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PDA (Posterior Descending Artery) & Coronary Dominance-A MDCT Coronary Angiographic Analysis of Anatomic Variations and Clinical Importance

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Abstract

Introduction: There is considerable variation in the arterial supply of diaphragmatic surface of the heart. Diaphragmatic myocardial infarction is one of the more common consequences of coronary artery disease. The aim of this study was to assess the incidence of anatomic variants of origin and termination of Posterior Descending Artery (PDA) and to determine the type of coronary dominance in North Indian population. **Subjects and Methods:** This prospective study was carried out on 50 routine subjects of different age groups who came to the Department of Radiodiagnosis, King George's Medical University UP, Lucknow in the year 2010- 2011 with known or suspected coronary artery disease. All the cases were investigated on a 64 slice Multidetector Computed Tomographic (MDCT) scanner, using retrospective Electrocardiographic gating. Endeavour was made to determine the incidence of sites of origin and termination of PDA as well as to determine the type of coronary dominance. **Results:** PDA arose from Right Coronary Artery (RCA) in 39 (78%) cases and from Left Circumflex (LCx) artery in 11(22%) cases. The PDA was found to terminate in the upper 1/4 of Posterior Inter-Ventricular Groove (PIVG) in 18 (36%) cases, in upper 1/2 of PIVG in 19 (38%) cases, in upper 3/4 of PIVG in 10 (20%) cases and at the apex of the heart in 1 (2%) case. None of the female had termination of PDA at the apex. Termination of PDA could not be determined in 2 (4%) cases. Right dominance was seen in 36 (72%) cases, Left dominance in 11 (22%) cases. and Co-dominance in 3 (6%) cases. **Conclusion:** Posterior descending artery most commonly terminated after traversing the upper half of posterior inter-ventricular groove. The incidence of left coronary dominance was more in females, it was approximately twice the incidence found in males. Co-dominance was observed only in male subjects.

Keywords: Coronary Angiography, Coronary Dominance, Multidetector Computed Tomography, Posterior Descending Artery.

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Introduction

There is a wide range of variations within normal anatomic distribution of Posterior descending artery (PDA). PDA arises from Right Coronary Artery (RCA) in right dominant and co-dominant hearts, while it arises from Left Circumflex (LCx) artery in left dominant hearts. PDA supplies inferior wall of heart and inferior third of the interventricular septum. The artery that supplies the PDA and a posterolateral branch determines the coronary dominance.[1] PDA is also known as Posterior Inter-Ventricular Artery (PIVA). The site of origin of PDA is variable. In approximately 70% individuals, it arises from RCA near the crux of the heart and ends by anastomosing with the Anterior Inter-Ventricular Artery (AIVA) [Left Anterior Descending (LAD) artery] of Left Coronary Artery (LCA). In approximately 10% individuals, it arises either as a branch or continuation of LCx artery. The PDA extends along the posterior inter-ventricular groove (PIVG), from the crux of the heart toward the apex. PDA passes forward along the interventricular sulcus for a variable distance toward the apex of the heart. When the PDA has a premature takeoff and then courses toward the cardiac apex along the diaphragmatic surface of the right ventricle, the variant is called early takeoff of the PDA.

The concept of RCA or LCA preponderance was first proposed by Schlesinger M.J. in 1940. The term 'dominant' coronary artery was introduced by Schlesinger who used it to indicate the areas of heart supplied by each artery. Coronary dominance is based on the arterial supply to the diaphragmatic surface of heart by either right or left coronary artery.[2] The dominant coronary artery is that which gives the posterior interventricular branch, traversing the posterior interventricular sulcus and supplying the posterior part of the ventricular septum and often part of the

posterolateral wall of the left ventricle as well.[3]

According to Dr. Matt A. Morgan coronary artery "dominance" is defined in terms of which coronary artery gives origin to the PDA and the Posterior Left Ventricular Branches (PLVBs). Most persons (approximately 89.1%) have a "right-dominant" system, which means that the RCA supplies these arteries. Approximately 8.4% of persons have a "left-dominant" system, which means that the LCx artery supplies these arteries. Approximately 2.5% persons have "co-dominant" system in which the RCA gives origin to the PDA and the LCx artery gives origin to the PLVBs.[4]

The artery that supplies the posterior descending artery (PDA) and the posterolateral Branch (PLB) determines the coronary dominance. If the PDA and PLB arise from the RCA, then the system is said to be right dominant. If the PDA and PLB arise from the LCx artery, then the system is said to be left dominant. If the PDA comes from the RCA and the PLB comes from the LCx artery, the system is codominant.[5]

Branches of both RCA and LCx arteries run in or near the PIVG in balanced pattern (co-dominance) of coronary distribution.[6]

Dominance has important implications in myocardial ischaemia and infarction, imaging of the coronary arteries (CTCA and invasive coronary angiography) and the planning for coronary artery bypass grafting.[7]

Subjects and Methods

Materials

In this study, digital copies of 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 after taking due permission from Institutional Ethical Committee.

Method

This was an observational study. The sites of origin and termination of PDA were observed. Coronary angiograms were also observed for origin of PLVB. Coronary Angiography (CA) was done on patients came to the Department of Radiodiagnosis, King George's Medical University UP, Lucknow in the year 2010- 2011 with known or suspected coronary artery disease.

Inclusion criteria

Patients presenting with symptoms and signs of cardiovascular diseases e.g. Chest pain and Dyspnoea.

Exclusion criteria

(1) Lack of consent.
(2) Renal insufficiency (High urea / creatinine level).
(3) Allergy to contrast agent.
(4) Contraindication to radiation exposure (e.g.pregnancy). \
(5) Uncontrolled Heart rate.
(6) Atrial fibrillation, frequent atrial or ventricular ectopics (>1/minute).
(7) Unable to hold breath for 20 seconds.

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's Medical University (KGMU), Lucknow, Uttar Pradesh (U.P.), India. Retrospective Electrocardiographically gated imaging was performed (Technical parameters are given in Table 1).

Table 1: Technical Parameters applied in Computed Tomographic Coronary Angiographic (CTCA) images acquisition.

DEVICE - BRILLIANSTMCT, Version 2.45.22042, manufactured by Philips	
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 (FOV)	220mm
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 subjects 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 (VR) images were also obtained using various orientations.

CTCA images were observed for the origin and termination of PDA and origin of PLVB. 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).

Results

Table 2: Gender-wise Comparison of frequency of Site of Origin of PDA

Site of origin	Male (Nm=32)	Female (Nf=18)	Total (Nt=50)
Right Coronary Artery (RCA)	27(84.38)	12 (66.67)	39(78)
Left circumflex (LCx) Artery	5(15.63)	6 (33.33)	11 (22.0)

Nm-Total number of males, Nf-Total number of females, Nt-Total number of study subjects

Figures in parentheses represent percentage.

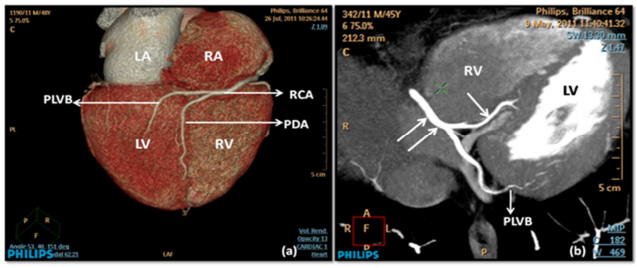


Figure 1: MDCT Images showing Origin of PDA from RCA & Right Dominance (a) 3D VR Image, (b) Axial MIP Image [PDA (single arrow), RCA (double arrow)] RA- Right Atrium, RV- Right Ventricle, LA- Left Atrium, LV- Left Ventricle, RCA- Right Coronary Artery, PDA- Posterior Descending Artery, PLVB- Posterior Left Ventricular Branch

PDA arose from RCA in 39 (78%) cases [27 (84.38%) males and 12 (66.67%) females] [Figure 1 a & b, Table 2]. PDA arose from LCX artery in 11(22%) cases [5 (15.63%) males and 6 (33.33%) females] [Figure 2 a & b, Table 2]. The PDA was found to terminate in the upper 1/4 of posterior inter-ventricular groove (PIVG) in 18 (36%) cases [10(31.25%) males and 8 (44.44%) females], in upper 1/2 of PIVG in 19 (38%) cases [12 (37. 5%) males and 7 (38.89%) females], in upper 3/4 of PIVG in 10 (20%) cases [7 (21.88%) males and 3 (16.67%) females] and at the apex of the heart in 1 (2%) case, a male (3.13%). None of the female had termination of PDA at the apex. Termination of PDA could not be determined in 2 (4%) cases [2(6.25%) males] because of suboptimal study [Figure 3a, b, c & d, Table 3].

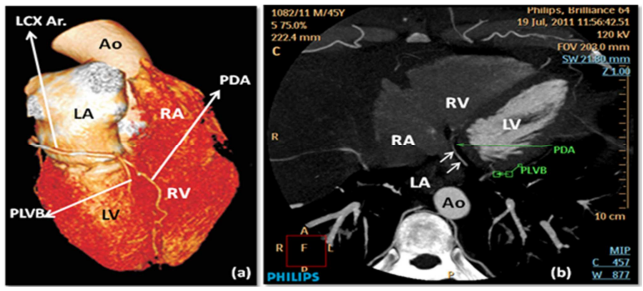


Figure 2: MDCT Images showing Origin of PDA from LCX Ar. & Left Dominance (a) 3D VR Image, (b) Axial MIP Image [(LCX Ar. (double arrow)]. RA- Right Atrium, RV- Right Ventricle, LA- Left Atrium, LV- Left Ventricle, RCA- Right Coronary Artery, PDA- Posterior Descending Artery, , PLVB- Posterior Left Ventricular Branch, LCx Ar.- Left Circumflex Artery Ao- Aorta

Table 3: Gender wise termination of PDA with reference to the length of Posterior Inter-Ventricular Groove (PIVG)

Site of termination of PDA	Male (Nm=32)	Female (Nf=18)	Total (Nt=50)
Upper 1/4 of PIVG	10(31.25)	8(44.44)	18(36)
Upper 1/2 of PIVG	12(37.50)	7(38.89)	19(38)
Upper 3/4 of PIVG	7(21.88)	3(16.67)	10(20)
Cardiac apex	1(3.13)	0	1(2)
Not determined	2(6.25)	0	2(4)

Nm-Total number of males, Nf-Total number of females, Nt-Total number of study subjects

Figures in parentheses represent percentage. χ^2 =2.407; p=0.661

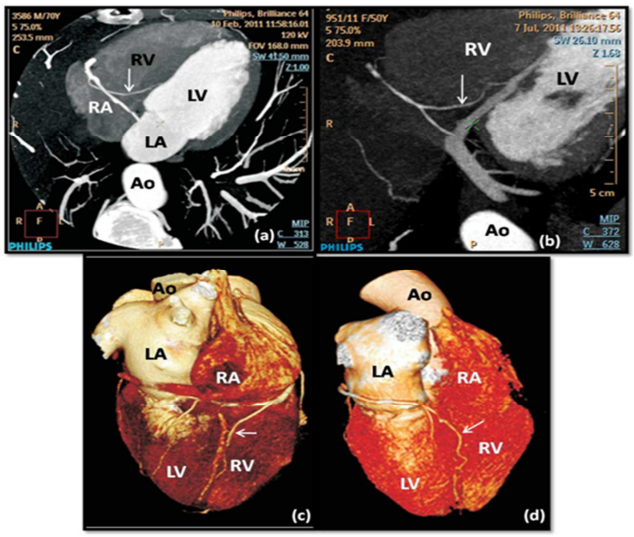
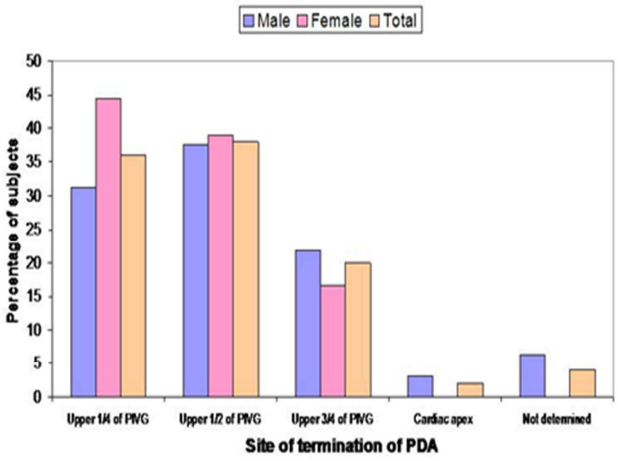


Figure 3: MDCT Images showing Termination of PDA (a) Axial MIP Image showing termination in upper 1/4 of PIVG,

(b) Axial MIP Image showing termination in upper 1/2 of PIVG, (c) 3D VR Image showing termination in upper 3/4 of PIVG (d) 3D VR Image showing termination at cardiac apex [PDA(arrow)]. RA- Right Atrium, RV- Right Ventricle, LA- Left Atrium, LV- Left Ventricle, Ao- Aorta

In the present study, the coronary dominance pattern results were: Right Dominance in 36 (72%) cases [24 (75%) males and 12 (66.67%) females] [Figure 1a&b], Left Dominance in 11 (22%) cases [5 (15.63%) males and 6 (33.33%) females] [Figure 2a&b] and Co-dominance in 3 (6%) cases [3(9.38%) males][Figure 4]. None of the female had co-dominance [Table 4].



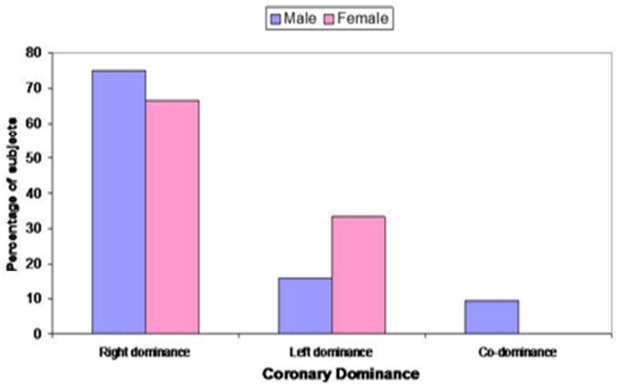
Graph 1: Bar Diagram showing Frequency of Termination of PDA in PIVG (PDA- Posterior Descending Artery, PIVG- Posterior Interventriucular Groove)

Table 4: Gender-wise Frequency of coronary dominance

Dominance pattern	Male(Nm=32)	Female(Nf=18)	Total(Nt=50)
Right Dominance	24(75)	12(66.67)	36(72%)
Left Dominance	5(15.63)	6(33.33)	11(22%)
Co-dominance	3(9.38)	0	3(6%)

Nm-Total number of males, Nf-Total number of females, Nt-Total number of study subjects

Figures in parentheses represent percentage.



Graph 2: Bar Diagram showing gender-wise frequency of Coronary Dominance

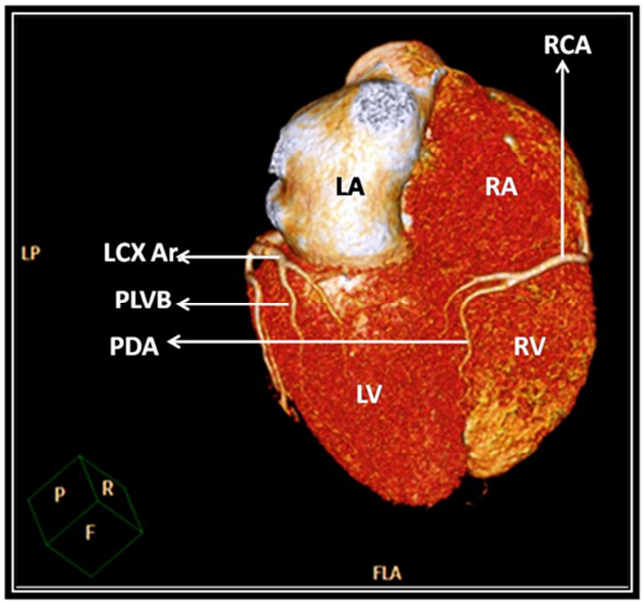
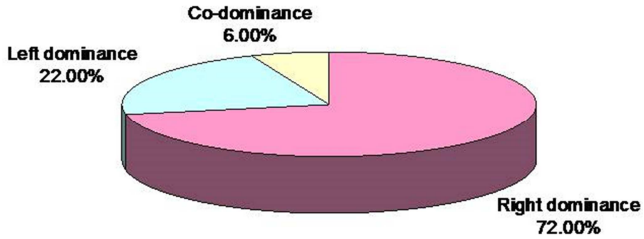


Figure 4: 3D VR Image showing co-dominance RA- Right Atrium, RV- Right Ventricle, LA- Left Atrium, LV- Left Ventricle, RCA- Right Coronary Artery, PDA- Posterior Descending Artery, PLVB- Posterior Left Ventricular Branch, LCx Ar.- Left Circumflex Artery



Graph 3: Pie Diagram showing percentage distribution of Coronary Dominance pattern

Discussion

Diaphragmatic myocardial infarction is one of the more common consequences of coronary artery disease. It can occur as a result of interruption of the blood supply to the posterior diaphragmatic portion of the inter-ventricular septum and/or the diaphragmatic surface of left ventricle. There is considerable variation in the arterial supply of this important region of the heart. A thorough understanding of these anatomic variations is required for proper interpretation of coronary angiograms. Understanding these variations is essential in diagnosing obstructions in these arteries and planning surgical therapy.

PDA, which is one of the most important branches of the RCA, supplies posterior diaphragmatic portion of the inter-ventricular septum. The David C. Levin and Harold A. Baltaxe found significant anatomic variations in the origin, course or distribution of PDA in 23 per cent of a series of 200 patients. They found double posterior descending branches, early origin of the PDA and partial supply of the diaphragmatic portion of the septum by acute marginal or posterior right ventricular branches. They found double PDA in 6% cases and early origin of PDA in 5% cases. The preponderant or “dominant” artery is the one which supplies

the posterior diaphragmatic portion of the inter-ventricular septum and the diaphragmatic surface of the left ventricle. In right dominant hearts, PDA arises from the RCA at or shortly before the crux. After passing the crux, the dominant RCA terminates by giving rise to one or more large Posterior Left Ventricular (PLV) arteries. These arteries are the main source of blood to the diaphragmatic surface of the left ventricle. In left dominant hearts, LCX artery passes around the left atrio-ventricular sulcus and gives PLV arteries. It then turns towards the apex of the heart as PDA. In co-dominant hearts, RCA reaches the crux of the heart where it turns towards the apex and continued as PDA. In these cases, PLV arteries originate from distal portion of LCX artery.[8]

The concept of coronary dominance is reflected by considerable variation in the blood supply to the inferior and posterior portion of the left ventricular wall.[9] If the circumflex branch of the left coronary artery terminates in the posterior inter-ventricular sulcus, then the heart is left dominant. If the posterior septum is vascularised either by descending branches from both the RCA and the LCx arteries, or by a network of small branches from these two passing obliquely, so that there is no posterior inter-ventricular branch. In such hearts the circulation is said to be 'balanced', as the posterior inter-ventricular branch is either bilateral or absent.[10]

In the past, several studies were conducted to determine the coronary dominance [Table 5 & 6]. In all studies, frequency of right dominance is more than that of left dominance and co-dominance except the study done by Fazliogullari Z et al. which showed the incidence of co-dominance is more than that of right dominance [Table 5].[11] The incidence of right dominance in the present study is similar to the findings of studies done by Allwork SP, Cavalcanti J.S. et al, Eren et al., Das H et al. and Pusala B et al [Table 5 & 6].[10,12-16]

In most of the studies done in the past, the incidence of left dominance is more than the incidence of co-dominance. But some studies showed the greater incidence of co-dominance over left dominance [Table 5 & 6].[2,11-13,17-22] The findings of a study done by Bharambe V K and Arole V U showed similar incidence of left dominance and co-dominance[Table 5].[23] The incidence of left dominance and co-dominance is same in studies of Allwork SP, Pusala B et al, Patel S, and Priyadharshini S and Sivakumar M [Table 5 & 6].[10,15,24,25] The incidence of left dominance in the present study is similar to the findings of Ramanathan L et al., Bhimalli S et al, and Abuchaim D C Soares et al [Table 5 & 6].[19,26,27] Left dominant hearts are at an increased risk of coronary heart diseases.[15]

No case of co-dominance was reported by James, Kalpana R, Anbumani TL et al, Khona P and Ashwini C., Gebhard C et al [Table 5 & 6].[28-32] Pusala B et al., Patel S, Priyadharshini S and Sivakumar M and Allwork SP reported the same incidence of left and co-dominance[Table 5 & 6].[15,24,25,33] In the present study, the incidence of co-dominance was 6%, which is similar to the reports of Kate G.J.R. ten et al.[34] In the present study, Co- dominance was seen only in male subjects. Knaapen M et al found that the prevalence of a left dominant or codominant coronary system decreased with increasing age.[22]

Goldberg A et al hypothesized that the prognosis of patients with Acute Coronary Syndrome (ACS) with Left Dominance (LD) would be worse than that of patients with right or mixed dominance. They concluded that in patients with ACS, Left Dominance is a significant and independent predictor of increased long-term mortality.[35] In a CT angiographic study, Eren et al found that the coronary diseases and the number and rate of coronary artery variations are significantly higher among the individuals with left dominant circulation.[13] Kuno T et al. observed that among ACS patients who underwent Percutaneous Coronary Intervention (PCI), patients with left dominance had significantly worse in-hospital outcomes compared with patients with right dominance, and left dominant anatomy was an independent predictor of in-hospital mortality due to heart failure, cardiogenic shock or cardiopulmonary arrest.[36] Murphy ES et al, found in patients of aortic stenosis with left dominance, an increased risk of perioperative myocardial infarction if there is associated obstructive coronary artery disease. Patients with left dominance have a shorter left main coronary artery than patients with right dominance. Preoperative information about the coronary arterial anatomy and extent of coronary artery disease may be helpful in planning the use of coronary perfusion and other myocardial preservation techniques during surgery in order to reduce the incidence of myocardial infarction.[37]

In cases where patients are being considered for right coronary bypasses, it is particularly important to call the attention of the surgeon to the presence of any of the anatomic variations. These variations affect the decision regarding the nature of bypasses to be constructed. Where the vessels do not conform to classical anatomic conceptions, it may be impossible, unless one is forewarned to the atypical configuration. In cases of dual supply of inter-ventricular septum, multiple stenoses might necessitate construction of two different bypasses to provide adequate vascularization.[8]

Table 5: Comparative percentages of coronary dominance among various autopsy and cadaveric studies

Authors and Year of Study	Type of Study	Population & No. of cases	Right Dominance	Left Dominance	Co- dominance
Nerantzis C and Avgoustakis D, 1980	Autopsy (X-ray films & Corrosion casting)	Greek 300	88.67	9.33	2
Kurjia HZ et al, 1986	Autopsy	Iraqi	46	14	40
Kalpana R, 2003	Cadaveric	South Indian 100	89	11	NIL
Abuchaim D C Soares et al, 2009	Corrosion casting	Brazilian 25	72	20	8
Das H et al, 2010	Cadaveric	East Indian (Assamese)70	70	18.57	11.43

Fazliogullari Z et al, 2010	Cadaveric	Turkish 50	42	14	44
Bhimalli S et al, 2011	Cadaveric	Indian 60	60	23.33	16.66
Bharambe V K and Arole VU., 2013	Cadaveric	Western India (Maharashtra) 50	60-78	12-24	10-24
Jaishree H and Ashwini H, 2015	Cadaveric	South Indian 76	83	14.5	2.5
Anbumani T L et al, 2016	Cadaveric	South Indian 50	84	16	NIL
Priyadharshini S & Sivakumar M, 2016	Cadaveric	South Indian (Kerala) 50	84	8	8
Pal M et al, 2016	Cadaveric	West Bengali 50	70	22	8
Pusala B et al., 2017	Cadaveric	South Indian (Telangana) 80	70	15	15
Khona P and Ashwini C, 2018	Cadaveric	South Indian (Karnatka) 100	83	17	NIL
Meshram SW, 2018	Cadaveric	Western India (Maharashtra) 50	68	8	12

Table 6: Comparative percentages of coronary dominance among various angiographic studies

Authors and Year of Study	Type of Study	Population & No. of cases	Right Dominance		Left Dominance		Co- dominance	
Schlesinger M.J, 1940			48		18		34	
James,1961			90		10		NIL	
Allwork SP, 1987			70		15		15	
Cavalcanti J S et al, 1995			69.09		11.82		19.09	
Angelini P et al, 2002	Angiography	1950	81.61		8.4		2.5	
Kini S et al., **2007**	64-slice CTCA		80-85		15-20		5	
Patel S, 2008	64-slice CTCA		85		7-8		7-8	
Cademartiri F et al, 2008	64-slice CTCA	543	86.6		9.2		4.2	
Eren et al., 2008	16-slice CTCA	325	70		12.5		17.5	
			M	F	M	F	M	F
			69	71	12	13	19	16
Kate G.J.R. ten et al, 2008	64-slice CTCA	Netherland 1000	85.1		8.8		6.1	
Vasheghani-Farahani A et al, 2008	Coronary angiography	Irani 12558	84.2		10.9		4.8	
Pınar Koşar et al, 2009	64-slice CT coronary angiography	Turkish 700	76		9.1		14.8	
Abdelmoneim AA Abdellah et al, 2009	Catheter angiography	Sudanese 429	77		8		15	
Ramanathan L et al, 2009	Catheter angiography	South Indian 300	53.66		22.33		24	
Kevin NC et al, 2010	CTCA	105	85.7		9.5		4.8	
Mian FA et al, 2011	Catheter angiography	Pakistani 200	60.5		19.5		20	
Knaapen M et al, 2013	Coronary angiography	Netherland 1553	81.2		9.1		9.7	
Gebhard C et al, 2015	CTCA	6382	91		9		NIL	
Present study, 2011	64-slice CTCA	North Indian 50	72		22		6	
			M	F	M	F	M	F
			75	66.67	15.63	33.33	9.38	NIL

M: Male, F: Female

Conclusion

In the present study, PDA most commonly arose from RCA and frequency of origin of PDA from LCX Ar. was more in females.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 half of posterior inter-ventricular groove and there is no significant difference in the termination pattern of PDA among males and females.

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