds after aortic peak density. Scanning coverage was from the level of carina to the diaphragm. 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). This work station enabled generation of the images of coronary arteries in the standard and in various other anatomical planes. 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 reconstructed images 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 imageswere also obtained using various orientations.

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 *number* and the *origin* of conus artery were observed.

Variable Number and Origin of Conus Artery-

Oneconus artery was seen in 47 (*94%*) subjects [29 (*90.63%*) males and 18 (*100%*) females]. (Table 1 & Bar Diagram 1).Out ofthese 47 subjects, conus artery was seen arising from the RCA in 38 (*76%*) cases (Fig.1a,b,c &d)and from the anterior aortic sinus of ascending aorta in9 (*18%*) cases(Fig.2 & Fig.3).In these 9 cases, conus artery acts as *third coronary artery*. In some cases RCA and

conus artery have separate orifice in the AAS(Fig.2)and some cases have common orifice for RCA and conus artery (Fig.3). Among the 38 cases of origin from RCA, 23 (*71.88%*) were males and 15 (*83.33%*) were females. Among the 9 cases of origin from ascending aorta6 (*18.75%*) were males and 3 (*16.67%*) were females(Table 2 & Bar Diagram 2).

Two conus arteries were observed in 1 (*2%*) case [1 (*3.13%*) male] (Table 1 & Bar Diagram 1).In this case one artery arose fromAAS (*third coronary artery*) and second from RCA (Fig.4a). In 2 (4%) cases [2 (*6.25%*) males], conus artery was not visualized. (Table 1& Bar Diagram 1)(Fig.4b).

IV. DISCUSSION

Usually the first branch of right coronary artery (RCA) is the pulmonary conus artery or conus artery (CA). If the conus artery arises directly from the aorta it is named as *third coronary artery* . Incidence of this type of origination is between7%to 50%(Table- 3)[21].

Present study has revealed the incidence of *third coronary artery* (TCA) to be 20%. Other studies have reported various incidences asshown in Table- 3. The findings of present study are similar to*Udaya Sankari et al, 2011*[21] and nearer to*Pınar Kosar etal,2009*[13].

The findings of different studies mentioned in Table3 show ethnic variability and appear to support a catheter angiographic study by*Naveen Garg et al., 2000*in which they proposedthat there are geographical differences in coronary artery variations, which may have a genetic basis [11].

The conus artery supplies the pulmonary infundibulum and the supraventricular crest. It usually anastomoses with a branch from theleft coronary artery. This anastomosis lies on the distal part of the bulbous cordis (truncus arteriosus) and is known as the Vieussen'sarterial ring [25].

Collateral circulation is a key factor in the pathophysiology of Coronary Artery Disease(CAD). Symptoms and prognosis amongpatients with advanced CAD depend largely on the degree of collateral circulation [18]. The conus branch of the RCA has a specialanatomic and functional significance in the development of collaterals between the right and left coronary arterial systems. The conusartery may also arise as a separate branch from the aorta, and may not even be visualized by selective angiography due to its small sizein patients with mild disease, only manifesting itself in advanced CAD when it is recruited to provide collateral circulation to under-perfused myocardial territories [14].

Kurjia HZ, et al., 1986 foundectopic orifice of conus artery in AAS to be anomalous rather than ubiquitous [9]. *Sahni and Jit in 1989*reported extra openings for conus artery in 34.8% of male hearts and 27.8% of female hearts [17]. In the present study, extra orificefor conus artery in AAS was seen in 21.88% of males and 16.67% of females (Table 2).

Since the conus artery does not arise from the RCA always, the study of its origin gains importance for angiographic dye injection. Anaberrant conus artery arising separately from the aorta is particularly at risk for injury from ventriculostomy or other maneuversperformed during heart surgery [22].According to the opinion of *Edwards*and *Miyazaki* the *third coronary artery* is more frequentlyfound in adult hearts than in fetal hearts, concluding thereof that it develops only after birth[2,10] .

In 1988 a stereoscopic study of *Miyazaki M& Kato T.*suggested that the *third coronary artery* develops and contributes to thecollateral circulation after birth. They also found that pathologic hearts had a higher incidence than normal hearts but there is no relation to age and the orifice of TCA was wider in pathologic hearts than normal hearts [10].

The separate orifices for the TCA and the RCA had been explained by insufficient unification of these two vessels, during their growth towards the ascending aorta [16, 26].The branches of TCA open up in some cardiac pathology to provide collateral perfusion and they have been shown to improve with age [20]. TCA may contribute to collateral circulation to the interventricular septum (IVS) during left anterior descending (LAD) occlusions hence protecting the septum. The clinical implication of this is that diagnostic tests carried out for the LAD occlusions may fail to detect any ischemic change in this region hence giving a false better report [26].

TheTCA may extend epicardially to supply the apex of the heart. Therefore a caution should be taken during surgical procedures around the anterior wall of the RV and infundibulum since such a long TCA may present a surgical hazard [12].*Ivan Stankovic et al. (2004)* suggested that the folding of the heart results in opening of the existing peritruncal capillaries at the cono truncal circle either directly into the newly formed aorta resulting in multiple ostia or secondarily attached to the existing blood vessels surrounding the atrioventricular circle resulting in the right conus artery arising from right coronary artery [6].The knowledge of ontogeny of the right conus artery requires further detailed study in foetus.

V. CONCLUSION

The present study adds to the growing body of data on intrapopulation frequencies of conus artery variants among North Indians and supports the contention that postpartum development may modify the pattern of coronary divergence from the aorta. As the number of Caucasian patients undergoing surgical treatment for ischemic or valvular heart disease increases, additional comparative data on racial, sexual, and ontogenetic variation of the origin and number of conus artery are required to improve the care of these patients

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FIGURES

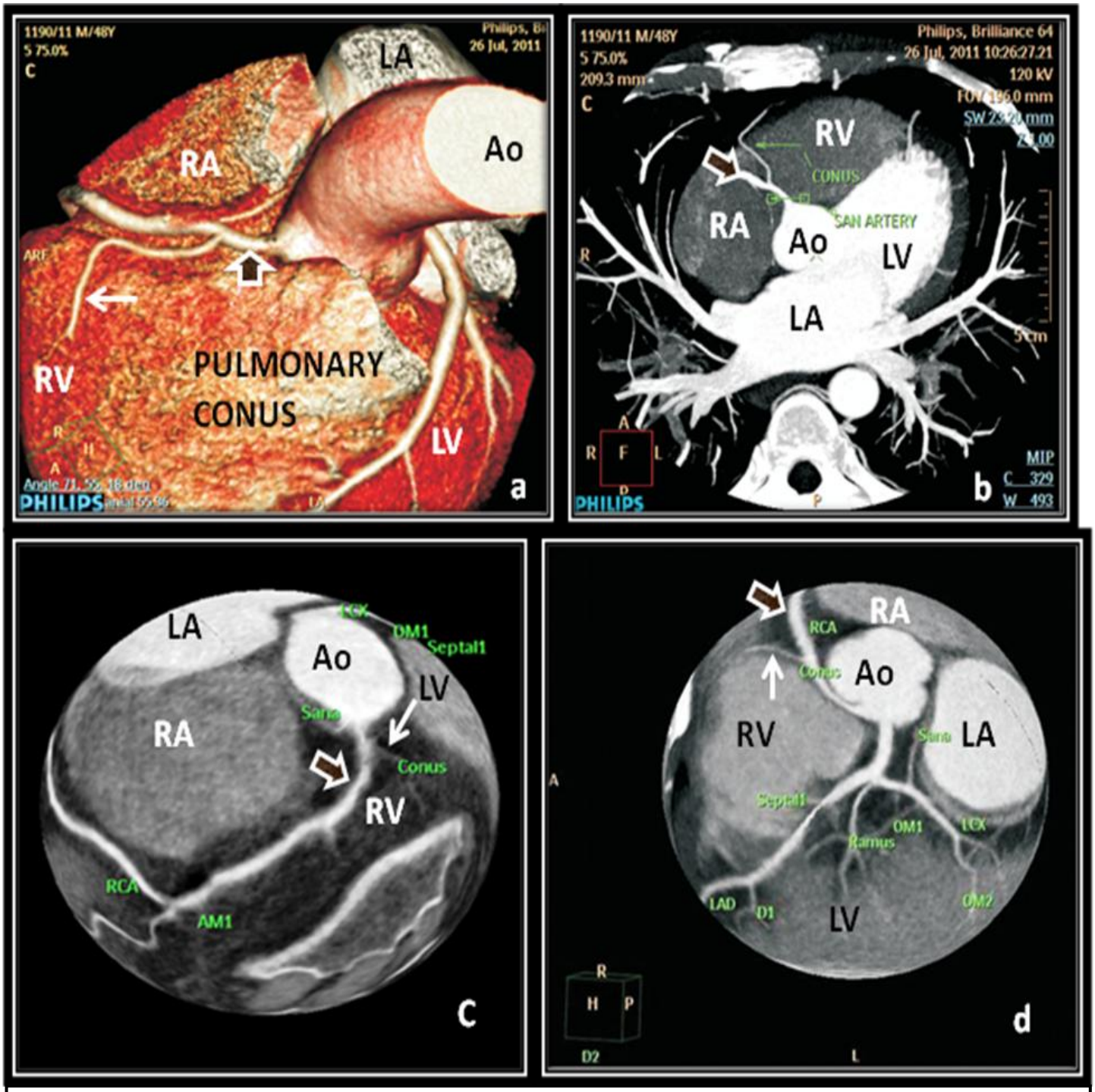


Fig.1-MDCTA images showing**single conus artery***(arrow)*arising from **RCA** (*outlined arrow*). **(a)-***3D VR image*, **(b)-** Axial *MIP image*, **(c & d)-***CT globe*. ***Image (*****d****)is* showing**single conus artery**arising froman anomalous **RCA. Ao-** *Aorta*, **LA-***Left Atrium*, **RA-** *Right Atrium*,**LV-***Left Ventricle.* **RV-** *Right Ventricle.*

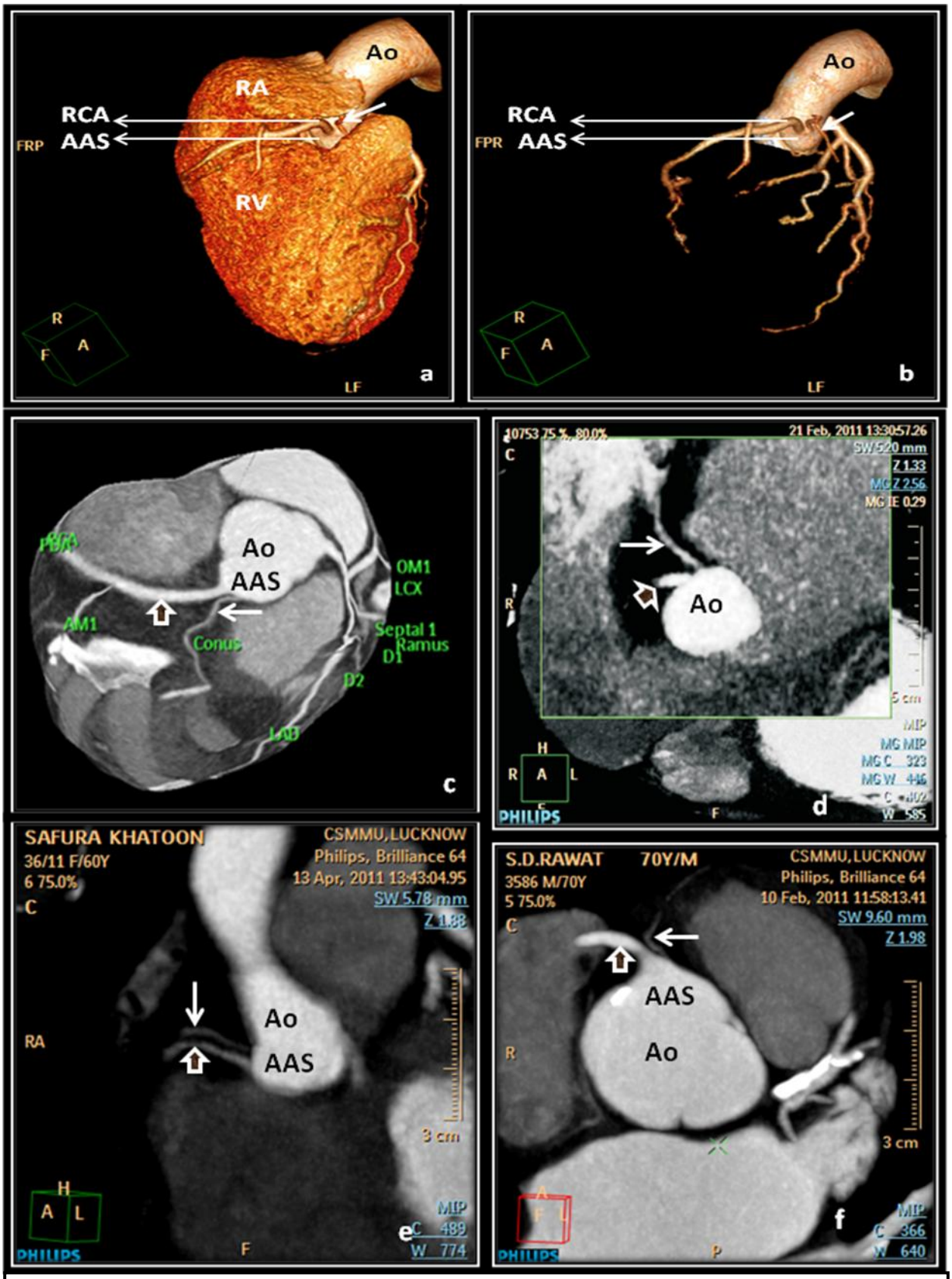


Fig.2MDCTA images showing**single conus artery***(arrow)*arising from AAS. **(a)-***3D VR image*,**(b)-***Contrast Vessel Tracking Tree*.**(c, d, e & f)-***MIP images.* **Ao-** *Aorta*, **AAS-** *Anterior Aortic Sinus*,**RA-** *Right Atrium*, **RV-** *Right Ventricle*, **RCA-** *Right Coronary Artery*. ***RCA and conus artery have separate orifice in the AAS.*** **RCA** *(outlined arrow*).

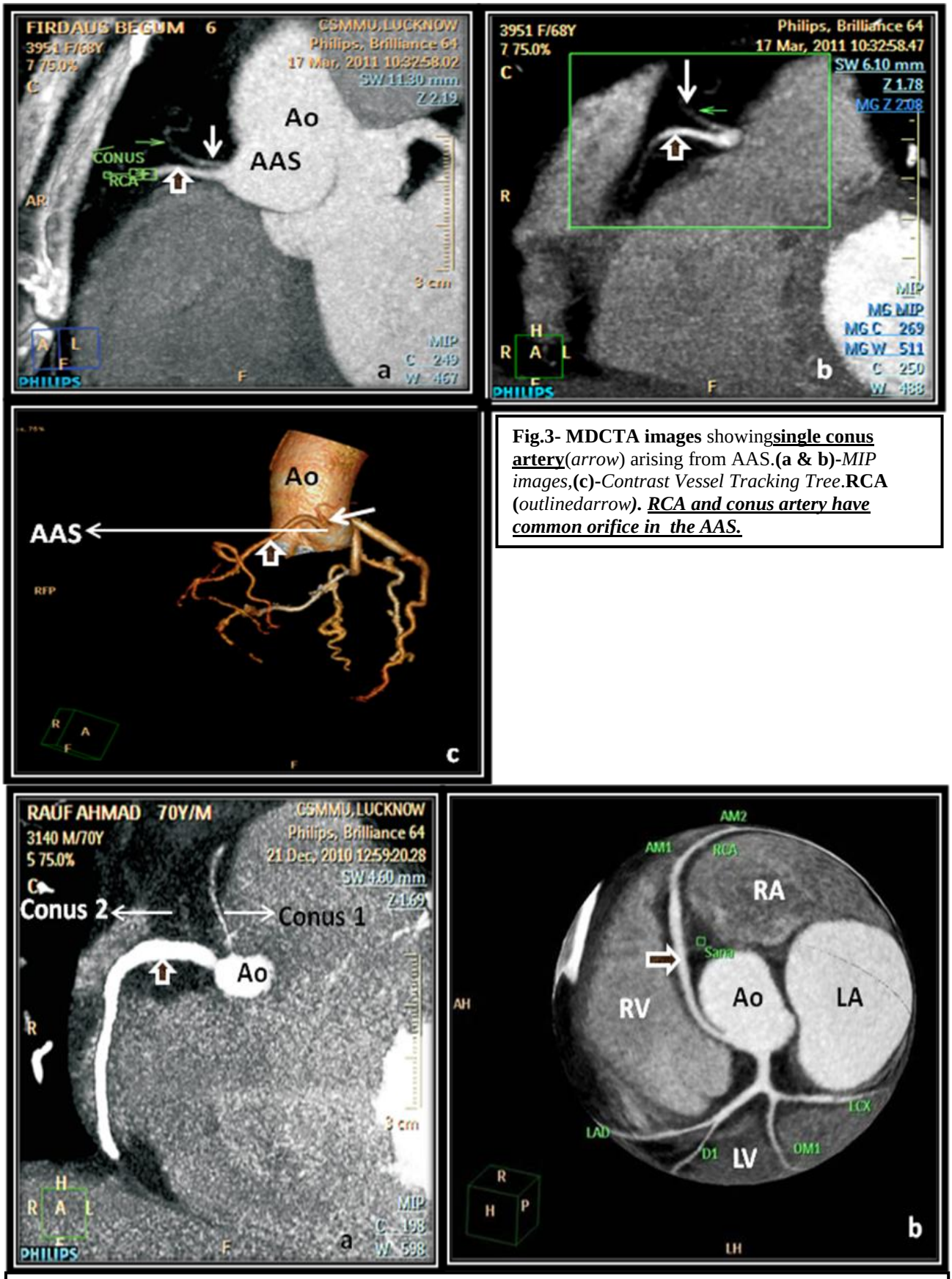
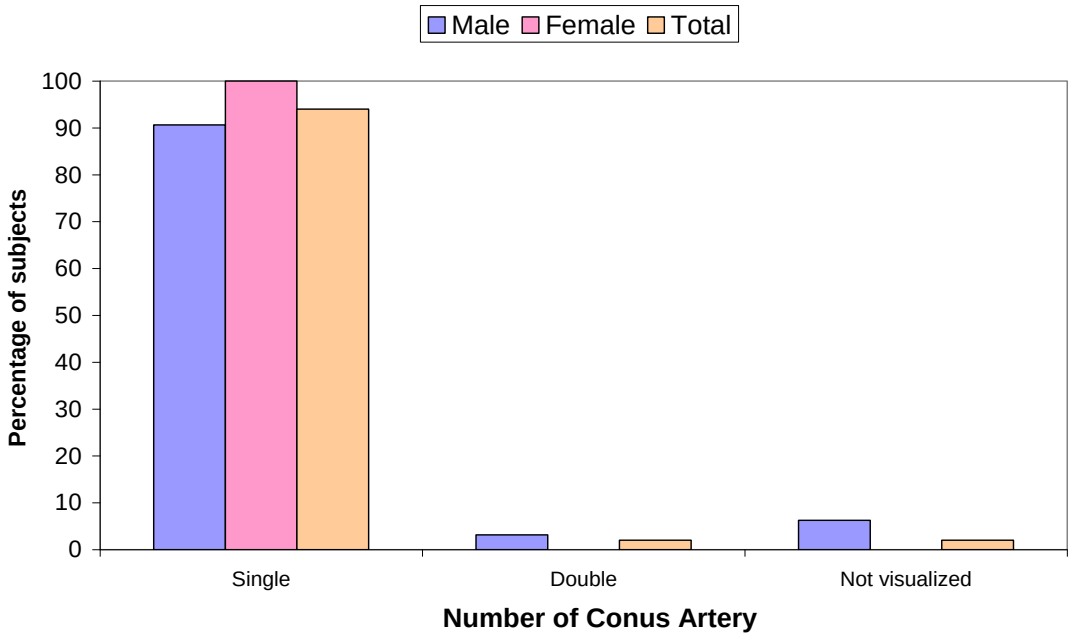


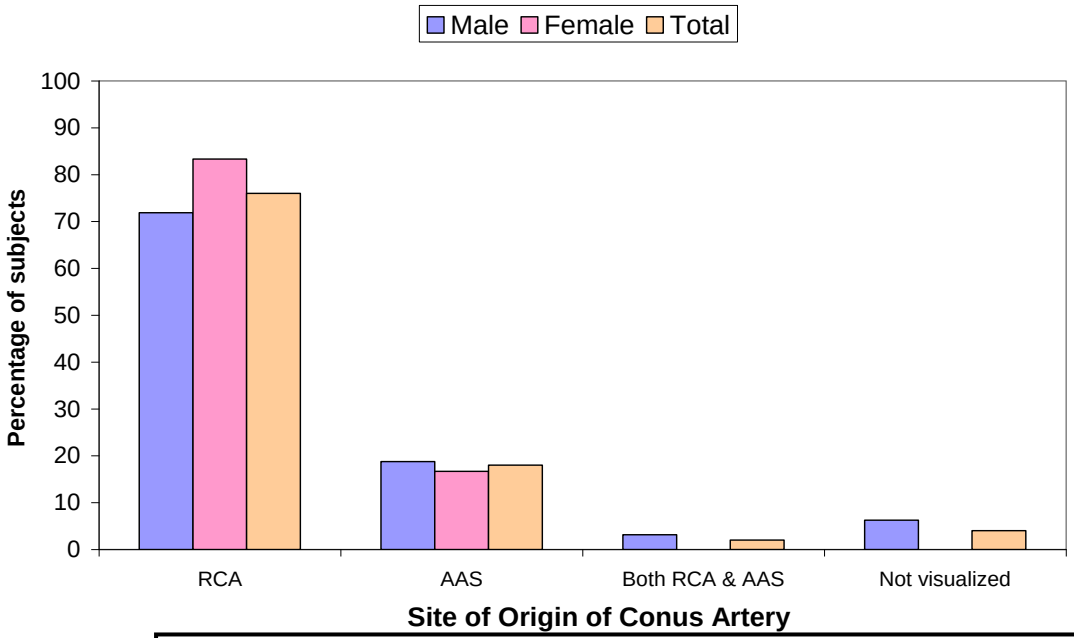
Fig.3- MDCTA images showing**single conus artery**(*arrow*) arising from AAS.**(a & b)-***MIP images*,**(c)-***Contrast Vessel Tracking Tree*.**RCA (***outlinedarrow***). *RCA and conus artery have common orifice in the AAS.***

Fig.4- MIP images showing **(a)-two conus arteries,** conus 1 is arising from AAS and conus 2 from RCA**, (b)- no conus artery.Ao**- *Aorta*, **LA-***Left Atrium*, **RA-** *Right Atrium*,**LV-***Left Ventricle***RV-** *Right Ventricle*,. **RCA (***outlinedarrow***).**

BAR DIAGRAMS



Bar Diag. 1-Gender wise distribution of number of conus artery



Bar Diag. 2-Gender wise distribution of the origin of conus artery

TABLES

Table- 1

Gender wise distribution of number of conus artery

Conus artery	Male(n=32)	Female(n=18)	Total(n=50)
Single	29(90.63)	18(100)	47 (94%)
Double	1(3.13)	0	1 (2%)
Not visualized	2(6.25)	0	2 (4%)

Figures in parentheses represent percentage.

$\chi^2 = 1.795$; p=0.407

Table-2

Gender wise distribution of the origin of conus artery

Site of origin of Conus artery	Males (n=32)	Females (n=18)	Total (n=48)	χ^2	'p' value
RCA	23(71.88)	15(83.33)	38(76)	0.829	0.362
AAS	6(18.75)	3(16.67)	9(18)	0.338	0.854
Both RCA & AAS	1(3.13)	0	1(2)	0.573	0.448
Not visualized	2(6.25)	0	2(4)	0.172	0.279

Figures in parentheses represent percentage.

$\chi^2 = 1.914$; p=0.590

Table - 3

Prevalence of the TCA in various populations

Authors and year of study	Type of study	Population	Incidence
Blake, 1964			23.5%
Kurjia *et al*.,1986	Dissection	Iraqi	8%
Miyazaki M. & Kato M., 1988	Dissection	Japanese	36.8%
Turner & Navaratnam, 1996	Dissection	English	15.8%
von Ludinghausen M. & Ohmachi N., 2001	Dissection	German	7.1%
Regi			33.8%
Kalpana R., 2003	Dissection	Indian	24%
Ivan Stankovic & Millica Jesic, 2004	Dissection	Bulgarians	34.8%
Koerig, 2006			50%
Almira Lujinović*et al*., 2008	Dissection	Bosnian	32%
Olabu B. O. *et al*., 2008.	Dissection	Kenyans	35.1%
Standring S, *et al*, 2008.			36%
Pınar Koşar et al, 2009	64-slice CT coronary angiographic study	Turkish	22%

Gajbe U.L., 2010	Dissection	West Indian	16%
Udaya Sankari et al, 2011.	Dissection	South Indian	23.33%
Udaya Sankari et al, 2011.	*CT coronary angiographic study*	*South Indian*	*20%*
Present study, 2011	*64-sliceCT coronary angiographic study*	***North Indian***	***20%***
Ritu Mehta, Sanjeev Agrawal, 2013	64-sliceCT coronary angiographic study	North Indian	***~33%***