AN OBSERVATIONAL STUDY ON HUMAN CORONARY ARTERIES IN TAMIL NADU ADULT AND FOETAL POPULATION

Dissertation submitted in
Partial fulfilment of the regulations required for the award of

M.D. DEGREE
In
ANATOMY – BRANCH V

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY
CHENNAI

May 2018

An observational study on human coronary arteries in Tamil Nadu adult and foetal population

Dissertation submitted to

The Tamil Nadu Dr.M.G.R. Medical University, Chennai

In partial fulfillment of the university regulations for the award of degree of

M.D Anatomy – Branch V

May 2018

Ethical committee approval

PSG Institute of Medical Sciences & Research
Institutional Human Ethics Committee

Recognized by The Strategic Initiative for Developing Capacity in Ethical Review (SIDCER)

POST BOX NO. 1674, PEELAMEDU, COIMBATORE 641 004, TAMIL NADU, INDIA

Phone : 91 422 - 2598822, 2570170, Fax : 91 422 - 2594400, Email : ihec@psgimsr.ac.in

To
Dr Nandhini Aishwarya
Postgraduate
Department of Anatomy
Guide: Dr M Jamuna
PSG IMS & R
Coimbatore

Ref: Project No.15/409

Date: December 30, 2015

Dear Dr Nandhini Aishwarya,

Institutional Human Ethics Committee, PSG IMS&R reviewed and discussed your application dated 21.12.2015 to conduct the research study entitled *"An observational study on human coronary arteries in Tamil Nadu adult and foetal population"* during the IHEC meeting held on 24.12.2015.

The following documents were reviewed and approved:

1. Project Submission form
2. Study protocol (Version 1 dated 21.12.2015)
3. Parental consent form (Version 2 dated 30.12.2015)
4. Confidentiality statement
5. Application for waiver of consent
6. Data collection tool (Version 1 dated 21.12.2015)
7. Permission letter from concerned Heads of the Department
8. Current CVs of Principal investigator, Co-investigators
9. Budget

The following members of the Institutional Human Ethics Committee (IHEC) were present at the meeting held on 24.12.2015 at IHEC Secretariat, PSG IMS & R between 10.00 am and 11.00 am:

Sl. No.	Name of the Member of IHEC	Qualification	Area of Expertise	Gender	Affiliation to the Institution Yes/No	Present at the meeting Yes/No
1	Mr. R. Nandakumar	BA., BL	Legal Expert, Chairperson	Male	No	Yes
2	Dr. S. Bhuvaneshwari (Member-Secretary, IHEC)	MD	Clinical Pharmacology	Female	Yes	Yes
3	Dr. S. Shanthakumari	MD	Pathology, Ethicist	Female	Yes	Yes
4	Dr D Vijaya	M Sc., Ph D	Basic Medical Sciences (Biochemistry)	Female	Yes	Yes

The study is approved in its presented form. The decision was arrived at through consensus. Neither PI nor any of proposed study team members were present during the decision making of the IHEC. The IHEC functions in accordance with the ICH-GCP/ICMR/Schedule Y guidelines. The approval is valid until one year from the date of sanction. You may make a written request for renewal / extension of the validity, along with the submission of status report as decided by the IHEC.

PSG Institute of Medical Sciences & Research
Institutional Human Ethics Committee
Recognized by The Strategic Initiative for Developing Capacity in Ethical Review (SIDCER)
POST BOX NO. 1674, PEELAMEDU, COIMBATORE 641 004, TAMIL NADU, INDIA
Phone : 91 422 - 2598822, 2570170, Fax : 91 422 - 2594400, Email : ihec@psgimsr.ac.in

Following points must be noted:

1. IHEC should be informed of the date of initiation of the study
2. Status report of the study should be submitted to the IHEC every 12 months
3. PI and other investigators should co-operate fully with IHEC, who will monitor the trial from time to time
4. At the time of PI's retirement/intention to leave the institute, study responsibility should be transferred to a colleague after obtaining clearance from HOD, Status report, including accounts details should be submitted to IHEC and extramural sponsors
5. In case of any new information or any SAE, which could affect any study, must be informed to IHEC and sponsors. The PI should report SAEs occurred for IHEC approved studies within 7 days of the occurrence of the SAE. If the SAE is 'Death', the IHEC Secretariat will receive the SAE reporting form within 24 hours of the occurrence
6. In the event of any protocol amendments, IHEC must be informed and the amendments should be highlighted in clear terms as follows:
   a. The exact alteration/amendment should be specified and indicated where the amendment occurred in the original project. (Page no. Clause no. etc.)
   b. Alteration in the budgetary status should be clearly indicated and the revised budget form should be submitted
   c. If the amendments require a change in the consent form, the copy of revised Consent Form should be submitted to Ethics Committee for approval
   d. If the amendment demands a re-look at the toxicity or side effects to patients, the same should be documented
   e. If there are any amendments in the trial design, these must be incorporated in the protocol, and other study documents. These revised documents should be submitted for approval of the IHEC and only then can they be implemented
   f. Any deviation-Violation/waiver in the protocol must be informed to the IHEC within the stipulated period for review
7. Final report along with summary of findings and presentations/publications if any on closure of the study should be submitted to IHEC

Kindly note this approval is subject to ratification in the forthcoming full board review meeting of the IHEC.

Thanking You,

Yours Sincerely,

SECRETARY
PSG IMS&R
COIMBATORE-641004.
INSTITUTIONAL HUMAN ETHICS COMMITTEE

Dr S Bhuvaneshwari
Member - Secretary
Institutional Human Ethics Committee

PSG Institute of Medical Sciences & Research
Institutional Human Ethics Committee

Recognized by The Strategic Initiative for Developing Capacity in Ethical Review (SIDCER)

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Phone : 91 422 - 2598822, 2570170, Fax : 91 422 - 2594400, Email : ihec@psgimsr.ac.in

December 9, 2016

To
Dr C Nandhini Aishwarya
Postgraduate
Department of Anatomy
Guide: Dr M Jamuna
PSG IMS & R
Coimbatore

The Institutional Human Ethics Committee, PSG IMS & R, Coimbatore - 4, has reviewed your proposal on 9th December 2016 in its expedited review meeting held at IHEC Secretariat, PSG IMS&R, between 10.00 am and 11.00 am, and discussed your request to renew the approval for the study entitled:

"An observational study on human coronary arteries in Tamil Nadu adult and foetal population"

The following documents were received for review:

1. Request for renewal dated 01.12.2016
2. Status Report

After due consideration, the Committee has decided to renew the approval for the above study.

The members who attended the meeting held on at which your proposal was discussed, are listed below:

Sl. No.	Name of the Member of IHEC	Qualification	Area of Expertise	Gender	Affiliation to the Institution Yes/No	Present at the meeting Yes/No
1	Mr R Nandakumar (Chairperson, IHEC)	BA., BL	Legal Expert	Male	No	Yes
2	Dr. S. Bhuvaneshwari (Member-Secretary, IHEC)	MD	Clinical Pharmacology	Female	Yes	Yes
3	Dr S Shanthakumari	MD	Pathology, Ethicist	Female	Yes	Yes
4	Dr Sudha Ramalingam	MD	Epidemiologist, Ethicist Alt. member-Secretary	Female	Yes	Yes
5	Dr D Vijaya	M Sc., Ph D	Basic Medical Sciences (Biochemistry)	Female	Yes	Yes

The approval is valid for one year (30.12.2016 to 29.12.2017).

This Ethics Committee is organized and operates according to Good Clinical Practice and Schedule Y requirements.

Non-adherence to the Standard Operating Procedures (SOP) of the Institutional Human Ethics Committee (IHEC) and national and international ethical guidelines shall result in withdrawal of approval (suspension or termination of the study). SOP will be revised from time to time and revisions are applicable prospectively to ongoing studies approved prior to such revisions.

Kindly note this approval is subject to ratification in the forthcoming full board review meeting of the IHEC.

Yours truly,

SECRETARY
PSG IMS&R
COIMBATORE-641004.
INSTITUTIONAL HUMAN ETHICS COMMITTEE

Dr S Bhuvaneshwari
Member – Secretary
Institutional Human Ethics Committee

Proposal No. 15/409

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septum, the right atrium and part of the left atrium.

Left coronary artery distribution is reciprocal, including most of the left ventricle, a narrow strip of right ventricle and the anterior two thirds of the interventricular septum.

ACCOMPANYING VEINS: The right coronary artery is accompanied by the small cardiac vein in the right side of atrioventricular groove, the left circumflex artery by the coronary sinus in the left side of atrioventricular groove, the left anterior descending artery by the great cardiac vein in the anterior interventricular groove and the posterior interventricular artery is accompanied by the middle cardiac vein in the posterior interventricular groove.

NOMENCLATURE OF THE CORONARY ARTERY SEGMENTS:

Coronary artery segments are named according to the CASS segments (Coronary Artery Surgery Study segments) by American Heart Association. There are 17 segments according to this classification (Figure 10). The right coronary artery with its branches contribute 5 segments, left main coronary trunk contributes 1 segment, left circumflex artery with its branches contribute 5 segments and left anterior descending artery with its branches contribute 5 segments and ramus intermedius, when present, contributes 1 segment (Austen WG et al, 1975; Braunwald E et al, 2012).

DEVELOPMENTAL ANATOMY OF THE CORONARY ARTERIES: Pro-epicardium, mesothelium covered protrusion of mesenchymal cells, arises from the pericardium in the region of the sinus venosus during week 5 (Carnegie stage 14,15). It forms the epicardium, coronary vascular bed and interstitial fibroblasts. The coronary vessels are formed by vasculogenesis. Mesenchymal cells in the subepicardial space forms the primitive vessels which invades the myocardium and spread over the myocardial surface to form a plexus during week 6 (Carnegie stage 16, 17). Sprouts of this plexus approaches the base of the outflow tract, and links to the sinuses of the aortic root during week 7 (Carnegie stage 18). Finally, only solitary right and left coronary arteries remain in a heart with no congenital coronary artery anomaly. (Hutchins GM, 1988; Standring S et al, 2015)

EVOLUTIONARY PERSPECTIVES: Fish and amphibia possess only one coronary artery. In birds, approximately 40% has only one coronary artery. Thus, the dual coronary artery system in humans is a recent evolutionary acquisition.

CLINICAL ANATOMY: The coronary artery disease, (or ischemic heart disease) is the most common among the cardiovascular diseases that includes stable angina, unstable angina, myocardial infarction, and sudden cardiac death. It occurs primarily as a result of interruption of blood supply to the myocardium. Coronary artery anomalies (or malformation of coronary vessels) are congenital abnormalities in the coronary anatomy of the heart. By definition, these abnormalities are variants of anatomy occurring in less than 1% of the general population. They often co-exist with other congenital heart defects. Coronary artery anomalies are some of the most confusing, neglected topics in cardiology (Angelini P et al, 2002). Many coronary anomalies do not cause symptoms and are identified only at the time of autopsy. Some are associated with sudden death. The risk of mortality or the ideal way to treat these patients is still ambiguous. Advancements in the Investigation and treatment modalities of diseases involving coronary arteries: 1924 – Willem Einthoven received Nobel Prize for development of electrocardiogram 1927 – Egas Moniz first developed technique of angiography (for brain vasculature) 1929 – Werner Forssmann performed first cardiac catheterization on himself 1937 – Taro Takemi invented the first portable electrocardiograph machine 1939 – Andre Cournard and Dickinson Richards developed the potentials of catheterization 1941 – Andre Cournard performed the first human heart catheterization 1950 – Steinberg I began to develop angiocardiography 1956 – Andre Cournard, Werner Forssmann and Dickinson Richards shared Nobel Prize for their work 1958 – Charles Dotter invented occlusive aortography to visualize

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Certificate

This is to certify that the dissertation "An Observational study on human coronary arteries in Tamil Nadu adult and foetal population" is an original work done by Dr.C.Nandhini Aishwarya, Post graduate student, Department of Anatomy, PSG Institute of Medical Sciences and Research, Coimbatore, under my supervision and guidance.

Dr.M.Jamuna. M.S

Professor and HOD (Guide),

Department of Anatomy,

PSG IMS&R.

Dr.S.Ramalingam. M.D

Dean,

PSG IMS&R.

Declaration

I solemnly declare that the dissertation "An Observational study on human coronary arteries in Tamil Nadu adult and foetal population" was done by me in the Department of Anatomy, PSG Institute of Medical Sciences and Research, Coimbatore, under the guidance of Dr.M.Jamuna. M.S, Professor and HOD, Department of Anatomy, PSG Institute of Medical Sciences and Research, Coimbatore.

This dissertation is submitted to The Tamil Nadu Dr.M.G.R Medical University, Chennai in partial fulfillment of the university regulations for the award of degree of M.D Anatomy – Branch V examinations to be held in May 2018.

Place: Coimbatore

Date:

Dr.C.Nandhini Aishwarya

Acknowledgement

Thank you Appa, Amma, my HOD, all the professors, assistant professors, lab technicians and non-teaching staffs of my department, sister, brother and friends.

An Observational study on human coronary arteries in Tamil Nadu adult and foetal population

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INTRODUCTION

The term ‘coronary’ stems from a Latin word *‘corona’* which denotes crown. These vessels were entitled so, owing to their crown like architecture at the base of the heart.

The coronary arteries are the exclusive endowers of blood to the entire heart except endothelial surface that gets nutrition directly from the cardiac chambers. These arteries deliver blood, auto regulated as per the needs of cardiac musculature, thereby ensuring uninterrupted, rhythmic and effective functioning of the heart in a healthy person.

The coronary vessels are esteemed to be the vasa vasorum *(vessel to the vessel)* of the aorta, because the heart is embryologically advanced by the amalgamation of two primitive endothelial tubes which portray ventral aorta.

Cognizance of these prime vessels retrogrades to at least the times of *Andreas Vesalius* in the sixteenth century. Phenomenal illustrations of coronary arteries were equipped by *Johann Dryander* in the same century.

Thenceforward, the anatomy of coronary arteries and its variations have been entailed and contemplated exhaustively in different parts of the world in the realms of morphology, morphometry, physiology, congenital anomalies, coronary artery diseases, diagnostics, pathogenesis and interventions.

Colossal advancement has been made in the treatment of cardiovascular diseases with the advent of cardiac catheterization and angiography that paved way for the beginning of the new era of percutaneous transluminal angioplasty and bypass surgery in saving lives.

Despite several decades of rigorous scrutiny, exploration and fact-finding on these arteries, there still lingers controversies appertain to the various factors that influence the origin, diameter, length, branching and termination of these arteries and also the role of these arterial parameters in enhanced disease susceptibility, disease pathogenesis, accelerated progression of diseases, postoperative complications, prognosis, morbidity and mortality.

Peculiarities:

These coronary arteries are out of the ordinary in many aspects. They are the first branches from aorta. They are the only arteries in the human body that has *peak flow during the cardiac diastole*. Structurally, the coronary arteries are end arteries since they anastomose with each other by their trunk, branch and sub-branch level, mostly at pre-capillary level. However, *functionally, they do not behave like end arteries* since their anastomosis remains impervious.

NORMAL AND ANOMALOUS CORONARY ARTERY:

The origin (number, source artery, aortic sinus, and level), course, branches, diameter, length, extent and level of termination of the coronary arteries are not unanimous. The pattern that is present in majority of population is termed as a *'normal'* coronary artery. Any variations in the normal pattern is termed as an *'anomalous'* coronary artery.

Angelini P et al (1989) and (2002) introduced the concepts of normal variant versus anomaly based on a statistical definition of normal range (99% of the presentations observed in a normal, unselected population) and suggested that the coronary arteries should not be defined by their origin or proximal course, but by their intermediate and distal segments or dependent microvascular bed.

Beneficial therapeutic options are increasingly available for coronary artery diseases. To obtain full benefits of these options and for optimal cardiac care, a detailed knowledge of the normal architecture and anatomic variations of the coronary arterial system is demanded.

ORIGIN:

Number:

Typically, the heart owns two coronary arteries – right coronary artery and left main coronary artery ***(Figure 1)***, originating from two separate ostia. Unrepresentative to this, the number of coronary arteries may be single or triple.

Both the major branches may arise from single ostium, that is, a heart perfused with single coronary artery.

The right coronary artery is usually single, but as many as four arteries have been observed.

The first branch of right coronary artery, the conus artery arises separately from the anterior aortic sinus in 36% of individuals. This is sometimes termed a ‘third coronary' artery.

The presence of a single left main coronary artery is not always concordant. When the left coronary artery doubles, it leads to origination two major initial branches, usually the circumflex and anterior interventricular (descending) arteries with independent aortic ostium.

Source artery:

The coronary arteries are the initial branches from the ascending aorta ***(Figure 1)***, with their inception from coronary sinus (anterior and left posterior aortic sinus of Valsalva). Aberrantly; these arteries may arise from pulmonary trunk or any adjacent vessel such as arch of aorta, Descending thoracic aorta, Innominate artery, Right carotid artery, Internal mammary artery, Bronchial artery or Subclavian artery. There are corroborations of right coronary artery originating from one of the branches of left main coronary artery and contrariwise.

Aortic sinus:

There are three semilunar cusps housed at the beginning of ascending aorta – anterior, left posterior and right posterior with corresponding sinuses cranial to them. The right coronary artery and left main coronary artery arises from *anterior sinus of Valsalva* (right coronary sinus) and *left posterior sinus of Valsalva* (left coronary sinus) respectively. The *right posterior aortic sinus of Valsalva* is a non-coronary sinus ***(Figure 2)***. Perplexingly, the right and/or left coronary arteries may arise from the opposite aortic sinuses, or even from the non-coronary sinus.

Level:

Sinotubular junction or *supravalvular ridge* is a level in ascending aorta, above the annulus of the aortic semilunar valve where the proximal dilated sinuous part of the ascending aorta continues as distal tubular part ***(Figure 2)***. In a majority of population, the coronary arteries originate below the sinotubular junction of ascending aorta.

It may also originate above the level of sinotubular junction, at the level of sinotubular junction or in some cases, they may originate even below the aortic semilunar cusps. For the right coronary artery the ostium is below the margin of the cusps in 10% and for the left coronary artery the ostium is below the margin of the cusps in 15%.

COURSE:

Anatomically, the right coronary artery passes forward and to the right and emerges between right appendage and pulmonary trunk. Then it courses down and to the right along the right part of anterior atrioventricular groove. Anomalies include artery coursing retrocardiac, retroaortic, intraseptal, between aorta and pulmonary artery or precardiac. The left main coronary artery travels behind the pulmonary trunk and then appears forward and to the left, between the pulmonary trunk and left appendage. Anomalies include artery coursing intraseptal, precardiac or between aorta and pulmonary trunk.

BRANCHES:

These two coronary arteries further branch, being in charge of perfusing different parts of the heart – atrial and ventricular walls inclusive of the septum, appendages, Sinoatrial node and Atrioventricular node.

Cardiac dominance:

Posterior interventricular artery is one of the branches from coronary artery. It may be one to three in number. The source artery could be either the right coronary artery or the left coronary artery or both. This governs the dominance of the heart – right dominant, left dominant and co-dominant (balanced dominance) respectively ***(Figure 3)***. This conceptualization of cardiac dominance was instigated by *Schlesinger* in 1940. The dominant artery is usually the right (60%).

The various branches of right coronary artery and left main coronary artery are catalogued and enumerated along with associated variations and anomalies. ***(Figure 4)***

Right coronary artery:

The branches from the first segment (up to the acute/ inferior border) include right conus artery (first branch), anterior branches to right atrium (supplies sinoatrial node in 65% population), lateral or marginal branches to right atrium, anterior branches to right ventricle (largest among which is the right or acute marginal artery). The right marginal artery is greater in calibre than the other anterior ventricular arteries and long enough to reach the apex in most hearts (93%). The sinoatrial nodal artery was described by *Spalteholz* in 1924.

The arteries arising from the second segment (beyond the acute/ inferior border) include posterior branches to right atrium, posterior branches to right ventricle and posterior interventricular artery (in right dominant and co-dominant hearts).

Variations may occur in the number of atrial or ventricular branches.

Left main coronary artery:

The two major branches from the left main coronary artery are left anterior descending artery or anterior interventricular artery and left circumflex artery.

Dissimilitude occurs in the branching of the left main coronary artery.

It does not unanimously bifurcate. In a few, the main trunk trifurcates with a ramus intermedius (median artery of Banchi or arteria diagonalis of Cranicianu) or even quadfurcates ***(Figure 5).*** There are also cases of absent left anterior descending artery or absent left circumflex artery. Peculiarly, the left anterior descending artery or the left circumflex artery arises from the right coronary artery or even from the right sinus of Valsalva.

These two major branches may duplicate and lie parallel to each other in rare instances.

Left anterior descending artery:

The branches arising from this artery are left conus artery, anterior branches to right ventricle, anterior branches to left ventricle, left diagonal artery, anterior septal branches and, in some, the posterior septal branches.

Variations occur in the number of ventricular branches.

Left diagonal artery may sometimes be the additional artery in trifurcating and quadfurcating left main trunk.

Left circumflex artery:

The branches arising from this artery are anterior branches to left atrium, lateral or marginal branches to left atrium, posterior branches to left atrium, anterior branches to left ventricle, posterior branches to left ventricle, left or obtuse marginal artery and posterior interventricular artery (in left dominant and co-dominant hearts).

Inconsistent branches of left circumflex artery include artery to sinoatrial node, artery to atrioventricular node and *Kugel's* anastomotic artery or *arteria anastomotica auricularis magna.*

The anterior segment of circumflex artery gives rise to sinoatrial nodal artery in 35%. This was first observed by *James TN* in 1961.

Anterior and posterior septal branches arise from posterior interventricular artery and the largest posterior septal artery supplies atrioventricular node (80%).

Thus, the cardiac dominance denotes the source artery to atrioventricular nodal artery and not that of the sinoatrial nodal artery.

DIAMETER:

The diameter of these arteries and their branches are protean, hypothesized to have several influencing factors - *age, sex, ethnicity, physical activity and pathology*. The diameter of coronary arteries, both main stems and larger branches, based on measurements of arterial casts or angiograms, ranged between 1.5 and 5.5 mm for the coronary arteries at their origins. The left exceeded the right in 60% of hearts, the right being larger in 17%, and both vessels being approximately equal in 23%.

LENGTH, EXTENT AND TERMINATION:

The length of left main coronary artery is significantly variable. The initial portion of left coronary artery, between its ostium and its first two branches, varies in length from a few millimetres to a few centimetres.

Crux of the heart is the juncture on the posterior surface of the heart where the inter-atrial septum, inter-ventricular septum and posterior atrioventricular groove meet.

Conventionally, both the right coronary artery and left circumflex artery ends reaching the crux of the heart.

Discrepancy occurs at the level of their termination. In a minority of individuals, the right coronary artery ends near the right cardiac border (10%), or between this and the crux (10%); more often (20%) it reaches the left border. ***(Figure 6)***

The circumflex artery may end either at left/obtuse border or anywhere between left border and crux or crux and right border in posterior atrioventricular groove or very rarely it may end at right border. ***(Figure 7)***

The left anterior descending artery terminates at the apex in one-third, but more often it turned round the apex into the posterior interventricular groove, and passed one-third to one-half of the way along its length. ***(Figure 8)***

Thus, it is obvious that there is no exclusive quintessential prototype of the coronary arteries; the variations are inevitably present in a considerable percentage of population and anomalies are found in less than one percent of the given population.

CORONARY ARTERIOVENOUS FISTULA:

It is an unusual anomaly that consists of a communication between one of the coronary arteries and a cardiac chamber or a vein.

MYOCARDIAL BRIDGES:

Usually, right coronary artery, left main coronary artery and most of their major branches course on the surface of the heart – *epicardial*. The branches that run deep within the walls, are referred to as *subendocardial, myocardial and subepicardial*.

'Myocardial bridge' is the term given for muscle overlying an abnormal intramural tunnelled segment of a typical epicardial artery ***(Figure 9)***. It was first endorsed by *Black* in eighteenth century. It may be present in any of the epicardial arteries, but, is more commonly associated with left anterior descending arteries

AREA OF SUPPLY:

The right coronary artery supplies entire right ventricle, except a small region to the right of the anterior interventricular sulcus, a variable part of left ventricular diaphragmatic aspect, the posteroinferior third of the interventricular septum, the right atrium and part of the left atrium.

Left coronary artery distribution is reciprocal, including most of the left ventricle, a narrow strip of right ventricle and the anterior two thirds of the interventricular septum.

ACCOMPANYING VEINS:

The right coronary artery is accompanied by the small cardiac vein in the right side of atrioventricular groove, the left circumflex artery by the coronary sinus in the left side of atrioventricular groove, the left anterior descending artery by the great cardiac vein in the anterior interventricular groove and the posterior interventricular artery is accompanied by the middle cardiac vein in the posterior interventricular groove.

NOMENCLATURE OF THE CORONARY ARTERY SEGMENTS:

Coronary artery segments are named according to the CASS segments *(Coronary Artery Surgery Study segments)* by American Heart Association**.** There are 17 segments according to this classification ***(Figure 10)***. The right coronary artery with its branches contribute 5 segments, left main coronary trunk contributes 1 segment, left circumflex artery with its branches contribute 5 segments and left anterior descending artery with its branches contribute 5 segments and ramus intermedius, when present, contributes 1 segment **(Austen WG et al, 1975; Braunwald E et al, 2012).**

DEVELOPMENTAL ANATOMY OF THE CORONARY ARTERIES:

Pro-epicardium, mesothelium covered protrusion of mesenchymal cells, arises from the pericardium in the region of the sinus venosus during week 5 *(Carnegie stage 14,15).* It forms the epicardium, coronary vascular bed and interstitial fibroblasts. The coronary vessels are formed by vasculogenesis. Mesenchymal cells in the subepicardial space forms the primitive vessels which invades the myocardium and spread over the myocardial surface to form a plexus during week 6 *(Carnegie stage 16, 17)*. Sprouts of this plexus approaches the base of the outflow tract, and links to the sinuses of the aortic root during week 7 *(Carnegie stage 18)*. Finally, only solitary right and left coronary arteries remain in a heart with no congenital coronary artery anomaly. **(Hutchins GM, 1988; Standring S et al, 2015)**

EVOLUTIONARY PERSPECTIVES:

Fish and amphibia possess only one coronary artery. In birds, approximately 40% has only one coronary artery. Thus, the dual coronary artery system in humans is a recent evolutionary acquisition.

CLINICAL ANATOMY:

The *coronary artery disease*, (or ischemic heart disease) is the most common among the cardiovascular diseases that includes stable angina, unstable angina, myocardial infarction, and sudden cardiac death. It occurs primarily as a result of interruption of blood supply to the myocardium.

Coronary artery anomalies (or malformation of coronary vessels) are congenital abnormalities in the coronary anatomy of the heart. By definition, these abnormalities are variants of anatomy occurring in less than 1% of the general population. They often co-exist with other congenital heart defects. Coronary artery anomalies are some of the most confusing, neglected topics in cardiology **(Angelini P et al, 2002).** Many coronary anomalies do not cause symptoms and are identified only at the time of autopsy. Some are associated with sudden death. The risk of mortality or the ideal way to treat these patients is still ambiguous.

Advancements in the Investigation and treatment modalities of diseases involving coronary arteries:

1924 – Willem Einthoven received Nobel Prize for development of electrocardiogram

1927 – Egas Moniz first developed technique of angiography (for brain vasculature)

1929 – Werner Forssmann performed first cardiac catheterization on himself

1937 – Taro Takemi invented the first portable electrocardiograph machine

1939 – Andre Cournard and Dickinson Richards developed the potentials of catheterization

1941 – Andre Cournard performed the first human heart catheterization

1950 – Steinberg I began to develop angiocardiography

1956 – Andre Cournard, Werner Forssmann and Dickinson Richards shared Nobel Prize for their work.

1958 – Charles Dotter invented occlusive aortography to visualize coronary anatomy

1959 – Mason Sones developed selective coronary arteriography

1967 – Melvin Judkins and Amplatz established femoral techniques

1968 – Rene Favalro and Dudley Johnson introduced coronary bypass surgery

1977 – Andreas Gruentzig performed first percutaneous transluminal coronary angioplasty on a human

The detailed knowledge about anatomy, morphometry, variations and congenital anomalies of coronary arteries is cardinal

- In order to understand the risk factors, cause, pathogenesis and thereby establishing treatment protocols for various coronary artery diseases and even sudden cardiac death.
- In evaluating the disease prognosis, interpreting angiography and decide the need for and choose the apt lifesaving interventional procedures such as stent, balloon angioplasty or Coronary Artery Bypass Graft
- In analysing the success rate of each surgical cardiac revascularisation procedures
- In being equipped to handle the precautions to be taken while performing certain surgeries in heart with variations or congenital coronary artery anomaly, example – aortic valve replacement surgery in a heart with high take off of right coronary artery.

The information about diameter is required for knowing the perfusion and thereby the effective functioning of heart and also for interventional procedures such as stent or balloon angioplasty.

This study is targeted at overcoming the inadequacy of anatomic and morphometric data of the coronary arteries in dissected adult specimens, dissected foetal specimens and angiography in this particular geographic locale – Tamil Nadu, India.

AIMS AND OBJECTIVES

Aims:

- To study the left and right coronary arteries and determine the cardiac dominance in dissected adult cadaveric heart specimens, dissected foetal cadaveric heart specimens and Coronary Computed Tomography Angiograms.
- To present the morphometric analysis by measuring the diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery and the length of the left main coronary artery in dissected adult cadaveric heart specimens and Coronary Computed Tomography Angiograms.

The valuable information obtained from dissected adult and foetal cadaveric heart specimens and the Coronary Computed Tomographic Angiograms were explored and analysed in this study.

Objectives:

Dissected foetal cadaveric heart specimens:

- To determine the cardiac dominance percentage in male and female gender
- To find out the terminal branching pattern of left main coronary artery
- To evaluate the presence of myocardial bridges

Dissected adult cadaveric heart specimens:

- To find out the incidence of congenital coronary artery anomalies
- To note the level and cusp of ostia of coronary arteries in aortic sinus of Valsalva
- To determine the cardiac dominance
- To measure the diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery.
- To measure the length of left main coronary artery.
- To study the terminal branching pattern of left main coronary artery.
- To determine the level of termination of right coronary artery, left circumflex artery and left anterior descending artery
- To evaluate the presence of myocardial bridges
- To check the statistical significance between cardiac dominance and measured diameters (diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery).
- To determine the statistical correlation between the various diameters measured (diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery).

Coronary Computed Tomography Angiography:

- To determine the cardiac dominance percentage in male and female gender.
- To measure the diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery.
- To measure the length of left main coronary artery.
- To study the terminal branching pattern of left main coronary artery.
- To check the statistical significance between cardiac dominance and measured diameters (diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery).
- To analyse the statistical significance between gender and measured diameters (diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery).
- To determine the statistical correlation between the various diameters measured (diameter of left main coronary artery, proximal segment of right coronary artery, proximal segment of left anterior descending artery and proximal segment of left circumflex artery).

REVIEW OF LITERATURE

There are several authentications apropos to the details of coronary arteries and why the mastery about coronary artery anatomy is imperative and ineluctable in the clinics. Some of the documentations are enunciated below.

Banchi A et al (1904) reported the following details about coronary arteries. The left coronary artery arose at the level of sinotubular junction in 48%, above it in 34% and below it in 18% cases. The right coronary artery arose at the level of sinotubular junction in 71%, above it in 19% and below it in 10% cases. The left main artery bifurcated in 64%, trifurcated in 31% and quadfurcated in 5%**.** The length of left main artery was less than 5mm in 2%, 5-10mm in 87% and more than 15mm in 11%. Left circumflex artery terminated at the obtuse margin in 19%, in crux cordis in 70% and between crux and acute margin in 11%. Right coronary artery terminated between the acute margin and crux in 12%, in crux cordis in 8%, between crux and obtuse margin in 75% and at obtuse margin in 5%.

Gross L et al (1921) reported that right coronary artery terminated at acute margin in 4%, at the crux cordis in 10%, between crux and obtuse margin in 66% and at obtuse margin in 20%.

Cranicianu A (1922) observed the following details. The left main coronary artery bifurcated in 38%, trifurcated in 60% and quadfurcated in 2% specimens. Left circumflex artery terminated at obtuse margin in 15%, between crux and obtuse margin in 75% and at the crux in 10%. Right coronary artery terminated between acute margin and crux in 10%, at the crux cordis in 10%, between crux and obtuse margin in 70% and at obtuse margin in 20%.

Left circumflex artery terminated at obtuse margin in 10%, between crux and obtuse margin in 82% and at the crux in 8% and the right coronary artery terminated between acute margin and crux in 8%, at the crux cordis in 12% and between crux and obtuse margin in 80% (**Mouchet A et al, 1933**).

The left main trunk bifurcated in 42%, trifurcated in 55% and was absent in 2%; left circumflex artery terminated at obtuse margin in 25%, between crux and obtuse margin in 45%, at the crux in 12% and between the crux and acute margin in 8% and the right coronary artery terminated between acute margin and crux in 8%, at the crux cordis in 22% and between crux and obtuse margin in 70% (**Bosco GA et al, 1935).**

Schlesinger MJ (1940) reported the percentages of right, left and co dominance as 48%, 18% and 34% respectively.

Ayer AA et al (1957) reported the dominance pattern in India. 85%, 8% and 7% were right, left and co dominant respectively.

James TN et al (1961) reported that left circumflex artery terminated at obtuse margin in 22%, between crux and obtuse margin in 60%, at the crux in 9% and between the crux and acute margin in 9%; left anterior descending artery terminated at apex in 16%, terminated immediately crossing the apex in 24%, and it upward in the posterior interventricular sulcus for 2cm or more and then terminated in 60% and that the right coronary artery terminated at acute margin in 2%, between acute margin and crux in 7%, at the crux cordis in 9%, between crux and obtuse margin in 64% and at obtuse margin in 18%.

Burck HC et al (1963) reported a case of high origin of right coronary artery which caused death.

Baroldi G et al (1965) reported that left circumflex artery terminated at obtuse margin in 25%, between crux and obtuse margin in 63%, at the crux in 5% and between the crux and acute margin in 7% and that the right coronary artery terminated between acute margin and crux in 10%, at the crux cordis in 9%, between crux and obtuse margin in 64% and at obtuse margin in 17%.

Green GE et al (1967) reported that the length of the left main artery was less than or equal to 10mm in 48% of Caucasians.

MacAlpin et al (1972) gave the mean diameters of right coronary artery (3.2mm), left main coronary artery (4.0mm), left anterior descending artery (3.4mm), left circumflex artery (3.0mm) and total coronary area (9.6mm) in Caucasian population.

Neches W H et al (1974) reported surgical correction of two cases with origin of left coronary artery from pulmonary artery in infant and young child.

Kronzon I et al (1974) observed that patients with either a left dominant or co dominant heart, the length of left main coronary artery was significantly shorter than that of patients with right dominant heart.

Vlodaver Z et al (1975) reported four position patterns regarding the levels of coronary arteries. (1) both the coronary ostia below the sinotubular junction in 56%; (2) right ostium below and left ostium above in 30%; (3) right ostium above and left ostium below in 8% and (4) both the ostium above the junction in 6%

Askenazi J et al (1975) reported 15 cases of origin of left coronary artery from pulmonary artery and discussed the possible management of this anomaly with its prognosis.

Gentzler RD et al (1975) reported 17 cases of absent left circumflex coronary artery with systolic click syndrome.

The majority of variations involved left coronary artery and the majority of ectopic ostia were located in right sinus of Valsalva. Failure to recognize the variations in coronary arterial origin can prolong arteriography procedures and lead to errors in interpretation of coronary artery anatomy and pathology **(Engel HJ et al, 1975)**.

Mc Alpine WA et al (1975) reported that the length of left main trunk was between 1 – 26mm before bifurcation in a study in New York. It was less than 5mm in 12%, 5-15mm in 74% and more than 15mm in 14% specimens.

Sometimes, there was only one aortic coronary ostium, usually owing to a left coronary artery originating from the pulmonary artery. A common aortic ostium for a single coronary artery was not frequent. Multiple ostia were the most common variations. An accessory artery may arise from a separate ostium (often the "third coronary artery" from the right aortic sinus; sometimes the anterior descending and the circumflex arteries may originate from separated orifices) **(Leguerrier A et al, 1976)**.

Left main coronary artery bifurcated in 41% and trifurcated in 53% specimens **(Kalbfleisch H et al, 1976)**

In a cadaveric study in France the left main trunk bifurcated in 89%, trifurcated in 9% and was absent in 2% (**Benther P et at, 1976).**

Vieweg CWVR et al (1976) reported the normal values for coronary artery diameters in California. Mean left main coronary artery diameter was 4.7+/-0.1mm, 5.2+/-0.2mm and 5.0+/-0.2mm in right, mixed and left dominant heart respectively. Mean proximal left anterior descending artery diameter was 3.9+/-0.1mm, 4.1+/-0.2mm and 3.8+/-0.2mm in right, mixed and left dominant heart respectively. Mean left circumflex artery diameter was 3.2+/-0.1mm, 3.8+/-0.2mm and 4.0+/-0.2mm in right, mixed and left dominant heart respectively. Mean proximal right coronary artery diameter was 4.1+/-0.1mm, 3.7+/-0.1mm and 2.7+/-0.1mm in right, mixed and left dominant heart respectively. Mean mid right coronary artery diameter was 3.4+/-0.1mm, 2.7+/-0.1mm and 1.9+/-0.1mm in right, mixed and left dominant heart respectively.

Vlodaver Z et al (1976) classified that the left main trunk was short when it is less than or equal to 5mm (7 – 12%) and long when it was above 15mm (11.5 – 18%)**.**

Omar BK et al (1977) reported the percentages of right, left and co dominance in India as 53.3%, 16.7% and 30% respectively.

Grondin P et al (1977) reported three cases of myocardial bridging of proximal left anterior descending artery suffering from angina and treated it by surgical decompression of the systolically constricted artery.

Abedin Z et al (1978) reported the mean length of left main coronary artery as 9.7 +/_ 4.3mm.

Arcinegas E et al (1980) suggested prompt surgical re-establishment on diagnosis of anomalous left coronary artery from pulmonary artery (ALCAPA), regardless of symptomatic status.

Benge W et al (1980) demonstrated that systolic compression at the origin in a right coronary artery anomalously originating from left sinus of Valsalva and concluded that it caused significant cardiovascular morbidity in the absence of atherosclerosis.

Myocardial bridges can be benign or be responsible for cardiac ischemia, myocardial infarction, ventricular fibrillation and sudden death by reducing myocardial blood flow in systole **(Kramer JR et al, 1981)**

Left main coronary artery bifurcated in 52%, trifurcated in 44% and quadfurcated in 4% specimens in a study in Thieme (**Hadziselimovic H, 1982)**.

Keren A et al (1982) documented two cases with coronary artery originating from the wrong sinuses. One patient had right coronary artery opening from left sinus of Valsalva and coursing between pulmonary artery and aorta, with obstruction in proximal one third. In the second patient, the left coronary artery opened from the right sinus of Valsalva, the main trunk crossed anteriorly the pulmonary artery conus, with both its main branches showing significant narrowing. In both, the patients had bicuspid aortic valve and in both the non-aberrant coronary vessels also had stigmata of atherosclerosis.

Baroldi G (1983) reported that the left main artery length ranges from 1mm to 25mm.

Anomalous left coronary artery from pulmonary trunk was associated with recurrent arrhythmias and sudden death **(Moodie DS et al, 1983)**.

Most haemodynamics agree that high or low coronary ostium represent an added difficulty in coronary angiography **(Paulin S et al, 1983).**

High left coronary orifice was usually associated with a long left coronary artery and was therefore at a greater risk of injury during surgery **(Neufeld HN et al, 1983).**

Kimbiris D (1985) observed that 6 out of 10 patients with anomalous origin of left main coronary artery from the right sinus of Valsalva had severe obstructive coronary artery disease.

Ishikawa T et al (1985) reported 5 cases of anomalous origin of the left main coronary artery from right anterior aortic sinus. In 4 , the anomalous artery ran a septal course through the floor of the right ventricular infundibulum and in 1 , an interarterial course between the aorta and pulmonary trunk.

Barth WB et al (1986) reported that the origin of left main and right coronary arteries from right aortic sinus of Valsalva was life threatening.

Kurjia HZ et al (1986) reported the dominance pattern of Iraqi population to be left in 14%, right in 46% and balanced (co dominant) in 40% and exclaimed that as the number of non-Caucasian patients undergoing surgical treatment for ischemic heart diseases increased, additional comparative data on racial, sexual and ontogenetic variation of the coronary arteries and their aortic ostia are required to improve the care for these patients**.**

Ishii T et al (1986) reported that the myocardial bridges were found in 48% males and 36% females.

Anomalously originating coronary artery coursing between aorta and pulmonary trunk was fatal **(Kragel AH et al, 1988).**

Bestetti RB et al (1988) stressed the fact that myocardial bridging of the left anterior descending artery can no longer be considered benign anomaly.

High and low levels of origin can make the angiographic procedures longer **(Greenberg MA et al, 1989).**

Sahni D et al (1989) reported a case of third coronary artery. They reported the incidence of the origin of right coronary artery above the supravalvular ridge in 3.4% males and 1.7% females; origin of left coronary artery above the supravalvular ridge in 7% in both sexes. They also reported the mean diameter of the right coronary artery in males to be 3.2+/-0.5 mm and that of females to be 2.8+/-0.4mm, the mean diameter of the left coronary artery in males to be 3.7+/-0.7 mm and that of females to be 3.2+/-0.6 mm and in unsexed heart the mean diameters of right and left coronary arteries as 3.1mm and 3.6mm respectively in a cadaveric study in North West Indian population.

Coronary artery anomalies were grouped by **Angelini P et al, 1989** ***(Table 1)*****.** They also reported the dominance pattern in Philadelphia as 89.1% right dominant, 8.4% left dominant and 2.5% codominant.

Click RL et al (1989) reported the incidence of anomalous coronary artery to be 0.3% in Washington and the most common anomaly present was left circumflex artery from right coronary sinus or right coronary artery.

Baptista CA et al (1989) classified the right coronary artery based on its termination. The long type was defined as the one that reached or ran distal to the crux cordis was found in 88.8% and short type was present in 11.2%. Among the long type, the artery terminated as one of the posterior branches of left ventricle in 71.6%.

Pelliccia A et al (1990) concluded in their study that training induced myocardial hypertrophy in athletes involves a proportionate increase of coronary artery dimension.

The incidence of coronary artery anomalies was 1.3% in Cleveland **(Yamanaka O et al, 1990).** They classified the coronary artery anomalies into benign (no signs, symptoms or complications) and potentially serious anomalies (angina pectoris, myocardial infarction, syncope, cardiac arrhythmias, congestive heart failure or sudden death). The former included separate origin of left circumflex artery end left anterior descending artery from left sinus of Valsalva, ectopic origin of the circumflex from the right sinus of Valsalva, ectopic coronary origin from the posterior sinus of Valsalva, anomalous coronary origin from the ascending aorta, absent circumflex, intercoronary communication and small coronary artery fistula. The latter included ectopic coronary origin from the pulmonary artery, ectopic coronary origin from the opposite coronary sinus, single coronary artery and large coronary fistula. He also suggested that the latter requires accurate recognition and at times surgical correction.

Baptista CA et al (1990) classified the left circumflex artery based on length and termination. In 86.4% hearts, it was short type (branch that did not reach the crux) and in 13.6% it was long type (crossed the crux). Among the long type, the artery terminated as one of the posterior branches of left ventricle in 76.5%.

Desseigne P et al (1991) reported that myocardial bridging causes sudden death, either during an acceleration of the cardiac rhythm (milking effect) or by thrombotic phenomena.

The incidence of coronary artery anomalies was 0.37% in Spain **(Iniguez Romo A et al, 1991).** The most common type of coronary artery anomaly reported by them was anomalous origin of left circumflex artery.

Recognition of absent left main coronary artery was needed to ensure accurate angiographic interpretation and was important for patients undergoing cardiac surgery to selectively perfuse these separate vessels during cardiopulmonary bypass **(Topaz O et al, 1991)**.

Left main coronary artery bifurcated in 54%, trifurcated in 38.4% and quadfurcated in 6.7% **(Baptista CA et al, 1991)**.

Dodge JT et al (1992) gave a reference normal data set of mean diameters of left main artery (4.5+/-0.5mm), proximal left anterior descending artery (3.7 +/- 0.4mm), proximal right coronary artery (3.9+/- 0.6mm in right dominant and 2.8+/- 0.5 mm for left dominant hearts) and left circumflex artery (3.4+/-0.5 mm for right dominant and 4.2+/-0.6mm for left dominant hearts) in an angiographic study in Seattle. It was also mentioned that the women had smaller diameter than men.

Waters DJ et al (1992) stressed the fact that when the left main coronary artery originating from right sinus of Valsalva, passes between the aorta and the pulmonary trunk, acute myocardial ischemia or sudden death may occur and that surgical correction or bypass surgery were sometimes indicated.

Leroy F et al (1992) demonstrated a patient who had electrocardiographic signs of myocardial ischemia with no other cause apart from anomalous origin of the left circumflex artery to explain the ischemia.

Anomalous origin of all three coronary arteries from separate ostia in the right sinus of Valsalva was reported by **Pollack BD et al (1992).**

The incidence of coronary artery anomalies was 0.61% in Miami. Anomalous coronary arteries were associated with a high incidence of congenital heart diseases **(Topaz O et al, 1992)**.

The incidence of coronary artery anomalies was 0.97% in Frankfurt **(Cieslinski G et al, 1993).**

Morales AR et al (1993) reported that 13 out of the total 39 hearts with deep intramural left anterior descending artery were associated with sudden death during vigorous exercise.

Guerra OR et al (1993) gave the mean values of left main coronary artery diameter (4.23+/- 0.85 mm) and right coronary artery diameter (3.06 +/- 1.08 mm) in an angiographic study in Miami.

Chadow H et al (1994) reported a case of anomalous origin of the right coronary artery above the left posterior sinus of Valsalva.

Cavalcanti JS (1995) reported the percentages of right and left dominance in Brazil as 88.18% and11.82% respectively.

Dhawan J et al (1995) observed significantly smaller total coronary vessel diameter in Asians compared to Caucasians and stated that this observation had important therapeutic implications regarding coronary intervention in the Asian immigrants in UK already suffering excess mortality from CAD.

Antonellis J et al (1996) recorded a rare case report with single coronary artery from the right sinus of Valsalva, associated with absence of left anterior descending artery and atrial septal defect.

Muriago M et al (1997) reported that left coronary artery arose at the level of sinotubular junction in 9%, above it in 22% and below it in 69% cases. The right coronary artery arose at the level of sinotubular junction in 9%, above it in 13% and below it in 78% cases.

The incidence of coronary artery anomalies was 1.34% in central Europe and the most common anomaly was separate left circumflex artery and left anterior descending artery **(Kardos A et al, 1997).**

The incidence of coronary artery anomalies was 2.25% in Italy and the most common anomaly was left main coronary artery from pulmonary trunk **(Frescura C et at, 1998)**. They also mentioned about the role of coronary artery anomalies in sudden cardiac death.

Dual left anterior descending artery associated with anomalous origin of the left circumflex artery was reported by **Tutar E et al (1999).**

Lip GY et al (1999) gave the mean diameters of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery for Indian Asians as 2.26 +/_ 0.41mm, 1.71 +/_ 0.39mm, 1.83 +/_ 0.34mm and 1.70 +/_ 0.39mm respectively and for Caucasians as 2.38 +/_ 0.47mm, 1.71 +/_ 0.32mm, 1.89 +/_ 0.37mm and 1.79 +/_ 0.39mm respectively in an angiographic study.

Mussarat J et al (1999) studied the Asian population and gave the right coronary artery mean diameter (2.7mm), left main coronary artery mean diameter (4.0mm), left anterior descending artery mean diameter (3.12mm), left circumflex artery mean diameter (3.1mm) and total coronary artery mean diameter (8.9mm) in an angiographic study.

Congenital coronary artery anomaly, although uncommon, are encountered in cases with sudden cardiac death of young healthy persons, in young competitive athletes. **(Basso C et al, 2000).**

The incidence of coronary artery anomalies was 0.95% in India and there is a possibility of genetic background in congenital coronary artery anomaly **(Garg N et al, 2000)**.

Anomalous left circumflex artery from right sinus was reported by **Samarendra P et al (2001)**.

The incidence of coronary artery anomalies was 0.5% in Spain with the presenting symptoms in adult as angina (59%), dyspnoea (25%), atypical chest pain (7%), syncope (3%), dizziness (3%) and palpitations (3%) **(Barriales Villa R et al, 2001)**.

Origin of right coronary artery from pulmonary artery was reported by **Rotzsch C (2002)**.

The incidence of coronary artery anomalies was 0.46% in India **(Harikrishnan S et al, 2002).**

Dodge-Khatami AD et al, 2002 reported a case of anomalous origin of left coronary artery from pulmonary artery mentioning its surgical correction.

A case of anomalous origin of the right coronary artery from the left posterior sinus of Valsalva was reported by **Ayalp R et al, 2002.**

Saidi HS et at (2002) recorded that there were about 82% right dominant hearts in black Kenyan population.

Cavalcanti JS et al (2003) reported that left coronary artery arose at the level of sinotubular junction in 18%, above it in 40% and below it in 42% cases. The right coronary artery arose at the level of sinotubular junction in 12%, above it in 28% and below it in 60% cases.

Left coronary artery from right sinus of Valsalva was associated with increased incidence of congenital heart diseases **(Gowda RM et al, 2003)**.

Reig J et al (2004) reported that in 4% cases, there was no left main coronary artery and that the mean length and diameter of left main coronary artery were 10.8+/-5.52mm and 4.86+/-0.80mm in a cadaveric study in Spanish population. Length was less than 5mm in 7.4%, 5-15mm in 73.7% and more than 15mm in 18.9%.

Right coronary artery arising from left sinus can be either asymptomatic or can cause sudden death **(Jim MH et al, 2004).**

The most common type of anomaly observed was separate ostia of left anterior descending artery and left circumflex artery **(Gowda RM et al, 2004).**

Kaimkhani A et al (2004) evaluated the mean diameter of right coronary artery (3.8+/-0.78mm), left main coronary artery (4.28+/-0.82mm), left anterior descending artery

(3.22+/-0.74mm), left circumflex artery (3.0+/-0.75mm) and total coronary diameter of 3 vessels (9.32+/-1.68mm) in an angiographic study.

A case of absent left anterior descending artery was reported by **Wasson S et al, 2005.**

The incidence of coronary artery anomalies was 0.6% to 1.5% in Turkey **(Aydinlar A et al, 2005).**

Vikram S et al (2005) did a research in Kerala and gave the proximal right coronary artery mean diameter (3.14mm), left main coronary artery mean diameter (4.3mm), proximal left anterior descending artery mean diameter (3.48mm), proximal left circumflex artery mean diameter (3.16mm) in an angiographic study.

Left main coronary artery bifurcated in 71% and trifurcated in 29% specimens **(Lujinovic A et al, 2005).**

Documentations regarding origin from wrong aortic sinus were anomalous origin of the right coronary artery from the left posterior sinus of Valsalva was reported by **Jim MH et al, 2005.**

Venkateshu KV et al (2005) reported the percentages of right, left and co dominance in Karnataka as 68.75%, 16.66% and 14.58% respectively.

A case report of single coronary artery with anomalous origin from the right sinus of Valsalva was documented by **Braun MU et al, 2006.**

The incidence of coronary anomalies was 0.24% in Turkey **(Tuncer C et al, 2006).**

Barriales Villa R et al (2006) reported anomalous coronary arteries originating in contralateral sinus of Valsalva with an overall incidence of 0.4%.

A case of both the right and left coronary artery originating from the right aortic sinus was reported by **Ishizawa A et al, 2006**.

Saikrishna C et al (2006) reported the dominance percentages of right, left and co dominance in New Delhi as 75%, 15% and 10% respectively. They also gave the following in the angiographic study. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in males were 3.72 +/_ 0.65 mm, 2.82 +/_ 0.63mm, 2.85 +/_0.59mm and 2.75 +/_ 0.60mm respectively. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in females were 3.40 +/_ 0.58mm, 2.68 +/_ 0.59mm, 2.72 +/_ 0.48mm and 2.55 +/_ 0.57mm respectively. The unsexed mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery were and 2.16 +/_ 0.42mm, 1.67 +/_ 0.37mm, 1.69 +/_ 0.37mm and 1.89 +/_ 0.39mm respectively.

Left main coronary artery bifurcated in 86% and trifurcated in 14% **(Kilic C, 2007).**

Duygu H et al (2007) concluded that myocardial bridge probability should be considered in young patients presenting with angina or if the same symptoms are persistent in the patients without more than one risk factor coronary artery disease and that myocardial bridges may initiate the development of atherosclerotic lesion or may facilitate progression of atherosclerosis in the proximal segment of the vessel.

Olabu BO et al, 2007 reported a case of third coronary artery.

Left circumflex artery arising from the right sinus or right coronary artery can be either benign or be the reason for earlier and more aggressive myocardial infarction or cause sudden death **(Carmelo V et al, 2007)**.

Coronary anomalies are associated with increased mortality depending on the myocardium at risk and the possibility of such anomaly should always be considered in young individuals with history of chest pain or syncope **(Larsen AI et al, 2007)**.

Kawawa Y et al (2007) reported that 15.8% patients had myocardial bridge over 1mm thickness with mean thickness and length 1.8+/-0.7 and 20+/-8.6 mm and that in 19 out of 24 patients in whom myocardial bridge were present, the segments proximal to it demonstrated coronary wall lesions and that in 3 patients , there were symptoms without any atherosclerotic lesions.

A case of left anterior descending artery arising from the right sinus of Valsalva was reported by **Yilmaz A et al, 2007.**

A case of all three major coronary arteries arising from the right sinus of Valsalva was documented by **Patel KB et al, 2007.**

Left main coronary artery bifurcated in 52%, trifurcated in 42.2% and tetrafurcated in 5.8%; the diameter of left main coronary artery was 3.58+/-0.59mm, that of left anterior descending artery was 2.94+/-0.54mm, that of left circumflex was 2.71+/-0.54 and the length of left main coronary artery was 6.48 +/- 2.57mm in the cadaveric study in Columbia **(Ballesteros LE et al, 2008)**.

Hussain MA et al (2008) studied the dominance pattern in adult Bangladeshi population aged 21 to 40 years. 91.2% males and 85.7% females were right dominant and the rest were left dominant.

Tillin T et al (2008) reported that the left anterior descending artery mean diameter was 2.8 mm in British south Asians whereas that of the white Europeans was 3.1 mm in an angiographic study. They reported that the increased left anterior descending artery stenosis, despite equivalent levels of calcified disease, in South Asians was attributable to narrower arteries and that the reduced diameter is associated with advanced disease in Europeans but not in South Asians, indicative of ethnic differences in vascular remodelling.

A case with anomalous prepulmonic course of the left coronary artery was reported by **Gleeson T et al, 2009.**

The incidence of coronary artery anomalies was 2.3% in Munich **(Von Zeigler F et al, 2009).**

Left main coronary artery bifurcated in 69% and trifurcated in 31% **(Kosar P et al, 2009).**

The incidence of coronary artery anomalies was 0.73% in Lebanon **(Eid AH et al, 2009).** They also stressed the fact that the diverse pattern of the coronary tree begs for caution during coronary investigation and interventional procedures.

Left main coronary artery bifurcated in 81% and trifurcated in 19% **(Christensen KN et al, 2010).**

A case of single coronary artery where the right coronary artery originated from middle of left anterior descending artery was documented by **Meric M et al, 2010.**

Candir N et al (2010) reported in a study in Ankara that the length of left main coronary trunk was less than 5mm in 6.5%, 5-15mm in 50.65% and more than 15mm in 42.85%.

Das H et al (2010) studied the dominance pattern in Assam and reported that 70%, 18.57% and 11.43% were right, left and co dominant respectively.

Left main coronary artery bifurcated in 46%, trifurcated in 44% and tetrafurcated in 10% **(Fazliogullari Z et al, 2010).** They reported the percentages of right, left and co dominance in Turkey as 42%, 14% and 44% respectively.

Chen HY et al (2010) reported a case of split right coronary artery arising by two ostia, pointed out the fact that how the second ostium might be missed on selective coronary angiography.

3% of sudden cardiac death was caused by non-atherosclerotic coronary pathology in which anomalous coronary artery contributed a bulk of 48% (**Hill SF et al, 2010)**.

Anomalous origins of coronary arteries were inducing sudden cardiac death, especially in athletes. **(Edwards CP et al, 2010).**

Tokmakoglu H et al (2010) studied a case of hypertension and chest pain in a sixty-six year old male who was diagnosed to have the right coronary artery originating from left anterior descending artery.

Hasan RK et al (2011) gave the mean diameters of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery for South Asians as 2.39 +/_ 0.49mm, 1.59 +/_ 0.40mm, 1.56 +/_ 0.45mm and 1.42 +/_ 0.42mm respectively and for Caucasians as 2.41 +/_ 0.68mm, 1.53 +/_ 0.50mm, 1.72 +/_ 0.44mm and 1.57 +/_ 0.42mm respectively in an angiographic study.

A case of single coronary artery, which arose from the right coronary cusp was reported by **Tariq S et al, 2012.**

The incidence of coronary artery anomalies was 0.6 to 1.3% in angiography and 0.3% in autopsy study in Taiwan **(Chen HY et al, 2012).** They reported that isolated single coronary artery was associated with angina, myocardial infarction and death.

The incidence of coronary artery anomalies was 1% in New York**.** People with coronary anomalies may present with chest pain, arrhythmia, presyncope or sudden death **(Surana SP et al, 2012)**.

The incidence of coronary artery anomalies was 0.29% in Turkey **(Yuksel S et al, 2013)**.

Left main coronary artery bifurcated in 93.3% cases and trifurcated in 6.7% **(Hosapatna M et al, 2013).** They reported in the cadaveric study in South India that short main trunk in 30% specimens, long main trunk in 3.3% specimens and the average length was 8.86 +/_ 2.96mm. it was less than 5mm in 10%, 6-15mm in 86.7% and more than 15mm in 3.3%.

Ullah QW et al (2013) reported in a cadaveric study in Islamabad that the mean diameters of right coronary artery, left anterior descending artery and left circumflex artery were 1.54 +/_ 0.46mm, 1.48 +/_ 0.31mm and 1.37 +/_ 0.56mm respectively.

Left main coronary artery bifurcated, trifurcated and quadfurcated in 78.2%, 20.4% and 1.4% respectively in a study in South African population **(Ajayi NO et al, 2013).** They reported the percentages of right, left and co dominance in South Africa as 81.5%, 15.2% and 3.3% respectively and the mean length of left main coronary artery in South African population as 10.4 +/_ 4.1mm.

Reddy VJ et al (2013) reported the percentages of right, left and co dominance in South India as 86.25%, 11.25% and 2.5% respectively.

Ogeng'o JA et al (2013) reported the mean luminal diameter of left anterior descending artery in a cadaveric study in black Kenyan population to be 2.12+/- 0.018 mm.

The three types of ectopic origin of coronary arteries are simple, multiple type (involving more than one coronary artery or branch) and complex type (associated with acquired heart disease or congenital heart defects). The diagnosis is usually missed by conventional non-invasive investigation designed to identify myocardial ischemic and that if diagnosed at the right time, sudden cardiac death could be prevented. **(Yuan SM et al, 2014).**

Yuksel IO et al (2014) pointed that a single coronary artery may be either asymptomatic or may be the culprit for myocardial infarction, arrhythmia or ischemia.

High take off of right coronary artery was associated with ventricular septal defect, right aortic arch and bridging bronchus **(Hu Y et al, 2014)**.

Coronary artery anomalies can be fatal without any forewarning **(Hill SF et al, 2014)**.

A case of third coronary artery was documented by **Aspara MP, 2014.**

Udhayakumar S et al (2014) reported in a cadaveric study in Sri Lanka that the left coronary artery was below the supravalvular ridge in 77%, at the level in 6% and above it in 7.5%. The left main coronary artery bifurcated in 75%, trifurcated in 20%, quadfurcated in 2.5% and was absent in 2.5%. The average diameter of left main coronary artery was 3.14 +/_ 0.7mm. The average length of left main coronary artery was 8.33 +/_ 3.7mm; short trunk (less than or equal to 5mm) was present in 13% and long trunk (more than 15mm) was present in 2% hearts.

Shukri IG et al (2014) reported the following in an angiographic study in Iraqi Kurdish population. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in males were 4.86 +/_ 0.77mm, 3.26 +/_ 0.62mm, 3.6 +/_ 0.58mm and 3.26 +/_ 0.65mm respectively. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in females were 4.50 +/_ 0.73mm, 3.03 +/_ 0.39mm, 3.31 +/_ 0.46mm and 3.02 +/_ 0.55mm respectively. The unsexed mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery were 4.68mm, 3.15mm, 3.46mm and 3.14mm respectively.

Lam MK et al (2014) reported that 9.8% were left dominant and 90.2% were non-left dominant (right and co dominant).

Hiteshi AK et al (2014) gave the mean diameters of coronary arteries in an angiographic study in California. Mean left main coronary artery diameter was 4.35mm and 3.91mm for male and female respectively. Mean left anterior descending artery diameter was 3.54mm and 3.24mm for male and female respectively. Mean left circumflex artery diameter was 3.18mm and 2.75mm for male and female respectively. Mean right coronary artery 3.70mm and 3.26mm for male and female respectively.

A case of third coronary artery was reported by **Dhobale MR, 2015.**

Kulkarni JP et al (2015) reported that left coronary artery arose at the level of sinotubular junction in 52.2%, above it in 30% and below it in 17.7% cases. The right coronary artery arose at the level of sinotubular junction in 56.6%, above it in 16.6% and below it in 26% cases.

Dhakal A et al (2015) reported that out of 57% right dominant circulation 56.1% were males and 44% were females; out of 17% left dominant circulation 52.9% were male and 47% were female; out of 17% co dominant circulation 61.5% were male and 38.4% were female in an angiographic study in Nepal. They gave the mean diameters of coronary arteries. Mean left main coronary artery diameter was 4.42 +/_ 0.45mm and 4.34 +/_ 0.54mm for males and females respectively. Mean left anterior descending artery diameter was 3.30 +/_ 0.37mm and 3.21 +/_ 0.31mm for males and females respectively. Mean left circumflex artery diameter was 3.10 +/_ 0.5mm and 3 +/_ 0.47mm for males and females respectively. Mean right coronary artery 3.23 +/_ 0.5mm and 3.03 +/_ 0.57mm for males and females respectively. The total coronary area was 9.65 +/_ 0.67mm and 9.25 +/_ 1.03 for males and females respectively.

A case of absent left anterior descending artery was documented by **Ruan W, 2015**.

Ghaffari S et al (2015) gave the mean diameters of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery for Northwestern Iranian population as 4.58 +/_ 0.80mm, 3.37 +/_ 0.73mm, 3.69 +/_ 0.64mm and 3.47 +/_ 0.68mm respectively.

Silitongo M et al (2016) reported that left coronary artery arose at the level of sinotubular junction in 26.4%, above it in 0% and below it in 73.6% cases. The right coronary artery arose at the level of sinotubular junction in 20.7%, above it in 0% and below it in 79.3% cases.

Left main coronary artery bifurcated in 62%, trifurcated in 32% and quadfurcated in 6% **(Sobana M et al, 2016).**

Mahadevappa M et al (2016) reported the dominance pattern in male and female - females were right dominant in 84.4%, left dominant in 9.1% and co dominant in 6.5% ; males were right dominant in 81.3%, left dominant in 7.6% and co dominant in 10.9%. They gave the mean diameters of coronary tree in South Indian population. Mean left main coronary artery diameter was 4.27+/-0.22mm and 3.85+/-0.17mm for male and female respectively. Mean left anterior descending artery diameter was 3.51+/-0.23mm and 3.24+/-0.23mm for male and female respectively. Mean left circumflex artery diameter was 3.19+/-0.35mm and 2.88+/-0.32mm for male and female respectively. Mean right coronary artery diameter was 3.27+/-0.33mm and 3.05+/-0.32mm for male and female respectively.

Agarwal R et al (2016) reported the percentages of right, left and co dominance in Bhopal as 86%, 8% and 6% respectively.

Mehrotra S et at (2016) reported the percentages of right, left and co dominance in Chandigarh as 73.5%, 18.7% and 7.8% respectively. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in males were 4.43 +/_ 0.60mm, 3.20 +/_ 0.52mm, 3.46 +/_ 0.46mm and 3.17 +/_ 0.54mm respectively. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in females were 4.13 +/_ 0.57mm, 3.04 +/_ 0.53mm, 3.22 +/_ 0.46mm and 3.04 +/_ 0.55mm respectively. The unsexed mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery were 4.28mm, 3.12mm, 3.34mm and 3.11mm respectively.

Turamaniar O et al (2016) gave the mean diameters of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery as 4.43 +/_ 0.76mm, 3.11 +/_ 0.67mm, 3.48 +/_ 0.53mm and 3.45 +/_ 0.50mm respectively in an angiographic study in Turkish population.

Tarantini G et al (2016) classified the different types of myocardial bridge based on its thickness and length and mentioned the positive association between myocardial bridging and myocardial ischemia.

Raut BK et al (2017) reported the percentages of right, left and co dominance in Bangalore as 59.83%, 17.03% and 23.14% respectively. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in males were 2.34 +/_ 0.28 mm, 1.70 +/_ 0.22mm, 1.88 +/_0.17mm and 1.82 +/_ 0.22mm respectively. The mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery in females were 2.33 +/_ 0.27mm, 1.69 +/_ 0.23mm, 1.86

+/_ 0.20mm and 1.83 +/_ 0.21mm respectively. The unsexed mean diameter of left main coronary artery, proximal circumflex artery, proximal left anterior descending artery and proximal right coronary artery were and 2.34 +/_ 0.28mm, 1.70 +/_ 0.23mm, 1.87 +/_ 0.21mm and 1.83 +/_ 0.22mm respectively.

These facts connote the momentousness of the details of coronary arteries. In spite of clear cut evidence of congenital coronary artery being the culprit for sudden cardiac death in considerable instances, there are no specific guidelines as in - whom to suspect and when to suspect. There exists confusion in the balance between avoiding unwanted invasive or expensive investigation in people with normal coronary arteries or benign anomalies and doing lifesaving invasive, expensive investigation in people with fatally abnormal coronary arteries.

MATERIALS AND METHODOLOGY

Ethical clearance:

Ethical clearance was obtained from IHEC (Institutional Human Ethics Committee).

Study design:

Observational - cross sectional study involving

- Dissected foetal cadaveric heart specimens
- Dissected adult cadaveric heart specimens
- Coronary computed tomography angiograms.

Parental consent was obtained for aborted foetuses and waiver of consent was obtained for studying the resources from Department of Anatomy (adult heart specimens) and Department of Cardiology (coronary computed tomography angiograms). The study was initiated with approval from the Heads of the department of Anatomy, Obstetrics and Gynaecology and Cardiology.

Study locale:

Coimbatore, Tamil Nadu.

Sample size:

- 50 dissected foetal cadaveric heart specimens from 50 foetuses that were obtained from labour room in Department of Obstetrics and Gynaecology.
- 50 dissected adult cadaveric heart specimens from Department of Anatomy.
- 50 coronary computed tomography angiograms from Department of Cardiology.

Total = 150.

Sample inclusion and exclusion criteria:

Dissected foetal cadaveric heart specimens

- *Inclusion criteria:* heart dissected from 12 to 38 weeks (84 to 266) foetuses that were spontaneously aborted, still born or dead born from labour room
- *Exclusion criteria:* heart from macerated foetuses, foetuses less than 12 weeks

Dissected adult cadaveric heart specimens

- *Inclusion criteria:* cadaveric heart specimens from Department of Anatomy.
- *Exclusion criteria:* cadaveric heart specimens with external morphology or coronary vessels or aortic root damage

Coronary computed tomography angiograms

- *Inclusion criteria:* coronary computed tomography angiograms of patients aged 40 to 70 years, both sex, normal, and anomalous coronary vessels without vessel block
- *Exclusion criteria:* coronary computed tomography angiograms of patients with coronary vessel block

Data collection methods:

- Primary data obtained by observation method in the coronary arteries of spontaneously aborted foetuses from labour room in Department of Obstetrics and Gynaecology.
- Primary data obtained by observation method in the coronary arteries of dissected specimens from Department of Anatomy.
- Secondary data obtained from Coronary Computed Tomography Angiograms from Department of Cardiology.

DISSECTED FOETAL CADAVERIC HEART SPECIMENS

Materials:

- 50 aborted foetuses of known gestational age and sex received from Labour room, embalmed, labelled and stored in 10% formalin
- Dissection instruments – scalpel, forceps, scissors.
- Magnifying lens

Methodology:

50 aborted foetuses were obtained from the Department of Obstetrics and Gynaecology. Parental consent for all the foetuses were obtained.

Foetuses were embalmed, labelled and preserved in 10% formalin.

Foetal heart along with the great vessels and lungs were removed in toto after the skin incision and opening of the musculoskeletal thoracic wall. The dissected-out components are thoroughly washed, the heart along with great vessels were separated from the lungs and the pericardium was stripped off ***(Figure 11)***.

The coronary arteries of the foetal heart were visualised ***(Figure 12).***

The specimens were labelled from 1 to 50. ***(Figure 13)*** The labelled foetal hearts stored in 10% formalin were utilized to obtain the following details with the aid of dissecting microscope.

Cardiac dominance:

The dominance of the foetal heart was observed by noting the posterior interventricular artery ***(Figure 14)***.

Terminal branching pattern of left main coronary artery:

The number of terminal branches of left main coronary artery in the foetal hearts, if present, were observed ***(Figure 15)***.

Myocardial bridges:

Myocardial bridges, if present were documented ***(Figure 16)***.

DISSECTED ADULT CADAVERIC HEART SPECIMENS

Materials:

- 50 adult heart specimens (with intact aortic root and pulmonary trunk) of unknown age and sex, preserved in 10% formalin
- Digital Vernier calliper
- Dissection instruments – scalpel, forceps, scissors.

Methodology:

50 adult dissected heart specimens with aortic root and pulmonary trunk were studied from the Department of Anatomy. The age and sex of the cadaver from which the hearts were dissected out are not known. The heart specimens were preserved in 10% formalin. Each heart was labelled, the coronary vessels were cleaned and the visceral pericardium was stripped off for clear visualization. ***(Figure 17)***

<u>*Congenital coronary artery anomalies:*</u>

The coronary arteries were looked for the presence of any congenital coronary artery anomalies.

<u>*Aortic sinuses of Valsalva:*</u>

The aorta of the adult cadaveric heart was opened in the posterior aspect up to the sinotubular ridge and the sinuses were noted for the location and level of both the right and left coronary arteries ***(Figure 18)***.

Cardiac dominance:

Dominance of the adult cadaveric heart was recorded by noting the posterior interventricular artery ***(Figure 19)***.

Right coronary artery:

The artery was identified in the right half of the atrioventricular groove coursing between right atrial appendage and pulmonary trunk. Any variation in initial course, if present were noted. The diameter of its proximal segment (segment of right coronary artery before the origin of first anterior right ventricular branch – *CASS segment 1*) was measured by using a digital Vernier caliper ***(Figure 20).*** The level of termination of the artery was also documented ***(Figure 21)***.

Left main coronary artery:

The artery, if present, was identified between left atrial appendage and pulmonary trunk. The length of the vessel and the diameter *(CASS segment 5)* were measured with the digital Vernier caliper and ***(Figure 22)***. The number of terminal branches were noted ***(Figure 23)***.

Left circumflex artery:

The proximal diameter (segment of the vessel before the origin of obtuse marginal artery – *CASS segment 11*) was measured ***(Figure 24)***. Level of termination of the artery was documented ***(Figure 25)***.

<u>Left anterior descending artery:</u>

The diameter of proximal segment (segment of the vessel before the origin of first septal branch – *CASS segment 6*) was measured ***(Figure 26).*** Level of termination of the artery was noted ***(Figure 27).***

<u>Myocardial bridges:</u>

Myocardial bridges if present were observed ***(Figure 28)***.

CORONARY COMPUTED TOMOGRAPHY ANGIOGRAM

Materials:

50 (26 males and 25 females) normal appearing digital multi-slice coronary computed tomography angiograms of patients aged 40 to 70 years were accessed from the Department of Cardiology with the aid of picture archiving and communication system (PACS) in DICOM (Digital Imaging and Communications in Medicine) format.

Methodology:

Normal appearing coronary angiograms with catheter tip and artery in the middle of the frame (minimizes Pincushion effect) without overlap and block were studied. The digital angiograms were obtained by Digital Cardio Imaging (DCI) system.

Standard angiographic views were ***(Figure 29)***

- Around 60 LAO (Left Anterior Oblique) projection for right coronary artery
- Around 30 RAO (Right Anterior Oblique) projection for left coronary artery

<u>*Cardiac dominance:*</u>

The dominance of the heart was observed by noting the posterior interventricular branch ***(Figure 30)***.

<u>*Right coronary artery:*</u>

In 60 Left Anterior Oblique projection, the diameter of proximal segment of the artery (segment of right coronary artery before the origin of first anterior right ventricular

branch – *CASS segment 1*) was measured ***(Figure 31)***.

Left main coronary artery:

In 30 Right Anterior Oblique projection, the diameter *(CASS segment 5)* of the artery was measured ***(Figure 32).*** The number of terminal branches of the left main trunk were also noted ***(Figure 33)***.

Left circumflex artery:

In 30 Right Anterior Oblique projection, the diameter of proximal segment of left circumflex artery (segment of the vessel before the origin of obtuse marginal artery – *CASS segment 11*) was measured ***(Figure 34)***.

Left anterior descending artery:

In 30 Right Anterior Oblique projection, the diameter of proximal segment of left anterior descending artery (segment of the vessel before the origin of first septal branch – *CASS segment 6*) was measured ***(Figure 35)***.

OBSERVATION AND RESULTS

<u>DISSECTED FOETAL CADAVERIC HEART SPECIMENS:</u>

There were 30 male foetuses and 20 female foetuses. The mean gestational age of the foetuses was 170 days. cardiac dominance, number of terminal branches of left main coronary artery and the presence of myocardial bridges were observed ***(Annexure 1)***.

CARDIAC DOMINANCE: *(Graph 1 – 5)*

Dominance percentage in total 50 dissected foetal cadaveric heart specimens:

Among the total 50 dissected foetal cadaveric heart specimens, 48% *(24 in number)* were right dominant, 46% *(23 in number)* were left dominant and 6% *(3 in number)* were co-dominant. ***(Graph 1)***

Dominance percentage in male dissected foetal cadaveric heart specimens:

Among the 30 male dissected foetal cadaveric heart specimens, 46.7% *(14 in number)* were right dominant, 46.7% *(14 in number)* were left dominant and 6.7% *(2 in number)* were co-dominant. ***(Graph 2)***

Dominance percentage in female dissected foetal cadaveric heart specimens:

Among the 20 female dissected foetal cadaveric heart specimens, 50% *(10 in number)* were right dominant, 45% *(9 in number)* were left dominant and 5% *(1 in number)* were co-dominant. ***(Graph 3)***

TERMINAL BRANCHING PATTERN OF LEFT MAIN CORONARY ARTERY: *(Graph 6 – 13)*

Terminal branching pattern of left main coronary artery in total 50 dissected foetal cadaveric heart specimens:

Among the total 50 dissected foetal cadaveric heart specimens, the left main coronary artery bifurcated in 84% *(42 in number)*, trifurcated in 12% *(6 in number)* and quadfurcated in 4% *(2 in number)*. ***(Graph 6)***

Terminal branching pattern of left main coronary artery in male dissected foetal cadaveric heart specimens:

Among the 30 male dissected foetal cadaveric heart specimens, the left main coronary artery bifurcated in 83.3% *(25 in number)*, trifurcated in 13.3% *(4 in number)* and quadfurcated in 3.3% *(1 in number)*. ***(Graph 7)***

Terminal branching pattern of left main coronary artery in female dissected foetal cadaveric heart specimens:

Among the 20 female dissected foetal cadaveric heart specimens, the left main coronary artery bifurcated in 85% *(17 in number)*, trifurcated in 10% *(2 in number)* and quadfurcated in 5% *(1 in number)*. ***(Graph 8)***

Terminal branching pattern of left main coronary artery in right dominant dissected foetal cadaveric heart specimens:

Among the 24 right dominant dissected foetal cadaveric heart specimens, the left main coronary artery bifurcated in 83.3% *(20 in number)*, trifurcated in 8.3% *(2 in number)* and quadfurcated in 8.3% *(2 in number)*. ***(Graph 10)***

Terminal branching pattern of left main coronary artery in left dominant dissected foetal cadaveric heart specimens:

Among the 23 left dominant dissected foetal cadaveric heart specimens, the left main coronary artery bifurcated in 82.6% *(19 in number)*, trifurcated in 17.4% *(4 in number)* and quadfurcated in 0%. ***(Graph 11)***

Terminal branching pattern of left main coronary artery in co-dominant dissected foetal cadaveric heart specimens:

Among the 3 co-dominant dissected foetal cadaveric heart specimens, the left main coronary artery bifurcated in 100% *(3 in number)*. ***(Graph 12)***

MYOCARDIAL BRIDGES:

Among the total 50 dissected foetal cadaveric heart specimens, myocardial bridge was present in 2% foetuses *(1 in number)* and absent in 98% foetuses *(49 in number).*

<u>DISSECTED ADULT CADAVERIC HEART SPECIMENS:</u>

There was a total of 50 dissected adult cadaveric heart specimens of unknown sex and age. Data was collected on origin, diameter and termination of the coronary vessels, length and terminal branching pattern of left main coronary artery as well as the anomalous coronary arteries, cardiac dominance and the presence of myocardial bridges ***(Annexure 2)***.

CONGENITAL CORONARY ARTERY ANOMALIES: ***(Graph 14)***

Anomalous coronary artery was present in 4% *(2 in number)* of the dissected adult cadaveric heart specimens. They are

- Absent left circumflex artery ***(Figure 36)*** – 2% *(1 in number)*
- Right coronary artery originating from pulmonary trunk ***(Figure 37) – 2%*** *(1 in number)*

CORONARY OSTIA:

Right coronary artery originated from the anterior aortic sinus (right coronary sinus) in 98% dissected adult cadaveric heart specimens *(49 in number)*. In the rest 2% dissected adult cadaveric heart specimens *(1 in number)*, the artery arose from pulmonary trunk.

Among the 49 dissected adult cadaveric heart specimens with right coronary artery arising from right coronary sinus, 100% *(49 in number)* arose below the sinotubular junction.

Left coronary artery originated from the left posterior sinus of Valsalva (left coronary sinus) in 100% dissected adult cadaveric heart specimens *(50 in number).*

Among the 50 dissected adult cadaveric heart specimens with left coronary artery arising from left coronary sinus, 100% *(50 in number)* arose below the level of sinotubular junction.

CARDIAC DOMINANCE: ***(Graph 15)***

Among the 50 dissected adult cadaveric heart specimens, 50% *(25 in number)* were right dominant, 42% *(21 in number)* were left dominant and 8% *(4 in number)* were co dominant.

DIAMETER: ***(Graph 16 – 20)***

The mean, minimum and maximum diameter of coronary arteries in dissected adult cadaveric heart specimens: ***(Graph 16)***

The *mean* diameter of 49 left main coronary arteries, proximal segment of 49 left circumflex arteries, proximal segment of 50 left anterior descending arteries and proximal segment of 50 right coronary arteries in dissected adult cadaveric heart specimens were 3.32+/_0.33mm, 3.03+/_0.26mm, 2.56+/_0.29mm and 3.18+/_0.39mm respectively.

The *minimum* diameter among 49 left main coronary arteries, proximal segment of 49 left circumflex arteries, proximal segment of 50 left anterior descending arteries and proximal segment of 50 right coronary arteries in dissected adult cadaveric heart specimens were 2.69mm, 2.60mm, 2.03mm and 2.28mm respectively.

The *maximum* diameter among 49 left main coronary arteries, proximal segment of 49 left circumflex arteries, proximal segment of 50 left anterior descending arteries and proximal segment of 50 right coronary arteries in dissected adult cadaveric heart specimens were 3.99mm, 3.69mm, 2.92mm and 3.81mm respectively.

The mean, minimum and maximum diameter of coronary arteries in right dominant dissected adult cadaveric heart specimens: *(Graph 17)*

The mean diameter of 24 left main coronary arteries, proximal segment of 24 left circumflex arteries, proximal segment of 25 left anterior descending arteries and proximal segment of 25 right coronary arteries in right dominant dissected adult cadaveric heart specimens were 3.31+/_0.37mm, 2.92+/_0.13mm, 2.54+/_0.28mm and 3.52+/_0.18mm respectively.

The minimum diameter among 24 left main coronary arteries, proximal segment of 24 left circumflex arteries, proximal segment of 25 left anterior descending arteries and proximal segment of 25 right coronary arteries in right dominant dissected adult cadaveric heart specimens were 2.69mm, 2.60mm, 2.08mm and 3.19mm respectively.

The maximum diameter among 24 left main coronary arteries, proximal segment of 24 left circumflex arteries, proximal segment of 25 left anterior descending arteries and proximal segment of 25 right coronary arteries in right dominant dissected adult cadaveric heart specimens were 3.99mm, 3.13mm, 2.92mm and 3.81mm respectively.

The mean, minimum and maximum diameter of coronary arteries in left dominant dissected adult cadaveric heart specimens: ***(Graph 18)***

The *mean* diameter of 21 left main coronary arteries, proximal segment of 21 left circumflex arteries, proximal segment of 21 left anterior descending arteries and proximal segment of 21 right coronary arteries in left dominant dissected adult cadaveric heart specimens were 3.33+/_0.28mm, 3.22+/_0.25mm, 2.57+/_0.30mm and 2.86+/_0.19mm respectively.

The *minimum* diameter among 21 left main coronary arteries, proximal segment of 21 left circumflex arteries, proximal segment of 21 left anterior descending arteries and proximal segment of 21 right coronary arteries in left dominant dissected adult cadaveric heart specimens were 2.92mm, 2.80mm, 2.08mm and 2.28mm respectively.

The *maximum* diameter among 21 left main coronary arteries, proximal segment of 21 left circumflex arteries, proximal segment of 21 left anterior descending arteries and proximal segment of 21 right coronary arteries in left dominant dissected adult cadaveric heart specimens were 3.91mm, 3.69mm, 2.92mm and 3.12mm respectively.

The mean, minimum and maximum diameter of coronary arteries in co dominant dissected adult cadaveric heart specimens: ***(Graph 19)***

The *mean* diameter of 4 left main coronary arteries, proximal segment of 4 left circumflex arteries, proximal segment of 4 left anterior descending arteries and proximal segment of 4 right coronary arteries in co dominant dissected adult cadaveric heart specimens were 3.33+/_0.42mm, 2.72+/_0.09mm, 2.62+/_0.40mm and 2.72+/_0.16mm respectively.

The *minimum* diameter among 4 left main coronary arteries, proximal segment of 4 left circumflex arteries, proximal segment of 4 left anterior descending arteries and proximal segment of 4 right coronary arteries in co dominant dissected adult cadaveric heart specimens were 3.04mm, 2.60mm, 2.03mm and 2.56mm respectively.

The *maximum* diameter among 4 left main coronary arteries, proximal segment of 4 left circumflex arteries, proximal segment of 4 left anterior descending arteries and proximal segment of 4 right coronary arteries in co dominant dissected adult cadaveric heart specimens were 3.96mm, 2.83mm, 2.91mm and 2.92mm respectively.

LENGTH OF LEFT MAIN CORONARY ARTERY: ***(Graph 21 – 25)***

Mean, minimum and maximum length of left main coronary artery in dissected adult cadaveric heart specimens: ***(Graph 21)***

Left main coronary trunk was absent in 2% dissected adult cadaveric heart specimens *(1 in number)*. The *mean* length of 49 left main coronary artery was 9+/_2.22mm. The *minimum* length among the 49 left main coronary artery was 3.24mm. The *maximum* length among the 49 left main coronary artery was 16.12mm.

Mean, minimum and maximum length of left main coronary artery in right dominant dissected adult cadaveric heart specimens: ***(Graph 22)***

The *mean* length of left main coronary artery in 25 right dominant dissected adult cadaveric heart specimens was 8.96+/_2.75mm. The *minimum* length among them was 3.24mm. The *maximum* length among them was 16.12mm.

Mean, minimum and maximum length of left main coronary artery in left dominant dissected adult cadaveric heart specimens: ***(Graph 23)***

The *mean* length of left main coronary artery in 21 left dominant dissected adult cadaveric heart specimens was 9.02+/_1.73mm. The *minimum* length among them was 6.32mm. The *maximum* length among them was 12.13mm.

Mean, minimum and maximum length of left main coronary artery in co-dominant dissected adult cadaveric heart specimens: ***(Graph 24)***

The *mean* length of left main coronary artery in 4 co-dominant dissected adult cadaveric heart specimens was 9.15+/_0.88mm. The *minimum* length among them was 8.21mm. The *maximum* length among them was 10.32mm.

Types of left main coronary artery based on its length: ***(Graph 26)***

Among the 49 dissected adult cadaveric heart specimens, the short type of left main coronary artery (less than 5mm) was present in 6.12% *(3 in number)* and the long type (more than 15mm) was present in 2.04% *(1 in number).*

TERMINAL BRANCHING PATTERN OF LEFT MAIN CORONARY ARTERY: ***(Graph 27 – 31)***

Terminal branching pattern of left main coronary artery in dissected adult cadaveric heart specimens: ***(Graph 27)***

The left main coronary artery was present in 98% dissected adult cadaveric heart specimens *(49 in number).* Among the 49 dissected adult cadaveric heart specimens with left main coronary artery, 87.8% *(43 in number)* bifurcated, 8.2% *(4 in number)* trifurcated and 4.1% *(2 in number)* quadfurcated.

Terminal branching pattern of left main coronary artery in right dominant dissected adult cadaveric heart specimens: ***(Graph 28)***

Among the 24 right dominant dissected adult cadaveric heart specimens with left main coronary artery, 87.5% *(21 in number)* bifurcated, 8.3% *(2 in number)* trifurcated and 4.2% *(1 in number)* quadfurcated.

Terminal branching pattern of left main coronary artery in left dominant dissected adult cadaveric heart specimens: *(Graph 29)*

Among the 21 left dominant dissected adult cadaveric heart specimens with left main coronary artery, 85.7% *(18 in number)* bifurcated, 9.5% *(2 in number)* trifurcated and 4.8% *(1 in number)* quadfurcated.

Terminal branching pattern of left main coronary artery in co-dominant dissected adult cadaveric heart specimens: *(Graph 30)*

Among the 4 co-dominant dissected adult cadaveric heart specimens with left main coronary artery, all 100% *(4 in number)* bifurcated.

LEVEL OF TERMINATION OF LEFT CIRCUMFLEX ARTERY, LEFT ANTERIOR DESCENDING ARTERY AND RIGHT CORONARY ARTERY

Level of termination of left circumflex artery in dissected adult cadaveric heart specimens: *(Graph 32)*

Left circumflex artery was present in 98% dissected adult cadaveric heart specimens *(49 in number)*. In the rest 2% *(1 in number)*, the left circumflex artery was absent. Among the 49 dissected adult cadaveric heart specimens, the artery terminated at the obtuse margin in 18.4% *(9 in number)*, between the obtuse margin and the crux in 28.6% *(14 in number)*, at the crux in 44.9% *(22 in number)* and between the crux and acute margin in 8.2% *(4 in number)*.

Level of termination of left anterior descending artery in dissected adult cadaveric heart specimens: ***(Graph 33)***

Left anterior descending artery was present in 100% dissected adult cadaveric heart specimens *(50 in number).* Among the 50 dissected adult cadaveric heart specimens, the artery terminated before reaching or at the apex in 90%*(45 in number)* and crossed the apex to enter and run in the posterior interventricular groove 10% *(5 in number).*

Level of termination of right coronary artery in dissected adult cadaveric heart specimens: ***(Graph 34)***

Right coronary artery was present in 100% dissected adult cadaveric heart specimens. Among the 50 dissected adult cadaveric heart specimens, the artery terminated between the acute margin and the crux in 12% *(6 in number),* at the crux in 26% *(13 in number) and* between the crux and obtuse margin in 62% *(31 in number).*

MYOCARDIAL BRIDGES

Among the 50 dissected adult cadaveric heart specimens, myocardial bridge was present in 6% *(3 in number)*

STATISTICAL SIGNIFICANCE BETWEEN CARDIAC DOMINANCE AND MEASURED DIAMETERS *(Annexure 3)*

Statistical significance between cardiac dominance and diameter of left main coronary artery in dissected adult cadaveric heart specimens:

There was no statistically significant difference in diameter of left main coronary artery between groups (right, left and co dominance) as determined by one-way ANOVA ($F(2,46) = 0.023$, $p = 0.978$).

Statistical significance between cardiac dominance and diameter of proximal segment of right coronary artery in dissected adult cadaveric heart specimens:

There was a statistically significant difference in diameter of proximal segment of right coronary arteries between groups (right, left and co dominance) as determined by one-way ANOVA ($F(2,47) = 84.927$, $p = 0.000$).

A LSD post hoc test revealed that the diameter of proximal segment of right coronary artery was statistically significantly lower in co dominant (2.72+/_0.16mm, $p = 0.00$) and left dominant (2.86+/_0.19mm, $p = 0.000$) when compared to right dominant heart (3.52+/_0.18mm) in dissected adult cadaveric heart specimens. There was no statistically significant difference between the co dominant and left dominant groups ($p = 0.190$).

Statistical significance between cardiac dominance and diameter of proximal segment of left anterior descending artery in dissected adult cadaveric heart specimens:

There was no statistically significant difference in diameter of proximal segment of left anterior descending arteries between groups (right, left and co dominance) as determined by one-way ANOVA ($F(2,47) = 0.125$, $p = 0.883$).

Statistical significance between cardiac dominance and diameter of proximal segment of left circumflex artery in dissected adult cadaveric heart specimens:

There was a statistically significant difference in diameter of proximal segment of left circumflex arteries between groups (right, left and co dominance) as determined by one-way ANOVA ($F(2,46) = 18.323$, $p = 0.000$).

A LSD post hoc test revealed that the diameter of proximal segment of left circumflex artery was statistically significantly lower in co dominant (2.72+/_0.09mm, $p = 0.00$) and right dominant (2.92+/_0.13mm, $p = 0.000$) when compared to left dominant heart (3.22+/_0.25mm) in dissected adult cadaveric heart specimens. There was no statistically significant difference between the co dominant and right dominant groups ($p = 0.066$).

STATISTICAL CORRELATION BETWEEN THE VARIOUS MEASURED DIAMETERS OF THE CORONARY ARTERIES *(Annexure 4)*

A Pearson product-moment correlation was run to determine the relationship between the various diameters measured. There was no statistically significant correlation between any of the two measured diameters, that is, there is no statistically significant correlation between any of the two external diameters (luminal diameter + twice the vessel wall thickness) measured in the dissected adult cadaveric heart specimens.

<u>CORONARY COMPUTER TOMOGRAPHY ANGIOGRAMS:</u>

There was a total of 50 coronary computer tomography angiograms (26 males and 24 females) between 40 to 70 years. Data was collected on diameter of the coronary vessels, length and terminal branching pattern of left main coronary artery as well as cardiac dominance ***(Annexure 5)***.

CARDIAC DOMINANCE: ***(Graph 35 – 39)***

Cardiac dominance percentage in total 50 coronary computer tomography angiograms: ***(Graph 35)***

Among the 50 coronary computer tomography angiograms, 52% *(26 in number)* were right dominant, 44% *(22 in number)* were left dominant and 4% *(2 in number)* were co dominant.

Cardiac dominance percentage in 26 coronary computer tomography angiograms of male patients: ***(Graph 36)***

Among the 26 coronary computer tomography angiograms of male patients, 53.8% *(14 in number)* were right dominant, 42.3% *(11 in number)* were left dominant and 3.8% *(1 in number)* were co dominant.

Cardiac dominance percentage in 24 coronary computer tomography angiograms of female patients: ***(Graph 37)***

Among the 24 coronary computer tomography angiograms of female patients, 50% *(12 in number)* were right dominant, 45.8% *(11 in number)* were left dominant and 4.2% *(1 in number)* were co dominant.

DIAMETER: ***(Graph 40 – 47)***

Mean, minimum and maximum diameter of coronary arteries in 50 coronary computer tomography angiograms: ***(Graph 40)***

The *mean* diameter of 50 left main coronary arteries, proximal segment of 50 left circumflex arteries, proximal segment of 50 left anterior descending arteries and proximal segment of 50 right coronary arteries in coronary computer tomography angiograms were 3.92+/_0.14mm, 3.14+/_0.27mm, 3.03+/_0.37mm and 3.35+/_0.42mm respectively.

The *minimum* diameter among 50 left main coronary arteries, proximal segment of 50 left circumflex arteries, proximal segment of 50 left anterior descending arteries and proximal segment of 50 right coronary arteries in coronary computer tomography angiograms were 3.39mm, 2.44mm, 2.50mm and 2.49mm respectively.

The *maximum* diameter among 50 left main coronary arteries, proximal segment of 50 left circumflex arteries, proximal segment of 50 left anterior descending arteries and proximal segment of 50 right coronary arteries in coronary computer tomography angiograms were 4.21mm, 3.64mm, 3.82mm and 3.99mm respectively.

Mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of male patients: ***(Graph 41)***

The *mean* diameter of 26 left main coronary arteries, proximal segment of 26 left circumflex arteries, proximal segment of 26 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of 26 male patients were 4.00+/_0,11mm, 3.28+/_0.25mm, 3.25+/_0.36mm and 3.56+/_0.35mm respectively.

The *minimum* diameter among 26 left main coronary arteries, proximal segment of 26 left circumflex arteries, proximal segment of 26 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of 26 male patients were 3.81mm, 2.44mm, 2.50mm and 2.86mm respectively.

The *maximum* diameter among 26 left main coronary arteries, proximal segment of 26 left circumflex arteries, proximal segment of 26 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of 26 male patients were 4.21mm, 3.64mm, 3.82mm and 3.99mm respectively.

Mean diameter of coronary arteries in coronary computer tomography angiograms of female patients: ***(Graph 42)***

The *mean* diameter of 24 left main coronary arteries, proximal segment of 24 left circumflex arteries, proximal segment of 24 left anterior descending arteries and proximal segment of 24 right coronary arteries in coronary computer tomography angiograms of 24 female patients were 3.85+/_0.12mm, 3.00+/_0.21mm, 2.80+/_0,19mm and 3.11+/_0.38mm respectively.

The *minimum* diameter among 24 left main coronary arteries, proximal segment of 24 left circumflex arteries, proximal segment of 24 left anterior descending arteries and proximal segment of 24 right coronary arteries in coronary computer tomography angiograms of 24 female patients were 3.39mm, 2.68mm, 2,60mm and 2.49mm respectively.

The *maximum* diameter among 24 left main coronary arteries, proximal segment of 24 left circumflex arteries, proximal segment of 24 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of 24 female patients were 4mm, 3.42mm, 3.31mm and 3.82mm respectively.

Mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of patients with right cardiac dominance: ***(Graph 44)***

The *mean* diameter of 26 left main coronary arteries, proximal segment of 26 left circumflex arteries, proximal segment of 26 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of patients with right cardiac dominance were 3.91+/_0.13mm, 3.09+/_0.26mm, 2.98+/_0.41mm and 3.63+/_0.28mm respectively.

The *minimum* diameter among 26 left main coronary arteries, proximal segment of 26 left circumflex arteries, proximal segment of 26 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of patients with right cardiac dominance were 3.39mm, 2.44mm, 2.50mm and 2.99mm respectively.

The *maximum* diameter among 26 left main coronary arteries, proximal segment of 26 left circumflex arteries, proximal segment of 26 left anterior descending arteries and proximal segment of 26 right coronary arteries in coronary computer tomography angiograms of patients with right cardiac dominance were 4.12mm, 3.43mm, 3.82mm and 3.99mm respectively.

Mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of patients with left cardiac dominance: *(Graph 45)*

The *mean* diameter of 22 left main coronary arteries, proximal segment of 22 left circumflex arteries, proximal segment of 22 left anterior descending arteries and proximal segment of 22 right coronary arteries in coronary computer tomography angiograms of patients with left cardiac dominance were 3.94+/_0.15mm, 3.20+/_0.28mm, 3.07+/_0.33mm and 2.98+/_0.28mm respectively.

The *minimum* diameter among 22 left main coronary arteries, proximal segment of 22 left circumflex arteries, proximal segment of 22 left anterior descending arteries and proximal segment of 22 right coronary arteries in coronary computer tomography angiograms of patients with left cardiac dominance were 3.69mm, 2.73mm, 2.60mm and 2.49mm respectively.

The *maximum* diameter among 22 left main coronary arteries, proximal segment of 22 left circumflex arteries, proximal segment of 22 left anterior descending arteries and proximal segment of 22 right coronary arteries in coronary computer tomography angiograms of patients with left cardiac dominance were 4.21mm, 3.64mm, 3.68mm and 3.41mm respectively.

Mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of patients with balanced cardiac dominance: *(Graph 46)*

The *mean* diameter of 2 left main coronary arteries, proximal segment of 2 left circumflex arteries, proximal segment of 2 left anterior descending arteries and proximal segment of 2 right coronary arteries in coronary computer tomography angiograms of patients with balanced cardiac dominance were 3.86+/_0.06mm, 3.23+/_0.13mm, 3.29+/_0.02mm and 3.65+/_0.38mm respectively.

The *minimum* diameter among 2 left main coronary arteries, proximal segment of 2 left circumflex arteries, proximal segment of 2 left anterior descending arteries and proximal segment of 2 right coronary arteries in coronary computer tomography angiograms of patients with balanced cardiac dominance were 3.82mm, 3.14mm, 3.28mm and 3.38mm respectively.

The *maximum* diameter among 2 left main coronary arteries, proximal segment of 2 left circumflex arteries, proximal segment of 2 left anterior descending arteries and proximal segment of 2 right coronary arteries in coronary computer tomography angiograms of patients with balanced cardiac dominance were 3.91mm, 3.33mm, 3.31mm and 3.92mm respectively.

LENGTH OF LEFT MAIN CORONARY ARTERY: ***(Graph 48 – 55)***

Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms: ***(Graph 48)***

The *mean* length of 50 left main coronary arteries in coronary computer tomography angiograms was 9.92+/_2.49mm. The *minimum* length among the 50 left main coronary arteries was 3.04mm. The *maximum* length among the 50 left main coronary arteries was 16.20mm.

Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of male patients: ***(Graph 49)***

The *mean* length of 26 left main coronary arteries in coronary computer tomography angiograms of male patients was 9.83+/_2.56mm. The *minimum* length among the 26 left main coronary arteries was 3.04mm. The *maximum* length among the 26 left main coronary arteries was 16.20mm.

Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of female patients: ***(Graph 50)***

The *mean* length of 24 left main coronary arteries in coronary computer tomography angiograms of male patients was 10.02+/_2.46mm. The *minimum* length among the 24 left main coronary arteries was 4.20mm. The *maximum* length among the 24 left main coronary arteries was 13.82mm.

Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of patients with right dominance: ***(Graph 52)***

The *mean* length of 26 left main coronary arteries in coronary computer tomography angiograms of patients with right dominance was 9.77+/_2.70mm. The *minimum* length among the 26 left main coronary arteries was 3.04mm. The *maximum* length among the 26 left main coronary arteries was 16.20mm.

Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of patients with left dominance: ***(Graph 53)***

The *mean* length of 22 left main coronary arteries in coronary computer tomography angiograms of patients with right dominance was 10.27+/_2.30mm. The *minimum* length among the 22 left main coronary arteries was 4.20mm. The *maximum* length among the 22 left main coronary arteries was 14.10mm.

Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of patients with balanced dominance *(Graph 54)*

The *mean* length of 2 left main coronary arteries in coronary computer tomography angiograms of patients with balanced dominance was 7.99+/_0.18mm. The *minimum* length among the 2 left main coronary arteries was 7.86mm. The *maximum* length among the 2 left main coronary arteries was 8.12mm.

Types of left main coronary artery based on its length: *(Graph 56)*

Among the 50 left main coronary arteries in coronary computer tomography angiograms, the short type of left main coronary artery (less than 5mm) was present in % *(3in number)* and the long type (more than 15mm) was present in % *(1 in number).*

TERMINAL BRANCHING PATTERN OF LEFT MAIN CORONARY ARTERY: *(Graph 57 – 64)*

Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms: (*Graph 57)*

Among the 50 coronary computer tomography angiograms, left main coronary artery 92% *(46 in number)* bifurcated and 8% *(4 in number)* trifurcated.

Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of male patients: ***(Graph 58)***

Among the 26 coronary computer tomography angiograms of male patients, left main coronary artery 92.3% *(24 in number)* bifurcated and 7.7% *(2 in number)* trifurcated.

Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of female patients: ***(Graph 59)***

Among the 24 coronary computer tomography angiograms of female patients, left main coronary artery 91.7% *(22 in number)* bifurcated and 8.3% *(2 in number)* trifurcated.

Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of patients with right dominance: ***(Graph 61)***

Among the 26 coronary computer tomography angiograms of patients with right dominance, left main coronary artery, 92.3% *(24 in number)* bifurcated and 7.7% *(2 in number)* trifurcated.

Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of patients with left dominance: ***(Graph 62)***

Among the 50 coronary computer tomography angiograms of patients with left dominance, left main coronary artery, 90.9% *(20 in number)* bifurcated and 9.1% *(2 in number)* trifurcated.

Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of patients with balanced dominance: ***(Graph 63)***

Among the 50 coronary computer tomography angiograms of patients with balanced dominance, left main coronary artery 100% *(2 in number)* bifurcated, % *(in number)* trifurcated and % *(in number)* quadfurcated.

STATISTICAL SIGNIFICANCE BETWEEN CARDIAC DOMINANCE AND MEASURED DIAMETERS *(Annexure 6)*

Statistical significance between cardiac dominance and diameter of left main coronary artery in coronary computer tomography angiograms:

There was no statistically significant difference in diameter of left main coronary artery between groups (right, left and co dominance) as determined by one-way ANOVA ($F(2,47) = 0.474$, $p = 0.625$).

Statistical significance between cardiac dominance and diameter of proximal segment of right coronary artery in coronary computer tomography angiograms:

There was a statistically significant difference in diameter of proximal segment of right coronary arteries between groups (right, left and co dominance) as determined by one-way ANOVA ($F(2,47) = 30.972$, $p = 0.000$).

A LSD post hoc test revealed that the diameter of proximal segment of right coronary artery was statistically significantly lower in left dominant (2.98+/_0.28mm) when compared to right dominant (3.63+/_0.28mm, $p = 0.000$) and co dominant heart

(3.65+/_0.38mm, p = 0.003) in dissected adult cadaveric heart specimens. There was no statistically significant difference between the co dominant and right dominant groups (p = 0.934).

Statistical significance between cardiac dominance and diameter of proximal segment of left anterior descending artery in coronary computer tomography angiograms:

There was no statistically significant difference in diameter of proximal segment of left anterior descending arteries between groups (right, left and co dominance) as determined by one-way ANOVA (F(2,47) = 0.783, p = 0.463).

Statistical significance between cardiac dominance and diameter of proximal segment of left circumflex artery in coronary computer tomography angiograms:

There was no statistically significant difference in diameter of proximal segment of left circumflex arteries between groups (right, left and co dominance) as determined by one-way ANOVA (F(2,47) = 1.222, p = 0.304).

STATISTICAL SIGNIFICANCE BETWEEN GENDER AND MEASURED DIAMETERS *(Annexure 7)*

Statistical significance between gender and diameter of left main coronary artery in coronary computer tomography angiograms:

Independent t test revealed that in the 50 coronary computer tomography angiograms, the diameter of left main coronary artery in males (4+/_0.11mm) was statistically higher than that in females (3.85+/_0.12mm) t(48) = 4.337, p = 0.000.

Statistical significance between gender and diameter of proximal segment of right coronary artery in coronary computer tomography angiograms:

Independent t test revealed that in the 50 coronary computer tomography angiograms, the diameter of proximal segment of right coronary artery in males (3.56+/_0.35mm) was statistically higher than that in females (3.11+/_0.38mm) t(48) = 4.290, p = 0.000.

Statistical significance between gender and diameter of proximal segment of left anterior descending artery in coronary computer tomography angiograms:

Independent t test revealed that in the 50 coronary computer tomography angiograms, the diameter of proximal segment of left anterior descending artery in males (3.25+/_0.36mm) was statistically higher than that in females (2.80+/_0.19mm) t(48) = 5.316, p = 0.000.

Statistical significance between gender and diameter of proximal segment of left circumflex artery in coronary computer tomography angiograms:

Independent t test revealed that in the 50 coronary computer tomography angiograms, the diameter of proximal segment if left circumflex artery in males (3.28+/_0.25mm) was statistically higher than that in females (3+/_0.21mm) $t(48) = 4.247$, $p = 0.000$.

STATISTICAL CORRELATION BETWEEN THE VARIOUS MEASURED DIAMETERS OF THE CORONARY ARTERIES *(Annexure 8)*

A Pearson product-moment correlation was run to determine the relationship between the various measured diameters.

There was a strong, positive correlation between diameter of proximal segment of left circumflex arteries and the diameter of proximal segment of left anterior descending arteries, which was statistically significant at the 0.01 level (2-tailed) ($r = 0.540$, $n = 50$, $p = 0.000$).

There was a strong, positive correlation between diameter of proximal segment of right coronary arteries and the diameter of proximal segment of left anterior descending arteries, which was statistically significant at the 0.05 level (2-tailed) ($r = 0.287$, $n = 50$, $p = 0.043$).

There was a strong, positive correlation between diameter of proximal segment of right coronary arteries and the diameter of proximal segment of left circumflex arteries, which was statistically significant at the 0.05 level (2-tailed) ($r = 0.347$, $n = 50$, $p = 0.013$).

There was a strong, positive correlation between diameter of proximal segment of left circumflex arteries and the diameter of left main coronary arteries, which was statistically significant at the 0.05 level (2-tailed) ($r = 0.296$, $n = 50$, $p = 0.037$).

There was no statistically significant correlation between diameter of left main coronary artery and diameter of proximal segment of right coronary artery or between diameter of left main coronary artery and diameter of proximal segment of left anterior descending artery.

Thus, there was a positive correlation between the luminal diameter of proximal segment of left circumflex arteries and the luminal diameter of proximal segment of left anterior descending arteries, the luminal diameter of proximal segment of right coronary arteries and the luminal diameter of proximal segment of left anterior descending arteries, the luminal diameter of proximal segment of right coronary arteries and the luminal diameter of proximal segment of left circumflex arteries and between the luminal diameter of proximal segment of left circumflex arteries and the luminal diameter of left main coronary arteries.

DISCUSSION

CONGENITAL CORONARY ARTERY ANOMALIES

The incidence of coronary artery anomalies in current study in dissected adult cadaveric heart specimen was 4 %. It was compared with that of the other reference studies ***(Table 2)***. The other studies in India depicted a lesser incidence

Author	**Year**	**Study location**	**%**
Garg N et al	2000	**India**	0.95
Harikrishnan S et al	2002	**India**	0.46

The two highest incidences reported in the reference studies were

Author	**Year**	**Study location**	**%**
Von Zeigler F et al	2009	Munich	**2.3**
Frescura C et at	1998	Italy	**2.25**

Thus, incidence of coronary artery anomalies observed in current study in dissected adult cadaveric heart specimens was marginally higher than the other reference studies.

The anomalies present were absent left circumflex artery (n = 1) and origin of right coronary artery from pulmonary artery (n = 1).

According to **Angelini P et al** classification ***(Table 1),*** the former (absent left circumflex artery) falls under group 2 **(Anomalies of intrinsic coronary arterial anatomy);** sub group d (Absent coronary artery) and the latter (origin of right coronary artery from pulmonary artery) falls under group 1 **(Anomalies of origination and course);** subgroup c (Anomalous location of coronary ostium outside normal "coronary" aortic sinuses).

Yamanaka O et al (1990) classified absent circumflex as benign anomaly and origin of coronary artery from pulmonary artery as potentially serious anomaly.

Absent left circumflex coronary artery was reported by **Gentzler RD et al (1975), Doven O et al (2006), Mittal SR et al (2008), Yoon YK et al (2009)** and **Majid Y et al (2010). Hashimoto N et al (2004)** reported a case of congenital absence of left circumflex coronary artery with acute myocardial infarction. **Ali F.S. et al (2009)** reported a case report of two patients with congenital absence of left circumflex artery: forty-year male with progressively worsening post myocardial infarction angina and thirty-nine-year-old with premature coronary artery disease and a positive family history. **Guo J et al (2012)** reported a case report of congenital absence of left circumflex artery with inferior myocardial infarction.

Roberts WC et al (1985) reported that the origin of left main coronary artery from the pulmonary trunk was far more common than the right coronary artery or left anterior descending artery arising from pulmonary trunk. They also specified that when both right and left main coronary arteries arose from the pulmonary trunk or when only one coronary artery was present and arose from the pulmonary trunk, survival past 1 year of life was impossible unless an associated anomaly coexisted. When one coronary artery arose from the pulmonary trunk and one or more from aorta, survival past 15 years of age may occur. Origin of right coronary artery from pulmonary artery was reported by **Rotzsch C (2002)**

CARDIAC DOMINANCE

The cardiac dominance percentages observed in current study were

Sample	Sample size	Right dominant %	Left dominant %	Co dominant %
Dissected foetal cadaveric heart specimens	50	**48**	**46**	**6**
Dissected adult cadaveric heart specimens	50	**50**	**42**	**8**
Coronary Computer Tomography angiograms	50	**52**	**44**	**4**

On comparing with the reference studies ***(Table 3),*** current pattern in which right dominance was common, followed by the left and then the co dominance is similar to the pattern reported by **Ayer AA et al (1957), Angelini P et al (1989), Venkateshu KV et al (2005), Saikrishna C et al (2006), Das H et al (2010), Ajayi NO et al (2013), Reddy VJ et al (2013), Agrawal R et al (2016)** and **Mehrotra S et al (2016).**

There were certain studies that portrayed a different pattern with more incidence of co dominance than the left dominance. **(Omer BK et al, 1977; Kurjia HZ et al,1986; Fazliogullari Z et al, 2010** and **Raut BK et al)**

The right and co dominance incidence percentages of our study fall within the range of that of the reference studies where right dominance incidence was between 42% to 89% and co dominance incidence was between 2.5% to 44%. The left dominance incidence percentage of our study is higher than that of the reference studies which ranged between 8% and 18.57%

Boucek RJ et al (1980) stated an anatomically disadvantaged status for the left dominant heart with respect to ventricular conduction disturbances and coronary atherogenesis.

Goldberg A et al (2007) reported at the end of a follow-up study that patients with left dominance had a significantly higher mortality.

Parikh NI et al (2012) reported that the left and co dominance are associated with modestly increased post percutaneous coronary intervention in-hospital mortality in patients with acute coronary syndrome.

Lam MK et al (2014) in his randomized trial concluded that there was a higher incidence of periprocedural myocardial infarction (myocardial infarction within 48 hours following percutaneous coronary intervention) in patients who had left coronary dominance. It was also observed that left dominance was associated with severe calcifications and more bifurcation lesions.

CORONARY OSTIAL LEVEL

The ostium of right coronary artery was below the sinotubular ridge in 100% dissected adult cadaveric heart specimens. The ostium of left coronary artery was also below the sinotubular ridge in 100% dissected adult cadaveric heart specimens.

On comparing the values with that of the reference studies ***(Table 4),*** our study shows only one level of origin. This was in contrast with the reference studies that had the coronary ostia at three different levels **(Banchi A et al, 1904; Muriago M et al, 1997; Cavalcanti JS et al, 2003** and **Kulkarni JP et al, 2015).**

The level of origin in the current study was mentioned as ‘normal’ and the levels above or at the sinotubular ridge was considered anomalous, **(Burck HC et al, 1963; Neufeld HN et al, 1983; Paulin S et al, 1983; Greenberg MA et al, 1989; Hu Y et al, 2014).**

DIAMETER OF LEFT MAIN CORONARY ARTERY, PROXIMAL SEGMENT OF LEFT CIRCUMFLEX ARTERY, PROXIMAL SEGMENT OF LEFT ANTERIOR DESCENDING ARTERY AND PROXIMAL SEGMENT OF RIGHT CORONARY ARTERY

CADAVERIC STUDIES:

The mean diameter of left main coronary arteries, proximal segment of left circumflex arteries, proximal segment of left anterior descending arteries and proximal segment of right coronary arteries in dissected adult cadaveric heart specimens were 3.32mm, 3.03mm, 2.56mm and 3.18mm respectively.

On comparing the values with that of the reference studies ***(Table 5),*** our values are comparable to those of **Sahni D et al, 1989; Ballesteros LE et al, 2008** and **Udhayakumar S et al, 2014.**

Our values were more than that of the values reported by **Ogeng'o JA et al, 2013** and **Ullah QW et al, 2013** and less than the values of **Reig J et al, 2004.**

ANGIOGRAPHIC STUDIES:

The mean diameter of left main coronary arteries, proximal segment of left circumflex arteries, proximal segment of left anterior descending arteries and proximal segment of right coronary arteries in coronary computer tomography angiograms were 3.92mm, 3.14mm, 3.03mm and 3.35mm respectively.

On comparing the values with that of the reference studies ***(Table 6),*** our values were comparable to those reported by **MacAlpin et al (1972), Mussarat et al (1999), Kaimkhani A et al (2004), Vikram S et al (2005), Shukri IG et al (2014), Turamaniar O et al (2016)** and **Mehrotra S et al (2016).**

Our values were more than those reported by **Lip GY et al (1999), Saikrishna C et al (2006), Hasan RK et al (2011)** and **Raut BK et al (2017)** and less than those reported by **Ghaffari S et al (2015).**

Mean diameter in males:

The mean diameter of left main coronary arteries, proximal segment of left circumflex arteries, proximal segment of left anterior descending arteries and proximal segment of right coronary arteries in coronary computer tomography angiograms of male patients were 4mm, 3.28mm, 3.25mm and 3.56mm respectively.

On comparing the values with that of the reference studies ***(Table 7),*** our values were comparable to the values obtained by **Hiteshi AK et al (2014), Dhakal A et al (2015), Mahadevappa M et al (2016)** and **Mehrotra S et al (2016).**

Our values were more than the values reported by **Saikrishna C et al (2006)** and **Raut BK et al (2016)** and less than the values obtained in a study by **Shukri IG et al (2014).**

Mean diameter in females:

The mean diameter of left main coronary arteries, proximal segment of left circumflex arteries, proximal segment of left anterior descending arteries and proximal segment of right coronary arteries in coronary computer tomography angiograms of female patients were 3.85mm, 3mm, 2.8mm and 3.11mm respectively.

On comparing the values with that of the reference studies ***(Table 8),*** our values were comparable to the values obtained by **Saikrishna C et al (2006), Shukri IG et al (2014), Hiteshi AK et al (2014), Dhakal A et al (2015), Mahadevappa M et al (2016)** and **Mehrotra S et al (2016).**

Our values were more than the values reported by **Raut BK et al (2017).**

Comparison of mean diameters in males and females:

On comparing the measured mean diameters between males and females, the values were higher in males than females. This is in accordance with the reference studies by **Yang FY et al (2006)**, **Saikrishna C et al (2006), Shukri IG et al (2014), Hiteshi AK**

et al (2014), Dhakal A et al (2015), Mahadevappa M et al (2016) and **Mehrotra S et al (2016).**

Size of coronary vessels are influenced by factors such as age, sex, body weight, body surface area, weight of the heart and ethnicity/ race. **(Leung WH et al, 1991; Dodge JT Jr et al, 1992; Lip GY et al, 1999).**

Knowledge about normal vessel calibre in that population can help in detecting the early changes of atherosclerosis in individual patients **(Vieweg WV et al, 1976; Guerra OR et al, 1993)**.

Elezi S et al (1998) reported that patients with small vessel calibre presented a higher risk for an adverse outcome after coronary stent placement because of higher incidence of restenosis.

Makaryus AN et al (2005) observed specifically smaller coronary arteries in female, with a statistically significant difference in the mean diameter even after correction for body surface area and attributed it to high rates and early incidence of coronary artery disease.

Yang FY et al (2006) concluded that gender is a strong independent predictor of coronary artery size even when taking into account differences in body size and that it may contribute to worse outcomes of women undergoing coronary revascularization.

Ilayaperuma I et al (2011) proved that females have significantly smaller mean coronary arterial diameters than males and that this was also one of the reasons for worse outcomes following myocardial infarction and coronary revascularization in females than males.

Faridullah et al (2012) reported that the left coronary arteries and its branches were found to be narrower in diabetic patients than in non-diabetics.

Hiteshi AK et al (2014) reported that the women had smaller coronary artery diameters than men even after adjusting for age, race, weight, height, body mass index, body surface index, left ventricular mass and coronary artery calcium and that this fact may warrant gender specific approaches during percutaneous coronary intervention and coronary artery bypass grafting.

Johnson MR et al (1992) remarked that until the normal size was known, even determination of absolute coronary liminal sizes was not very helpful, except in the case of lesions with very small coronary lumina. The calibre of the vessel is proposed to be influenced by patient characteristics, ventricular wall mass, ethnicity, dominance, age, sex, heart weight and body surface area.

LENGTH OF LEFT MAIN CORONARY ARTERY

The mean length of left main coronary artery was 9mm in dissected adult cadaveric heart specimens and 9.92mm in coronary computer tomography angiograms.

On comparing the values with that of the reference studies ***(Table 9),*** our values are comparable to the values observed by **Abedin Z et al (1978)** and **Ajayi NO et al (2013),** more than the mean length observed by **Ballesteros LE et al (2008), Hosapatna M et**

al (2013) and **Udhayakumar S et al (2014)** and less than the mean length of left main coronary artery observed by **Reig J et al (2004).**

TYPES OF LEFT MAIN CORONARY ARTERY BASED ON ITS LENGTH

The percentages of short, medium and long left main coronary artery in our study were

Sample	**Left main coronary artery %**		
	Short	**Medium**	**Long**
Dissected adult cadaveric heart specimen	**6.12**	**91.84**	**2.04**
Coronary computer tomography angiogram	**6**	**92**	**2**

On comparing the values with that of the reference studies ***(Table 10),*** our pattern with the highest incidence of medium left main coronary artery followed by the short type and then the long type left main coronary artery is similar to the observations made by **Hosapatna M et al (2013)** and **Udhayakumar S at al (2014)**.

Banchi A et al (1904), McAlpine WA et al (1975), Reig J et al (2004) and **Candir N et al (2010)** observed highest incidence of medium left main coronary artery followed by the long type and then the short type of left main coronary artery.

Short left coronary artery was a risk factor in atherosclerosis and it should be considered as a congenital factor predisposing to development of coronary artery disease **(Gazetopoulos N et al, 1976)**.

The atherogenic deviations, characterised by an excessive size and length of left coronary artery and an underdeveloped right coronary artery or vice versa led to a more precocious development and more severe evolution of atherosclerotic plaque in hyperperfused vessel **(Velican D et al, 1981)**.

TERMINAL BRANCHING PATTERN OF LEFT MAIN CORONARY ARTERY

The terminal branching patterns in current study are

Sample	**Sample size**	**No. of terminal branches of left main coronary artery (%)**		
		2 (%)	**3 (%)**	**4 (%)**
Dissected foetal cadaveric heart specimens	50	**84**	**12**	**4**
Dissected adult cadaveric heart specimens	50	**87.8**	**8.2**	**4.1**
Coronary Computer Tomography angiograms	50	**92**	**8**	**0**

On comparing it with the values of reference studies ***(Table 11),*** our pattern with highest incidence of bifurcating left main coronary artery followed by trifurcation and then by quadfurcation incidence was similar to the observations made by most of the studies **(Banchi A et al, 1904; Hadziselimovic H et al, 1982; Baptista CA et al, 1991; Ballesteros LE et al, 2008; Fazliogullari Z et al, 2010; Ajayi NO et al, 2013** and **Sobana M et al, 2016).**

Few authors observed only bifurcation and trifurcation of the left main coronary artery **(Kalbfleisch H et al, 1976; Lujinovic A et al, 2005; Kilic C et al, 2007; Kosar P et al, 2009; Christensen KN et al, 2010** and **Hosapatna M et al, 2013)** while others observed trifurcating left main coronary artery more common than bifurcation, followed by quadfurcation of left main coronary artery **(Cranicianu A et al, 1922; Bosco GA et al, 1935)**

Trifurcation of left coronary artery with ramus diagonalis had a special meaning in coronary insufficiency **(Lujinovic A et al, 2005)**.

TERMINATION LEVEL

Left circumflex artery:

The artery terminated at the obtuse margin in 18.4%, between the obtuse margin and the crux in 28.6%, at the crux in 44.9% and between the crux and acute margin in 8.2% dissected adult cadaveric heart specimens.

On comparing it with the reference studies ***(Table 12)***, our pattern with highest incidence of level of termination at the crux was similar to that by **Banchi A et al (1904).** The other studies showed pattern with highest incidence of level of termination between obtuse margin and crux **(Cranicianu A et al, 1922; Mouchet A et al, 1933; Bosco GA et al, 1935; James TN et al, 1961** and **Baroldi G et al, 1965)**

Left anterior descending artery:

Left anterior descending artery terminated before reaching or at the apex in 90% and crossed the apex to enter and run in the posterior interventricular groove 10%.

James TN et al (1961) studied the termination of left anterior descending artery and reported that it terminated at apex in 16%, terminated immediately crossing the apex in

24%, and it upward in the posterior interventricular sulcus for 2cm or more and then terminated in 60%.

Ilia R et al (2014) reported in an angiographic study in Israel that 57% of left anterior descending artery wrapped around the apex and 43% terminated before reaching the apex and remarked that the length of left anterior descending artery was a strong predictor of prognosis in patients with anterior wail myocardial infarction undergoing primary percutaneous coronary intervention to isolated proximal left anterior descending artery occlusion – the shorter the artery , the better the prognosis.

Right coronary artery:

The artery terminated between the acute margin and the crux in 12%, at the crux in 26% and between the crux and obtuse margin in 62% dissected adult cadaveric heart specimens.

On comparing it with the reference studies ***(Table 13)***, all the reference study shows increased incidence of termination between crux and obtuse margin. **(Banchi A et al, 1904; Gross L et al, 1921; Cranicianu A et al, 1922; Mouchet A et al, 1933; Bosco GA et al, 1935; James TN et al, 1961** and **Baroldi G et al, 1965).** Our pattern coincides with their observations.

CONCLUSION

The morphology and morphometry of the vasa vasorum of the heart, the coronary arteries, were elaborately discussed in the realms of its origin (number, source artery, aortic sinus, and level), course, branches, dominance, diameter, length, extent and level of termination.

The normal and anomalous forms were portrayed in the review of literature along with its clinical correlation in congenital coronary artery anomaly, ischemic heart diseases, sudden death, investigatory aspects, treatment modality and prognostic view.

In the fifty foetal cadaveric heart specimens, the cardiac dominance, the number of terminal branches of left main coronary artery and the presence of myocardial branches were studied.

In the fifty adult cadaveric heart specimens, the presence of anomalous coronary artery, the coronary ostial level, cardiac dominance, the number of terminal branches of left main coronary artery and myocardial bridges were observed. The length and diameter of left main coronary artery, the diameter of proximal segments of right coronary artery, left circumflex artery and left anterior descending artery were measured. The level of termination of right coronary artery, left circumflex artery and left anterior descending artery were noted.

In the fifty coronary computer tomography angiograms, the cardiac dominance and the number of terminal branches of left main coronary artery were studied. The length and diameter of left main coronary artery, the diameter of proximal segments of right coronary artery, left circumflex artery and left anterior descending artery were measured.

The total and gender-based frequencies of dominance were analysed. The total, gender-based and dominance-based frequencies of number of terminal branches of left main coronary artery were calculated and compared. The total, gender-based and dominance-based means were calculated for the length and measured diameters, compared and analysed (statistical significance and statistical correlation).

The observations of the current study were compared with the reference articles.
The difference in values may be attributed to genetic and geographical factors.

The normal range of values in the current study are essential for interpreting angiograms, designing stents, disease diagnosis and disease prognosis in the current locale; the observation regarding increased incidence of congenital anomalies in the study locale is essential for genetic research, for drafting guidelines to suspect and prevent sudden cardiac death and for devising an efficient investigatory modality to screen for congenital anomalies on a large scale; the differences in values between males and females calls for special precautions in female subgroup.

The following are the limitations of this study

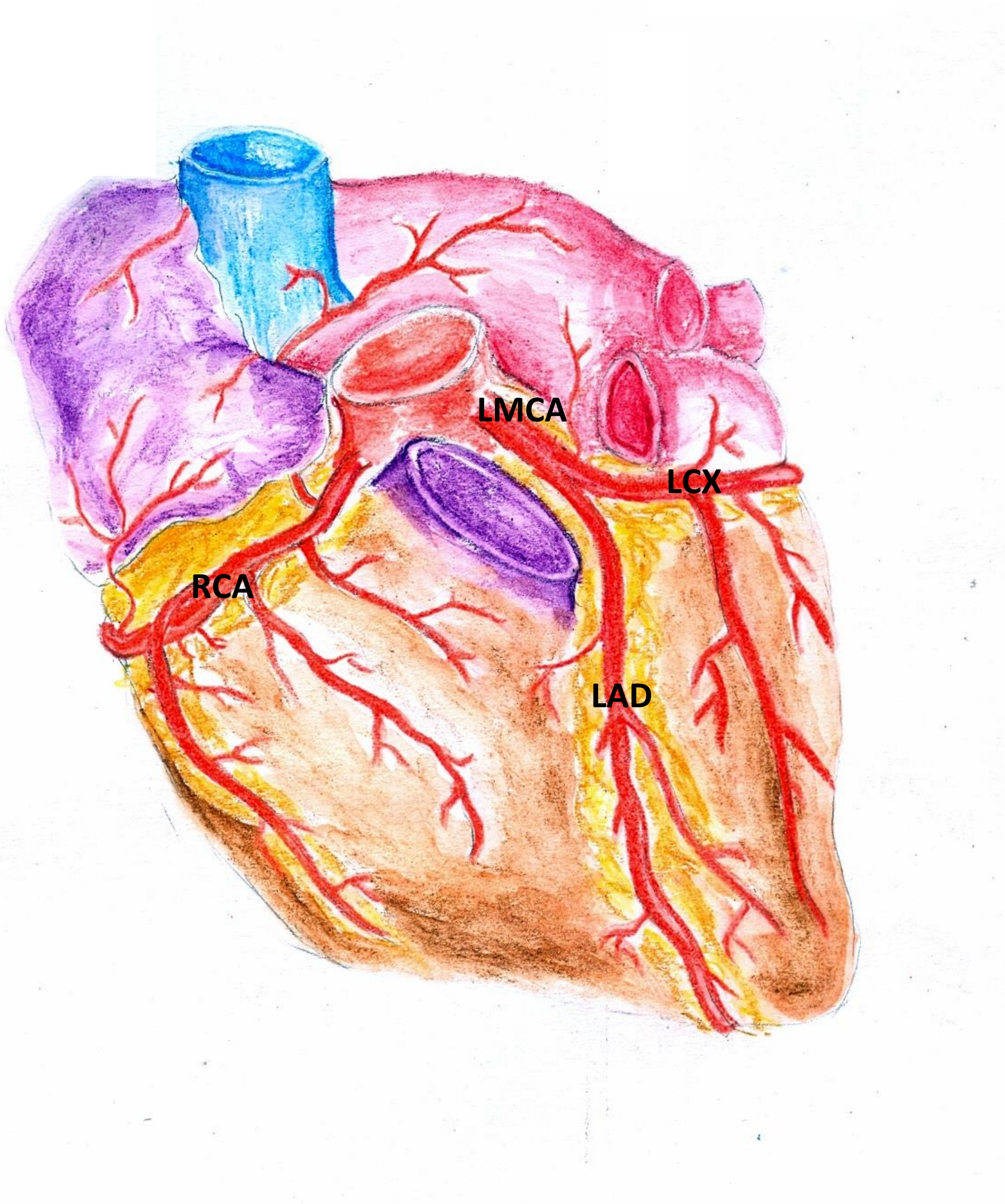
- the sample size was determined based on time and resource constraint
- the sex and age of the adult cadaveric heart specimens were unknown, thereby limiting the statistical analysis
- the familial history, drug history, body mass index, and body surface areas of the patients undergone angiograms were not known since they were studied retrospectively; thus, the corrected diameters could not be analysed
- the tissue processing may account for minimal shrinkage of the coronary vessels in adult cadaveric hearts.

Future studies can be done in coronary arteries with increased sample size, in fresh cadavers and as a prospective study in angiograms with relevant patient details so that more accurate values can be obtained for clinical correlation.

FIGURES

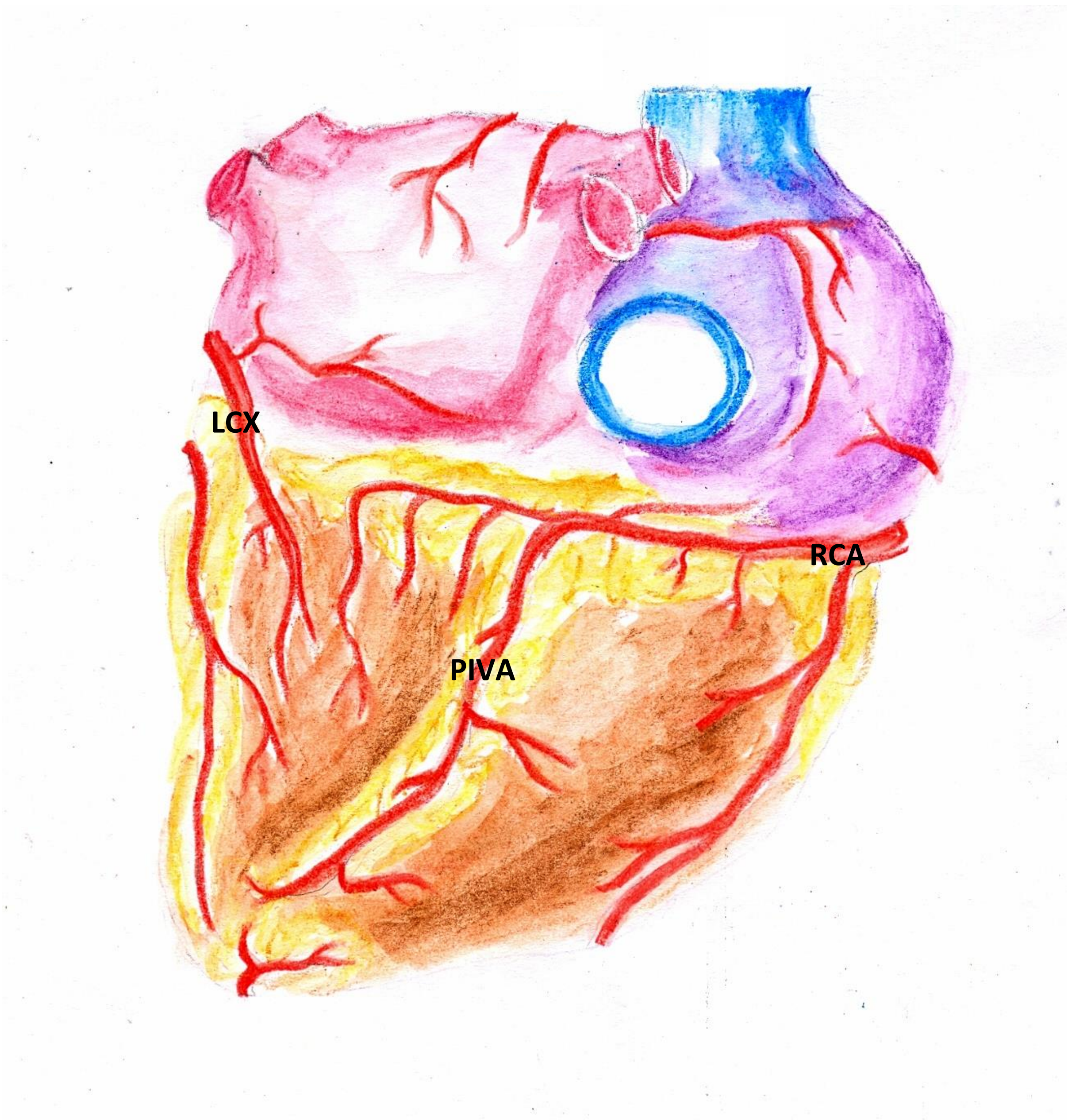
Figure 1: Normal coronary arteries

Anterior view of heart



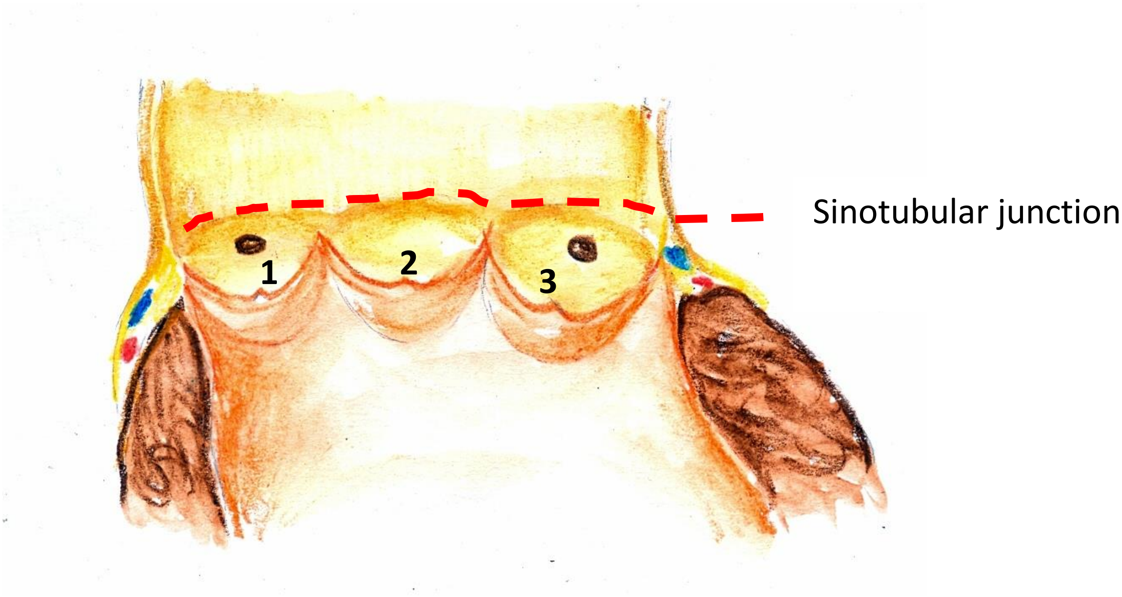
Key: RCA – right coronary artery; LMCA – left main coronary artery; LAD – left anterior descending artery; LCX – left circumflex artery

Posterior view of heart



Key: RCA – right coronary artery; PIVA – posterior interventricular artery; LCX – left circumflex artery

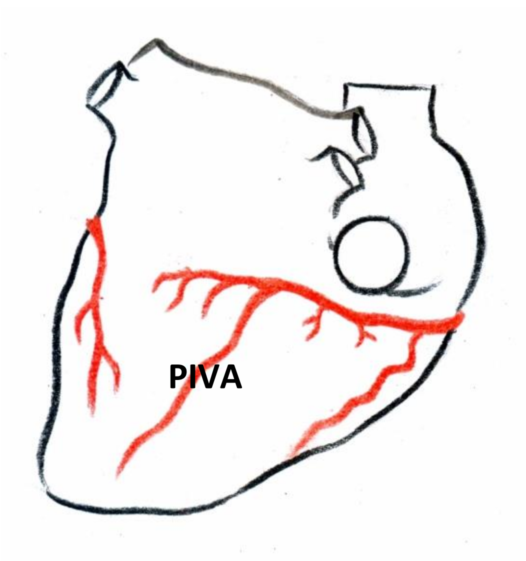
Figure 2: Aortic sinuses of Valsalva

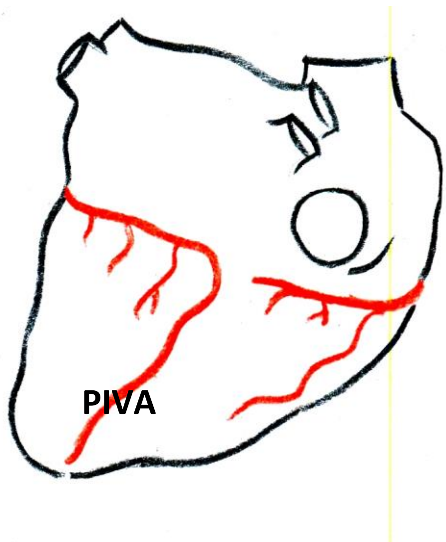


Key: STJ – sinotubular junction; 1 – anterior aortic sinus of Valsalva with right coronary ostia; 2 – right posterior aortic sinus of Valsalva; 3 – left posterior aortic sinus of Valsalva with left coronary ostia

Figure 3: Right and left dominant heart

Right dominant ***Left dominant***





Key: PIVA – posterior interventricular artery

Figure 4: Branches of right and left coronary arteries

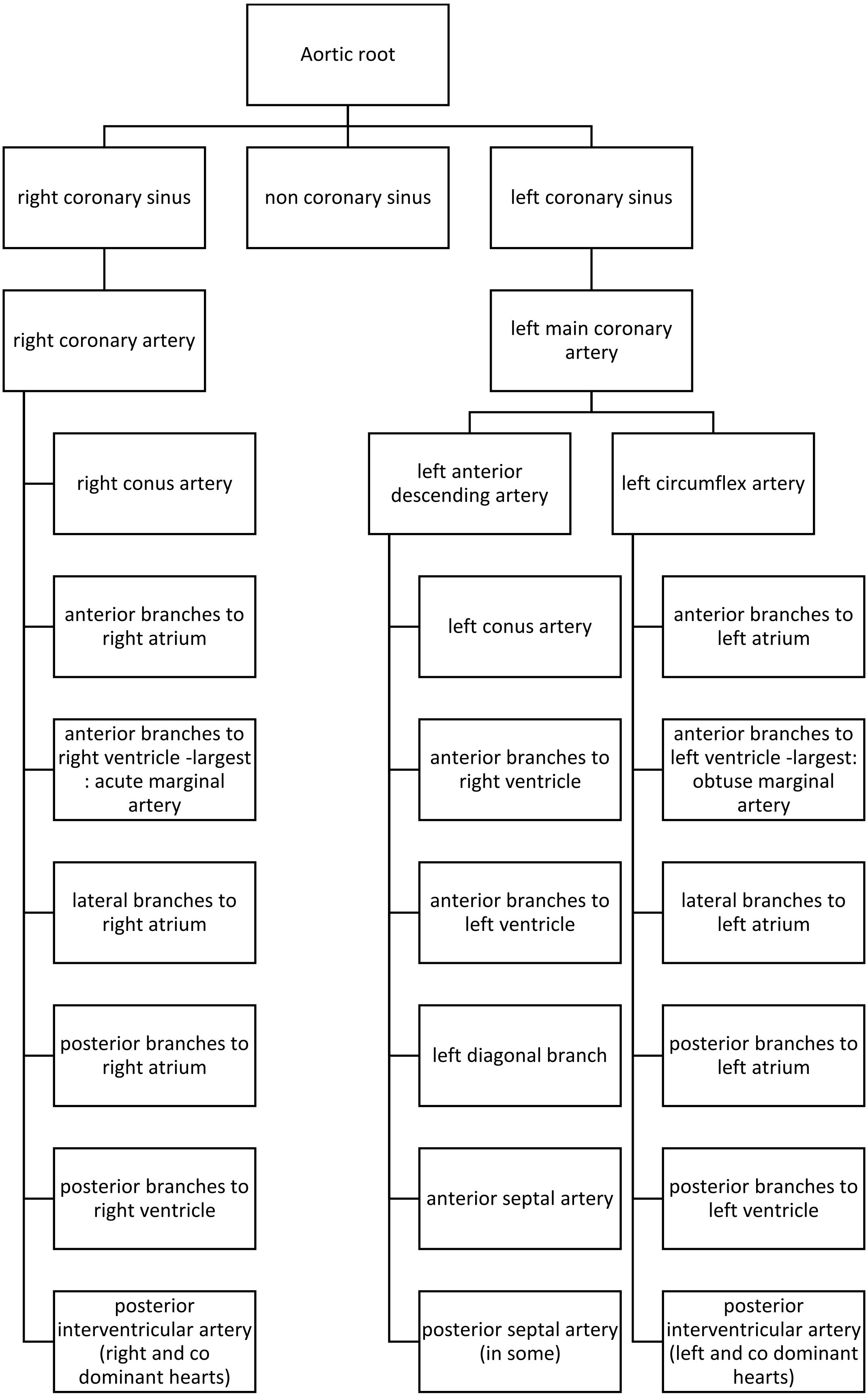
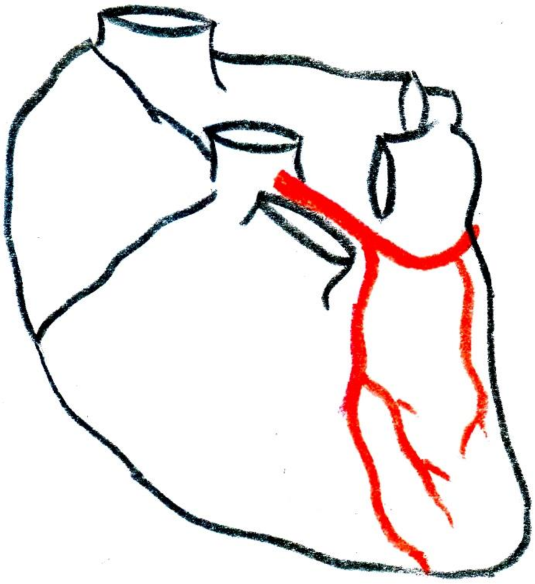
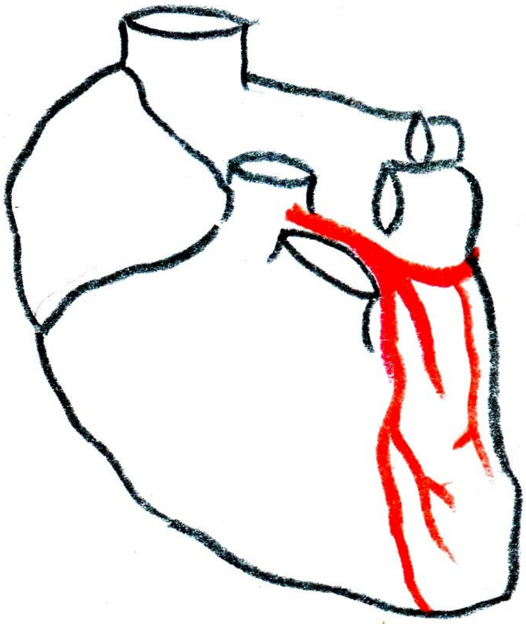


Figure 5: Terminal branching pattern of left main coronary artery

Bifurcation



Trifurcation



Quadfurcation

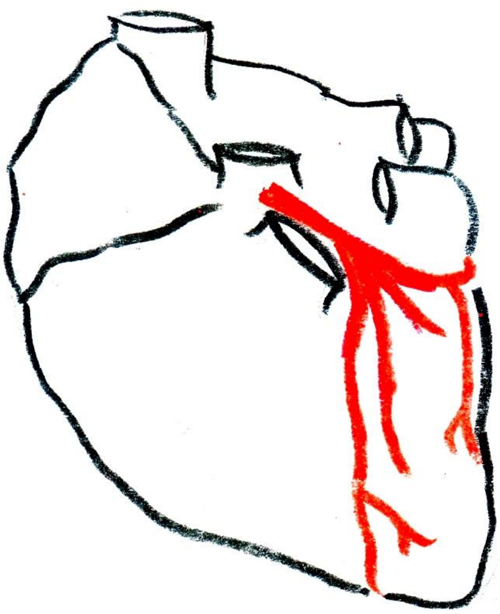
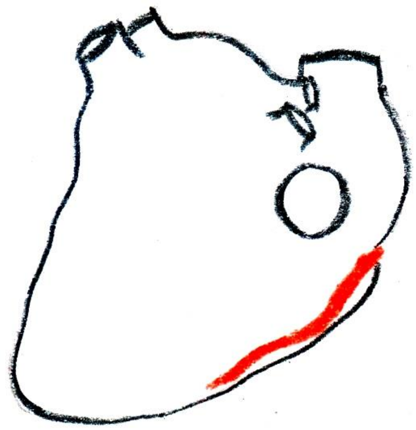
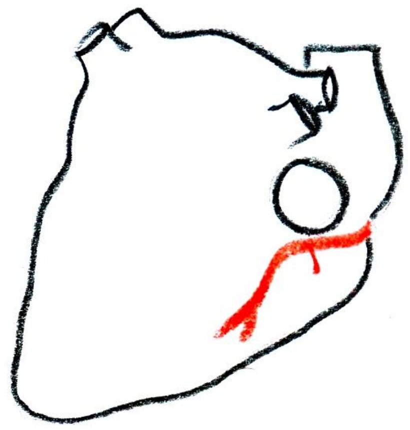


__Figure 6: Levels of termination of right coronary artery__

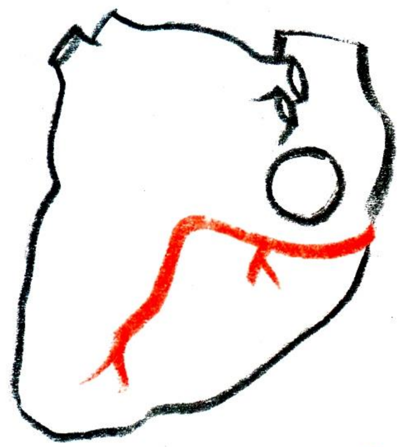
__At acute margin__



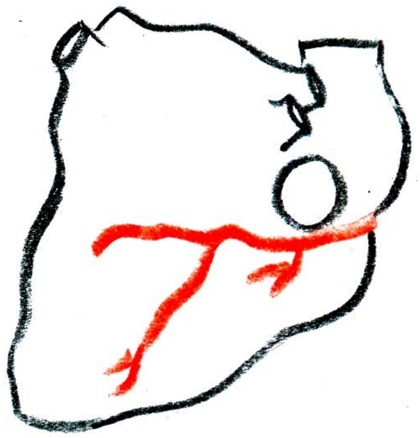
__Between acute margin and crux__



__At the crux cordis__



__Between crux and obtuse margin__



__At obtuse margin__

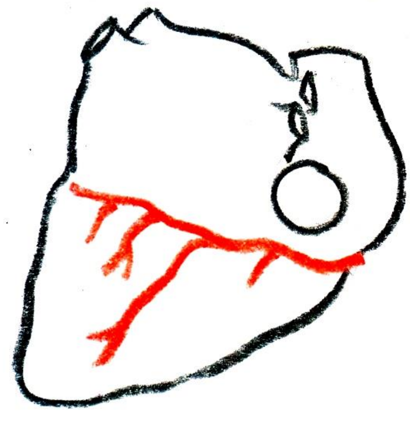
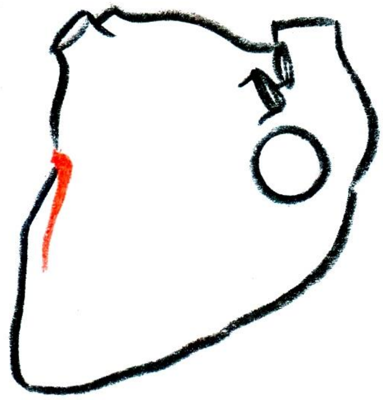
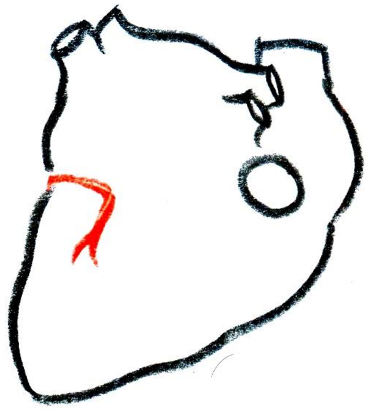


Figure 7: Levels of termination of left circumflex artery

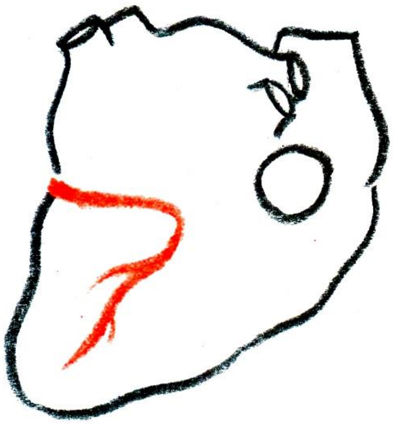
At obtuse margin



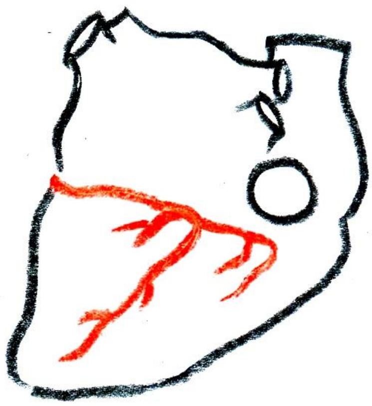
Between obtuse margin and crux



At the crux cordis



Between crux and acute margin



At acute margin

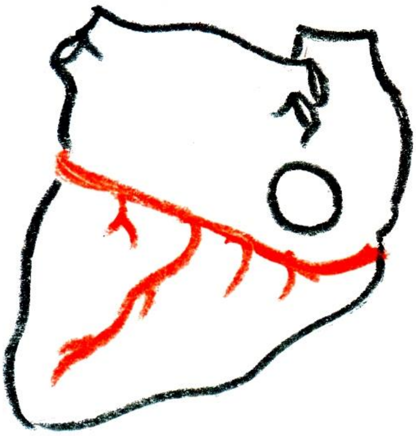
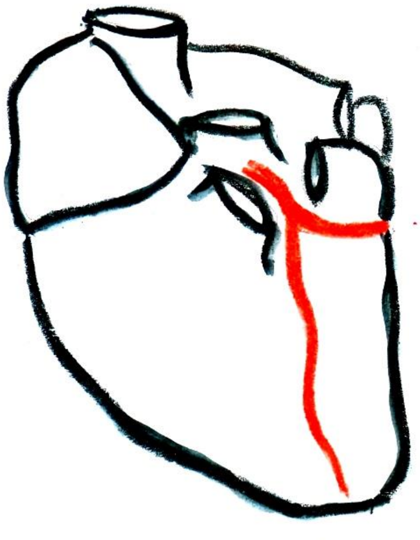


Figure 8: Levels of termination of left anterior descending artery

At the apex



In the posterior interventricular groove

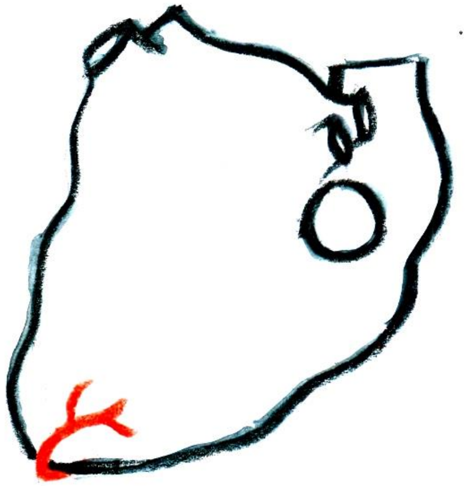
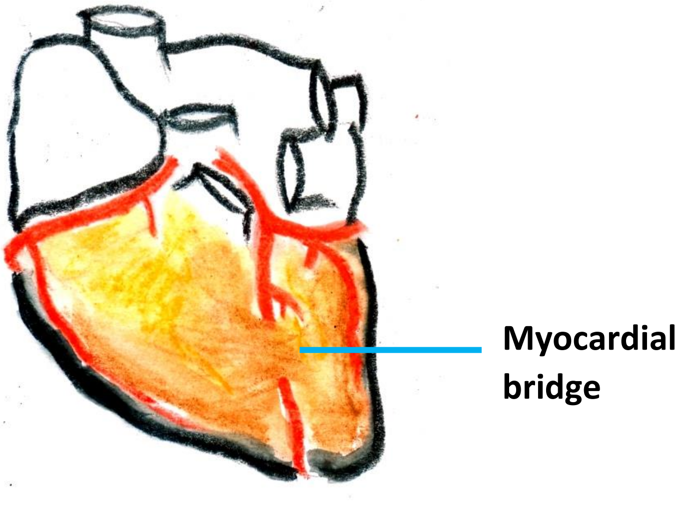


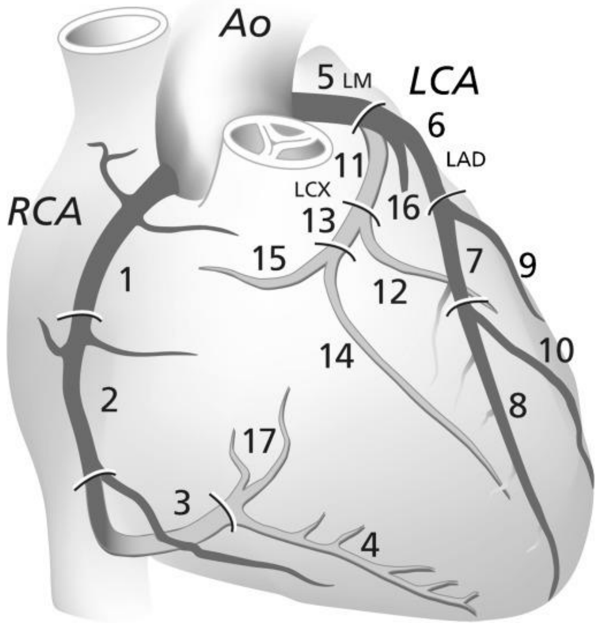
Figure 9: Myocardial bridge



Normal epicardial coronary artery

Tunnelled coronary artery

Figure 10: CASS nomenclature of the coronary artery segments



Ao – aorta, RCA – right coronary artery, LCA – left coronary artery, LM – left main coronary trunk, LCX – left circumflex artery, LAD – left anterior descending artery, Segment 1: proximal right coronary artery, Segment 2: mid right coronary artery, Segment 3: distal right coronary artery, Segment 4: posterior descending/ posterior interventricular artery, Segment 5: left main coronary artery, Segment 6: proximal left anterior descending artery, Segment 7: mid left anterior descending artery, Segment 8: distal left anterior descending artery, Segment 9: first diagonal branch, Segment 10: second diagonal branch, Segment 11: proximal left circumflex artery, Segment 12: first obtuse marginal branch, Segment 13: mid left circumflex artery, Segment 14: second obtuse marginal branch, Segment 15: distal left circumflex artery, Segment 16: ramus intermedius, Segment 17: right posterior branch of right coronary artery

Figure 11: Steps in dissection of cadaveric foetal heart

a) skin incision on the thorax

b) skin flap reflected

c) thoracic contents entered by incision on the thoracic cage

d) thoracic contents of the foetus dissected out

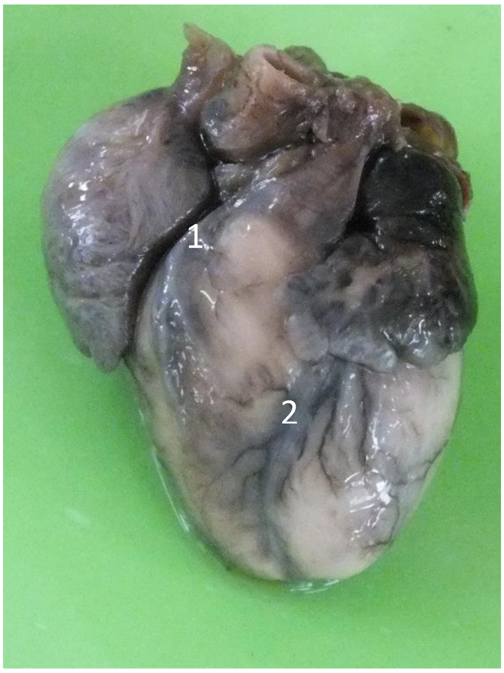
heart separated from other thoracic organs and pericardium stripped off

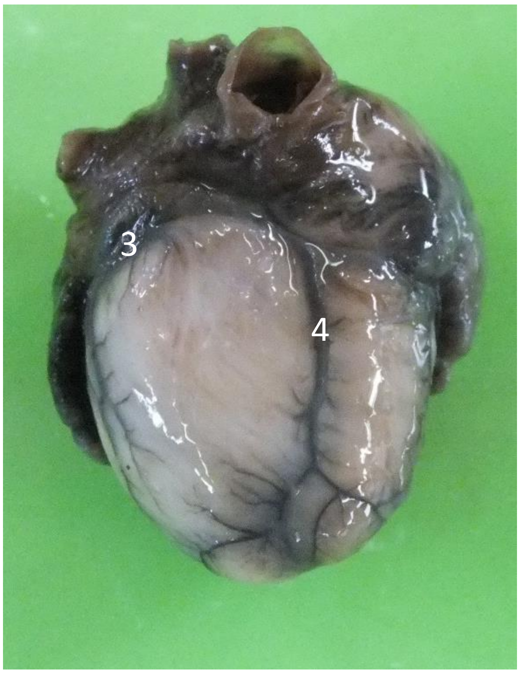
e) anterior view of the foetal heart

f) posterior view of the foetal heart

<u>Figure 12: Coronary arteries of dissected foetal cadaveric heart specimen</u>

<u>Anterior view:</u> ***<u>Posterior view:</u>***



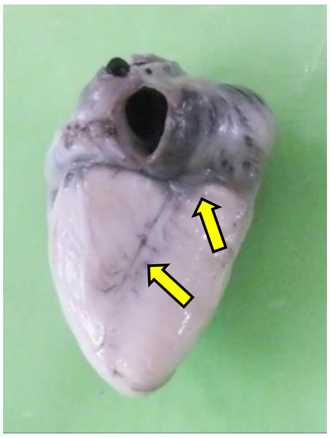


Key: 1 – Right coronary artery; 2 – Left anterior descending artery; 3 – Left circumflex artery; 4 – Posterior interventricular artery

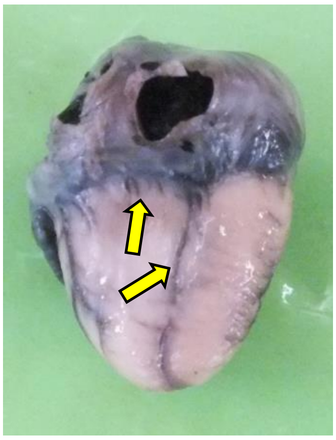
<u>Figure 13: Sample size of dissected foetal cadaveric heart specimen – 50</u>

__Figure 14: Cardiac dominance in dissected foetal cadaveric heart specimens__

__Right dominant__



__Left dominant__



__Co dominant__

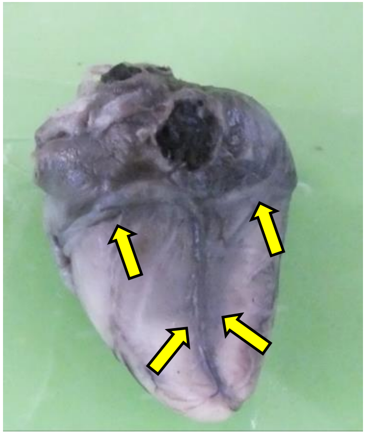
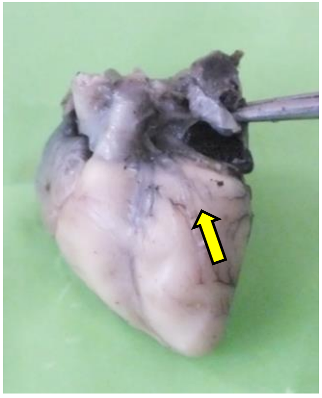


__Figure 15: Terminal branching pattern of left main coronary artery in dissected foetal cadaveric heart specimens__

__Bifurcation__

__Trifurcation__



__Quadfurcation__

__Figure 16: Myocardial bridge in dissected foetal cadaveric heart specimens__

Figure 17: Sample size of dissected adult cadaveric heart specimens – 50

Figure 18: Location of coronary ostia in dissected adult cadaveric heart specimens – below the sino tubular junction

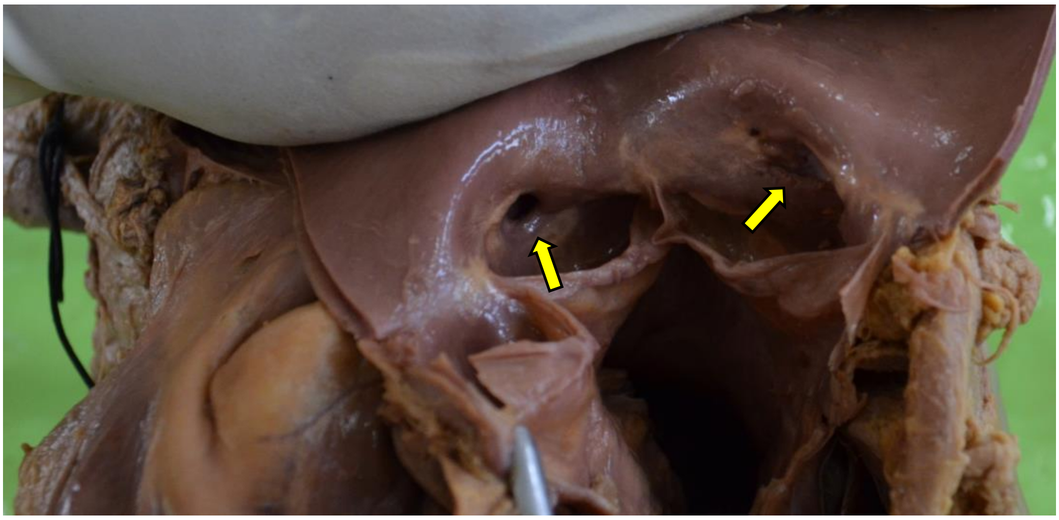


Figure 19: Cardiac dominance in dissected adult cadaveric heart specimens

Right dominant ***Left dominant*** ***Co dominant***

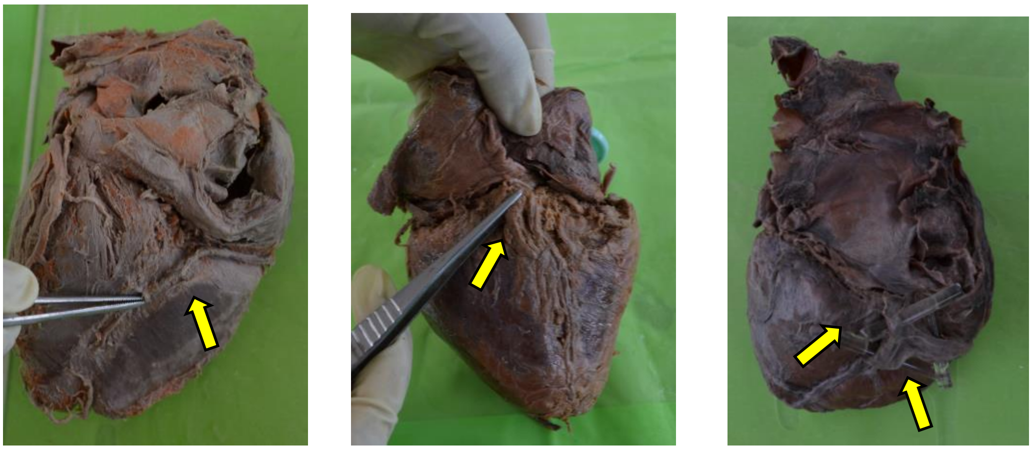


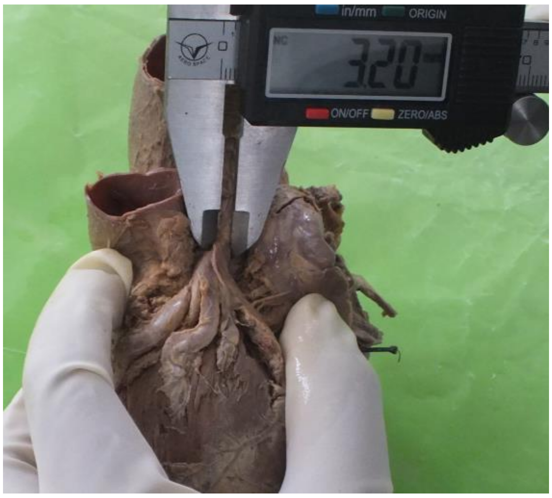
Figure 20: Measurement of diameter of proximal segment of right coronary artery in dissected adult cadaveric heart specimens

Figure 21: Levels of termination of right coronary artery in dissected adult cadaveric heart specimens

Between acute margin and the crux ***At the crux*** ***Between crux and obtuse margin***

<u>Figure 22: Measurement of length and diameter of left main coronary artery in dissected adult cadaveric heart specimens</u>

<u>Diameter</u> ***<u>Length</u>***



<u>Figure 23: Terminal branching pattern of left main coronary artery in dissected adult cadaveric heart specimens</u>

<u>Bifurcation</u> ***<u>Trifurcation</u>*** ***<u>Quadfurcation</u>***

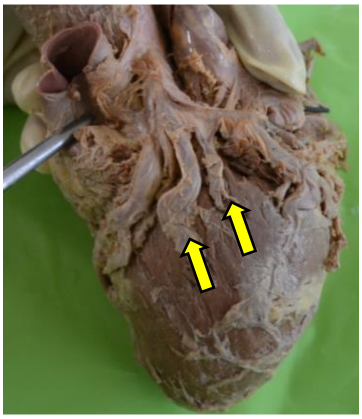


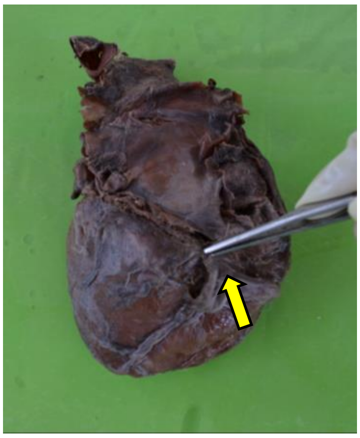
Figure 24: Measurement of diameter of proximal segment of left circumflex artery in dissected adult cadaveric heart specimens

Figure 25: Levels of termination of left circumflex artery in dissected adult cadaveric heart specimens

At the obtuse margin

Between obtuse margin and crux

At the crux



Between the crux and acute margin

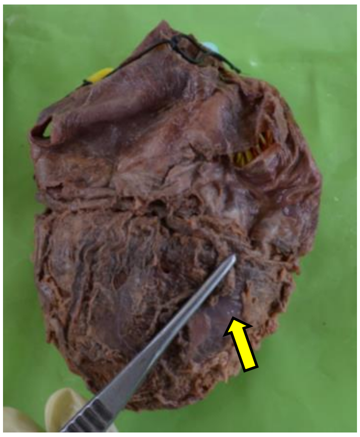


Figure 26: Measurement of diameter of proximal segment of left anterior descending artery in dissected adult cadaveric heart specimens

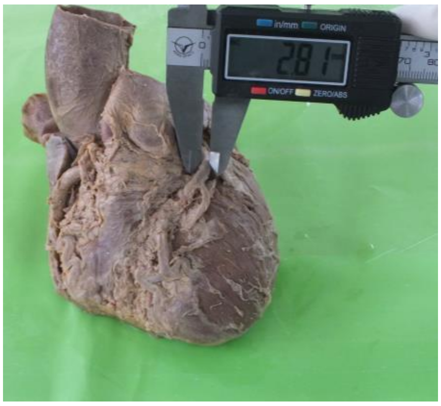
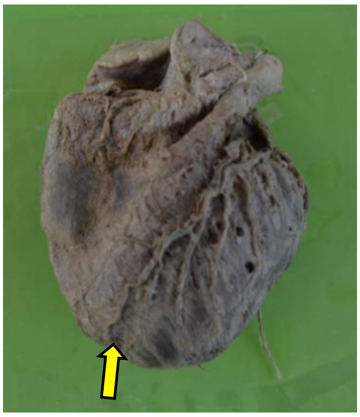


Figure 27: Levels of termination of left anterior descending artery in dissected adult cadaveric heart specimens

At the apex ***In the posterior interventricular groove***



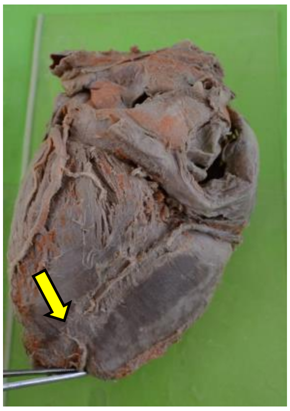


Figure 28: Myocardial bridge in dissected adult cadaveric heart specimen

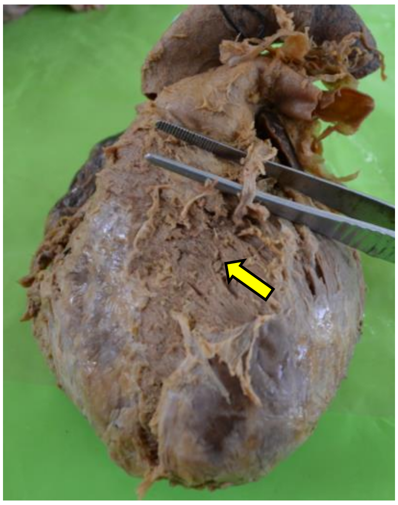
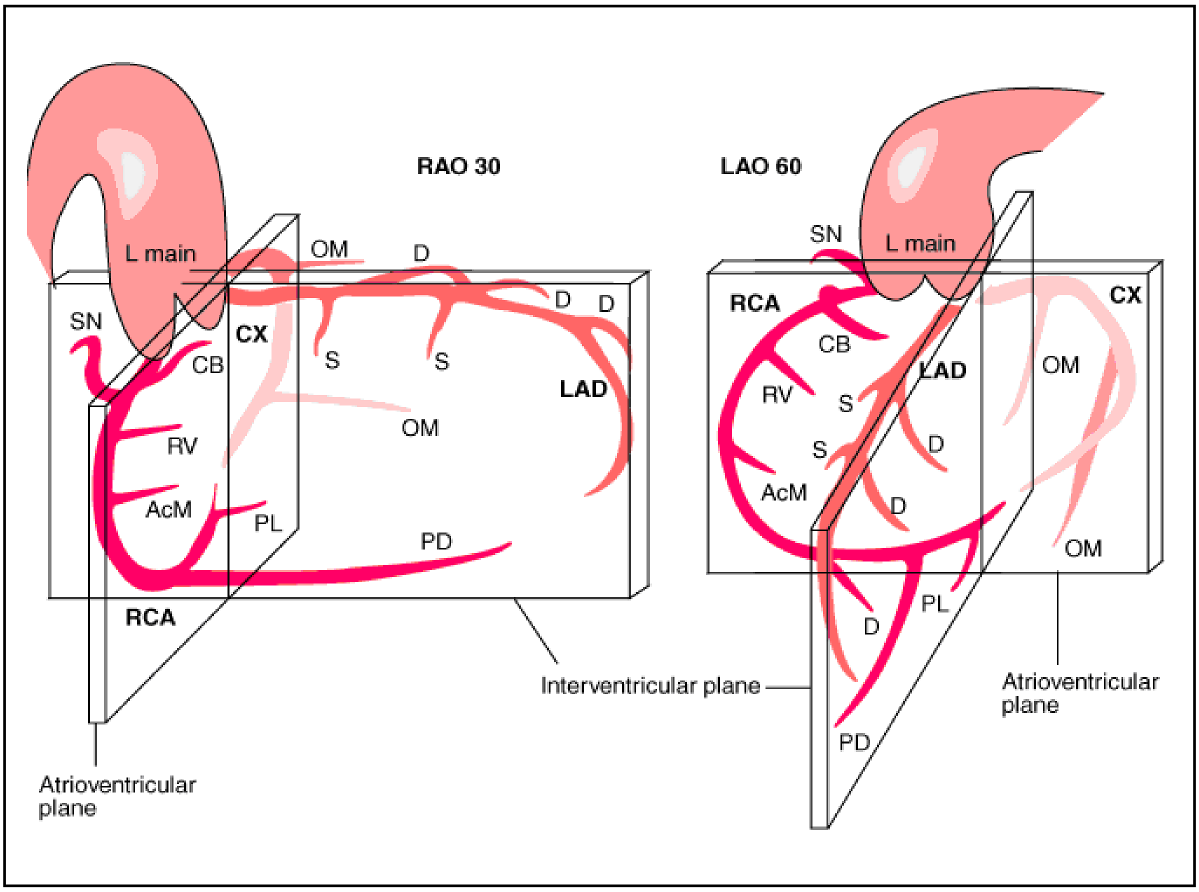


Figure 29: Standard angiographic views for right and left coronary artery



RAO 30 **_LAO 60_**

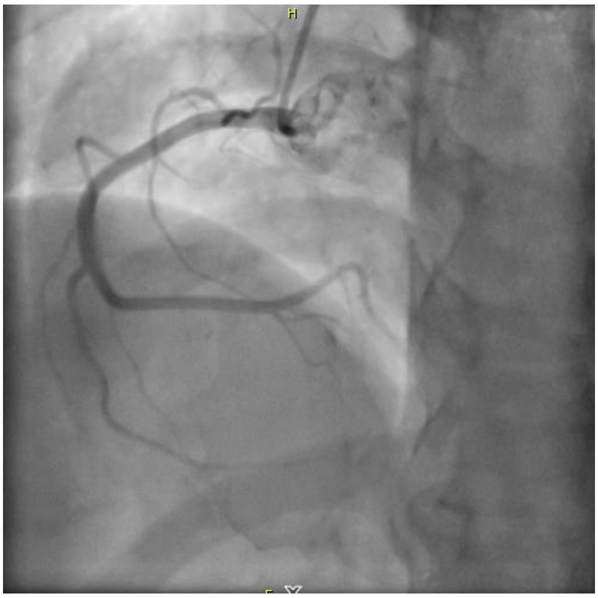
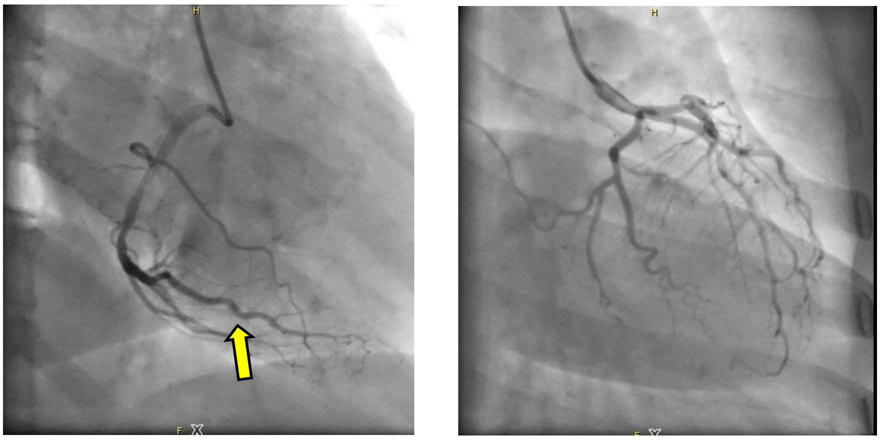
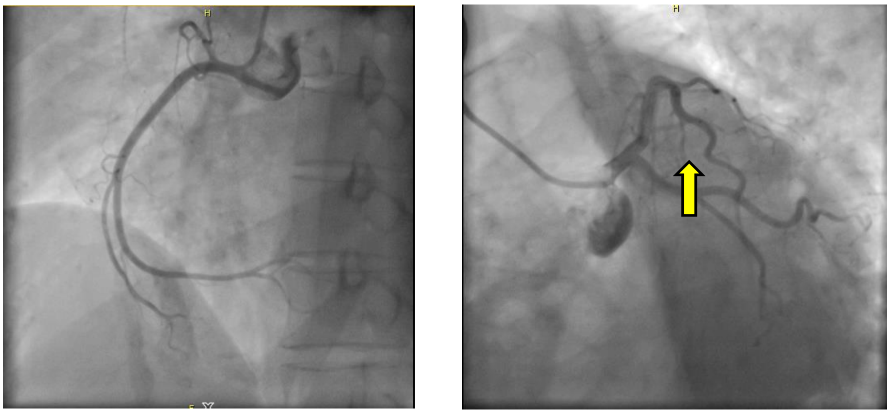


Figure 30: Cardiac dominance in coronary computer tomography angiograms

Right dominant



Left dominant



Co dominant

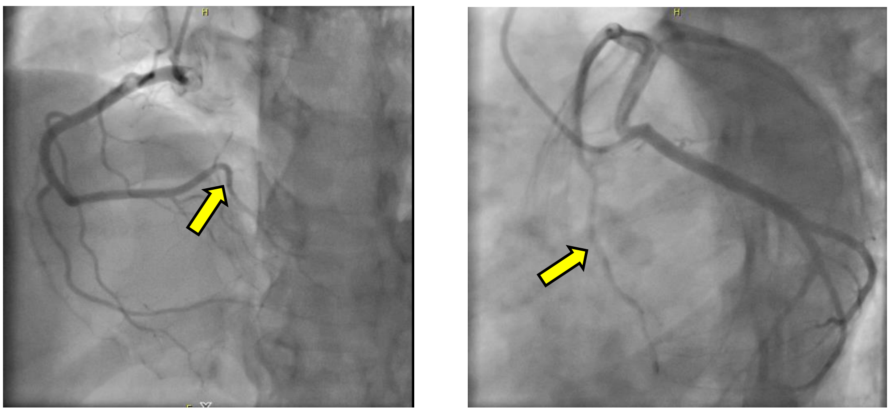


Figure 31: Measurement of diameter of proximal segment of right coronary artery in coronary computer tomography angiograms

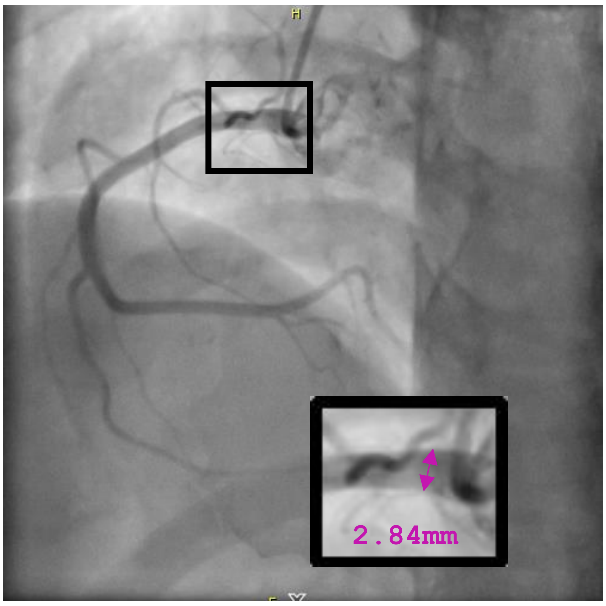


Figure 32: Measurement of length and diameter of left main coronary artery in coronary computer tomography angiograms

Length ***Diameter***

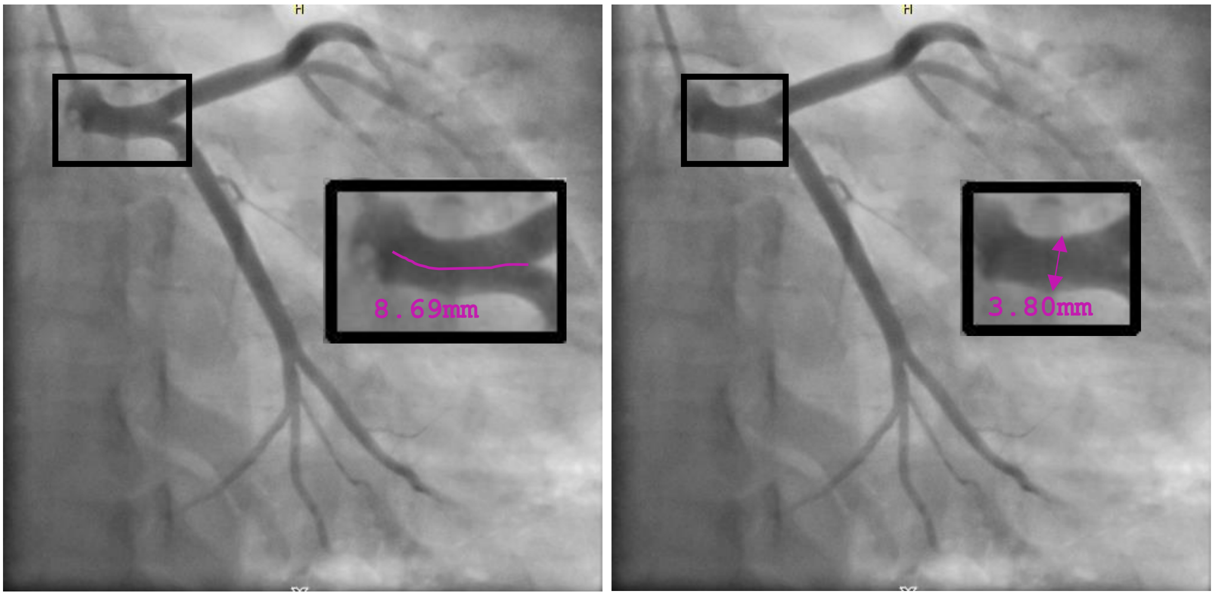
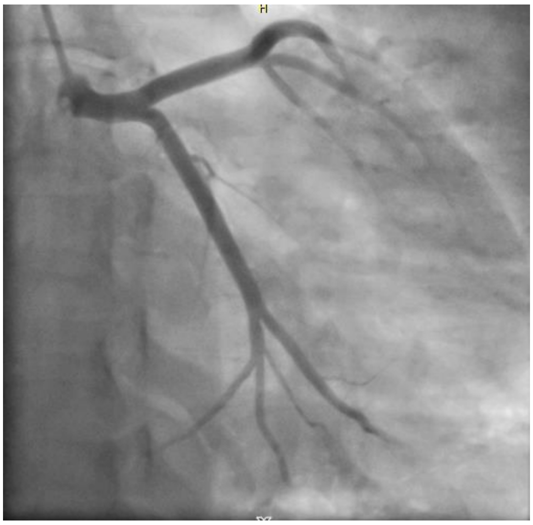


Figure 33: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms

Bifurcation



Trifurcation

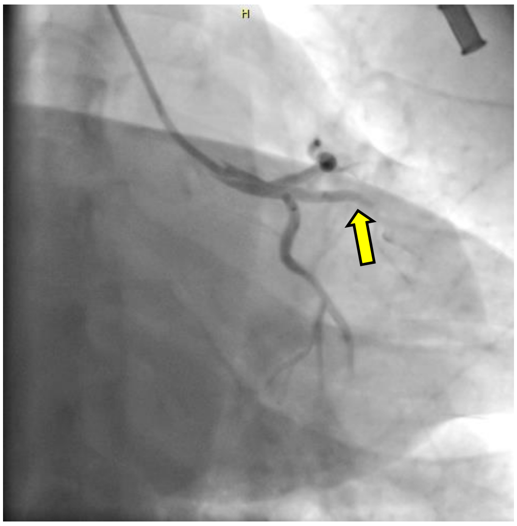


Figure 34: Measurement of diameter of proximal segment of left circumflex artery in coronary computer tomography angiograms

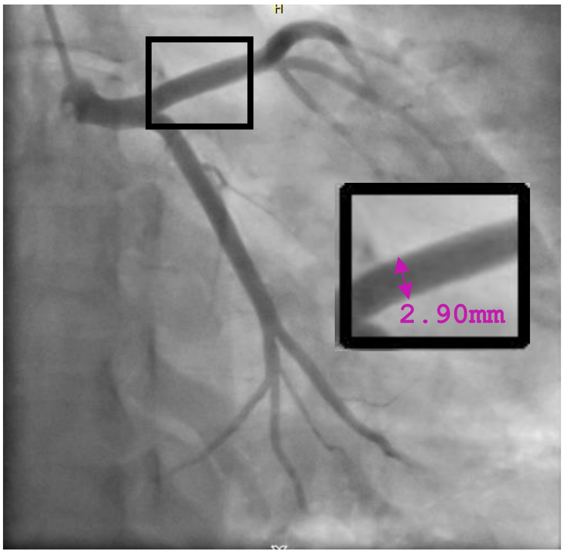


Figure 35: Measurement of diameter of proximal segment of left anterior descending artery in coronary computer tomography angiograms

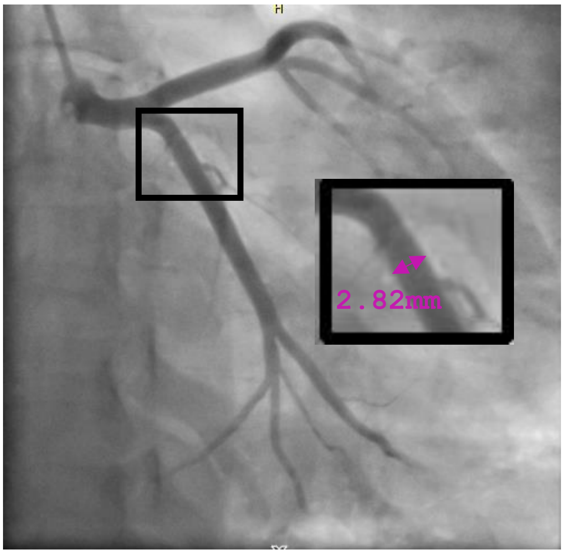


Figure 36: Congenital coronary artery anomaly – Absent left circumflex artery

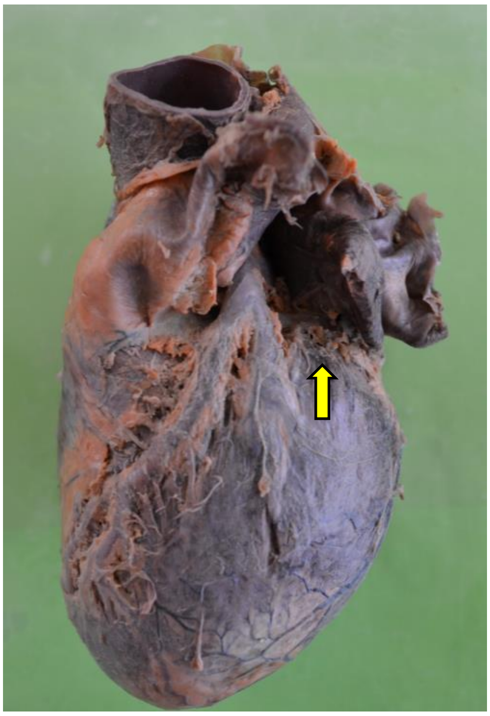


Figure 37: Congenital coronary artery anomaly – Right coronary artery from pulmonary artery

TABLES

Table 1: Classification of the congenital coronary artery anomalies- Angelini P et al

Group	Classification	
1	**Anomalies of origination and course**	
	a	Absent left main trunk (split origination of LCA)
	b	Anomalous level of location of coronary ostium within aortic root or near proper aortic sinus of Valsalva (for each artery):
	c	Anomalous location of coronary ostium outside normal “coronary” aortic sinuses
		Right posterior aortic sinus
		Ascending aorta, Aortic arch, Descending thoracic aorta, Innominate artery, Right carotid artery, Internal mammary artery, Bronchial artery, Subclavian artery
		Left ventricle, Right ventricle
		Pulmonary artery
	d	Anomalous origination of coronary ostium from opposite, facing “coronary” sinus (which may involve joint origination or adjacent double ostia).
		RCA arising from left anterior sinus
		LAD arising from right anterior sinus
		Cx arising from right anterior sinus
		LCA arising from right anterior sinus
		Single coronary artery
2	**Anomalies of intrinsic coronary arterial anatomy**	
	a	Congenital ostial stenosis or atresia (LCA, LAD, RCA, Cx)
	b	Coronary ostial dimple
	c	Coronary ectasia or aneurysm
	d	Absent coronary artery
	e	Coronary hypoplasia
	f	Intramural coronary artery (muscular bridge)
	g	Subendocardial coronary course
	h	Coronary crossing
	i	Anomalous origination of PD from anterior descending branch or septal penetrating branch
	j	Absent PD or split RCA
	k	Absent LAD or split LAD
	l	Ectopic origination of first septal branch
3	**Anomalies of coronary termination**	
	a	Decreased number of arteriolar/capillary ramifications
	b	Fistulas from RCA, LCA, or infundibular artery
4	**Anomalous collateral vessels**	

<u>Table 2: Comparison of our incidence of congenital coronary artery anomalies with reference studies</u>

S. No	Author	Year of study	Study location	%
1	***Click RL et al***	*1989*	*Washington*	0.35
2	***Yamanaka O et al***	*1990*	*Cleveland*	1.3
3	***Iniguez Romo A et al***	*1991*	*Spain*	0.37
4	***Topaz O et al***	*1992*	*Miami*	0.61
5	***Cieslinski G et al***	*1993*	*Frankfurt*	0.97
6	***Kardos A et al***	*1997*	*Central Europe*	1.34
7	***Frescura C et at***	*1998*	*Italy*	**2.25**
8	***Garg N et al***	*2000*	***India***	0.95
9	***Barriales Villa R et al***	*2001*	*Spain*	0.5
10	***Harikrishnan S et al***	*2002*	***India***	0.46
11	***Aydinlar A et al***	*2005*	*Turkey*	0.6 -1.5
12	***Tuncer C et al***	*2006*	*Turkey*	0.24
13	***Eid AH et al,***	*2009*	*Lebanon*	0.73
14	***Von Zeigler F et al***	*2009*	*Munich*	**2.3**
15	***Chen HY et al***	*2012*	*Taiwan*	0.6 – 1.3
16	***Surana SP et al***	*2012*	*New York*	1
17	***Yuksel S et al***	*2013*	*Turkey*	0.29
18	***Current study (Cadaveric, adult)***	***2017***	***Tamil Nadu, India***	**4**

Table 3: Comparison of current dominance percentages with reference studies

S.No.	Author	Year	Study location	RD* %	LD* %	CD* %
1	***Ayer AA et al***	*1957*	***India***	85	8	7
2	***Omer BK et al***	*1977*	***India***	53.3	16.7	30
3	***Kurjia HZ et al***	*1986*	*Iraq*	46	14	40
4	***Angelini P et al***	*1989*	*Philadelphia*	89.1	8.4	2.5
5	***Venkateshu KV et al***	*2005*	*Karnataka,* ***India***	68.75	16.66	14.58
6	***Saikrishna C et al***	*2006*	*Delhi,* ***India***	75	15	10
7	***Fazliogullari Z et al***	*2010*	*Turkey*	42	14	44
8	***Das H et al***	*2010*	*Assam*	70	18.57	11.43
9	***Ajayi NO et al***	*2013*	*South Africa*	81.5	15.2	3.3
10	***Reddy VJ et al***	*2013*	***South India***	86.25	11.25	2.5
11	***Dhakal A et al***	*2015*	*Nepal*	57	17	17
12	***Agarwal R et al***	*2016*	*Bhopal,* ***India***	86	8	6
13	***Mehrotra S et at***	*2016*	*Chandigarh,* ***India***	73.5	18.7	7.8
14	***Raut BK et al***	*2017*	*Bangalore,* ***India***	59.83	17.03	23.14
15	***Current study (cadaver, foetus)***	***2017***	***Tamil Nadu, India***	**48**	**46**	**6**
16	***Current study (cadaver, adult)***			**50**	**42**	**8**
17	***Current study (Angiogram)***			**52**	**44**	**4**

*RD – right dominant; LD – left dominant; CD – co dominant

<u>Table 4: Comparison of the right and left coronary artery ostial level of current study with reference studies:</u>

S.No.	**Author**	**Year**	**Right coronary ostia**			**Left coronary ostia**		
			Above STJ* %	**At STJ* %**	**Below STJ* %**	**Above STJ* %**	**At STJ* %**	**Below STJ* %**
1	***Banchi A et al***	*1904*	19	71	10	34	48	18
2	***Muriago M et al***	*1977*	13	9	78	22	9	69
3	***Cavalcanti JS et al***	*2003*	28	12	60	40	18	42
4	***Kulkarni JP et al***	*2015*	16.6	56.6	26	30	52.2	17.7
5	***Silitongo M et al***	*2016*	-	20.7	79.3	-	26.4	73.6
6	***Current study (cadaver, adult)***	***2017***	**-**	**-**	**100**	**-**	**-**	**100**

*STJ – sinotubular junction

Table 5: Comparison of current mean diameters of coronary arteries in adult cadaveric heart specimens with that of reference studies:

S. No	Author	Year	Study location	Mean diameter (mm)			
				PRCA*	**LMCA***	**PLCX***	**PLAD***
1	***Sahni D et al***	*1989*	***India***	3.1	3.6	-	-
2	***Reig J et al***	*2004*	*Spain*	-	4.86	-	-
3	***Ballesteros LE et al***	*2008*	*Columbia*	-	3.58	2.71	2.94
4	***Ogeng'o JA et al***	*2013*	*Kenya*	-	-	-	2.12
5	***Ullah QW et al***	*2013*	*Islamabad*	1.54	-	1.37	1.48
6	***Udhayakumar S***	*2014*	*Sri Lanka*	-	3.14	-	-
7	***Current study (cadaver, adult)***	***2017***	***India***	**3.18**	**3.32**	**3.03**	**2.56**

**PRCA – proximal segment of right coronary artery; LMCA – left main coronary artery; LCX – left circumflex artery; LAD – left anterior descending artery*

Table 6: Comparison of current mean diameters of coronary arteries in coronary computer tomography angiograms with that of reference studies:

S. No	**Author**	**Year**	**Population**	**Mean diameter (mm)**			
				PRCA*	**LMCA***	**PLCX***	**PLAD***
1	***MacAlpin***	*1972*	*Caucasian*	3.2	4	3	3.4
2	***Mussarat J***	*1999*	***Asian***	2.7	4	3.1	3.12
3 4	***Lip GY***	*1999*	***Indian*** *Caucasian*	1.7 1.79	2.26 2.38	1.71 1.71	1.83 1,89
5	***Kaimkhani A***	*2004*	*Pakistani*	3.8	4.28	3	3.22
6	***Vikram S***	*2005*	***Indian***	3.14	4.3	3.16	3.48
7	***Saikrishna C***	*2006*	***Indian***	1.89	2.16	1.67	1.69
8 9	***Hasan RK***	*2011*	***South Asian*** *Caucasian*	1.42 1.57	2.39 2.41	1.59 1.53	1.56 1.72
10	***Shukri IG***	*2014*	*Iraqi*	3.14	4.68	3.15	3.46
11	***Ghaffari S***	*2015*	*Iranian*	3.47	4.58	3.37	3.69
12	***Turamaniar O***	*2016*	*Turkish*	3.45	4.43	3.11	3.48
13	***Mehrotra S***	*2016*	***Indian***	3.11	4.28	3.12	3.34
14	***Raut BK***	*2017*	***Indian***	1.83	2.34	1.70	1.87
15	***Current study (angiogram)***	***2017***	***Indian***	**3.35**	**3.92**	**3.14**	**3.03**

**PRCA – proximal segment of right coronary artery; LMCA – left main coronary artery; LCX – left circumflex artery; LAD – left anterior descending artery*

Table 7: Comparison of current mean diameters of coronary arteries in coronary computer tomography angiograms of male patients with that of reference studies:

S. No	Author	Year	Population	Mean diameter in males (mm)			
				PRCA*	**LMCA***	**PLCX***	**PLAD***
1	***Saikrishna C***	*2006*	***Indian***	2.75	3.72	2.82	2.85
2	***Shukri IG***	*2014*	*Iraqi*	3.26	4.86	3.26	3.6
3	***Hiteshi AK***	*2014*	*Californian*	3.70	4.35	3.18	3.54
4	***Dhakal A***	*2015*	*Nepalese*	3.23	4.42	3.10	3.30
5	***Mahadevappa M***	*2016*	***Indian***	3.27	4.27	3.19	3.51
6	***Mehrotra S***	*2016*	***Indian***	3.17	4.43	3.20	3.46
7	***Raut BK***	*2017*	***Indian***	1.82	2.34	1.70	1.88
8	***Current study (angiogram)***	***2017***	***Indian***	**3.56**	**4.00**	**3.28**	**3.25**

**PRCA – proximal segment of right coronary artery; LMCA – left main coronary artery; LCX – left circumflex artery; LAD – left anterior descending artery*

<u>Table 8: Comparison of current mean diameters of coronary arteries in coronary computer tomography angiograms of female patients with that of reference studies:</u>

S. No	Author	Year	Population	Mean diameter in females (mm)			
				PRCA*	**LMCA***	**PLCX***	**PLAD***
1	***Saikrishna C***	*2006*	***Indian***	2.55	3.4	2.68	2.72
2	***Shukri IG***	*2014*	*Iraqi*	3.02	4.50	3.03	3.31
3	***Hiteshi AK***	*2014*	*Californian*	3.26	3.91	2.75	3.241
4	***Dhakal A***	*2015*	*Nepalese*	3.03	4.34	3	3.21
5	***Mahadevappa M***	*2016*	***Indian***	3.05	3.85	2.88	3.24
6	***Mehrotra S***	*2016*	***Indian***	3.04	4.13	3.04	3.22
7	***Raut BK***	*2017*	***Indian***	1.83	2.33	1.69	1.86
8	***Current study (angiogram)***	***2017***	***Indian***	**2.86**	**3.81**	**2.44**	**2.50**

**PRCA – proximal segment of right coronary artery; LMCA – left main coronary artery; LCX – left circumflex artery; LAD – left anterior descending artery*

<u>Table 9: Comparison of mean length of left main coronary artery in current study with that of reference studies</u>

S. No.	Author	Year	Study location	Mean length of left main coronary artery (mm)
1	**Abedin Z et al**	*1978*	*Illinois*	9.7
2	**Reig J et al**	*2004*	*Spain*	10.8
3	**Ballesteros LE et al**	*2008*	*Columbia*	6.48
4	**Hosapatna M et al**	*2013*	***India***	8.86
5	**Ajayi NO et al**	*2013*	*South Africa*	10.4
6	**Udhayakumar S et al**	*2014*	*Sri Lanka*	8.33
7	***Current study (cadaver, adult)***	***2017***	***India***	**9.00**
8	***Current study (angiogram)***			**9.92**

Table 10: Comparing the percentages of short, medium and long left main coronary artery of current study with reference studies:

S.No	Author	Year	Study location	Left main coronary artery		
				Short %	**Medium %**	**Long %**
1	***Banchi A***	*1904*	*Italy*	2	87	11
2	***Mc Alpine WA***	*1975*	*New York*	12	74	14
3	***Reig J***	*2004*	*Spain*	7.4	73.7	18.9
4	***Candir N***	*2010*	*Ankara*	6.5	50.65	42.85
5	***Hosapatna M***	*2013*	***India***	10	86.7	3.3
6	***Udhayakumar S***	*2014*	*Sri Lanka*	13	85	2
7	***Current study (Cadaver, adult)***	***2017***	***India***	**6.12**	**91.84**	**2.04**
8	***Current study (Angiogram)***			**6**	**92**	**2**

Table 11: Comparing the percentages of specimens with 2, 3 and 4 terminal branches of left main coronary artery in current study with reference studies:

S. No	Author	Year	No. of terminal branches of left main coronary artery		
			2 (%)	**3 (%)**	**4 (%)**
1	***Banchi A et al***	*1904*	64	31	5
2	***Cranicianu A et al***	*1922*	38	60	2
3	***Bosco GA et al***	*1935*	42	55	2
4	***Kalbfleisch H et al***	*1976*	41	53	0
5	***Hadziselimovic H et al***	*1982*	52	44	4
6	***Baptista CA et al***	*1991*	54	38.4	6.7
7	***Lujinovic A et al***	*2005*	71	29	0
8	***Kilic C et al***	*2007*	86	14	0
9	***Ballesteros LE et al***	*2008*	52	42.2	5.8
10	***Kosar P et al***	*2009*	69	31	0
11	***Christensen KN et al***	*2010*	81	19	0
12	***Fazliogullari Z et al***	*2010*	46	44	10
13	***Hosapatna M et al***	*2013*	93.3	6.7	0
14	***Ajayi NO et al***	*2013*	78.2	20.4	1.4
15	***Sobana M et al***	*2016*	62	32	6
16	***Current study (cadaver, foetus)***	***2017***	**84**	**12**	**4**
17	***Current study (cadaver, adult)***		**87.8**	**8.2**	**4.1**
18	***Current study (angiogram)***		**92**	**8**	**0**

<u>Table 12: Comparison of the termination levels of left circumflex artery in current study with reference studies:</u>

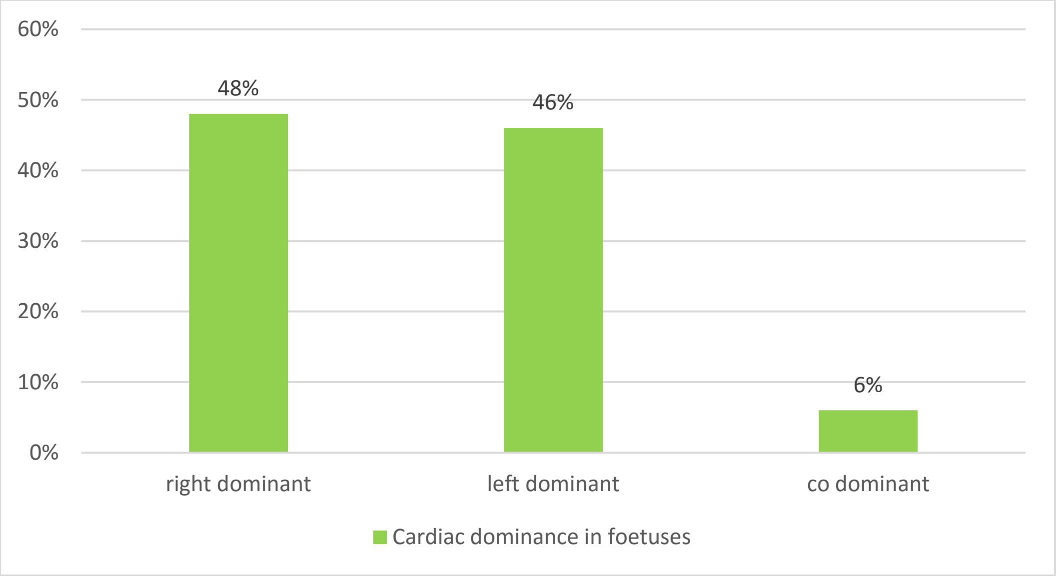
S. No	Author	Year	Termination levels of left circumflex artery				
			At obtuse margin %	**Between obtuse margin & crux %**	**At crux cordis %**	**Between crux & acute margin %**	**At acute margin %**
1	***Banchi A***	*1904*	19	-	70	11	-
2	***Cranicianu A***	*1922*	15	75	10	-	-
3	***Mouchet A***	*1933*	10	82	8	-	-
4	***Bosco GA***	*1935*	25	45	12	8	-
5	***James TN***	*1961*	22	60	9	9	-
6	***Baroldi G***	*1965*	25	63	5	7	-
7	***Current study (cadaver, adult)***	***2017***	**18.4**	**28.6**	**44.9**	**8.2**	**-**

Table 13: Comparison of the termination levels of right coronary artery in current study with reference studies:

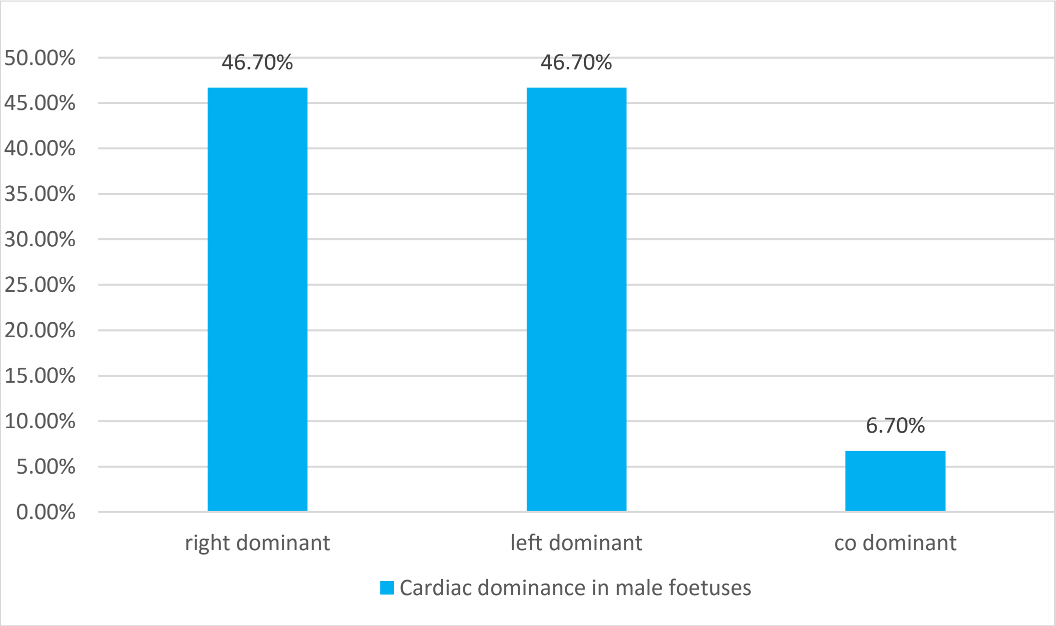
S. No	Author	Year	Termination levels of right coronary artery				
			At acute margin %	**Between acute margin & crux %**	**At crux cordis %**	**Between crux & obtuse margin %**	**At obtuse margin %**
1	***Banchi A***	*1904*	-	12	8	75	5
2	***Gross L***	*1921*	4	-	10	66	20
3	***Cranicianu A***	*1922*	-	10	10	70	20
4	***Mouchet A***	*1933*	-	8	12	80	-
5	***Bosco GA***	*1935*	-	8	22	70	-
6	***James TN***	*1961*	2	7	9	64	18
7	***Baroldi G***	*1965*	-	10	9	64	17
8	***Current study (cadaver, adult)***	***2017***	**-**	**12**	**26**	**62**	**-**

GRAPHS

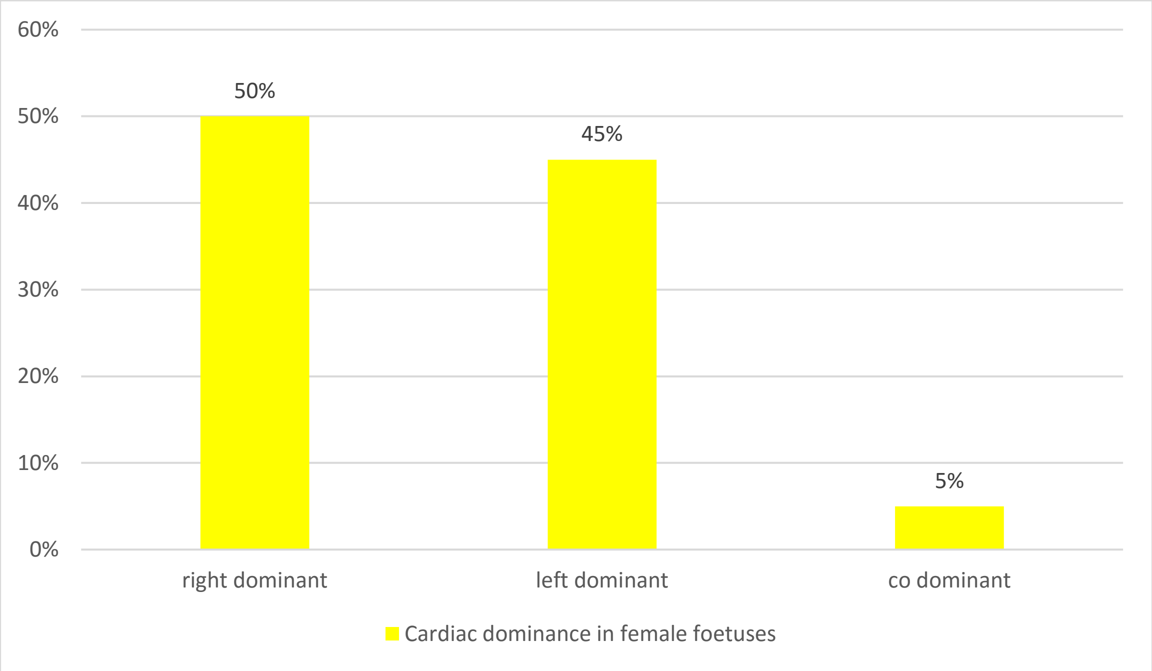
Graph 1: Dominance percentage in dissected foetal cadaveric heart specimens (n = 50)



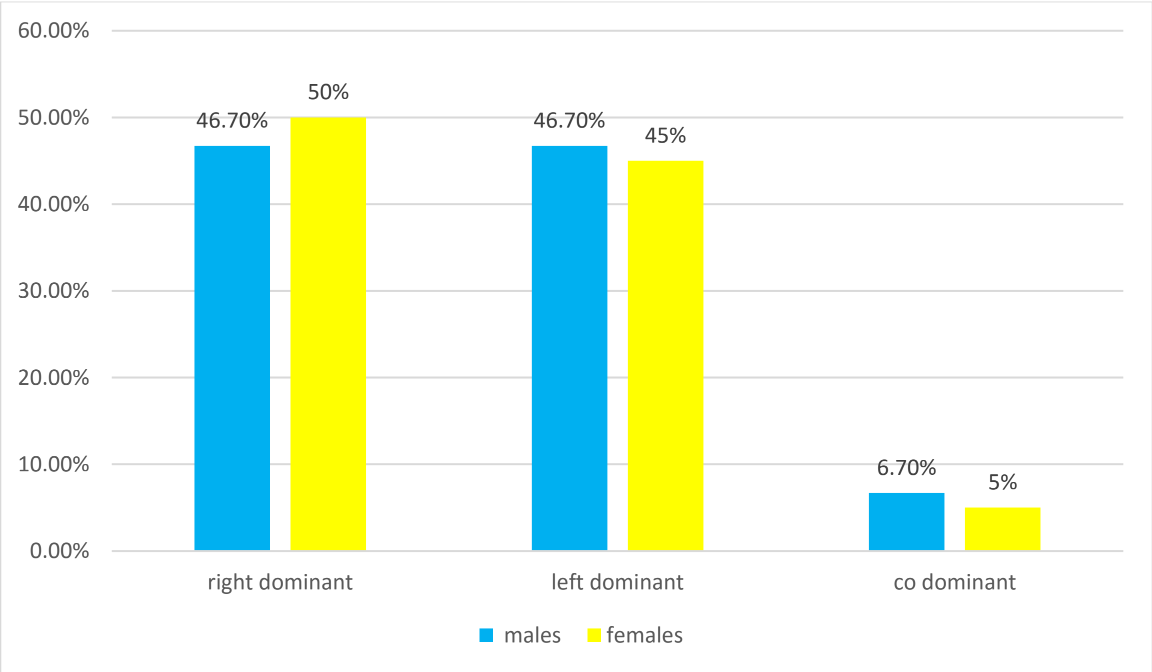
Graph 2: Dominance percentage in male dissected foetal cadaveric heart specimens (n = 30)



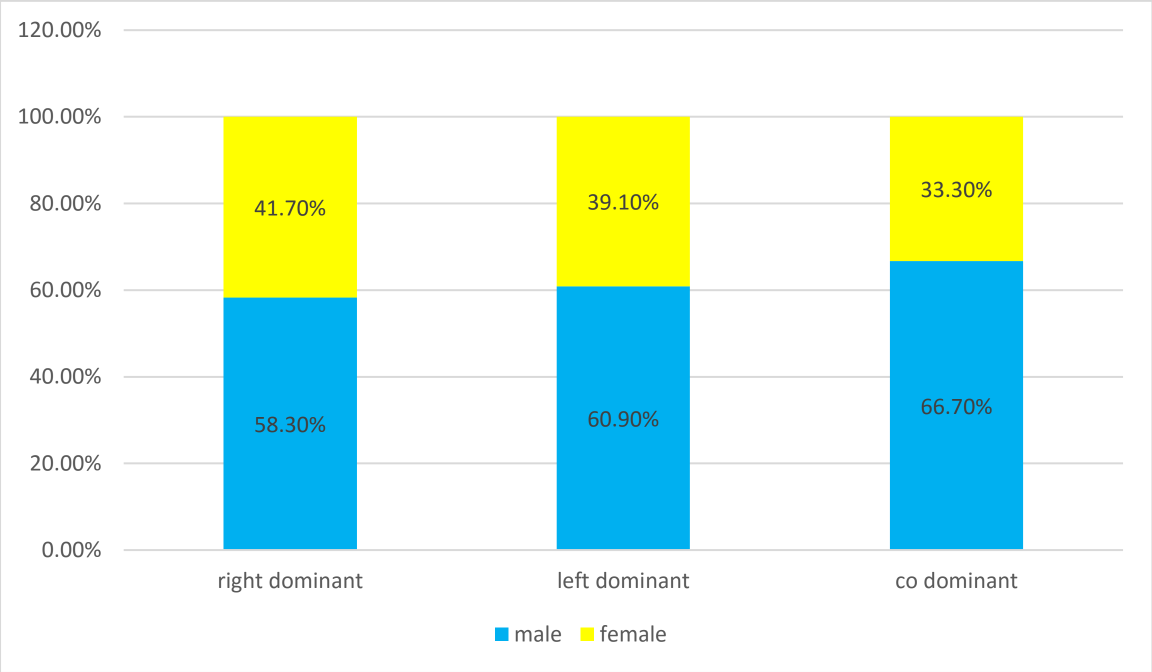
Graph 3: Dominance percentage in female dissected foetal cadaveric heart specimens (n = 20)



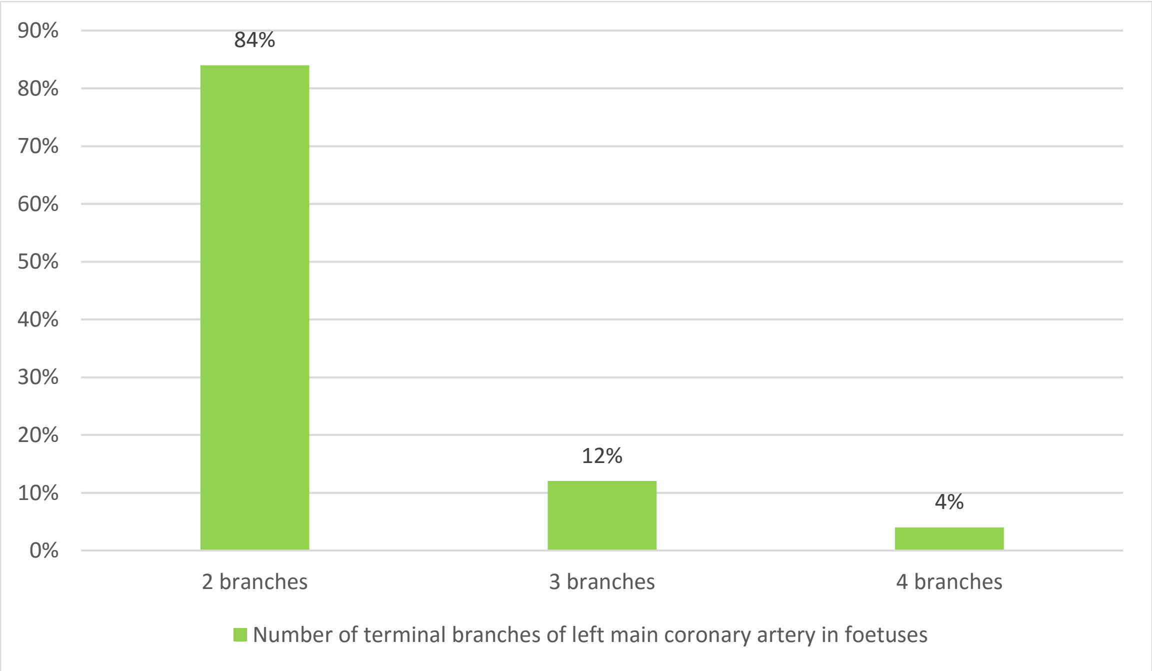
Graph 4: Comparison of Dominance percentage between males and females in dissected foetal cadaveric heart specimens (male. n = 30; female, n = 20)



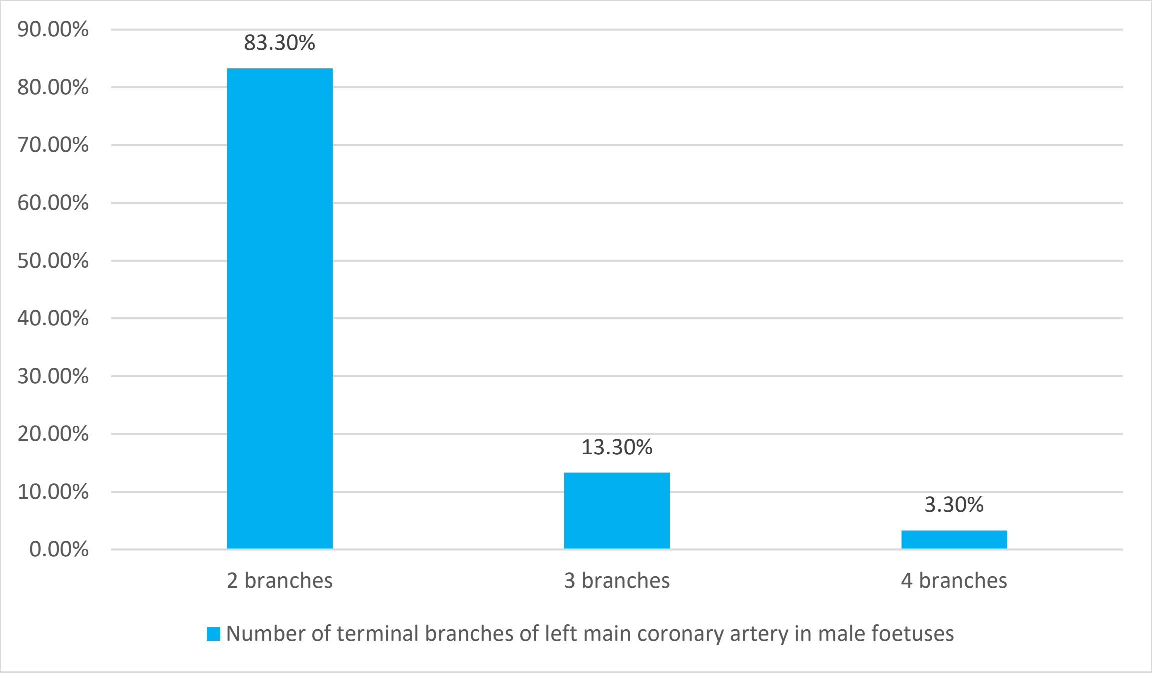
Graph 5: Percentage of males and females in right, left and co-dominant hearts in dissected foetal cadaveric heart specimens (male. n = 30; female, n = 20)



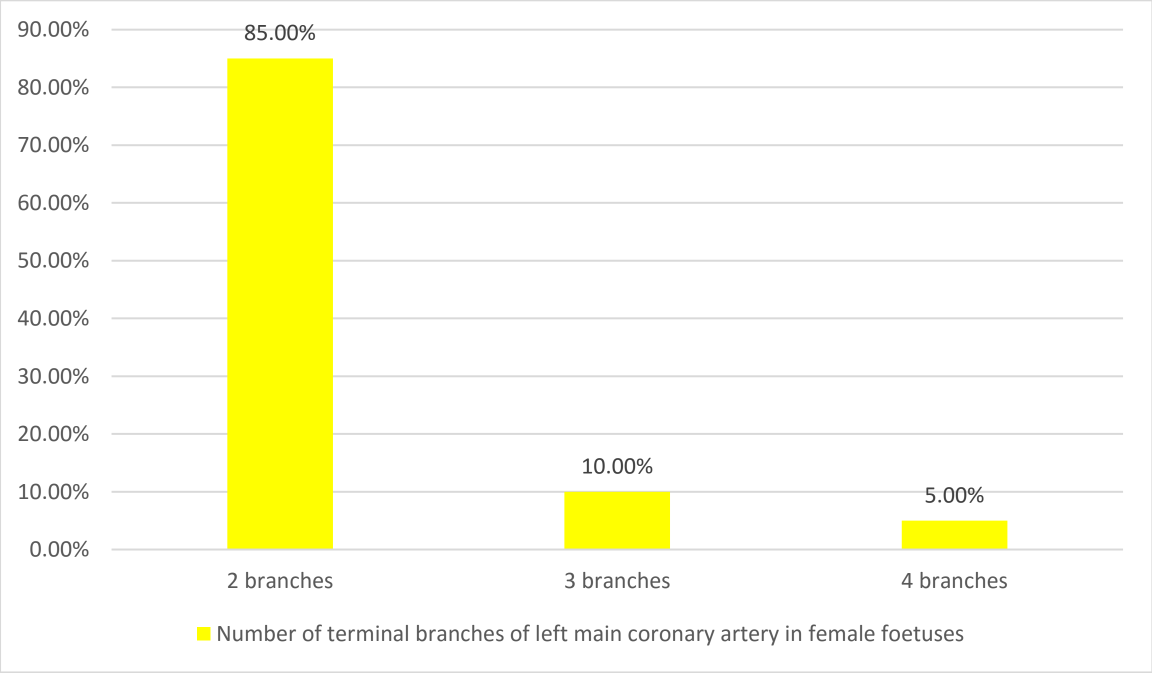
Graph 6: Terminal branching pattern of left main coronary artery in dissected foetal cadaveric heart specimens (n = 50)



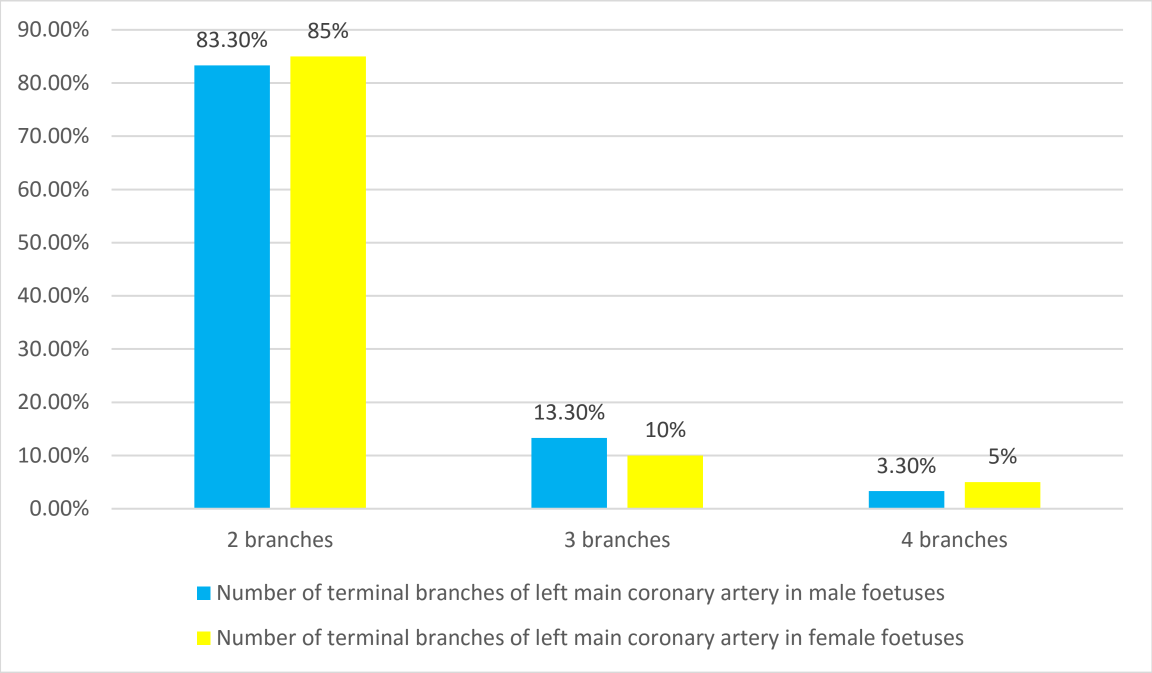
Graph 7: Terminal branching pattern of left main coronary artery in male dissected foetal cadaveric heart specimens (n = 30)



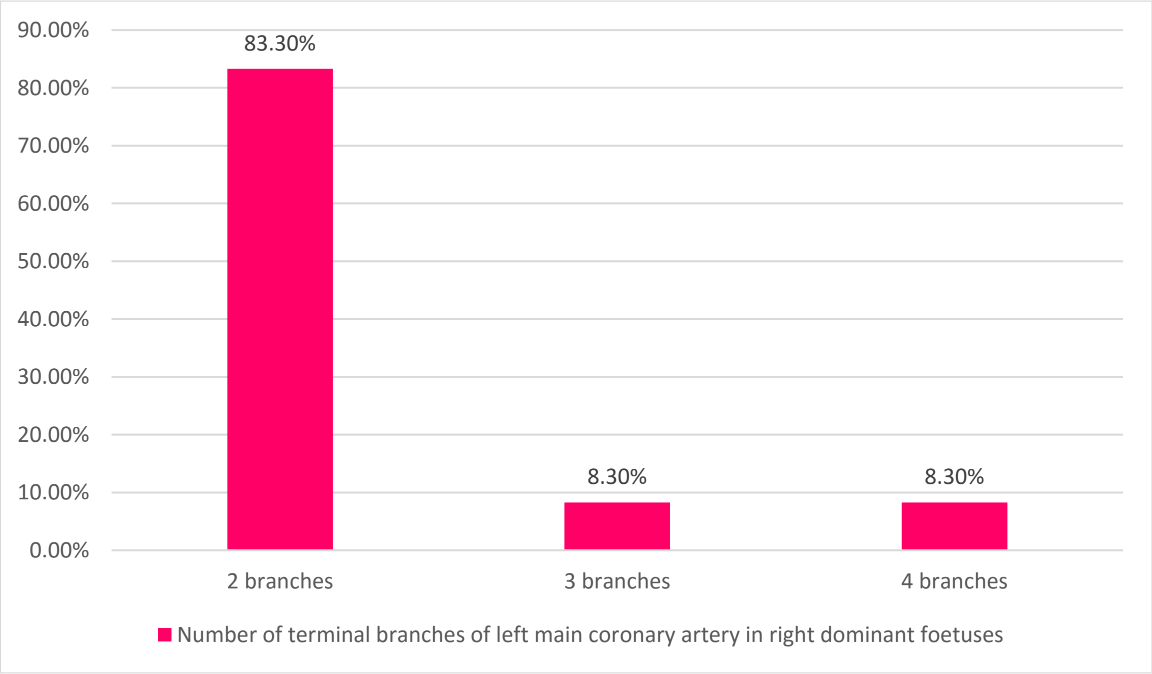
Graph 8: Terminal branching pattern of left main coronary artery in female dissected foetal cadaveric heart specimens (n = 20)



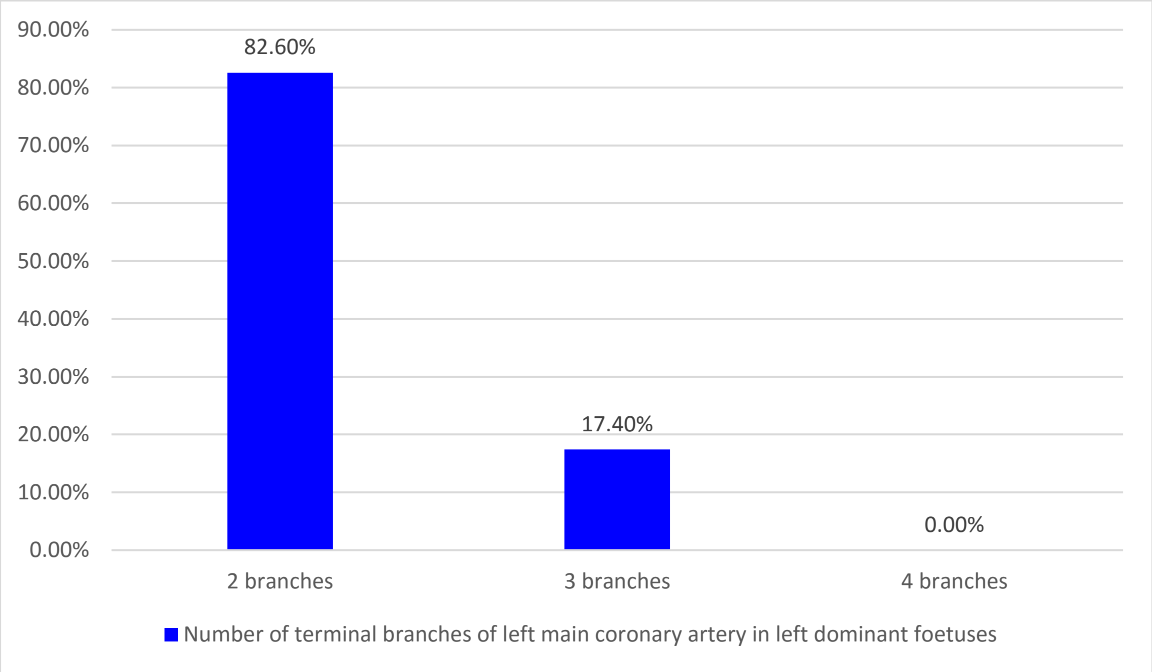
Graph 9: Comparison between males and females of dissected foetal cadaveric heart specimens in terminal branching pattern of left main coronary artery



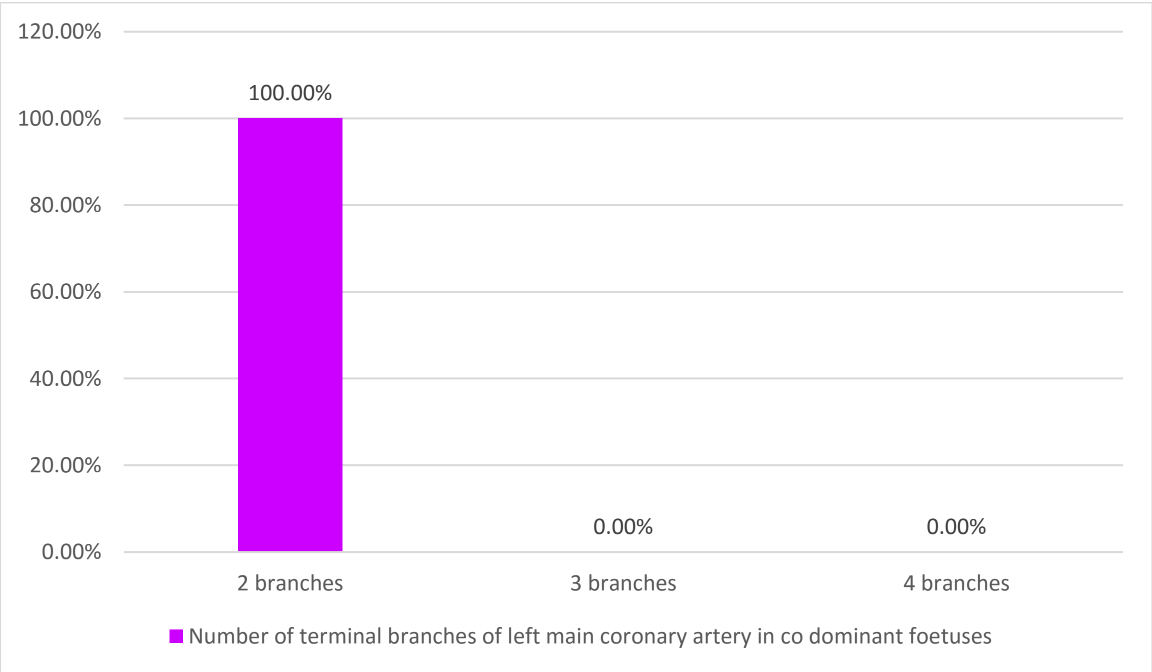
Graph 10: Terminal branching pattern of left main coronary artery in right dominant dissected foetal cadaveric heart specimens (n = 24)



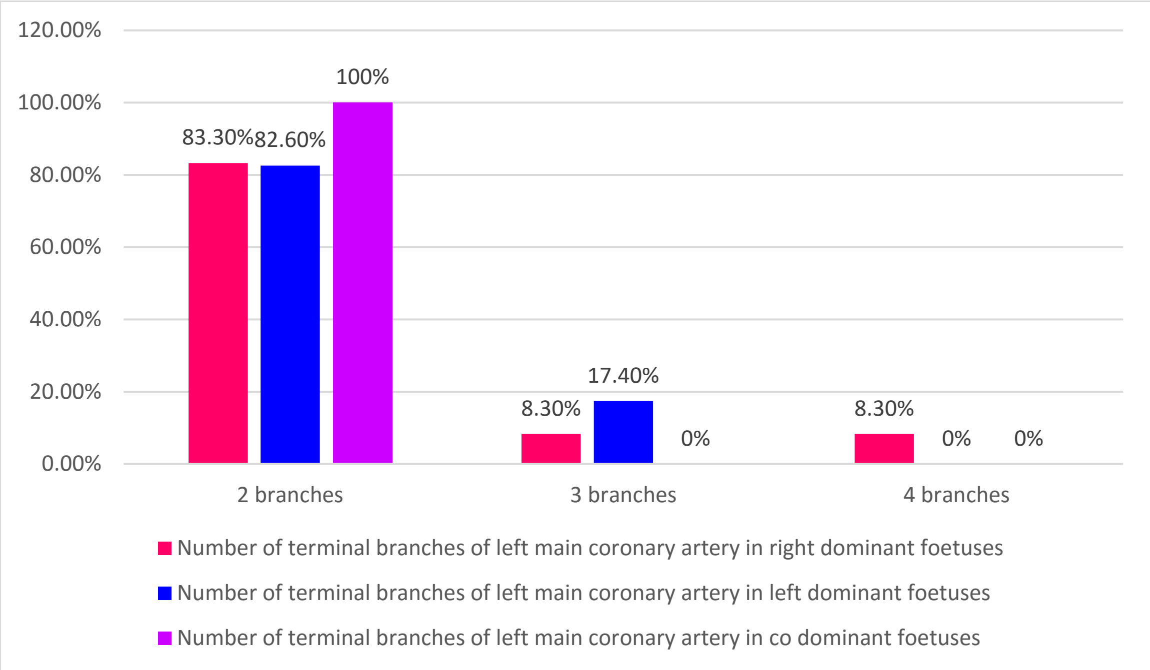
Graph 11: Terminal branching pattern of left main coronary artery in left dominant dissected foetal cadaveric heart specimens (n = 23)



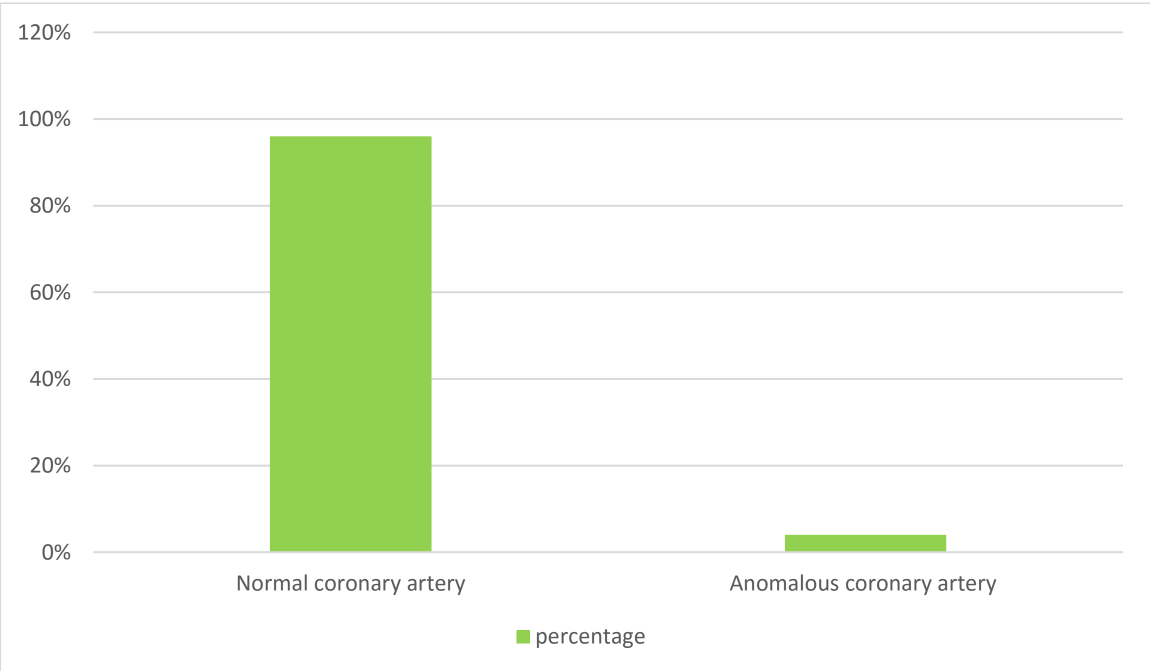
Graph 12: Terminal branching pattern of left main coronary artery in co dominant dissected foetal cadaveric heart specimens (n = 3)



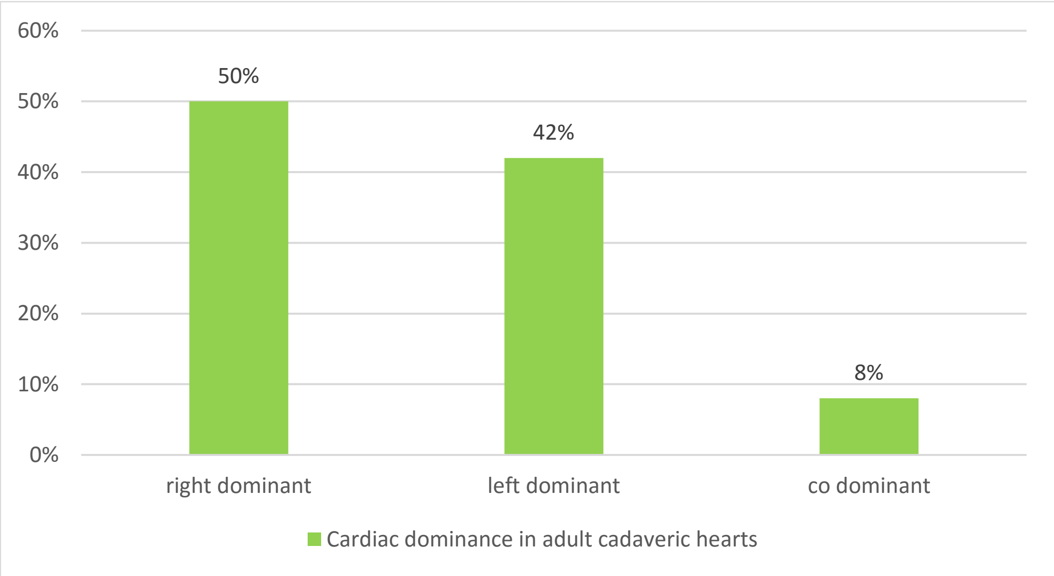
Graph 13: Comparison between right, left and co dominant hearts of dissected foetal cadaveric heart specimens in terminal branching pattern of left main coronary artery



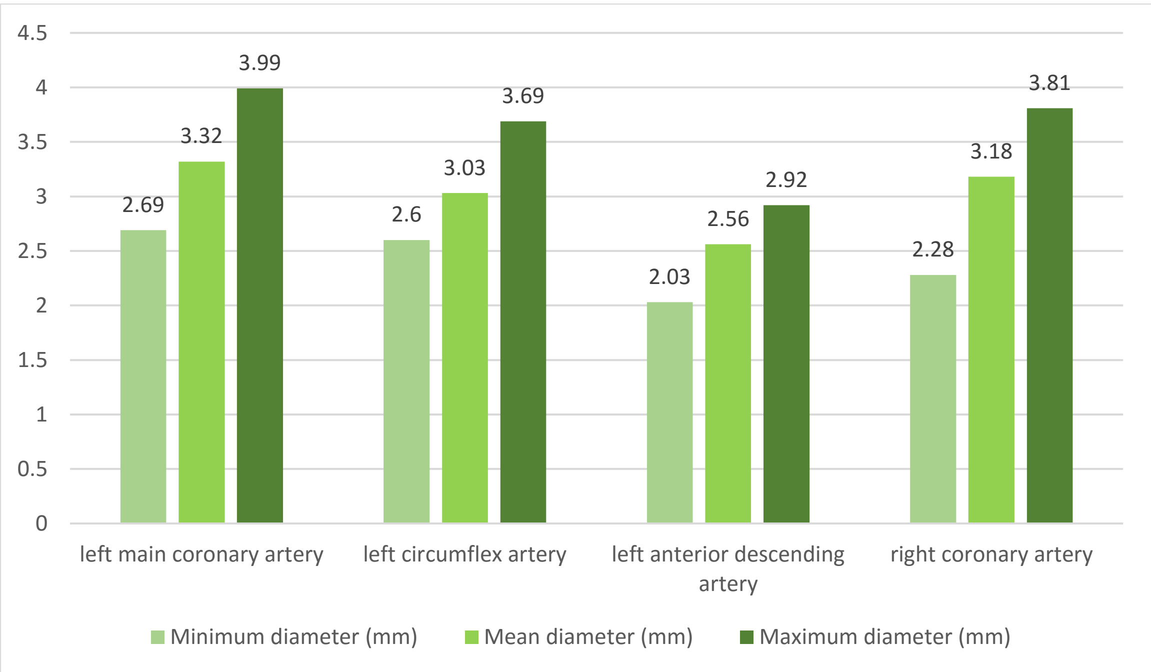
Graph 14: Incidence of congenital coronary artery anomalies in dissected adult cadaveric heart specimens



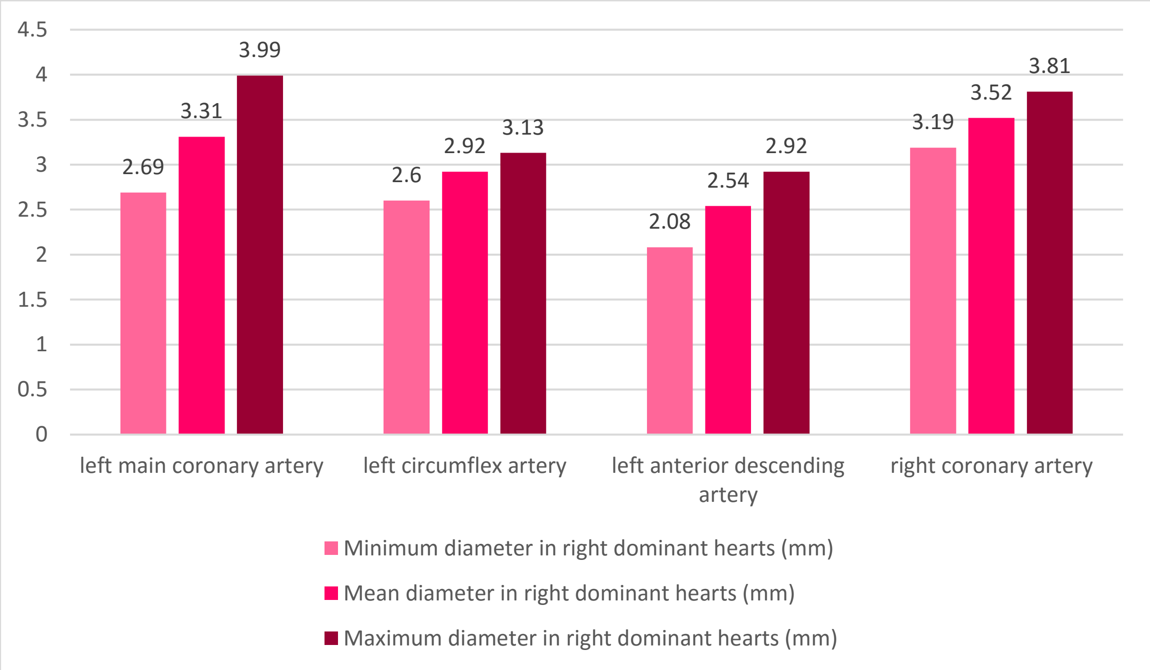
<u>Graph 15: Dominance percentage in dissected adult cadaveric heart specimens (n = 50)</u>



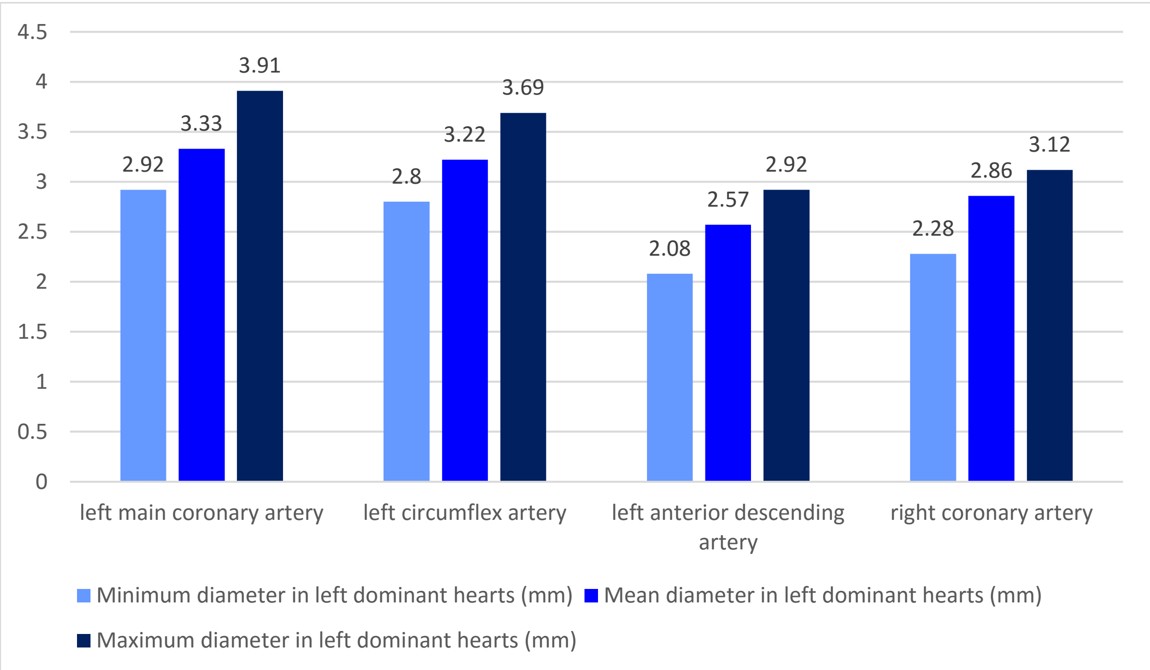
<u>Graph 16: The mean, minimum and maximum diameter of coronary arteries in dissected adult cadaveric heart specimens</u>



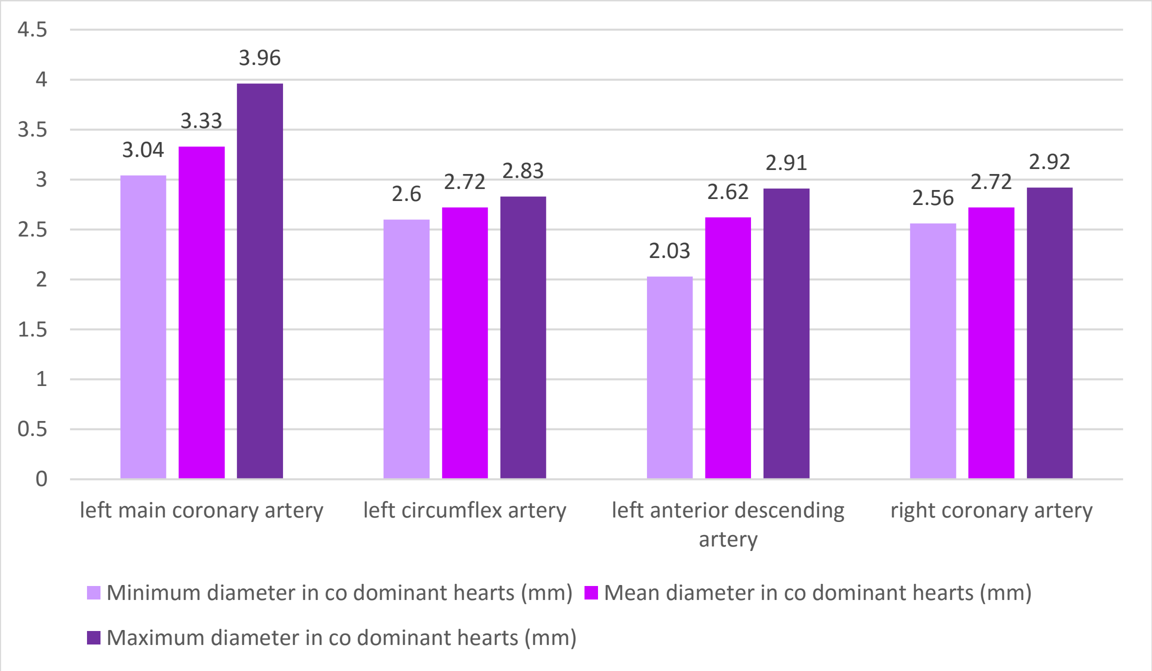
<u>Graph 17: The mean, minimum and maximum diameter of coronary arteries in right dominant dissected adult cadaveric heart specimens</u>



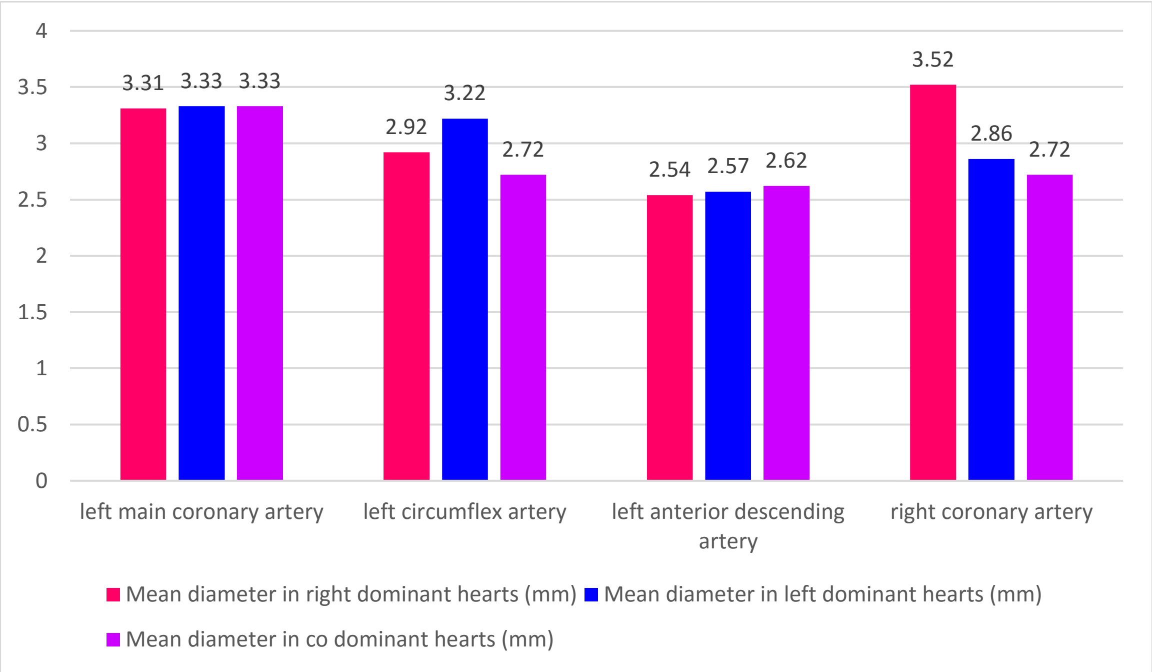
<u>Graph 18: The mean, minimum and maximum diameter of coronary arteries in left dominant dissected adult cadaveric heart specimens</u>



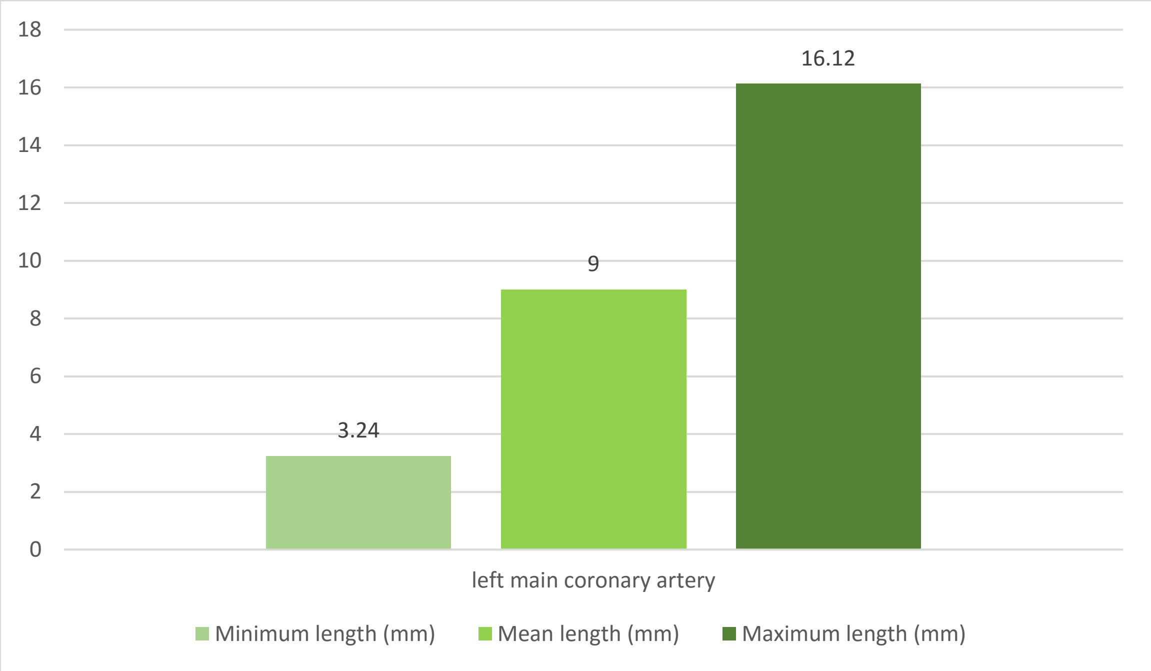
Graph 19: The mean, minimum and maximum diameter of coronary arteries in co dominant dissected adult cadaveric heart specimens



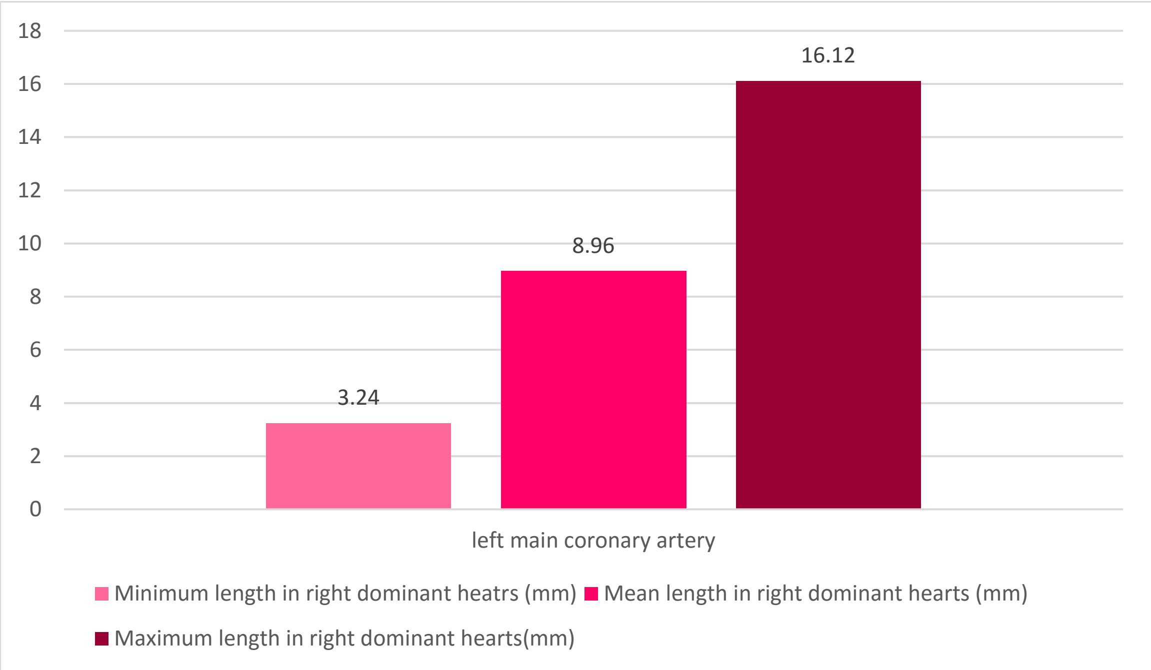
Graph 20: Comparison of mean diameters of coronary arteries in right, left and co dominant dissected adult cadaveric heart specimens



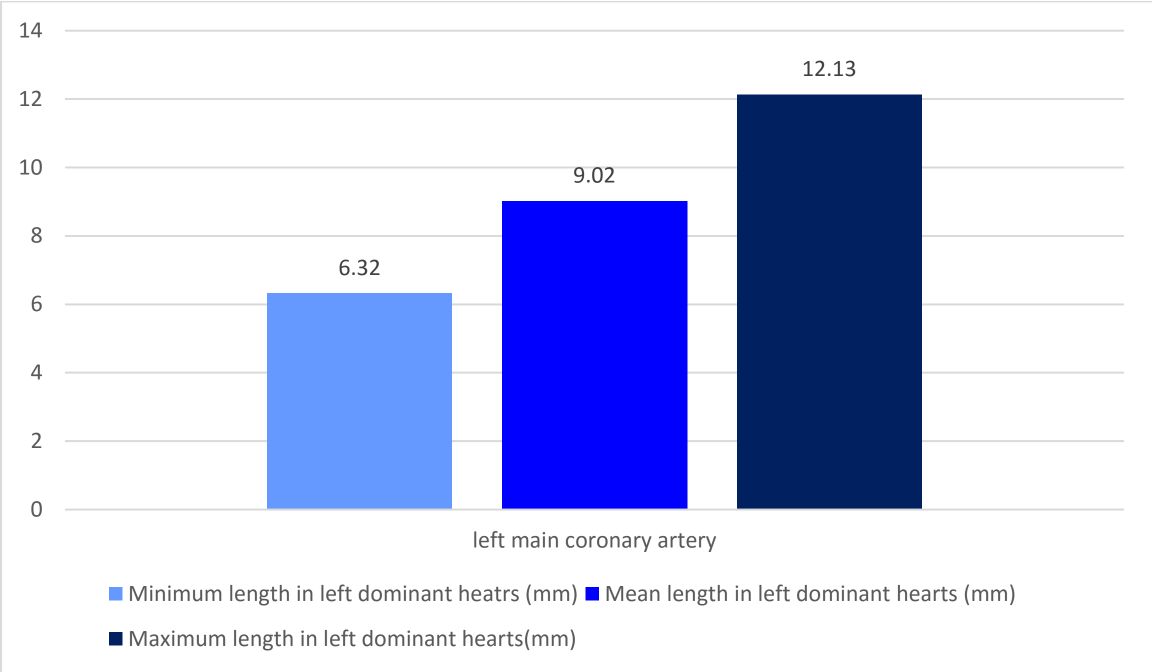
Graph 21: Mean, minimum and maximum length of left main coronary artery in dissected adult cadaveric heart specimens



Graph 22: Mean, minimum and maximum length of left main coronary artery in right dominant dissected adult cadaveric heart specimens

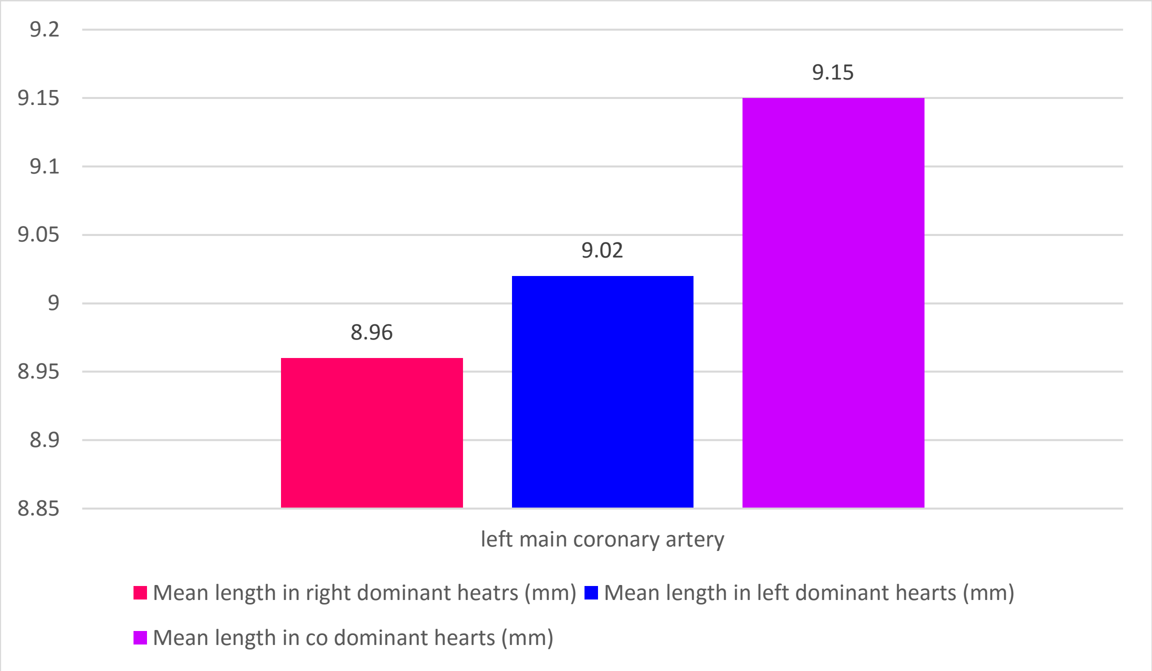


<u>Graph 23:</u> <u>Mean, minimum and maximum length of left main coronary artery in left dominant dissected adult cadaveric heart specimens</u>

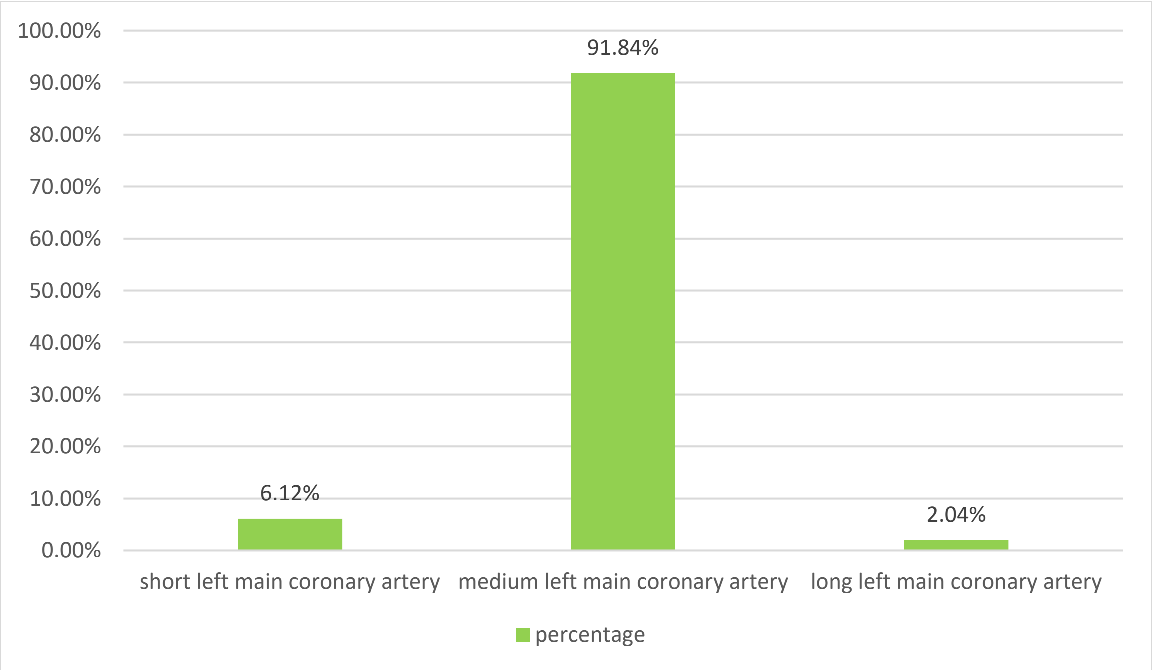


<u>Graph 24:</u> <u>Mean, minimum and maximum length of left main coronary artery in co dominant dissected adult cadaveric heart specimens</u>

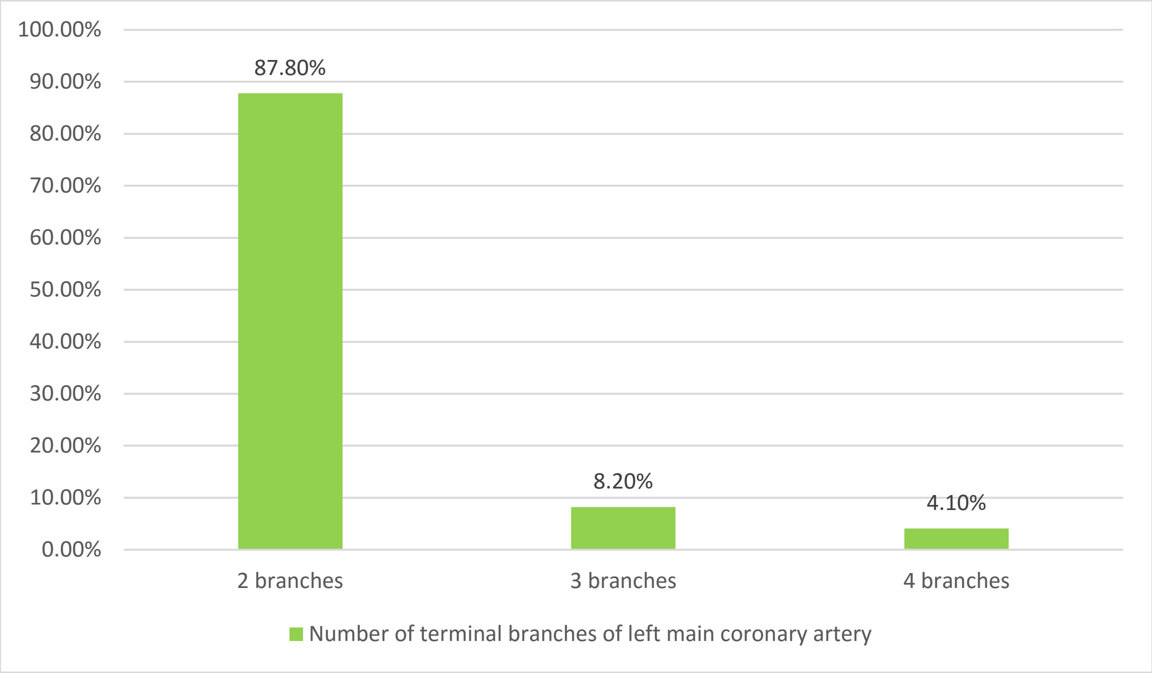
Graph 25: Comparison of mean diameters of left main coronary artery in right, left and co dominant dissected adult cadaveric heart specimens



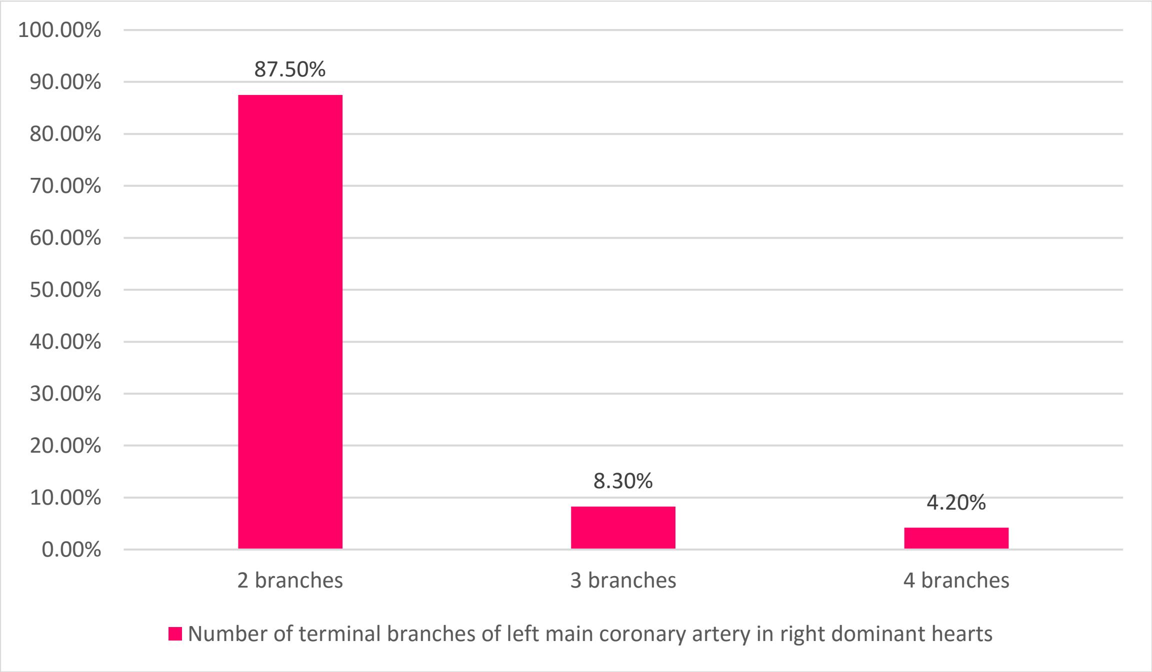
Graph 26: Percentages of short, medium and long left main coronary artery in dissected adult cadaveric heart specimens



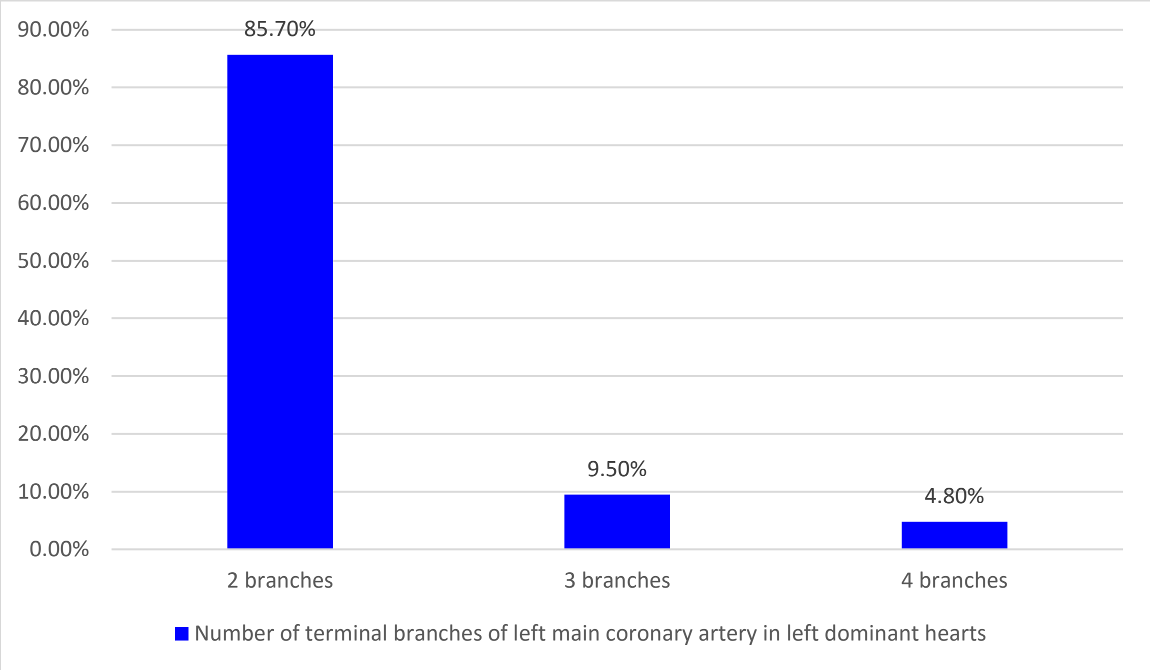
Graph 27: Terminal branching pattern of left main coronary artery in dissected adult cadaveric heart specimens (n = 50)



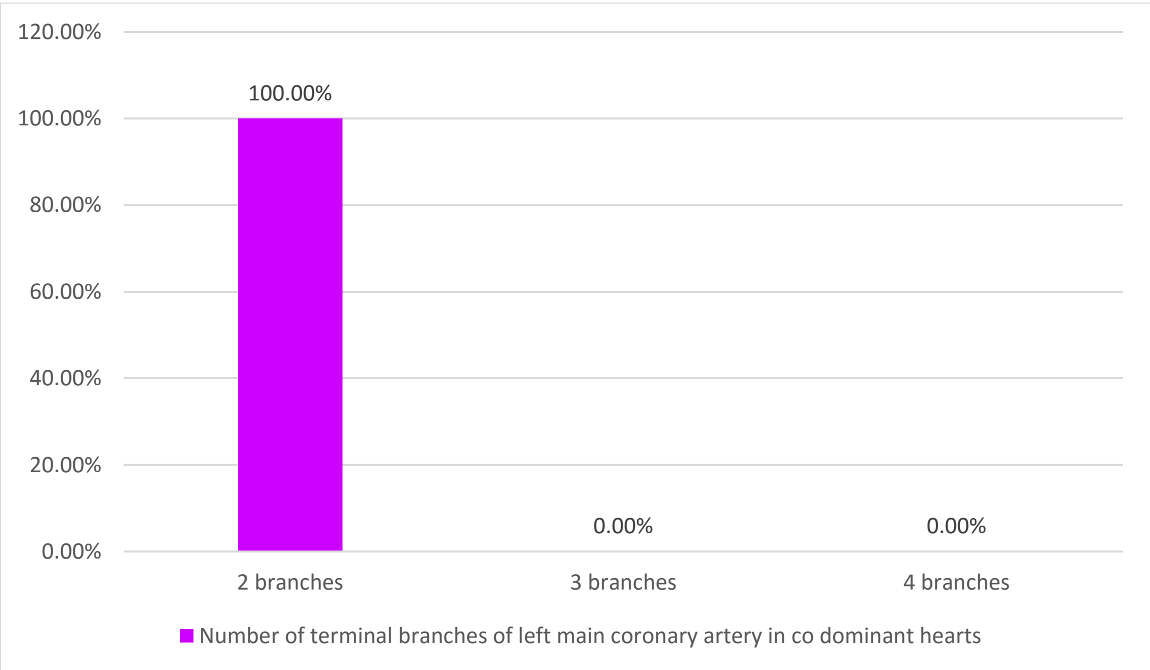
Graph 28: Terminal branching pattern of left main coronary artery in right dominant dissected adult cadaveric heart specimens (n = 24)



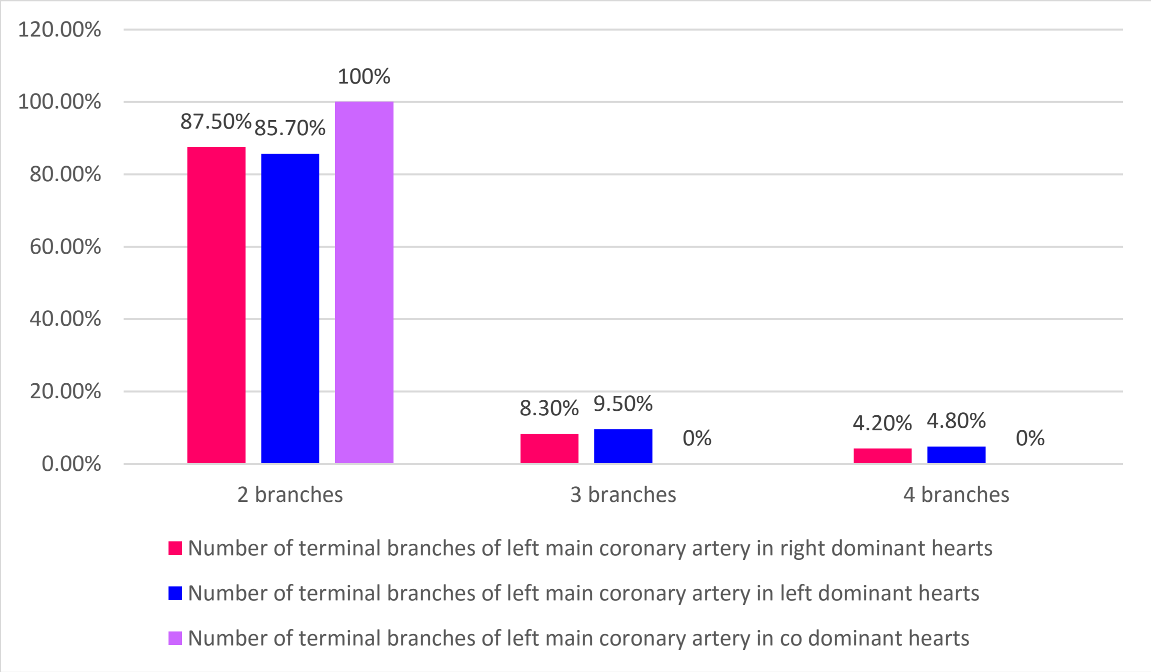
Graph 29: Terminal branching pattern of left main coronary artery in left dominant dissected adult cadaveric heart specimens (n = 21)



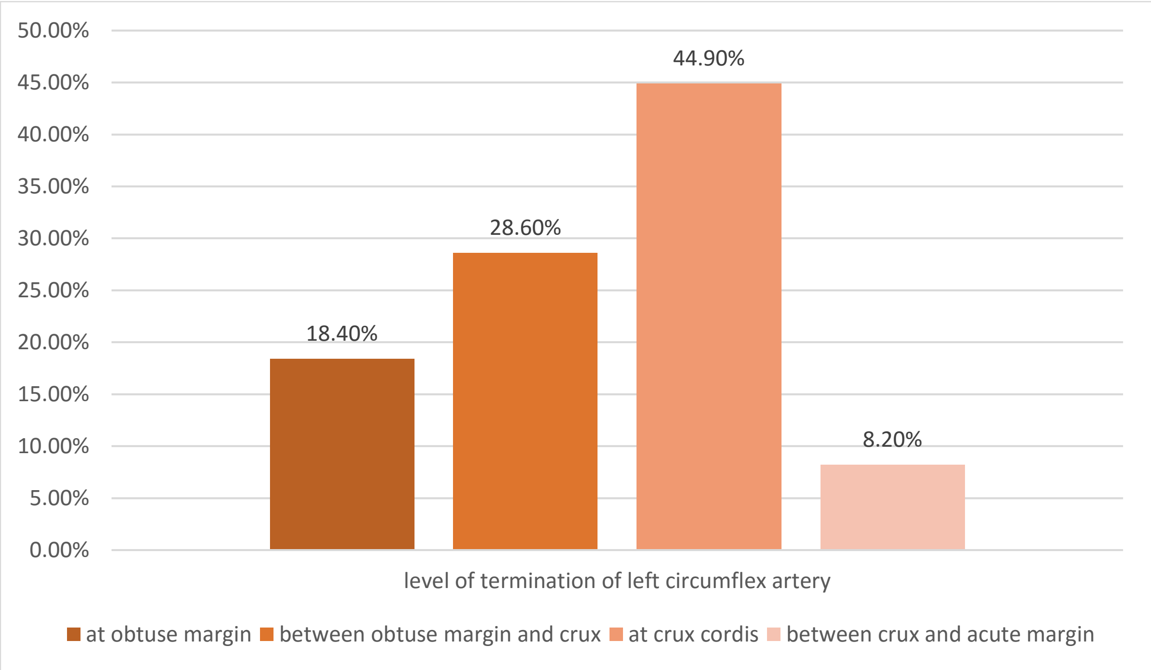
Graph 30: Terminal branching pattern of left main coronary artery in co dominant dissected foetal cadaveric heart specimens (n = 4)



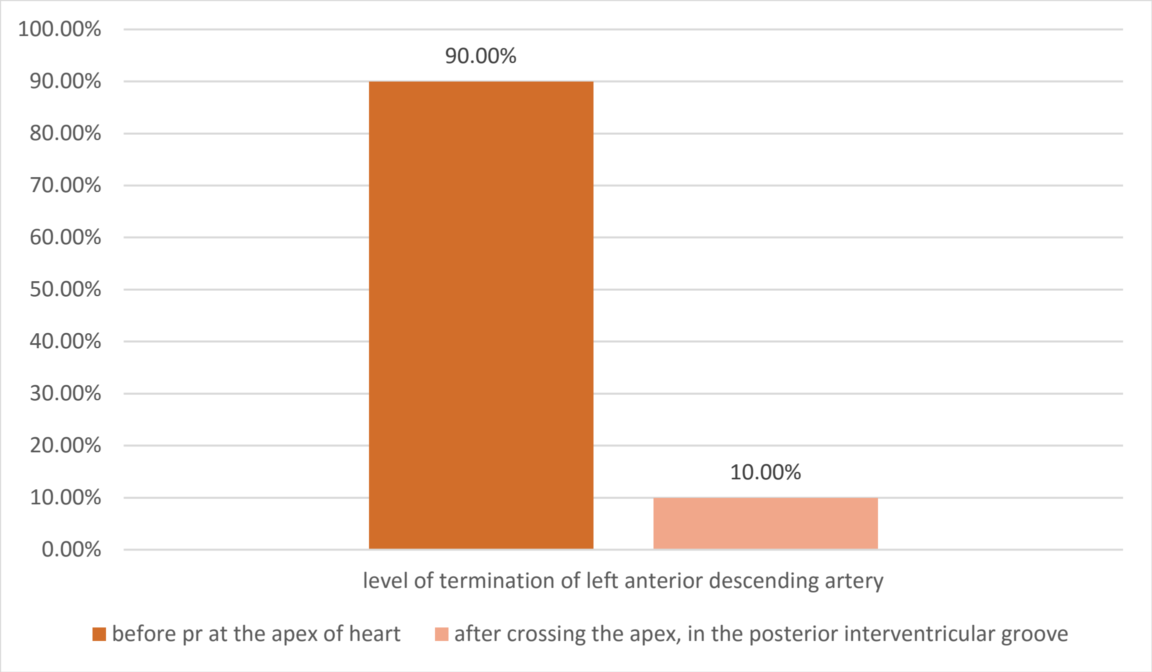
Graph 31: Comparison between right, left and co dominant hearts of dissected foetal cadaveric heart specimens in terminal branching pattern of left main coronary artery



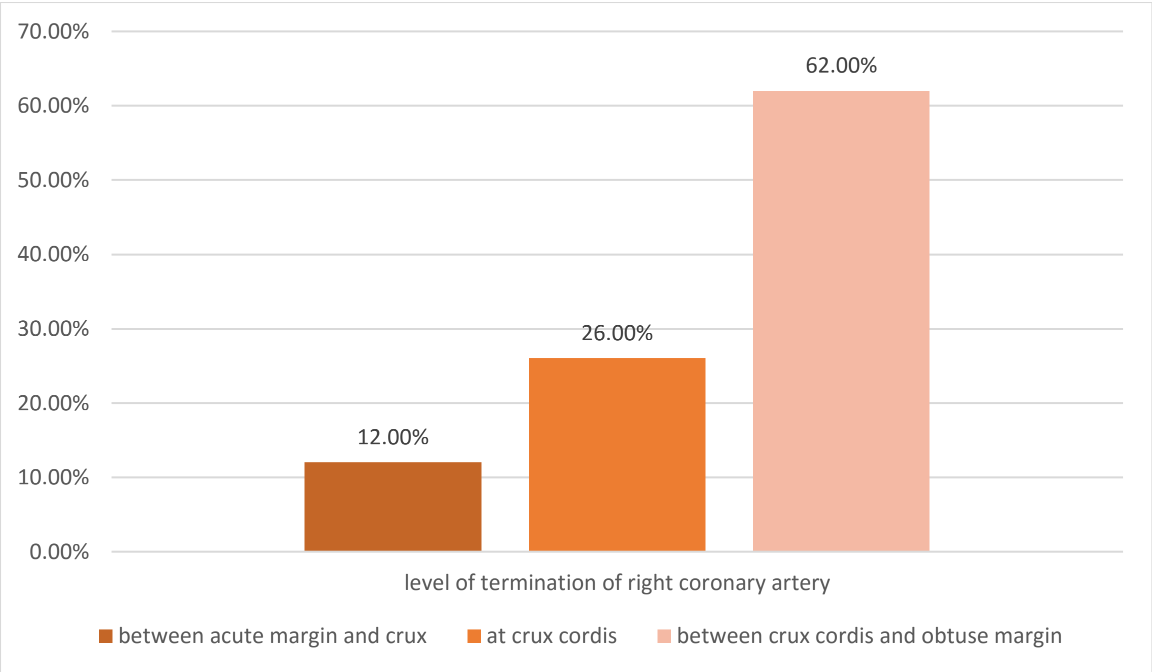
Graph 32: Level of termination of left circumflex artery in dissected adult cadaveric heart specimens



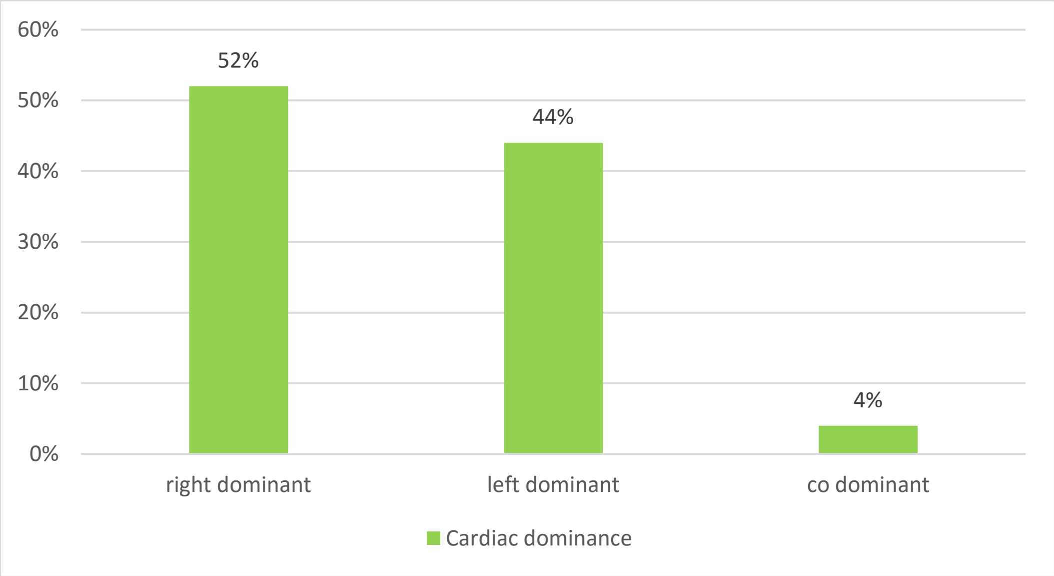
Graph 33: Level of termination of left anterior descending artery in dissected adult cadaveric heart specimens



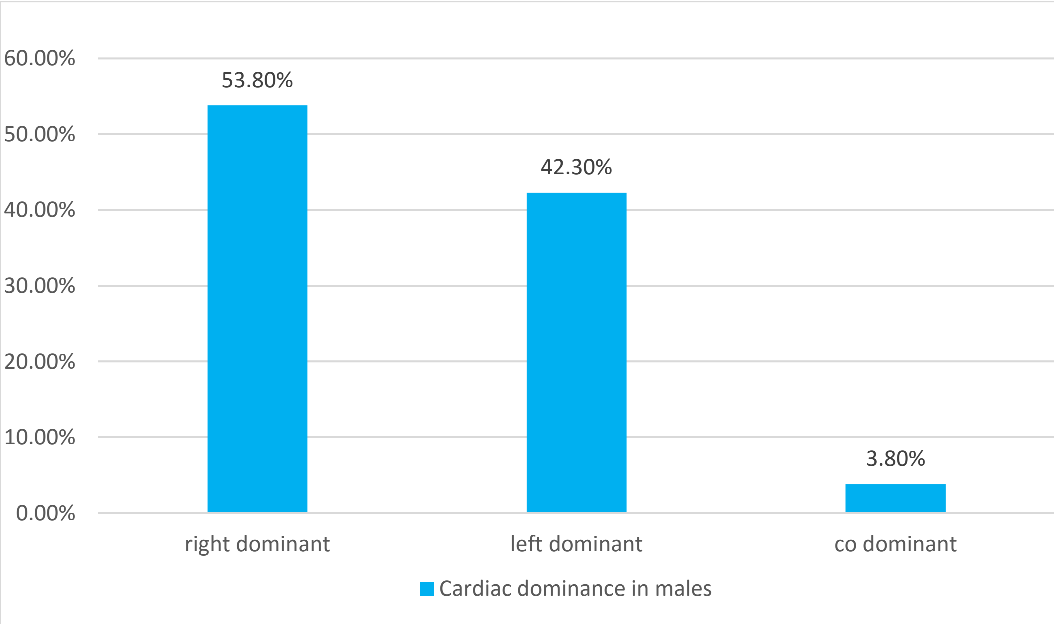
Graph 34: Level of termination of right coronary artery in dissected adult cadaveric heart specimens



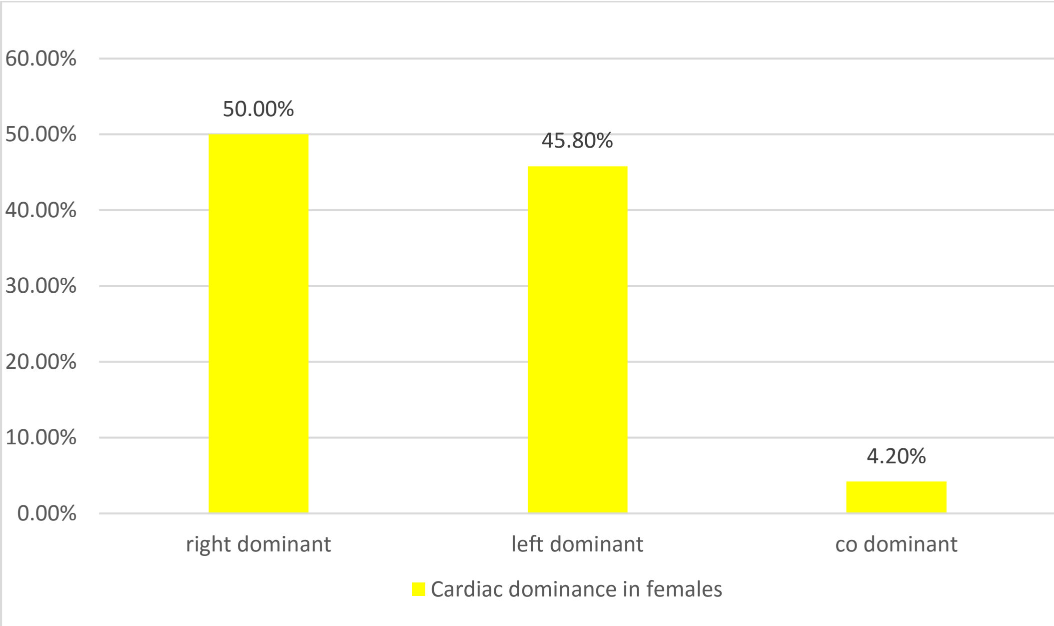
Graph 35: Cardiac dominance percentage in coronary computer tomography angiograms (n = 50)



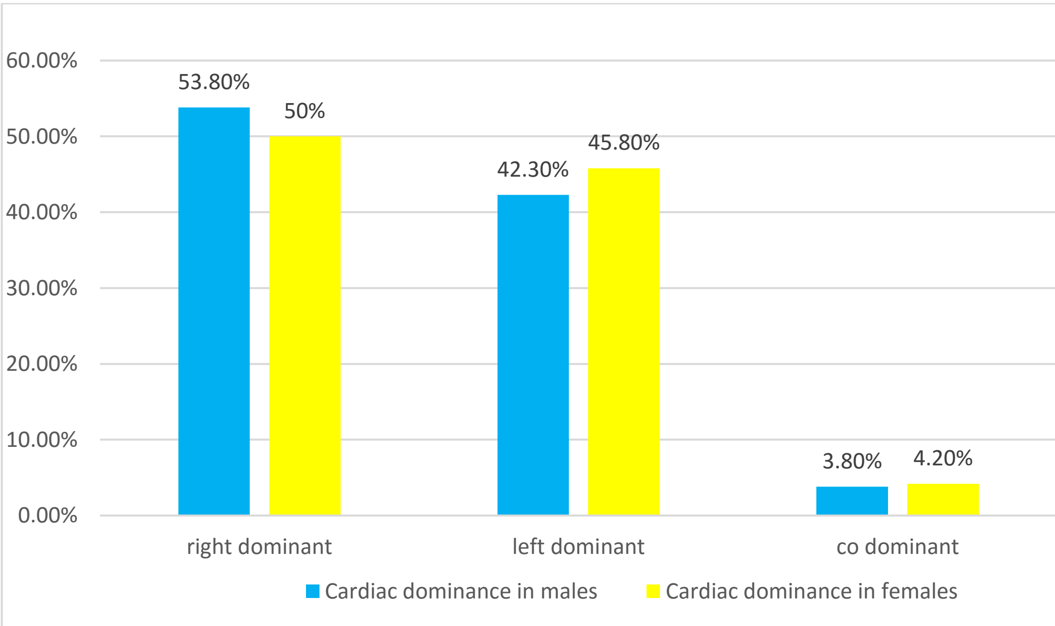
Graph 36: Dominance percentage in coronary computer tomography angiograms of male patients (n = 26)



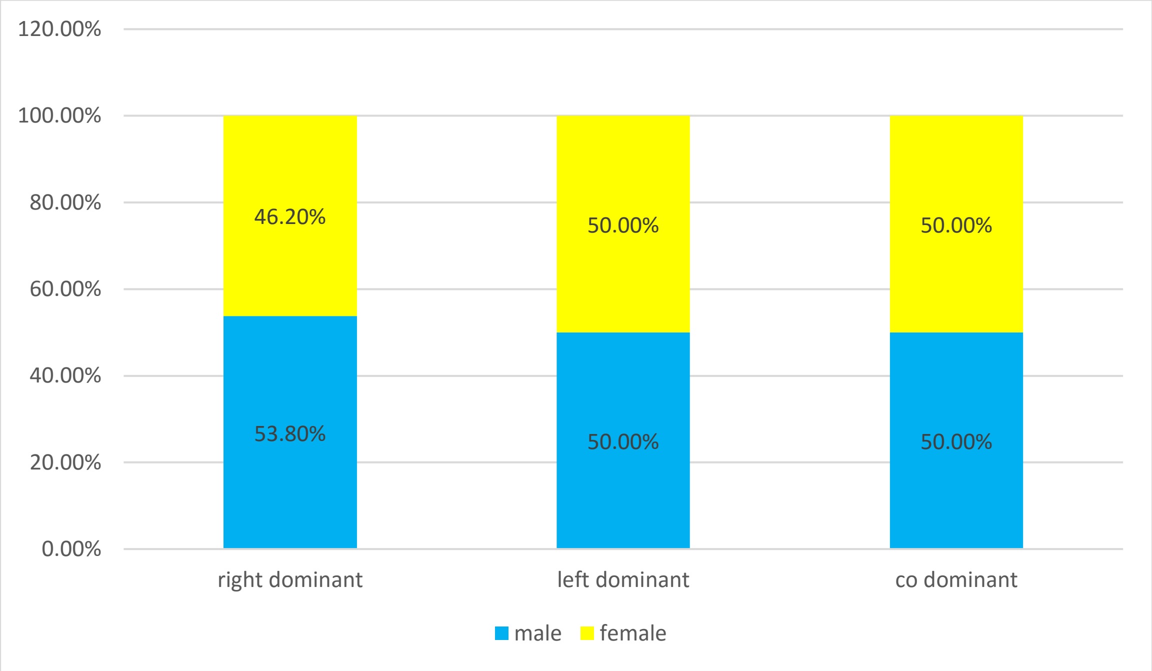
Graph 37: Dominance percentage in coronary computer tomography angiograms of female patients (n = 24)



Graph 38: Comparison of Dominance percentage in between male and female patients in coronary computer tomography angiograms (male. n = 26; female, n = 24)

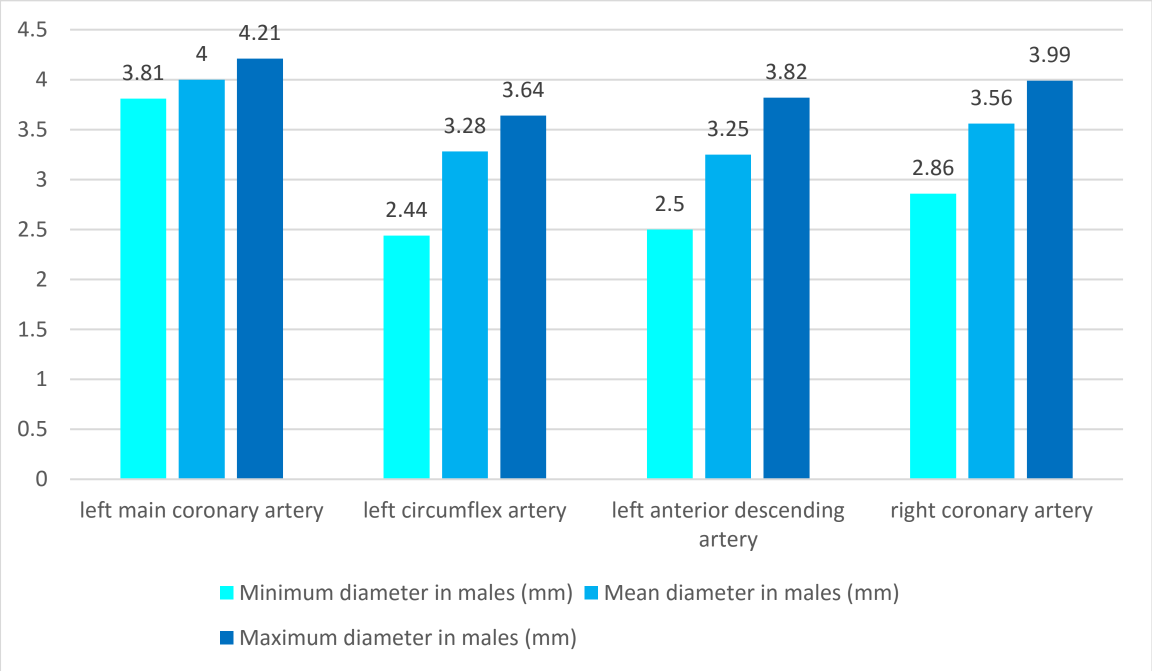


Graph 39: Percentage of males and females in right, left and co-dominant hearts in coronary computer tomography angiograms (male. n = 26; female, n = 24)



Graph 40: The mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms

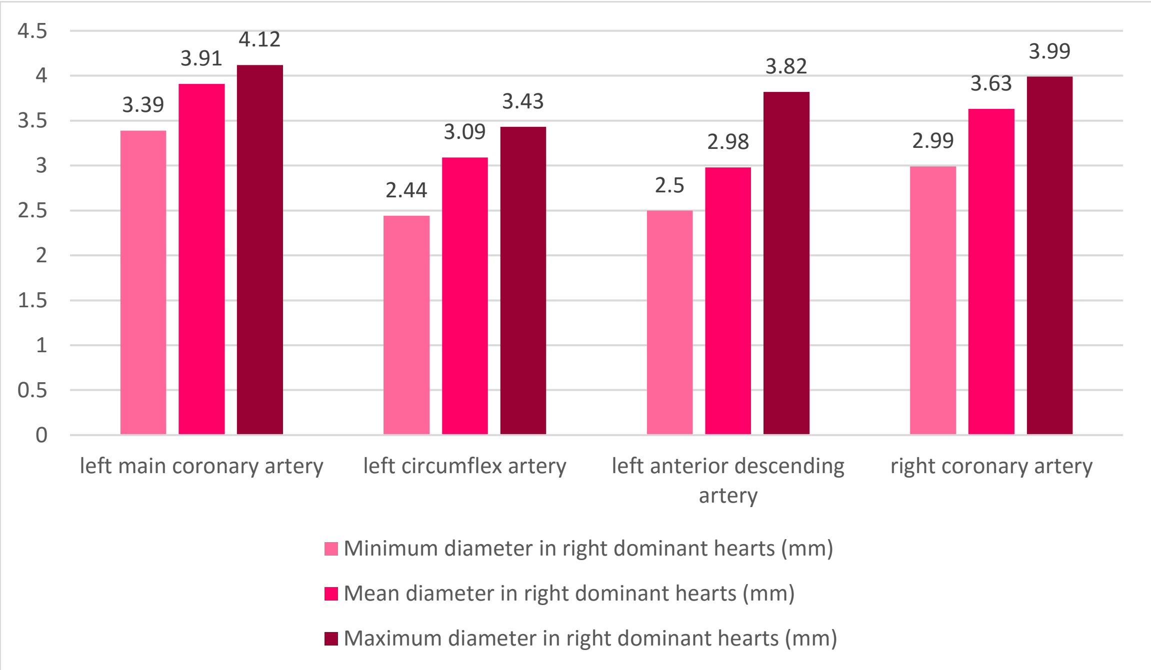
Graph 41: The mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of male patients



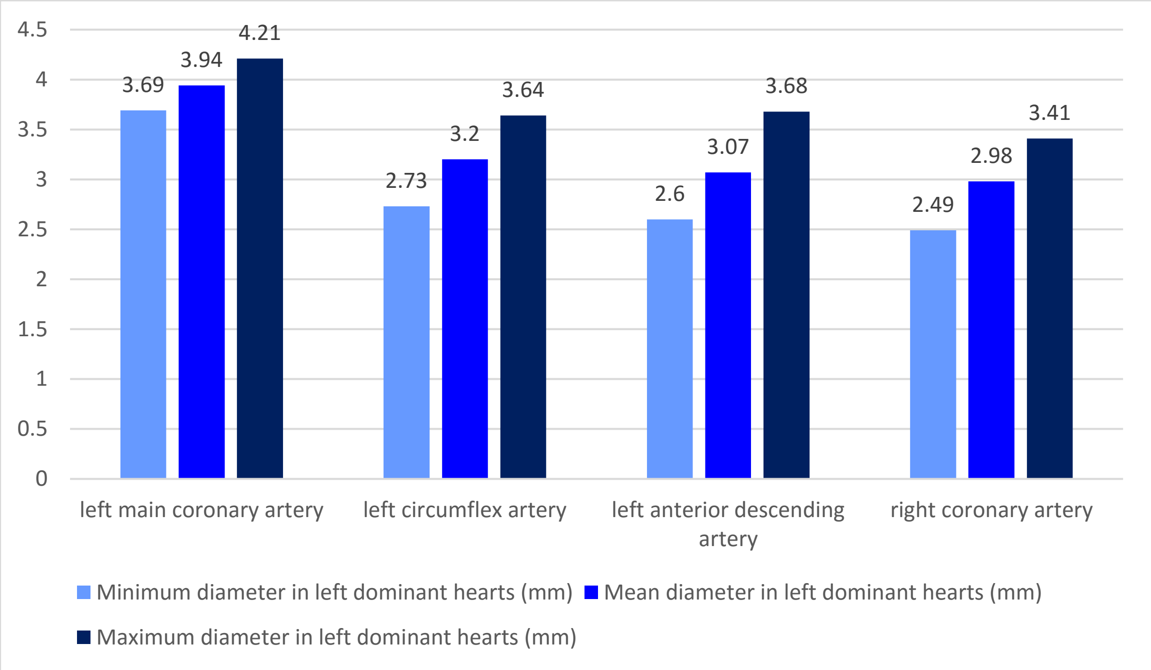
Graph 42: The mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of female patients

Graph 43: Comparison of mean diameters of coronary arteries in male and female patients in coronary computer tomography angiograms

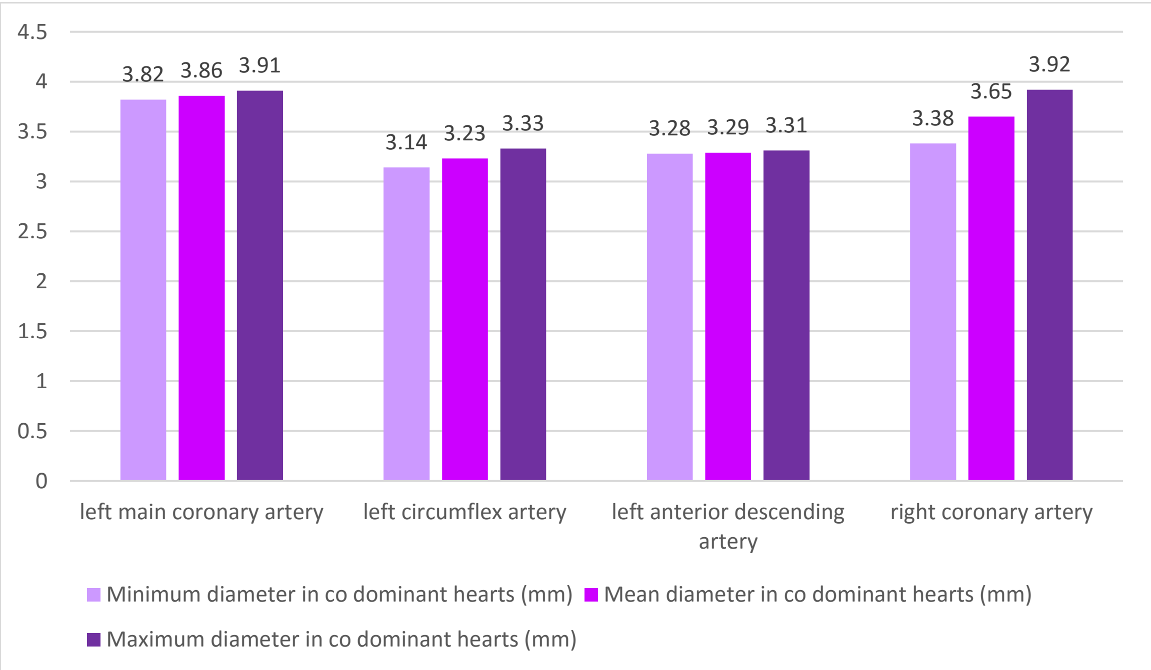
Graph 44: The mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of patients with right dominance



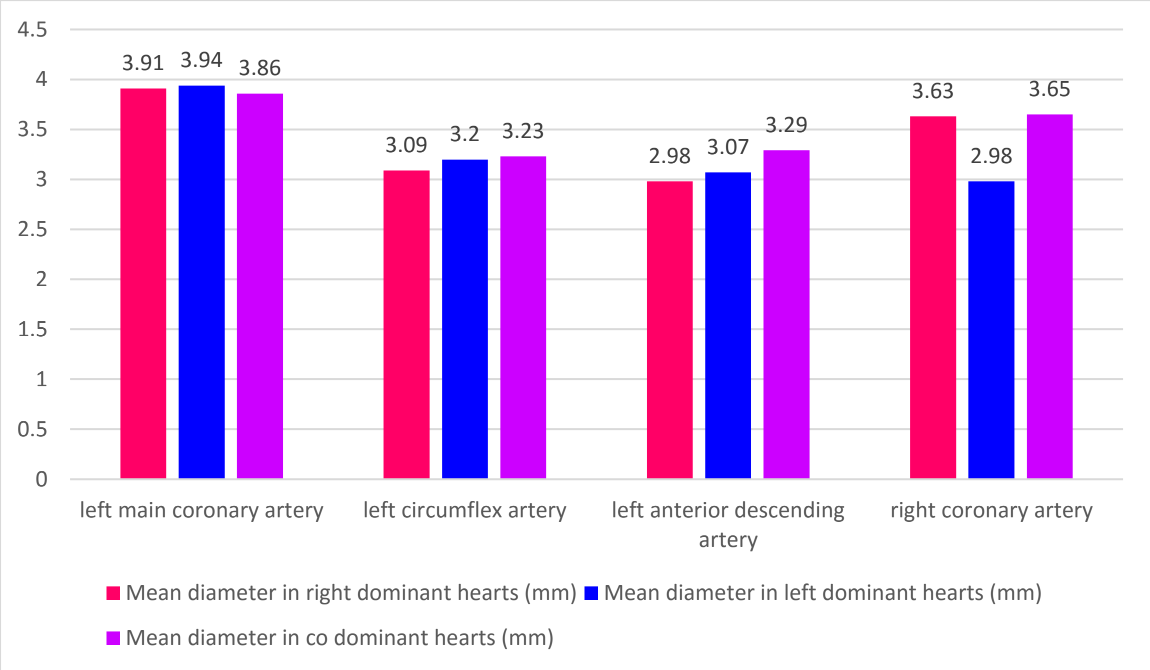
<u>Graph 45: The mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of patients with left dominance</u>



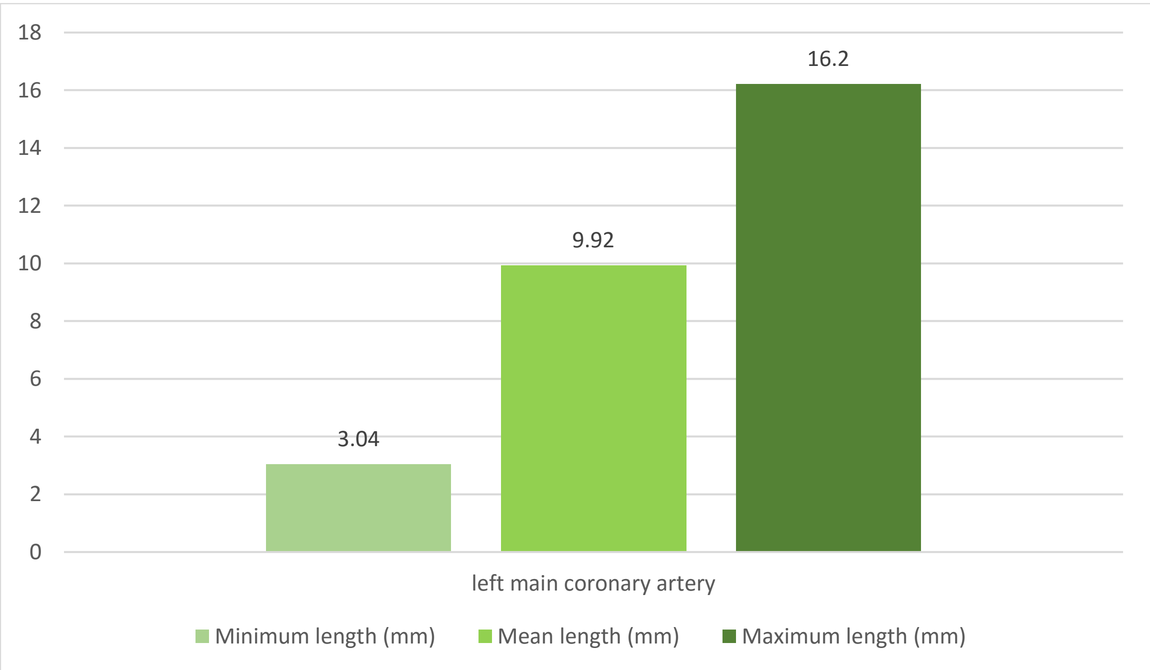
<u>Graph 46: The mean, minimum and maximum diameter of coronary arteries in coronary computer tomography angiograms of patients with balanced dominance</u>



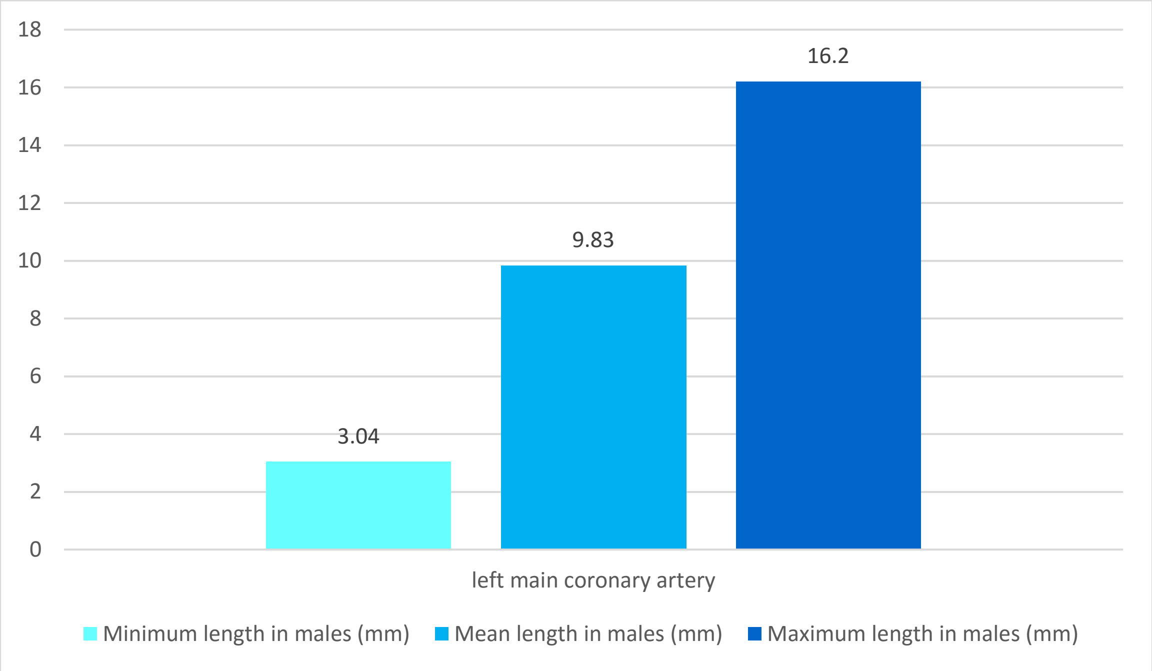
<u>Graph 47: Comparison of mean diameters of coronary arteries in coronary computer tomography angiograms between patients with right, left and balanced dominance</u>



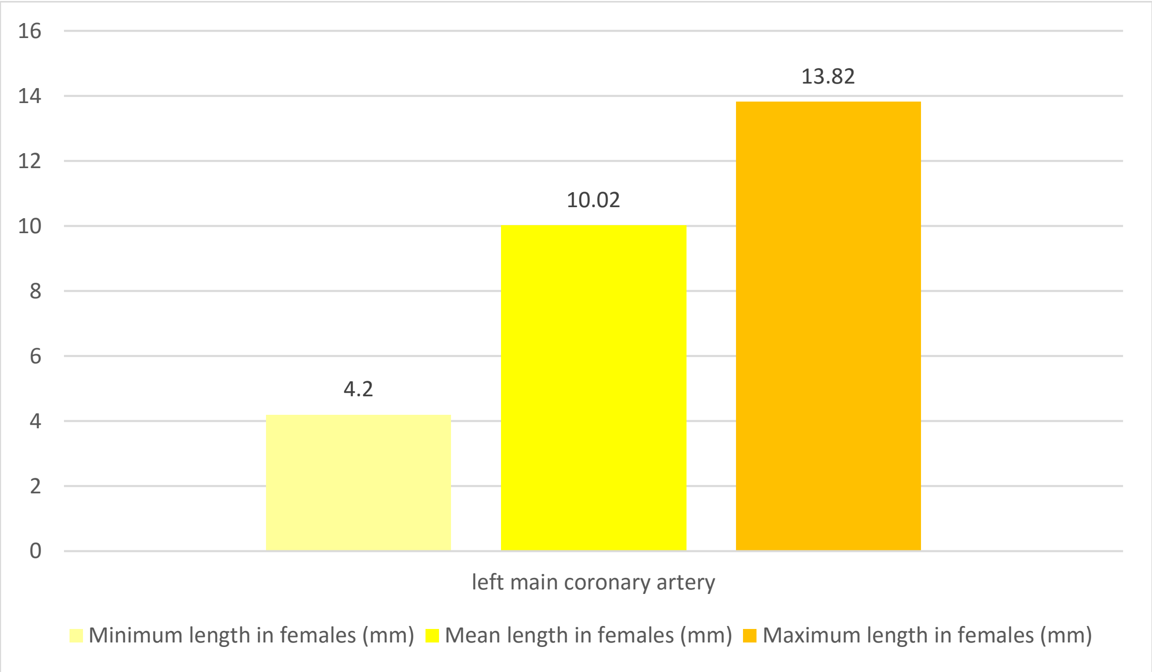
<u>Graph 48: Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms</u>



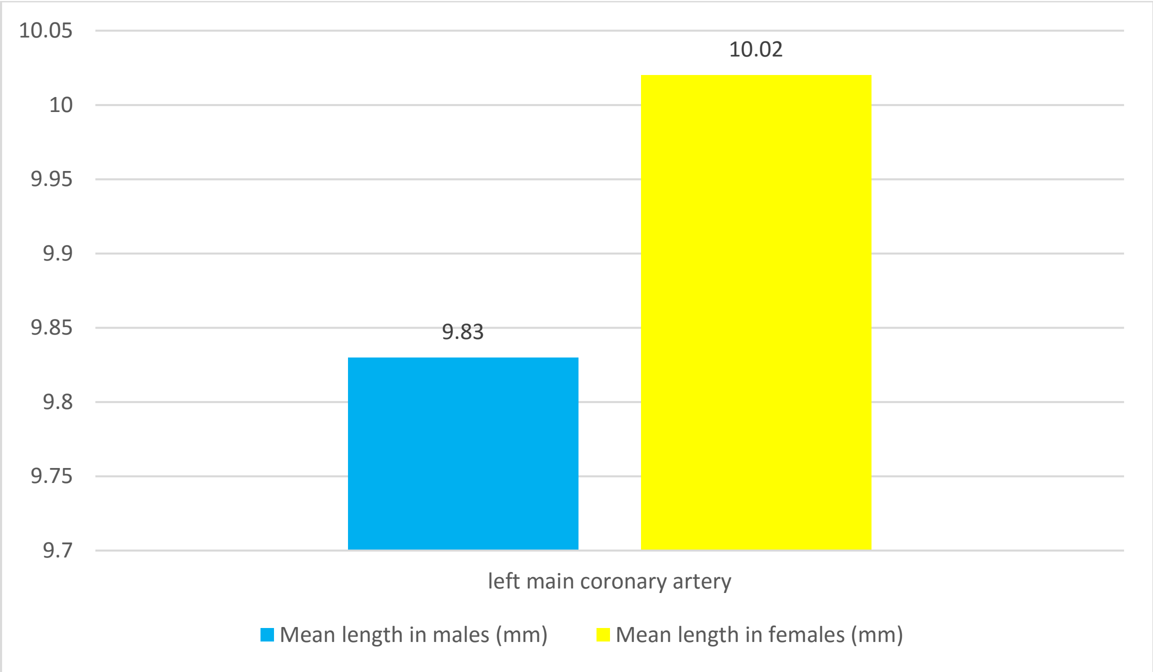
Graph 49: Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of male patients



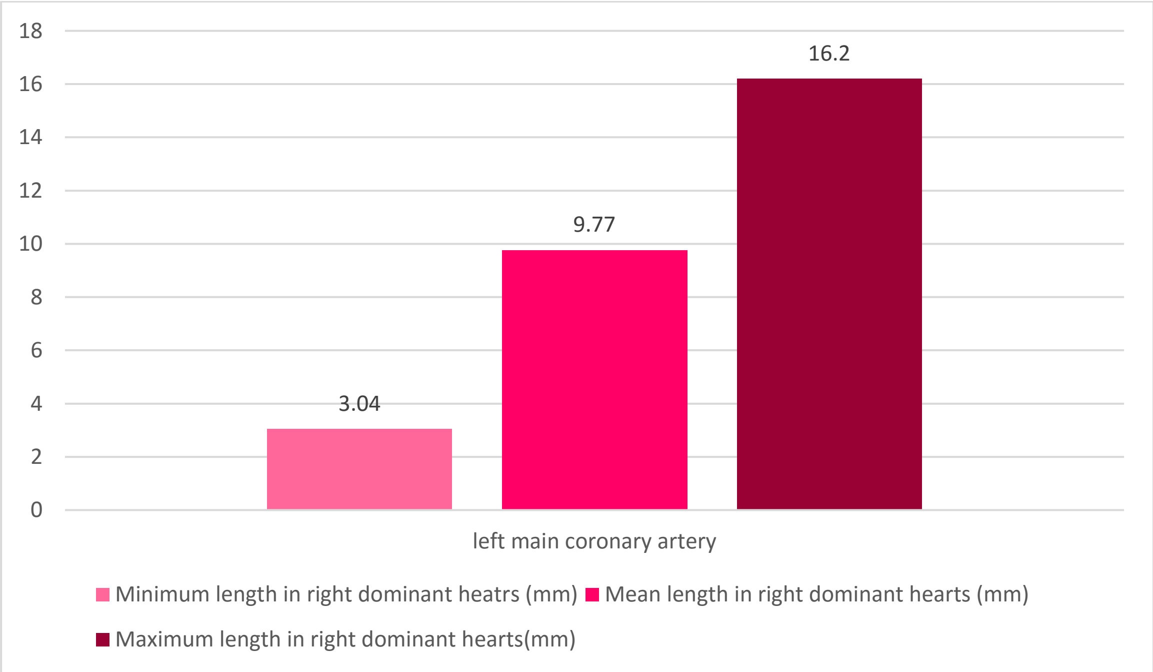
Graph 50: Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of female patients



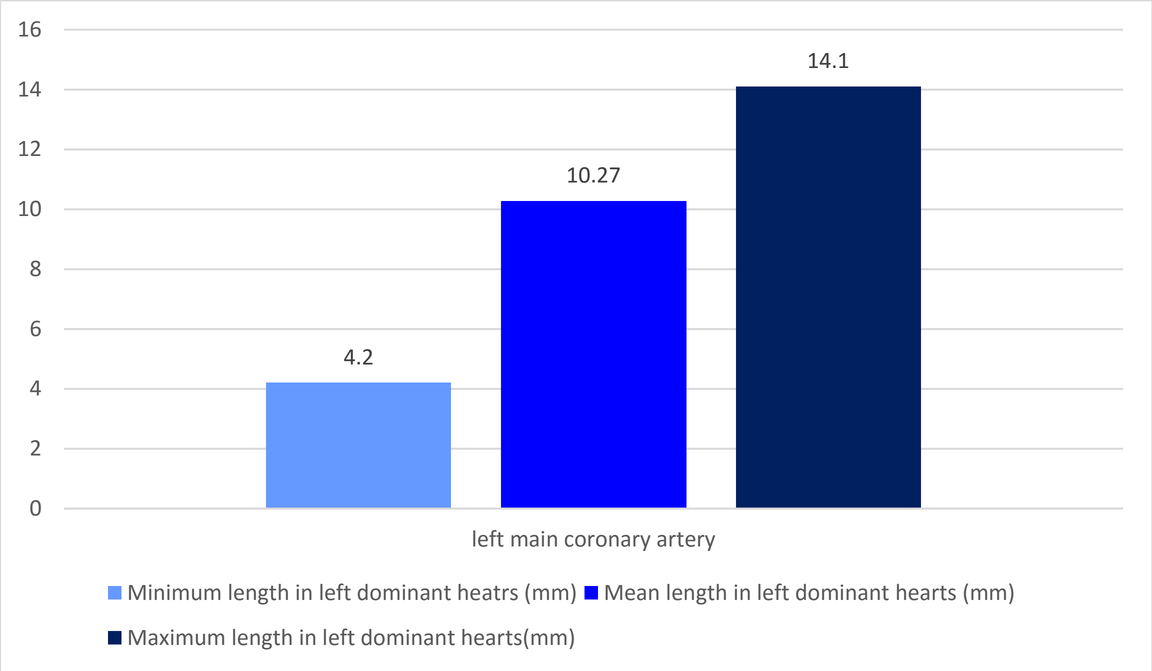
Graph 51: Comparison of mean length of left main coronary artery between male and female patients in coronary computer tomography angiograms



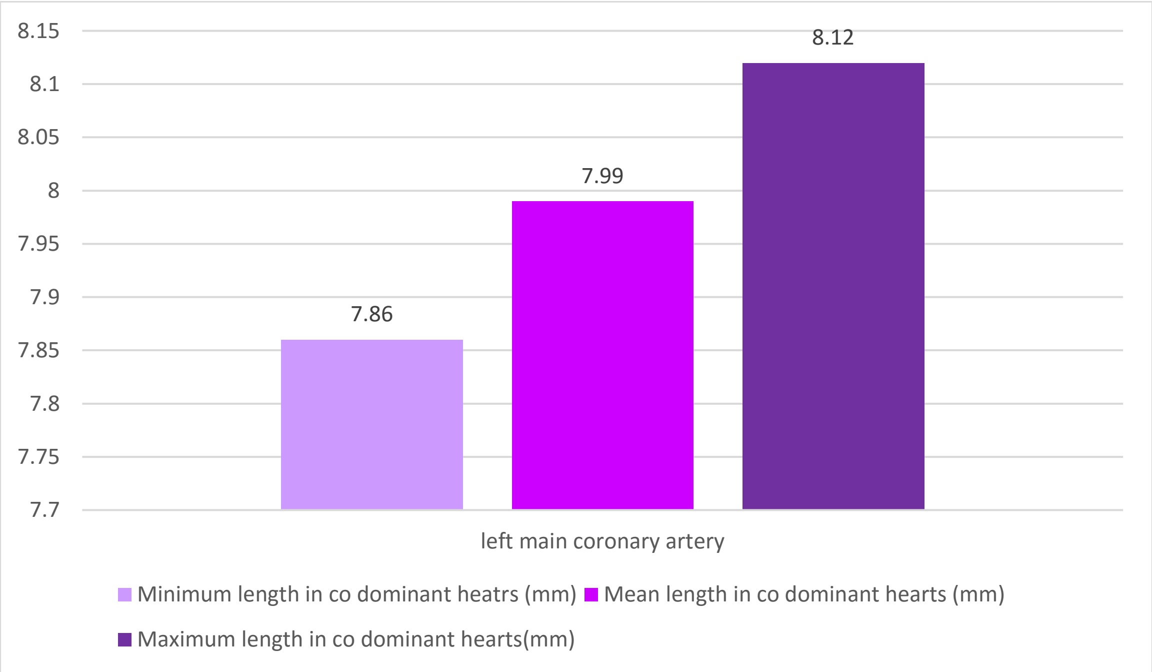
Graph 52: Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of patients with right dominance



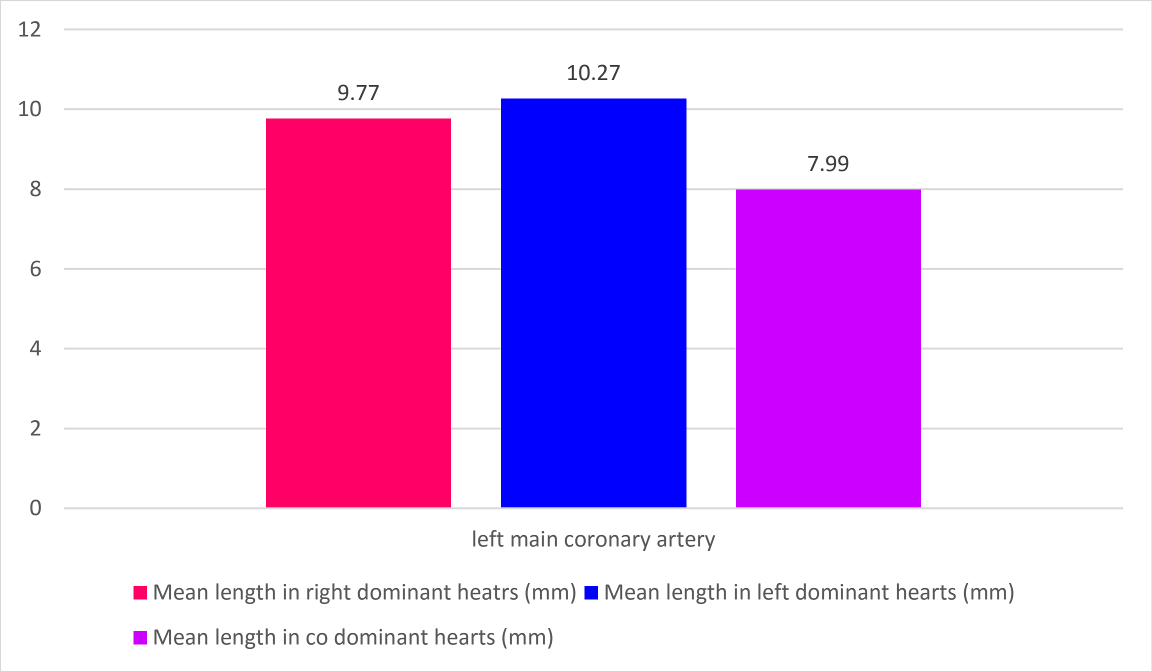
Graph 53: Mean, minimum and maximum length of left main coronary artery in coronary computer tomography angiograms of patients with left dominance



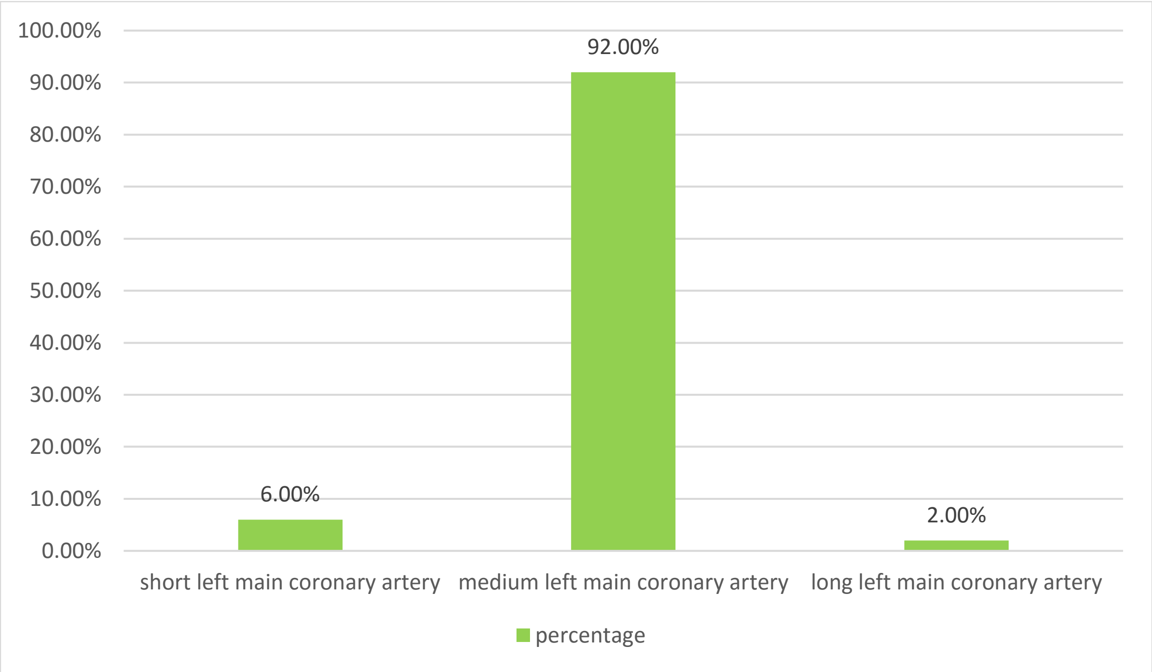
Graph 54: Mean, minimum and maximum length of left main coronary artery in in coronary computer tomography angiograms of patients with balanced dominance



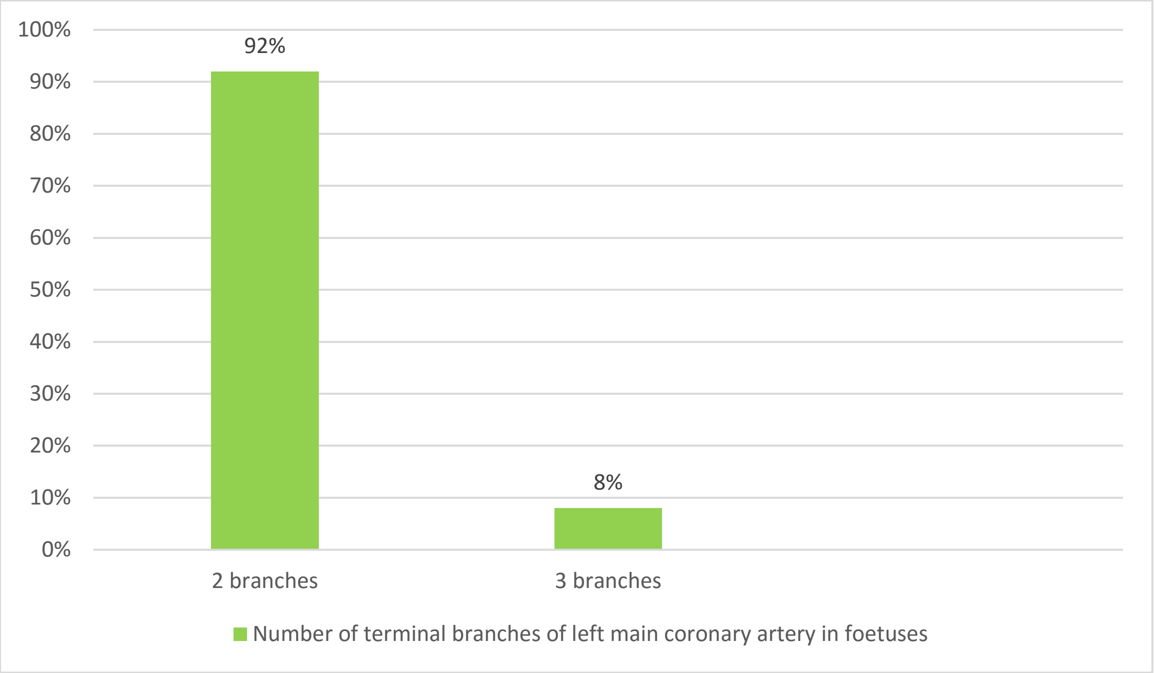
Graph 55: Comparison of mean diameters of left main coronary artery in coronary computer tomography angiograms between patients with right, left and balanced dominance



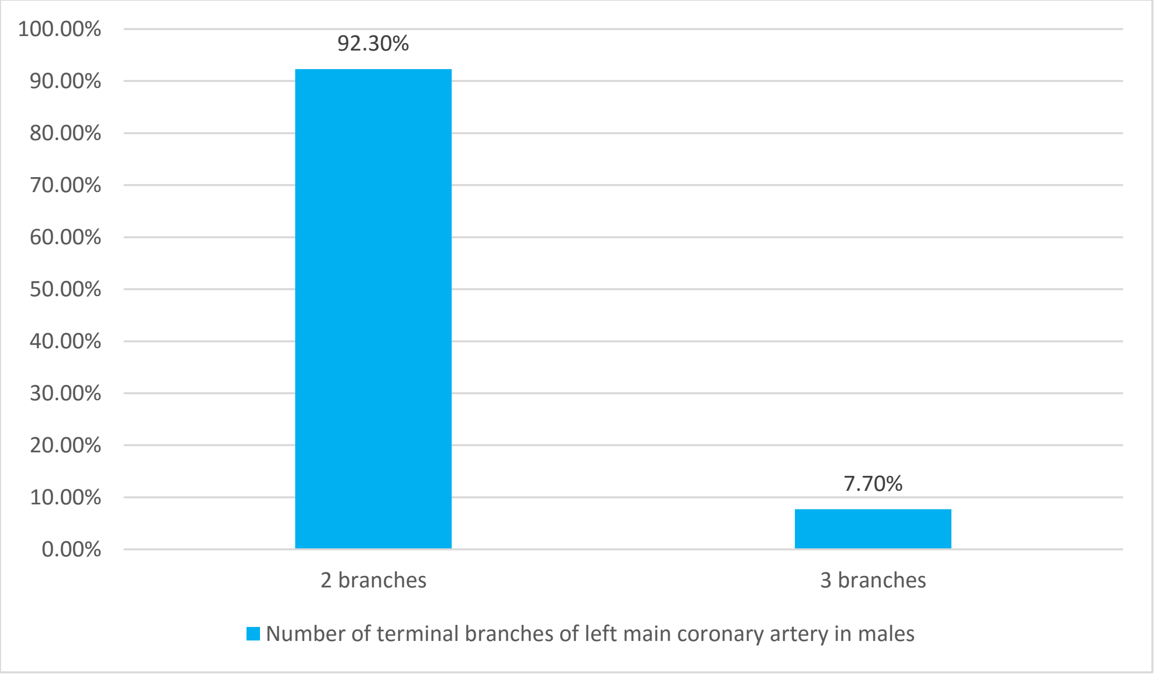
Graph 56: Percentages of short, medium and long left main coronary artery in dissected adult cadaveric heart specimens



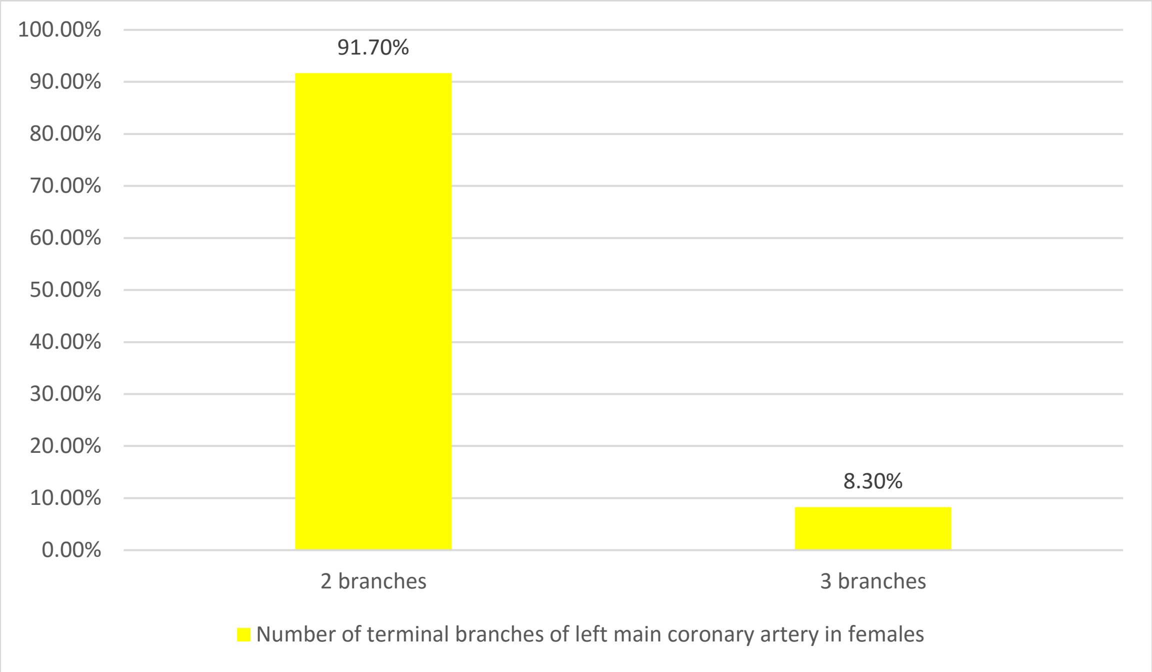
Graph 57: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms (n = 50)



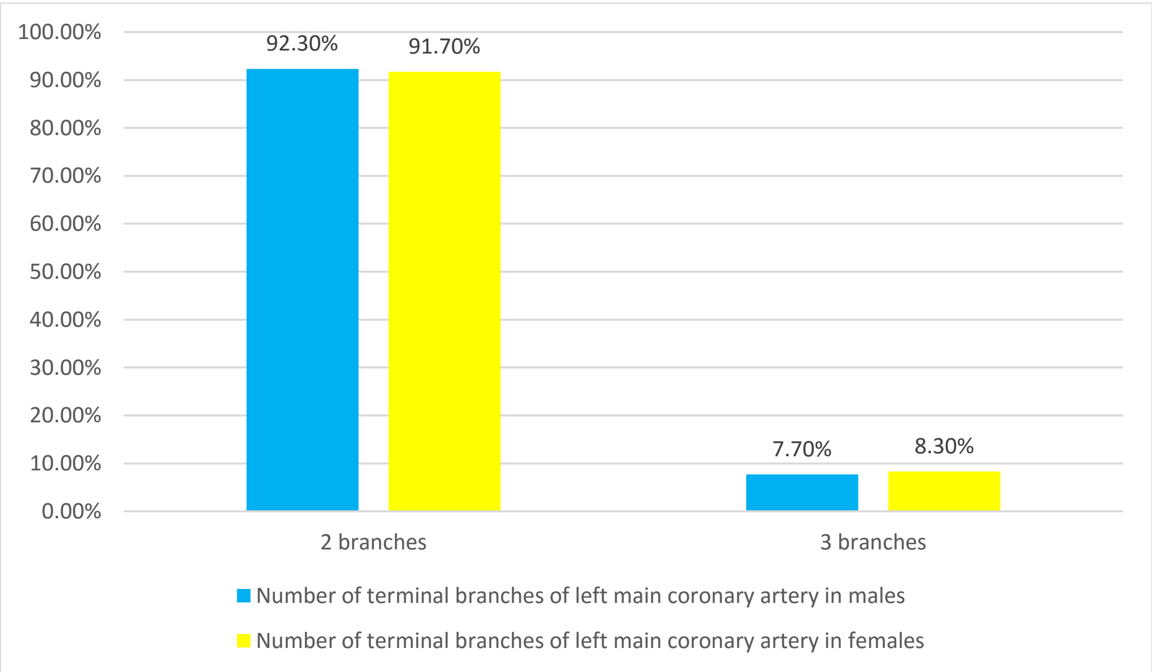
Graph 58: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of male patients (n = 26)



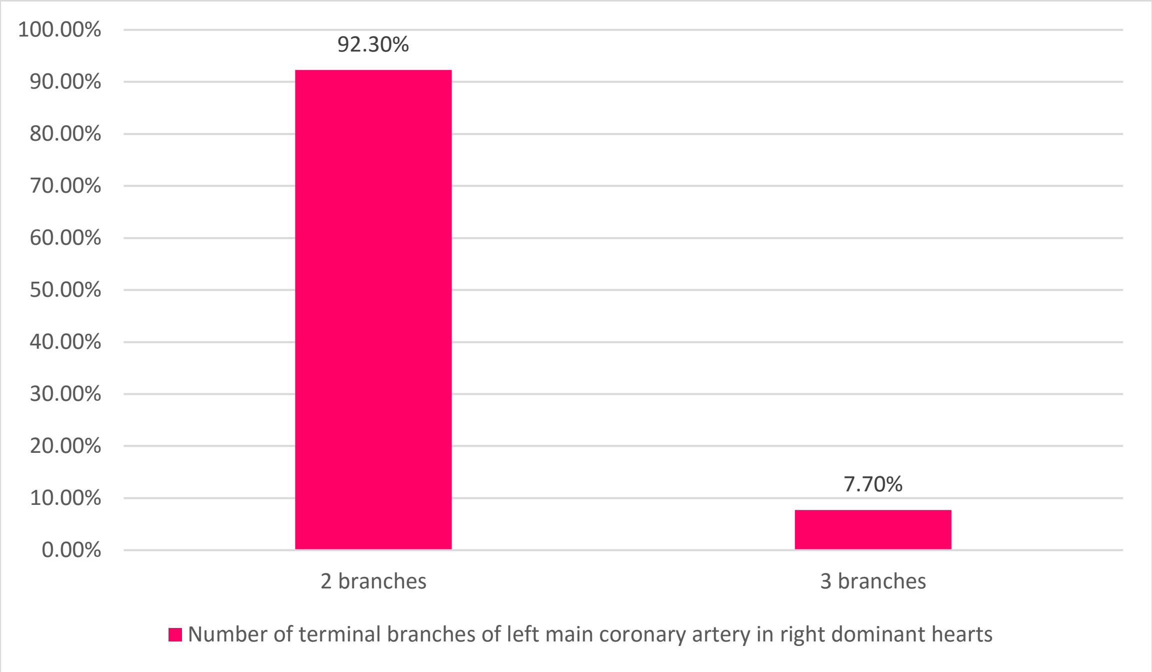
Graph 59: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of female patients (n = 24)



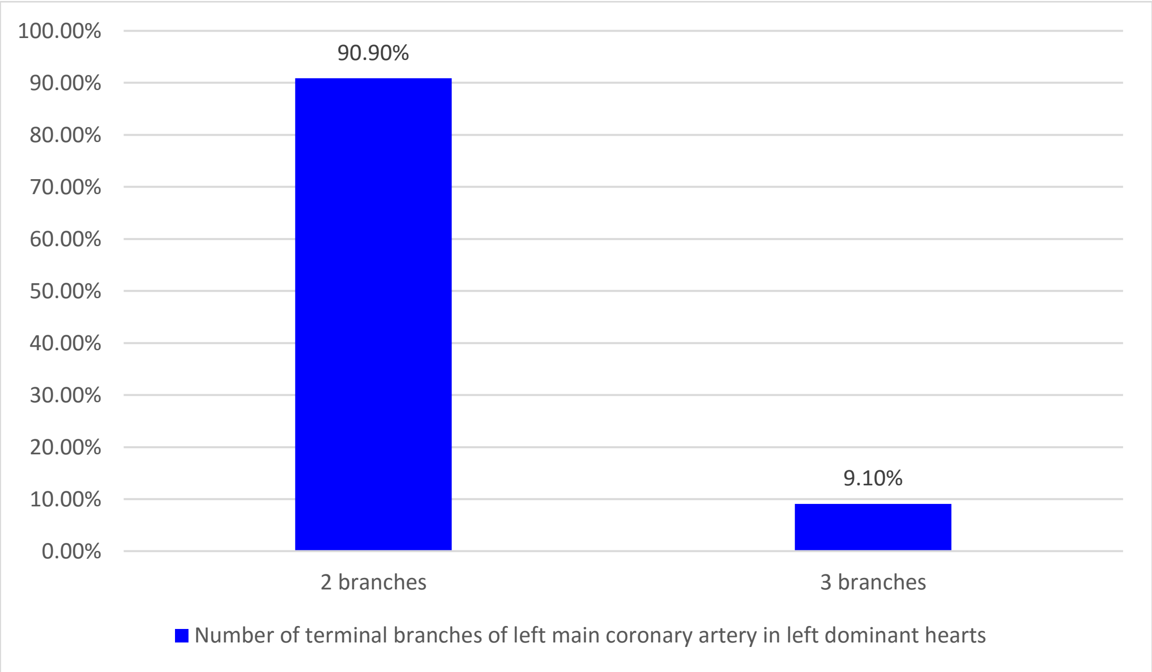
Graph 60: Comparison between male and female patients of coronary computer tomography angiograms in terminal branching pattern of left main coronary artery



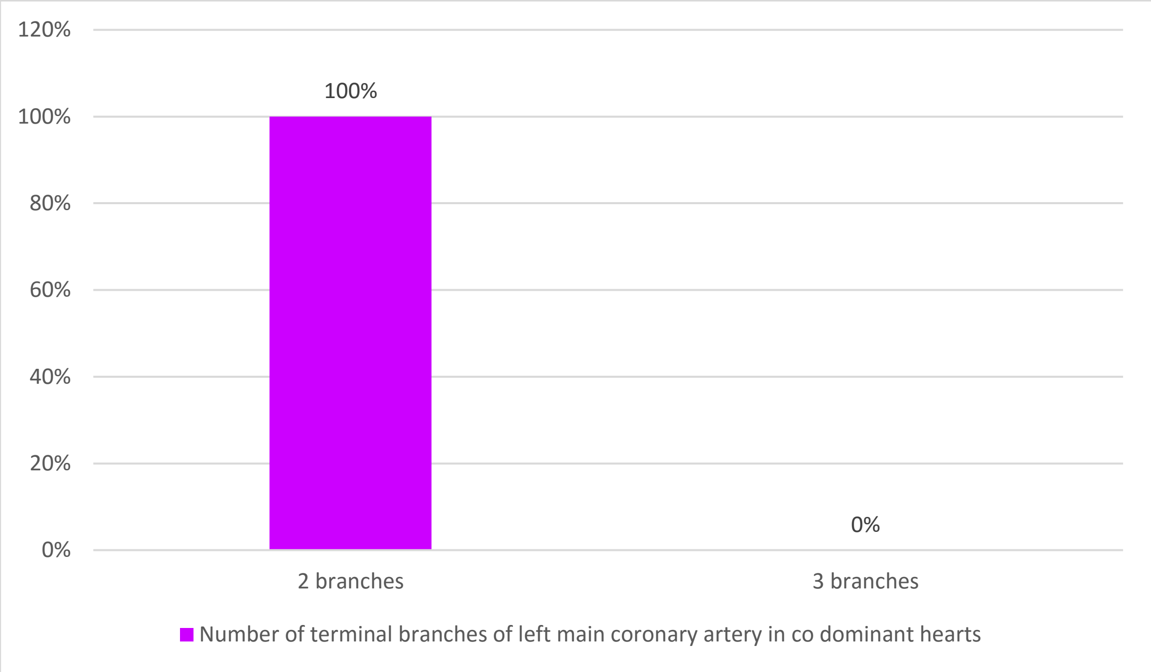
Graph 61: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of patients with right dominance (n = 26)



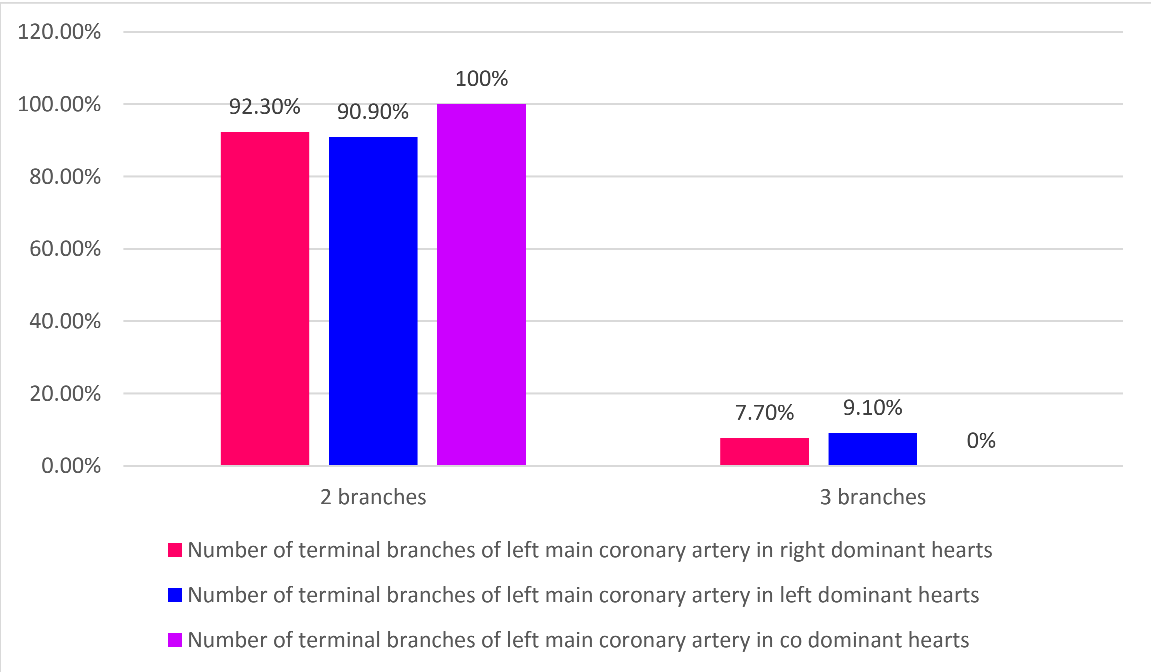
Graph 62: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of patients with left dominance (n = 22)



Graph 63: Terminal branching pattern of left main coronary artery in coronary computer tomography angiograms of patients with balanced dominance (n = 2)



Graph 64: Comparison of terminal branching pattern of left main coronary artery between right, left and co dominant hearts of patients in coronary computer tomography angiograms



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ANNEXURES

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Annexure 1: Data collection form (foetal cadaveric heart)

Dissected foetal cadaveric heart specimens – Data collection *(page 1 of 2)*

S.no	sex	g age	domi	bran	my bri
1	Male	236	Left	3	Absent
2	Male	141	Left	2	Absent
3	Male	140	Right	2	Absent
4	Male	143	Left	2	Absent
5	Male	166	Right	2	Absent
6	Male	126	Right	2	Absent
7	Male	126	Right	2	Absent
8	Male	126	Right	4	Absent
9	Male	238	Left	2	Absent
10	Male	177	Left	2	Absent
11	Male	175	Co	2	Absent
12	Male	149	Left	3	Absent
13	Male	188	Left	2	Absent
14	Male	182	Right	2	Absent
15	Male	173	Right	2	Absent
16	Male	142	Left	2	Absent
17	Male	210	Right	2	Absent
18	Male	202	Right	2	Absent
19	Male	196	Left	2	Absent
20	Male	199	Right	2	Absent
21	Male	144	Left	2	Absent
22	Male	170	Right	2	Absent
23	Male	172	Left	2	Absent
24	Male	180	Co	2	Absent
25	Male	147	Right	3	Absent

Dissected foetal cadaveric heart specimens – Data collection *(page 2 of 2)*

S.no	**sex**	**g age**	**domi**	**bran**	**my bri**
26	Male	150	Right	2	Absent
27	Male	206	Left	2	Present
28	Male	172	Left	3	Absent
29	Male	133	Left	2	Absent
30	Male	153	Right	2	Absent
31	Female	128	Right	2	Absent
32	Female	133	Right	2	Absent
33	Female	132	Left	2	Absent
34	Female	143	Left	2	Absent
35	Female	206	Left	2	Absent
36	Female	193	Left	2	Absent
37	Female	207	Right	3	Absent
38	Female	130	Right	4	Absent
39	Female	133	Right	2	Absent
40	Female	140	Left	2	Absent
41	Female	142	Co	2	Absent
42	Female	211	Left	2	Absent
43	Female	201	Right	2	Absent
44	Female	130	Left	2	Absent
45	Female	212	Right	2	Absent
46	Female	215	Left	3	Absent
47	Female	204	Right	2	Absent
48	Female	209	Right	2	Absent
49	Female	207	Left	2	Absent
50	Female	149	Right	2	Absent

S.no – serial number; sex – sex of the foetus; g age – gestational age of the foetus in days; domi – cardiac dominance; bran – number of terminal branches of left main coronary artery; my bri -myocardial bridges

Annexure 2: Data collection form (adult cadaveric hearts)

Dissected adult cadaveric heart specimens – data collection *(page 1 of 2)*

N	Ost	domi	r dia	r ext	lm dia	lm l	branc	la dia	la ext	lx dia	lx ext	my br
1	2	co	2.92	cx	3.04	9.21	2	2.03	apex	2.83	cxab	absent
2	2	co	2.56	cxob	3.12	10.32	2	2.91	apex	2.60	cx	absent
3	2	co	2.81	cxob	3.21	8.89	2	2.66	apex	2.77	cx	absent
4	2	co	2.62	cxob	3.96	8.21	2	2.88	apex	2.70	cx	absent
5	2	right	3.62	cx				2.68	apex			absent
6	2	right	3.43	cxob	3.12	3.24	2	2.69	apex	2.96	ob	absent
7	2	right	3.61	cxob	3.24	11.02	2	2.08	apex	3.06	ob	absent
8	2	right	3.29	cxob	3.02	8.94	3	2.21	apex	2.82	ob	absent
9	2	right	3.33	cxob	2.95	9.63	2	2.92	piv	2.90	obcx	present
10	2	right	3.46	cxob	2.69	16.12	2	2.84	apex	3.05	obcx	absent
11	2	right	3.80	cx	2.88	9.86	2	2.28	apex	3.10	obcx	absent
12	2	right	3.60	cxob	2.84	9.81	2	2.92	apex	2.98	obcx	absent
13	2	right	3.31	cxob	3.41	4.12	2	2.81	piv	2.69	ob	absent
14	2	right	3.52	cxob	3.68	10.31	4	2.24	apex	2.92	obcx	absent
15	2	right	3.71	cx	3.99	10.42	2	2.60	apex	3.06	cx	absent
16	2	right	3.80	cxob	3.71	11.34	2	2.41	apex	3.11	obcx	absent
17	2	right	3.39	cxob	3.12	8.68	2	2.61	apex	2.99	ob	absent
18	2	right	3.42	cxob	3.80	9.04	2	2.48	apex	2.86	ob	absent
19	2	right	3.62	cxob	3.12	9.33	2	2.69	apex	2.79	ob	absent
20	2	right	3.66	cx	3.81	9.86	2	2.71	apex	2.90	obcx	absent
21	2	right	3.71	cxob	3.24	7.68	2	2.28	apex	2.85	obcx	absent
22	2	right	3.41	cxob	3.61	7.32	2	2.89	apex	2.89	obcx	absent
23	2	right	3.28	cxob	3.82	8.11	2	2.09	piv	2.75	obcx	absent
24	2	right	3.19	cxob	2.99	8.69	3	2.64	apex	2.60	ob	absent
25	2	right	3.46	cxob	3.29	11.32	2	2.84	apex	3.03	ob	absent
26	2	right	3.81	cxob	3.08	7.46	2	2.09	apex	3.05	obcx	absent
27	2	right	3.39	cxob	3.21	7.31	2	2.88	apex	2.85	obcx	absent
28	2	right	3.61	cx	3.82	11.82	2	2.29	apex	2.91	obcx	absent

Dissected adult cadaveric heart specimens – data collection *(page 2 of 2)*

N	Ost	domi	r dia	r ext	lm dia	lm l	branc	la dia	la ext	lx dia	lx ext	my br
29	2	right	3.78	cxob	3.14	3.81	2	2.45	apex	3.13	obcx	absent
30	1	left	2.84	abcx	3.18	8.63	2	2.66	apex	3.62	cxab	absent
31	2	left	2.89	cx	3.10	8.91	2	2.52	apex	3.35	cx	absent
32	2	left	2.76	cx	3.20	7.88	2	2.81	apex	2.99	cx	absent
33	2	left	3.01	cxob	3.43	11.24	3	2.12	apex	3.19	cx	absent
34	2	left	3.10	abcx	3.82	12.13	2	2.89	apex	3.62	cxab	present
35	2	left	3.08	cx	3.88	9.86	2	2.92	piv	3.69	cx	absent
36	2	left	2.96	abcx	3.20	7.80	2	2.66	apex	3.11	cx	absent
37	2	left	2.89	cxob	3.41	9.81	2	2.28	apex	3.18	cx	absent
38	2	left	2.71	abcx	3.33	10.32	2	2.90	apex	3.28	cx	absent
39	2	left	2.76	cx	3.34	11.11	2	2.12	apex	3.31	cx	absent
40	2	left	2.88	cxob	3.03	12.04	2	2.89	apex	2.98	cx	absent
41	2	left	2.84	abcx	3.23	7.84	2	2.84	apex	3.10	cx	absent
42	2	left	2.75	cxob	2.99	10.81	2	2.69	apex	2.84	cx	absent
43	2	left	2.76	cxob	2.98	8.23	2	2.14	apex	2.88	cx	absent
44	2	left	2.69	cx	3.40	9.42	3	2.80	apex	3.18	cx	absent
45	2	left	2.71	cxob	3.39	7.66	2	2.25	piv	3.14	cx	absent
46	2	left	2.28	cx	2.92	7.22	4	2.68	apex	2.80	cxab	absent
47	2	left	3.04	abcx	3.63	8.24	2	2.28	apex	3.42	cx	absent
48	2	left	3.12	cxob	3.91	6.32	2	2.84	apex	3.61	cx	present
49	2	left	3.06	cx	3.32	6.99	2	2.08	apex	3.28	cx	absent
50	2	left	3	cxob	3.39	7.12	2	2.63	apex	3.21	cx	absent

N– serial number; Ost- number of ostium; domi- cardiac dominance; r dia – diameter of right coronary artery (millimetre); r ext- extent of right coronary artery; lm dia- diameter of left main coronary artery (millimetre); lm l- length of left main coronary artery (millimetre); branc- number of terminal branches of left main coronary artery; la dia – diameter of left anterior descending artery (millimetre); la ext- extent of left anterior descending artery; lx dia- diameter of left circumflex artery (millimetre); lx ext- extent of left circumflex artery; my br- myocardial bridges; cx- at crux cordis; ob- at obtuse border; ab- at acute border; cxob- between crux and obtuse border; abcx- between acute border and crux; obcx- between obtuse border and crux; cxab- between crux and acute border

Annexure 3: Statistics - One way ANOVA, LSD Post Hoc test (adult cadaveric hearts)

<u>Statistics – One way ANOVA with LSD Post Hoc test to determine the statistical significance between cardiac dominance and measured diameters in dissected adult cadaveric heart specimens</u> *(page 1 of 3)*

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Diameter of proximal segment of right coronary artery (mm)	co dominant	4	2.7275	.16681	.08340	2.4621	2.9929	2.56	2.92
	right dominant	25	3.5284	.18393	.03679	3.4525	3.6043	3.19	3.81
	left dominant	21	2.8633	.19407	.04235	2.7750	2.9517	2.28	3.12
	Total	50	3.1850	.39401	.05572	3.0730	3.2970	2.28	3.81
Diameter of left main coronary artery (mm)	co dominant	4	3.3325	.42406	.21203	2.6577	4.0073	3.04	3.96
	right dominant	24	3.3158	.37215	.07596	3.1587	3.4730	2.69	3.99
	left dominant	21	3.3371	.28390	.06195	3.2079	3.4664	2.92	3.91
	Total	49	3.3263	.33361	.04766	3.2305	3.4222	2.69	3.99
Diameter of proximal segment of left anterior descending artery (mm)	co dominant	4	2.6200	.40882	.20441	1.9695	3.2705	2.03	2.91
	right dominant	25	2.5448	.28380	.05676	2.4277	2.6619	2.08	2.92
	left dominant	21	2.5714	.30347	.06622	2.4333	2.7096	2.08	2.92
	Total	50	2.5620	.29620	.04189	2.4778	2.6462	2.03	2.92
Diameter of proximal segment of left circumflex artery (mm)	co dominant	4	2.7250	.09883	.04941	2.5677	2.8823	2.60	2.83
	right dominant	24	2.9271	.13719	.02800	2.8692	2.9850	2.60	3.13
	left dominant	21	3.2276	.25961	.05665	3.1094	3.3458	2.80	3.69
	Total	49	3.0394	.26030	.03719	2.9646	3.1142	2.60	3.69

Statistics – One way ANOVA with LSD Post Hoc test to determine the statistical significance between cardiac dominance and measured diameters in dissected adult cadaveric heart specimens *(page 2 of 3)*

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Diameter of proximal segment of right coronary artery (mm)	Between Groups	5.958	2	2.979	84.927	.000
	Within Groups	1.649	47	.035		
	Total	7.607	49			
Diameter of left main coronary artery (mm)	Between Groups	.005	2	.003	.023	.978
	Within Groups	5.337	46	.116		
	Total	5.342	48			
Diameter of proximal segment of left anterior descending artery (mm)	Between Groups	.023	2	.011	.125	.883
	Within Groups	4.276	47	.091		
	Total	4.299	49			
Diameter of proximal segment of left circumflex artery (mm)	Between Groups	1.442	2	.721	18.323	.000
	Within Groups	1.810	46	.039		
	Total	3.252	48			

<u>Statistics – One way ANOVA with LSD Post Hoc test to determine the statistical significance between cardiac dominance and measured diameters in dissected adult cadaveric heart specimens</u> *(page 3 of 3)*

Multiple Comparisons

LSD Post Hoc test

Dependent Variable	(I) dominance	(J) dominance	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Diameter of proximal segment of right coronary artery (mm)	co dominant	right dominant	-.80090*	.10086	.000	-1.0038	-.5980
		left dominant	-.13583	.10218	.190	-.3414	.0697
	right dominant	co dominant	.80090*	.10086	.000	.5980	1.0038
		left dominant	.66507*	.05544	.000	.5535	.7766
	left dominant	co dominant	.13583	.10218	.190	-.0697	.3414
		right dominant	-.66507*	.05544	.000	-.7766	-.5535
Diameter of left main coronary artery (mm)	co dominant	right dominant	.01667	.18395	.928	-.3536	.3869
		left dominant	-.00464	.18582	.980	-.3787	.3694
	right dominant	co dominant	-.01667	.18395	.928	-.3869	.3536
		left dominant	-.02131	.10178	.835	-.2262	.1836
	left dominant	co dominant	.00464	.18582	.980	-.3694	.3787
		right dominant	.02131	.10178	.835	-.1836	.2262
Diameter of proximal segment of left anterior descending artery (mm)	co dominant	right dominant	.07520	.16244	.646	-.2516	.4020
		left dominant	.04857	.16456	.769	-.2825	.3796
	right dominant	co dominant	-.07520	.16244	.646	-.4020	.2516
		left dominant	-.02663	.08929	.767	-.2062	.1530
	left dominant	co dominant	-.04857	.16456	.769	-.3796	.2825
		right dominant	.02663	.08929	.767	-.1530	.2062
Diameter of proximal segment of left circumflex artery (mm)	co dominant	right dominant	-.20208	.10713	.066	-.4177	.0136
		left dominant	-.50262*	.10822	.000	-.7205	-.2848
	right dominant	co dominant	.20208	.10713	.066	-.0136	.4177
		left dominant	-.30054*	.05928	.000	-.4199	-.1812
	left dominant	co dominant	.50262*	.10822	.000	.2848	.7205
		right dominant	.30054*	.05928	.000	.1812	.4199

*. The mean difference is significant at the 0.05 level.

Annexure 4: Statistics – Pearson Correlation (adult cadaveric hearts)

Statistics – Pearson Correlation to determine the statistical correlation between the various measured diameters of the coronary arteries in dissected adult cadaveric heart specimens:

Correlations

		Diameter of left main coronary artery (mm)	Diameter of proximal segment of left anterior descending artery (mm)	Diameter of proximal segment of left circumflex artery (mm)	Diameter of proximal segment of right coronary artery (mm)
Diameter of left main coronary artery (mm)	Pearson Correlation	1	-.007	.269	.101
	Sig. (2-tailed)		.964	.062	.489
	N	49	49	49	49
Diameter of proximal segment of left anterior descending artery (mm)	Pearson Correlation	-.007	1	.010	-.176
	Sig. (2-tailed)	.964		.944	.226
	N	49	49	49	49
Diameter of proximal segment of left circumflex artery (mm)	Pearson Correlation	.269	.010	1	-.097
	Sig. (2-tailed)	.062	.944		.508
	N	49	49	49	49
Diameter of proximal segment of right coronary artery (mm)	Pearson Correlation	.101	-.176	-.097	1
	Sig. (2-tailed)	.489	.226	.508	
	N	49	49	49	49

Annexure 5: Data collection form (angiograms)

Coronary computer tomography angiogram – Data collection ***(page 1 of 2)***

S.no	sex	domi	lm l	bran	lm dia	lx dia	la dia	r dia
1	male	co	7.86	2	3.82	3.33	3.28	3.92
2	female	co	8.12	2	3.91	3.14	3.31	3.38
3	male	right	9.31	2	4.10	3.09	3.24	3.94
4	male	right	9.88	2	4.08	3.06	3.46	3.99
5	male	right	3.04	2	3.92	3.43	3.26	3.89
6	male	right	10.10	2	3.88	3.12	3.38	3.82
7	male	right	8.68	2	3.91	3.43	3.29	3.89
8	male	right	9.04	2	3.89	3.09	3.40	3.68
9	male	right	9.81	3	3.85	3.14	3.82	3.82
10	male	right	10.21	2	3.92	3.41	3.68	3.84
11	male	right	9.84	2	3.81	3.38	3.24	3.71
12	male	right	16.20	2	3.92	3.24	3.81	3.78
13	male	right	11.62	2	4.02	3.41	2.50	3.89
14	male	right	12.01	2	4.08	2.44	2.58	3.82
15	male	right	9.84	2	4.12	3.20	2.64	3.84
16	male	right	3.92	2	4	3.12	2.68	3.86
17	female	right	10.32	2	3.92	3.42	2.81	3.82
18	female	right	8.42	2	3.94	3.36	2.63	3.69
19	female	right	7.29	2	3.90	2.94	2.61	3.08
20	female	right	8.64	2	3.88	2.91	2.72	3.39
21	female	right	9.88	2	3.39	2.97	2.68	3.32
22	female	right	11.12	2	4	2.82	2.61	3.36
23	female	right	12.38	2	3.95	2.80	2.64	3.29
24	female	right	13.82	3	3.92	2.79	2.68	3.24
25	female	right	13.01	2	3.96	2.74	2.61	3.28
26	female	right	7.99	2	3.83	2.68	3.09	2.99
27	female	right	8.02	2	3.84	3.24	2.80	3.62

Coronary computer tomography angiogram – Data collection *(page 2 of 2)*

S.no	**sex**	**domi**	**lm l**	**bran**	**lm dia**	**lx dia**	**la dia**	**r dia**
28	female	right	9.78	2	3.83	3.13	2.83	3.59
29	male	left	9.72	2	3.99	3.42	3.24	3.09
30	male	left	10.19	2	4.02	3.36	3.31	3.33
31	male	left	8.82	2	4.21	3.29	3.12	3.08
32	male	left	9.34	2	4.04	3.64	3.26	3.41
33	male	left	9.64	2	3.88	3.39	3.36	3.12
34	male	left	10.41	2	4.06	3.61	3.14	3.31
35	male	left	9.63	3	4.08	3.58	3.42	3.28
36	male	left	14.10	2	4.18	3.42	3.50	3.21
37	male	left	11.01	2	4.09	3.61	3.64	3.29
38	male	left	12.43	2	4.21	3.21	3.68	3.01
39	male	left	9.03	2	3.94	2.99	2.68	2.86
40	female	left	10.12	2	3.96	2.96	2.63	2.81
41	female	left	8.69	2	3.80	2.90	2.82	2.72
42	female	left	7.26	2	3.90	3	2.77	2.69
43	female	left	4.20	2	3.98	2.99	2.60	2.84
44	female	left	8.12	2	3.80	2.98	2.72	2.63
45	female	left	9.81	2	3.82	2.79	2.65	2.52
46	female	left	11.32	2	3.70	2.98	2.99	2.81
47	female	left	12.81	2	3.69	2.73	2.81	2.49
48	female	left	13.02	2	3.82	3.02	3.12	2.82
49	female	left	13.21	3	3.88	3.42	3.03	3.26
50	female	left	13.24	2	3.81	3.31	3.09	3.18

S.no- serial number; sex- sex of the patient; domi- cardiac dominance; lm l- length of the left main coronary artery (millimetre); bran- number of terminal branches of left main coronary artery; lm dia- diameter of left main coronary artery (millimetre); lx dia- diameter of left circumflex artery (millimetre); la dia- diameter of left anterior descending artery (millimetre); r dia- diameter of right coronary artery (millimetre)

Annexure 6: Statistics – One way ANOVA, LSD Post Hoc test (coronary computer tomography angiograms)

Statistics – One way ANOVA with LSD Post Hoc test to determine the statistical significance between cardiac dominance and measured diameters in coronary computer tomography angiograms *(page 1 of 3)*

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Diameter of proximal segment of left circumflex artery (mm)	co dominant	2	3.2350	.13435	.09500	2.0279	4.4421	3.14	3.33
	right dominant	26	3.0908	.26797	.05255	2.9825	3.1990	2.44	3.43
	left dominant	22	3.2091	.28398	.06055	3.0832	3.3350	2.73	3.64
	Total	50	3.1486	.27439	.03880	3.0706	3.2266	2.44	3.64
Diameter of proximal segment of right coronary artery (mm)	co dominant	2	3.6500	.38184	.27000	.2193	7.0807	3.38	3.92
	right dominant	26	3.6323	.28841	.05656	3.5158	3.7488	2.99	3.99
	left dominant	22	2.9891	.28097	.05990	2.8645	3.1137	2.49	3.41
	Total	50	3.3500	.42859	.06061	3.2282	3.4718	2.49	3.99
Diameter of proximal segment of left anterior descending artery (mm)	co dominant	2	3.2950	.02121	.01500	3.1044	3.4856	3.28	3.31
	right dominant	26	2.9881	.41702	.08178	2.8196	3.1565	2.50	3.82
	left dominant	22	3.0718	.33202	.07079	2.9246	3.2190	2.60	3.68
	Total	50	3.0372	.37485	.05301	2.9307	3.1437	2.50	3.82
Diameter of left main coronary artery (mm)	co dominant	2	3.8650	.06364	.04500	3.2932	4.4368	3.82	3.91
	right dominant	26	3.9177	.13773	.02701	3.8621	3.9733	3.39	4.12
	left dominant	22	3.9482	.15324	.03267	3.8802	4.0161	3.69	4.21
	Total	50	3.9290	.14222	.02011	3.8886	3.9694	3.39	4.21

<u>Statistics – One way ANOVA with LSD Post Hoc test to determine the statistical significance between cardiac dominance and measured diameters in coronary computer tomography angiograms</u> *(page 2 of 3)*

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Diameter of proximal segment of left circumflex artery (mm)	Between Groups	.182	2	.091	1.222	.304
	Within Groups	3.507	47	.075		
	Total	3.689	49			
Diameter of proximal segment of right coronary artery (mm)	Between Groups	5.118	2	2.559	30.972	.000
	Within Groups	3.883	47	.083		
	Total	9.001	49			
Diameter of proximal segment of left anterior descending artery (mm)	Between Groups	.222	2	.111	.783	.463
	Within Groups	6.663	47	.142		
	Total	6.885	49			
Diameter of left main coronary artery (mm)	Between Groups	.020	2	.010	.474	.625
	Within Groups	.971	47	.021		
	Total	.991	49			

Statistics – One way ANOVA with LSD Post Hoc test to determine the statistical significance between cardiac dominance and measured diameters in coronary computer tomography angiograms *(page 3 of 3)*

Multiple Comparisons

LSD Post Hoc

Dependent Variable	(I) dominance	(J) dominance	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Diameter of left main coronary artery (mm)	co dominant	right dominant	-.05269	.10550	.620	-.2649	.1595
		left dominant	-.08318	.10618	.437	-.2968	.1304
	right dominant	co dominant	.05269	.10550	.620	-.1595	.2649
		left dominant	-.03049	.04165	.468	-.1143	.0533
	left dominant	co dominant	.08318	.10618	.437	-.1304	.2968
		right dominant	.03049	.04165	.468	-.0533	.1143
Diameter of proximal segment of left circumflex artery (mm)	co dominant	right dominant	.14423	.20044	.475	-.2590	.5475
		left dominant	.02591	.20174	.898	-.3799	.4318
	right dominant	co dominant	-.14423	.20044	.475	-.5475	.2590
		left dominant	-.11832	.07913	.142	-.2775	.0409
	left dominant	co dominant	-.02591	.20174	.898	-.4318	.3799
		right dominant	.11832	.07913	.142	-.0409	.2775
Diameter of proximal segment of left anterior descending artery (mm)	co dominant	right dominant	.30692	.27629	.272	-.2489	.8627
		left dominant	.22318	.27808	.426	-.3362	.7826
	right dominant	co dominant	-.30692	.27629	.272	-.8627	.2489
		left dominant	-.08374	.10907	.446	-.3032	.1357
	left dominant	co dominant	-.22318	.27808	.426	-.7826	.3362
		right dominant	.08374	.10907	.446	-.1357	.3032
Diameter of proximal segment of right coronary artery (mm)	co dominant	right dominant	.01769	.21092	.934	-.4066	.4420
		left dominant	.66091*	.21228	.003	.2338	1.0880
	right dominant	co dominant	-.01769	.21092	.934	-.4420	.4066
		left dominant	.64322*	.08326	.000	.4757	.8107
	left dominant	co dominant	-.66091*	.21228	.003	-1.0880	-.2338
		right dominant	-.64322*	.08326	.000	-.8107	-.4757

*. The mean difference is significant at the 0.05 level.

Annexure 7: Statistics – Independent t test (coronary computer tomography angiograms)

Statistics – Independent t test to determine the statistical significance between gender and measured diameters in coronary computer tomography angiograms

(page 1 of 2)

Group Statistics

	sex	N	Mean	Std. Deviation	Std. Error Mean
Diameter of left main coronary artery (mm)	male	26	4.0008	.11682	.02291
	female	24	3.8512	.12698	.02592
Diameter of proximal segment of left circumflex artery (mm)	male	26	3.2850	.25138	.04930
	female	24	3.0008	.21885	.04467
Diameter of proximal segment of left anterior descending artery (mm)	male	26	3.2542	.36964	.07249
	female	24	2.8021	.19976	.04078
Diameter of proximal segment of right coronary artery (mm)	male	26	3.5646	.35604	.06982
	female	24	3.1175	.38089	.07775

Statistics – Independent t test to determine the statistical significance between gender and measured diameters in coronary computer tomography angiograms

(page 2 of 2)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Diameter of left main coronary artery (mm)	Equal variances assumed	.322	.573	4.337	48	.000	.14952	.03448	.08020	.21884
	Equal variances not assumed			4.322	46.734	.000	.14952	.03459	.07991	.21912
Diameter of proximal segment of left circumflex artery (mm)	Equal variances assumed	.177	.676	4.247	48	.000	.28417	.06690	.14965	.41869
	Equal variances not assumed			4.271	47.846	.000	.28417	.06653	.15039	.41794
Diameter of proximal segment of left anterior descending artery (mm)	Equal variances assumed	3.946	.053	5.316	48	.000	.45215	.08505	.28113	.62316
	Equal variances not assumed			5.436	39.071	.000	.45215	.08317	.28392	.62037
Diameter of proximal segment of right coronary artery (mm)	Equal variances assumed	.000	.995	4.290	48	.000	.44712	.10421	.23758	.65665
	Equal variances not assumed			4.279	46.959	.000	.44712	.10450	.23688	.65735

Annexure 8: Statistics – Pearson Correlation (coronary computer tomography angiograms)

<u>Statistics – Pearson Correlation to determine the statistical correlation between the various measured diameters of the coronary arteries in coronary computer tomography angiograms:</u>

Correlations

		Diameter of proximal segment of right coronary artery (mm)	Diameter of proximal segment of left anterior descending artery (mm)	Diameter of proximal segment of left circumflex artery (mm)	Diameter of left main coronary artery (mm)
Diameter of proximal segment of right coronary artery (mm)	Pearson Correlation	1	.287*	.347*	.224
	Sig. (2-tailed)		.043	.013	.118
	N	50	50	50	50
Diameter of proximal segment of left anterior descending artery (mm)	Pearson Correlation	.287*	1	.540**	.223
	Sig. (2-tailed)	.043		.000	.120
	N	50	50	50	50
Diameter of proximal segment of left circumflex artery (mm)	Pearson Correlation	.347*	.540**	1	.296*
	Sig. (2-tailed)	.013	.000		.037
	N	50	50	50	50
Diameter of left main coronary artery (mm)	Pearson Correlation	.224	.223	.296*	1
	Sig. (2-tailed)	.118	.120	.037	
	N	50	50	50	50

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).