Angiographic Study of Normal Coronary Arteries as First Experience in Basrah

A thesis

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Chapter One

Introduction

1.1. Anatomy of the heart :

Heart is a hallow muscular organ [1,2] it is pyramidal in shape as in **Figure 1.1**, lies within middle mediastinum between the two lungs[1,2,3] , its base lies on the diaphragm but the apex directed downward , forward and to the left side. The base connected to the great blood vessels but otherwise the heart lies free within the pericardium.[1,2]

The heart weights between 200 to 425 grams (7 - 15 ounces) and is a little larger than the size of its owner fist. By the end of a long life, a person's heart may have beated (expanded and contracted) more than 3.5 billion times. In fact, each day the average heart beats 100,000 times , pumping about 7571 liters (2,000 gallons)of blood.[3,4]

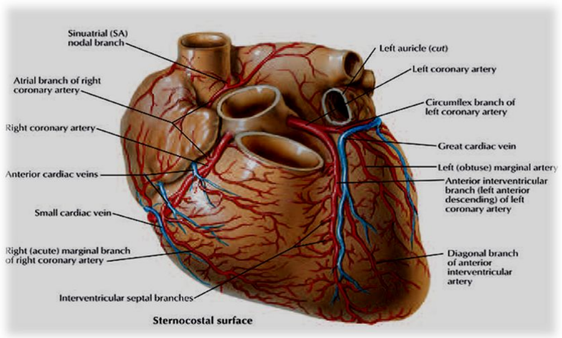


Figure 1.1. Normal heart anatomy viewed from the sternocostal (anterior) surface [1]

The heart has three surfaces : [1,2]

1) Sternocostal surface or the anterior surface : It formed mainly by right atrium and right ventricle .

2) Diaphrgmatic surface or the inferior surface : It formed mainly by right ventricle ,left ventricle , inferior surface of right atrium and the entrance of inferior vena cava to right atrium .

3) Posterior surface or the base of the heart : It formed mainly by left atrium and four pulmonary veins .

The heart has three borders : [1,2]

1) Right border: It formed mainly by the right atrium.

2) Left border: It formed by the left auricle and left ventricle.

3) Lower border : It formed mainly by right atrium , right ventricle and the apex of the heart .

The heart consists of three layers:[1-3]

- Pericardium : It is a fibro serous sac that encloses the heart and the roots of the great vessels. It consists of two components the fibrous pericardium and the serous pericardium in between them is the pericardial fluid .
- Myocardium : It is the middle layer which correspond to the cardiac muscles.
- Endocardium : It is the internal endothelial layer that lined the cardiac champers internally.

The heart has four champers two atria and two ventricles. On the right side the right atrium and the right ventricle connected between each other by right atrioventricular opening . On left side the left atrium and left ventricle connected to each other by left atrioventricular opening.[1-3] Normally there is no connection between right and left side of the heart but there are multiple openings enter and leave it [1,2] :

- Right atrium : It received superior vena cava , inferior vena cava and coronary sinus openings .
- Right ventricle: It received the right atrioventricular opening and pulmonary artery opening
- Left atrium: It received the openings of four pulmonary veins .
- Left ventricle : It received the opening of left atrioventricular opening and the aortic opening.

Four types of valves regulate blood flow through the heart:[1-3]

1) The tricuspid valve : It regulates blood flow between the right atrium and the right ventricle.

2) The pulmonary valve : It controls blood flow from the right ventricle into the pulmonary artery which carries the deoxygenated blood to the lungs.

3) The mitral valve : It regulates oxygenated blood flow from the left atrium into the left ventricle.

4) The aortic valve : It opens the way for oxygenated blood to pass from the left ventricle into the aorta where it is delivered to the rest of the body.

1.2. Conduction system of the heart:

Electrical impulses cause heart contraction. These electrical signals begin in the sinoatrial node which is located at the top of the right atrium the SA node sometimes called " heart natural pacemaker." An electrical impulse from this natural pacemaker travels through the muscle fibers of the atria causes atrial contraction . The second node located in the lower part of atrial septum is known as the atrioventricular node. The AV node serves as a relay station slowing down the signal and giving the atria chance to fully contract before passing the signal in to the ventricles then the impulses flow along the lower border of the membranous part of the interventricular septum to right and left bundles of Hiss . Because of the functional importance and constancy of the conduction system of the heart therefore, it has its own blood supply from coronary circulation.[1-6]

1.3. Function of the heart :

Heart and circulatory system make up the cardiovascular system. The heart works as a pump that pushes blood to the organs, tissues and cells of the body. Blood delivers oxygen and nutrients to every cell and removes the carbon dioxide and waste products made by the cell. Blood is carried from the heart to the rest of the body through a complex network of arteries, arterioles and capillaries but the blood is returned to the heart through venules and veins.[1,3]

1.4. Myocardial Oxygen Demand :

The heart is an aerobic organ depending almost on the oxidation of substrates for the generation of energy. At rest the heart receives five percent of the cardiac output (250 ml /min) consequently the coronary blood flow must be coupled to compensate the energy demand . When oxygen demand increases the oxygen supply must increase proportionaly e.g. in exercise myocardial oxygen demand can increase as much as six times so the myocardial oxygen supply must increase as much as five times and the coronary resistance decreases to 1/5 .[5,6]

1.5. Coronary blood flow :

Coronary blood flow can be described as a phasic flow because during systole the coronary arteries compressed due to the contraction of the heart which squeezes these arteries but during diastole these arteries become patent. The blood flows under aortic pressure into these coronary arteries, capillaries and finally into the coronary veins, this known as **"**coronary perfusion pressure**"** which means the difference between the diastolic pressure in the aorta and the diastolic pressure in the right atrium creating a pressure gradient which results in coronary blood flow. [1,7]

1.6. Blood supply of the heart :

1) Venus drainage: Cardiac veins carry deoxygenated blood from the heart muscles and drains it to the coronary sinus then to the right atrium. The coronary sinus receives four major tributaries of cardiac veins[1,2,8]:

1) Great cardiac vein. 2) Middle cardiac vein.

3) Small cardiac vein. 4) Posterior cardiac vein.

2) Arterial circulation : The coronary arteries carry oxygenated blood to the heart, these run on the surface of the heart called "epicardial coronary arteries". It originated from the root of the aorta one centimeter above the aortic valve as anatomical dilations or pocket-like sinuses called "aortic sinus or sinus

of Valsalva" : the right, left and posterior aortic sinuses. The anterior right aortic sinus gives origin to the right coronary artery, the left posterior sinus gives origin to the left coronary artery and the posterior aortic sinus referred to it as the non coronary sinus .[1,2,7-9] as in **Figure 1.2**.

Figure 1.2. CT angiography images of three coronary cusps or sinuses; Left coronary (LC), right coronary (RC) and posterior non-coronary cusp(NC) .[9]

1)Left coronary artery (LCA) or left main stem artery (LMS) : It arises from the aorta above the left cusp of the aortic valve, it runs for **1 - 25** mm and pass between the pulmonary trunk and the left auricle before entering the coronary sulcus but still posterior to the pulmonary trunk . Normally it has a horizontal course then it bifurcates into left anterior descending artery and left circumflex artery[1.2.7.8.9]as in **Figure1.3** and **Figure1.4 .**

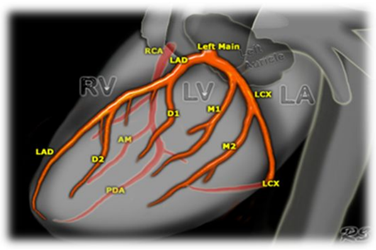
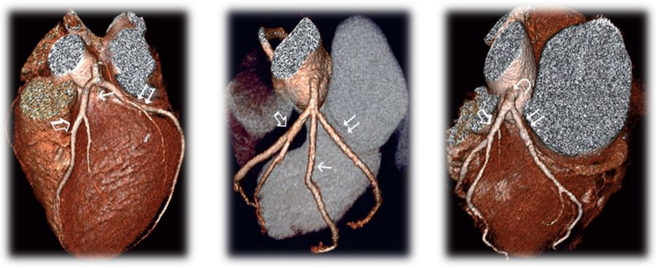


Figure 1.3. Left coronary artery arised from Aorta give left anterior descending &left circumflex arteries. [10]



a b c

Figure 1.4. a–c. 3D volume-rendered CT angiography images of 3 different patients (a–c) show the left main coronary artery *(curved arrow)* that bifurcates to the left anterior descending artery (LAD) *(open arrow)* and circumflex artery (LCX) *(double arrow)* (a) and trifurcates where ramus intermedius *(straight arrow)* is seen in between the LAD *(open arrow)* and LCX *(double arrow)* (b). Ramus intermedius *(straight arrow)* may be variable in size, changing from a well-developed branching artery to a small one (c) (LAD, *open arrow*; LCX, *double arrow*). [9]

***A) The left anterior descending* (LAD)** : it runs down in the anterior interventricular groove and continues around the left side of the pulmonary trunk then descends obliquely toward the apex of the heart. It supplies the anterolateral wall of left ventricle , apex and superior two thirds of interventricular septum. The LAD typically supplies 45-55% of the left ventricle . The LAD gives off two types of branches:[1,2,4,7-11] as in **Figure 1.3 .**

1) Septal branches: originate from the LAD at 90 degree on the surface of the heart then perforates the interventricular septum and supplies it **.**

2) Diagonal branches : run along the surface of the heart and supply the lateral wall of the LV and the anterolateral papillary muscle**.**

***B)The left circumflex artery* (LCX)**: runs across the left atrioventricular groove toward the left and into the diaphragmatic surface of the heart and usually ends before reaching the posterior interventricular sulcus .The LCX artery supplies the posterolateral LV , the anterolateral papillary muscle and supplies the sinoatrial node in 38% of people. It supplies 15-25% of the left ventricle in right-dominant circulation but in the left-dominant it supplies 40-50% of the left ventricle .It gives two branches [1,2,7-11] as in **Figure 1.3.**

1) Obtuse marginal branch : It is relatively large branch, it located approximately halfway between the anterior and posterior wall of the left ventricle along the obtuse margin.

2) Septal branch: It supplies the anterior interventricular septum of heart.

C) Ramus intermedius or median artery or intermediate artery : the median artery occurs in 37% of the general population and it is considered as a normal variant running toward the mid portion of the lateral wall of the left ventricle. it arises from the angle between the division of the anterior descending artery and the left circumflex artery. This creates the appearance of a trifurcation of the main trunk. This branch is sometimes so large that it may even reach the apex region. [1,2,8,9] as in **Figure 1.5.**

Figure 1.5. Division of the left coronary artery into branches: anterior interventricular, median and circumflex. The median artery clearly occupies the angle formed by the two other terminal branches, crossing the surface of the great cardiac vein. (LCX: circumflex artery; IVA: anterior interventricular artery; M: Median artery) . [10]

2)Right coronary artery(RCA) :

It passes anteriorly and to the right between the right auricle and the pulmonary trunk, then descends vertically through the right atrioventricular sulcus between the right atrium and the right ventricle. The initial portion of the right coronary artery (15–25 mm) follows in a horizontal course when reaching the inferior margin of the heart it turns posteriorly and continues in the sulcus in the diaphragmatic surface . The RCA supplies oxygen and nutrient to the right atrium, right ventricle, the bottom of the left ventricle , the interatrial septum, portion of the left atrium, the posteroinferior one-third of the interventricular septum and supplies 25% - 35% of the left ventricle as in **Figure 1.6** and **Figure 1.7.** RCA divides into the following branches :[1,2,4,8 -14]

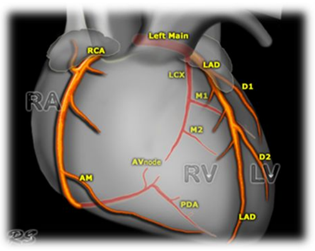


Figure 1.6. The right coronary artery arised from aorta .[10]

Figure 1.7. The right coronary artery arised from aorta and its branches . [12]

***A) Sinoatrial branch**:* it passes in the groove between the right auricle and ascending aorta then gives off the sinoatrial nodal branch which passes posteriorly around the superior vena cava to supply the sinoatrial node as in **Figure 1.8** . In 60% of cases the SA nodal artery arised from RCA and in 40% arised from the LCX artery .[1,2,8,9,12]

Figure 1.8. Sinus node artery originating in the initial portion of the right coronary artery. This artery divides to form a pericaval arterial ring. (RA: right atrium; RCA: right coronary artery; SA: sinoatrial artery; SVC: superior vena cava). [14]

B)Conus artery : is branched from RCA then directed anteriorly and passed around outflow tract of the right ventricle close to the level of the pulmonary valve . The conus branch is relatively constant in its distribution but frequently has its own orifice closely adjacent to right coronary artery ostium in the right aortic sinus and because of the frequent appearance of this small branch it has been denoted as the "third coronary artery" that presented in 23-51% of normal hearts. It regarded as a collateral anastomosis with left coronary artery , this anastomosis is known as the "annulus of Vieussens " .(1,2,8-12) as shown in **Figure 1.9.**

Figure 1.9. Photograph shows the conus branch originating from the right coronary artery . (13)

C) Acute marginal branch: it is given from right coronary artery at the inferior margin of the heart and continues along this border toward the apex of the heart because it is close to the acute margin of the right ventricle it is called " the acute marginal branch ". (1,2,8-12)

D) Atrioventricular branch :as the right coronary artery continues on the diaphragmatic surface of the heart it gives a small branch to the atrioventricular node .(1,2,4,8-12)

E) Posterior interventricular branch: In 85% of cases the RCA gives off the posterior descending artery (PDA) but in the other 15% of cases the PDA is given by the left circumflex artery which lies in the posterior interventricular sulcus. The PDA supplies the inferior wall of both ventricles, ventricular septum, and the posteromedial papillary muscle. (1,2,4,8-12)

Crux cordis : It is a point on the diaphragmatic surface of the heart where the left and right atrioventricular sulci and the posterior interventricular sulcus come together . It is an important landmark in the coronary artery dominancy (8) as in **Figure 1.10.**

Figure 1.10 .View of the diaphragmatic surface of the heart; the right coronary artery passes the crux cordis, irrigating the right ventricle (right dominance). The circumflex artery is short, terminating a little after the margo obtusus. (8)

1.7. Coronary artery dominancy :

Reciprocity exists between the right and left coronary arteries of the human heart. The variations have the greatest implication with regard to the blood supply of the crux and the posterior interventricular sulcus. In 80% - 90% of the cases the right coronary artery reaches and supplies this area so called " right-dominant " as in **Figure1.10.** . In 20 % of cases the left circumflex artery supplies the area so called "left-dominant". When right and left coronary artery branches share rather equally in the supply of the crux the term is " co- dominant " it has been constituted 10% of population as in **Figure1.11** . Consequently the supply of the posterior third of the interventricular septum and the atrioventricular node is depending on the integrity of the coronary artery that serves this area. .(1,2,4,8-14)

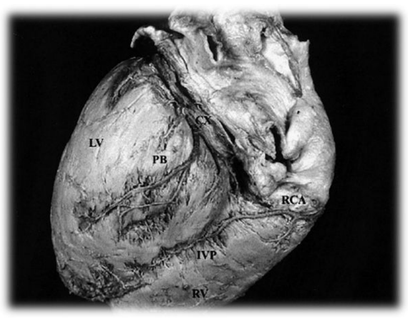


Figure 1.11. View of the diaphragmatic surface of the heart in a situation of cardiac co-dominant circulation in which the right coronary and the circumflex arteries irrigate the diaphragmatic surface of its corresponding ventricle. (LCX: circumflex artery; IVP: posterior interventricular artery; LV: left ventricle; PB: posterobasal artery; RV: right ventricle; RCA: right coronary artery).(8)

1.8. Embryology of coronary arteries :

The coronary arteries are derived from two sources :

1) Angioblast : they distribute over the heart surface by their migration in epicardium as pro-epicardial cells . (15-17)

2) Epicardium : some epicardial cells undergo an epithelial-mesenchymal transition induced by underlying myocardium . Mesenchymal cells contributed to the endothelial and smooth muscle cells of coronary arteries.(15,16,17) Neural crest also contributed to smooth muscle cells of proximal part of these coronary arteries. (15) The various factors such as Ang.1, FGF-2, bFGF are causing growth of mesenchymal cells in the subepicardial space whose sources seem to be the epicardium or the extra cardiac proepicardial organ . These precursors developed to capillary plexus and then grow toward the cardiac wall from the dorsal interventricular sulcus to form the coronary arteries . (16-19)

An embryological investigations have offered a few hypotheses about the development of coronary arteries. Several studies suggested that coronary arteries did not grow out of aorta but grew into aorta from proximal peritruncal circles of coronary arterial vasculature. These circles are : .(20 - 22)

1) the atrioventicular circle formed the RCA and LCX arteries .
2) interampulary circle formed the LAD and PDA arteries .
3) conotruncal circle "embryological circle of Vieussens" which communicated with lumen of truncus arteriosus by way of coronary ostia also this circle anastomised with two circles up there by to establish the definitive coronary artery circulation.

1.9. Diagnostic Procedures :

Since the beginning of the 1990s a variety of non-invasive techniques have been introduced in coronary artery imaging in an attempt to replace the invasive conventional Coronary angiography (CCA). These techniques have shown promising results although they were considered inadequate for large-scale clinical implementation. Furthermore, advanced modalities such as magnetic resonance (MR) and electron-beam computed tomography (EBCT) are still not widely available. Therefore, radiologists should be familial with normal anatomy and the anatomical variants of the heart . (5,12,23)

In general the wrong interpretations of a coronary variants or anomalies might cause:

- Techniques difficulties during interventional procedures.
- The clinical misdiagnosis.
- Major complications might occur during graft surgery.

So that we need an accurate anatomical evaluation of the coronary arterial tree which should be relevant during angioplasty for revascularization purposes.

1.10. Types of diagnostic procedures:

1) Conventional coronary angiography (CCA):

CCA has been the "gold standard" for the diagnosis of coronary variations for several decades. Despite its common uses, it is regarded an invasive procedure. Selective catheterization and subsequent interpretation of the vessels anatomy may be difficult in CCA because the operator is not aware of an atypical location of the vessel orifice. Therefore, the diagnosis of coronary variations are often established on the impossibility of finding of the coronary arteries in their normal anatomical positions. Finally the interpretation of the courses of variable coronary arteries may be erroneous because CCA is two dimensional and cannot provide enough information about the complex three-dimensional vessel anatomy and absence of soft tissue information . (24 - 26).

2) Electron-beam computed tomography (EBCT) :

It is still not widely available on. EBCT scanner may be used as a conventional CT scanner in conditions where CT scanning is usually indicated. (27,28,29)

3) Trans-thoracic echocardiography (TTE) :

TTE which is used mainly in pediatric radiology, it does not always provide a reliable diagnostic result. When performed on adult patients it shows difficultly to obtain diagnostic images owing to the interposition of the bones of the ribcage (ribs and sternum), pulmonary parenchyma and subcutaneous adipose tissue (28,29) . TTE is able to assess only the proximal tract of the coronary arteries. Therefore, the diagnostic capability is limited to only a part of coronary arteries (24,29) .

4) Trans-esophageal echocardiography (TEE) :

TEE is more sensitive than TTE in identifying coronary anomalies and assessing their courses although it remains an invasive technique (i.e. insertion of a probe down the esophagus with varying degree of sedation according to patient tolerance). TEE characterized by a significant level of operator dependence and therefore impossible to perform as a screening test, also it is able to assess only the proximal tract of the coronary arteries therefore the diagnostic capability is limited to only a part of coronary arteries (29,30) .

5) Magnetic resonance angiography (MRA) :

MRA is a highly promising technique since no ionizing radiation is used . The study of the origin of the coronary arteries by MRA can provide more complete information than CCA particularly in patients with other concomitant congenital cardiac anomalies.(29) The main limitation of MRA is incomplete visualization of the coronary vessels particularly their distal tracts. This limits the diagnostic capabilities for the assessment of fistulae , the origin of coronary arteries other than the aortic sinuses (i.e. from the pulmonary artery) and the collateral vessels . However MRA provides optimal functional assessment of complex congenital heart disease including anomalies of great vessels, cardiac chambers and valves (the procedures may include evaluation of ventricular mass and volumes, quantification of valvular disease and contrast enhancement) .(29,31,23)

6) Computed tomography coronary angiography (CT-CA) :

It is reviewed for coronary artery variants and anomalies .Recent advances in CT-CA equipments have continuously improved the quality of non-invasive coronary artery imaging. Various studies have demonstrated a high accuracy of coronary angiography with CT-CA for the diagnosis than CCA in patients prior to cardiac valve surgery. The technique offers high temporal and excellent spatial resolution capabilities of MSCT scanners enable detailed three dimensions visualization of complex coronary artery anatomy without motion artifacts with the possibility of performing a flexible post-processing (i.e. MPR, VR). So it defined the normal anatomical variants from potentially dangerous anomalies and supports the clinical management of referring cardiologists and cardiac surgeons. .(29-35)

The disadvantage of CT-CA: it requires radiation and uses of the contrast agent also limited by the myocardium, cardiac chambers and the gross coronary calcifications . The high radiation exposure should be a matter of concern in young patients which the first-choice imaging modality with these patients could be MRA. (29, 31-36)

7) Dissection autopsy:

The procedure is a cadaveric study that compatible with the ethical standards of the faculty's committee which is responsible for human experimentation which is based on the Helsinki Declaration . The Helsinki Declaration is the corner stone statement of ethical principles in biomedical research adopted in Helsinki (1964) as a set of principles to guide physicians and others engaged in medical research to protect human participants and conduct their research in an ethical manner) . The hearts speciments showed no macroscopic pathological changes and there were no history of any cardiac disease in an attempt to clarify the variability of the coronary artery tree .(25,29,37,38)

1.11. Conventional Coronary Angiography (CCA):

The technique was first performed by Dr. Mason Sones at the Cleveland Clinic in 1958 and still involves the same basic principles . A series of special designed catheters to deliver X-ray contrast medium to show the luminal integrity of the coronary arteries in the epicardial bed. Each chamber of the heart can be hemodynamically assessed . Typically a complete left heart catheterization does not involve only the coronary angiography but also the measurement of the ventricular filling pressures and cardiac hemodynamic(24) so it provides the most reliable anatomical information (23) .

Indications for Coronary Angiography : (23)

- Certain patient with stable Angina .

- Unstable Angina .
- Post revascularization Ischemia .
- Nonspecific Chest Pain .
- ST elevation and non ST elevation myocardial infarction .

Contraindications of CCA: There are no absolute contraindications to CCA, but there are relative contraindications which included : [23, 24]

- Coagulopathy .
- Decompensate congestive heart failure.
- Uncontrolled hypertension .
- Cerebrovascular accident .
- Refractory arrhythmia .
- Gastrointestinal hemorrhage .
- Pregnancy .
- Inability for patient cooperation
- Active infection .
- Renal failure.
- Contrast medium allergy .
- Unexplained fever .
- Severe anemia with hemoglobin less than 8 mg/dl .
- Severe electrolyte imbalance .
- Digitalis toxicity .

Complications of CCA : the overall risk of major complications with left heart catheterization are constituted about 1-2% .These complications included : [23 - 25,29]

- Death
- Bleeding
- Cerebrovascular accident
- Vascular complications
- Myocardial infarction
- Contrast reaction

Complications from arterial access included: [23,24]

- Arterial dissection .
- Arterovenous Fistula formation .
- Retroperitoneal hemorrhage .
- Pseudoanuerysm formation.

Risk factors of complications in CCA : The factors increasing patient risk include: [24 - 26]

- Age >70 years old .
- Morbid obesity
- Left main stem lesion or three vessels coronary disease.
- Decompensate heart failure.
- Severe aortic stenosis.
- Diabetes.
- Renal failure or renal insufficiency with serum creatinine greater than 1.5mg/dl
- Prior cerebrovascular accident .

1.12. Anatomical variations of coronary arteries :

1.12.1. Definitions of anatomical variations :

In an attempt to clarify the variability of the coronary artery tree these definitions are proposed :

- ***Normal:*** any morphological features observed in >1% of unselected population .
- ***Normal variant:*** an alternative or relatively unusual morphological features seen in >1% of the population .
- ***Anomaly:*** a morphological feature rarely encountered in <1% in the general population.

However the incidence of anatomical variations and coronary anomalies are relevant not only for conceptual and educational purposes but more importantly for public health issues . [14,25,29,39]

Variations are classified according to the ***American Heart Association (AHA) scheme*** as the following:

The variants are made with respect to the site of origin, the position of the ostium, the distance from supravalvar ridge, the angle between the coronary artery origin and aorta(aortocoronary angles), length and diameter of the vascular segments, the branching pattern, dominance of the artery, the origin of the conus branch, the origin of the sinoatrial node artery, the presence of the intermediate branch. [29,40,41].

1.12.2.The purposes for the studying of the anatomical variations of coronary arteries :

1) They are influenced the pathological processes of the chronic diseases (hypertension ,diabetes mellitus…etc). Each coronary variations characterized by particular clinical signs or symptoms by considering these factors the coronary artery variations are important in influencing the spread of the diseases e.g. The right conus artery bridges shared in collateral circulation between the right and left coronary system which is really significant in ischemic changes of heart. [41- 43]

2) An intimate knowledge of the anatomy of coronary arteries which regarded as the "Crown of the heart " important for a complete understanding of the coronary artery disease and for intelligent planning of surgery. These findings would be of great significance in the interpretation of coronary angiography, surgical revascularization of myocardium and embryological interpretations.[43]

3) Pathological examination of coronary arteries in autopsies is essential for explanation of the sudden death and for the improvement of the therapeutic procedures e.g. sometimes the position of the ostia not arised at the level of sinotubular junction and be slit-like lead to high risk of sudden death during exertion it can lead to hemodynamically significant changes resulting in myocardial ischemia and sudden death that frequently observed in these patients. [9,44]

1.12.3. Causes of anatomical variations :

- **Genetic factors :** Neural crest cells contribute to many types of tissues, during heart development the preotic neural crest cells (which migrates from anterior region of otic area) transform to the coronary artery smooth muscle cells then form the proper coronary artery. The factors influenced the coronary artery smooth muscle cells transformation are the entothelin-1 (ET-1) and endothelin A receptor (ETAR). These findings indicate that the ET-1/ETAR signaling is involved in coronary artery development by acting on neural crest cells contributing to the septal branch formation.[45,46]
- **Environmental factors:** The environmental factor has a mitogenic effect . The mitogen act by two mechanisms : [46,48 - 50]

1)The endogenous inhibition mechanism: its action either on the fibroblast growth factor (FGF) or other agents as angiotensin II, bradykinin, thrombin and catecholamine that disrupt cell-cell junctions.

2)The separate mechanism: this mechanism acts on the FGF and made the cells respond to the effect of mitogen e.g. Platelet-derived growth factor regards as a major mitogen .

The agents that control the endothelium and smooth muscles cells replications are FGF, angiotensin II, bradykinin, thrombin and catecholamine these played a major role in initiating smooth-muscle replication. Both genetic and environmental factors are acting together as the causative factors to these variations .

1.12.4.Types of anatomical variations:

The types of anatomical variations of coronary arteries are observed either in dissection autopsy or in angiographical studies are the following:[47]

A)Variations in the position of the coronary orifices:

1) ***Angle of origin*** *:*

It is the most frequent variations in the origin of coronary arteries regarded to the aortic wall that observed in the cross section .The coronary arteries are branching from aortic wall at a variety of angles: 90 degree (perpendicular origin), < 90 degree (tangential origin), practically zero degree (intramural course) when the small portion of coronary artery is embedded in the aortic wall e.g. hearts showed the angulations of origin of the right conus artery normally ranging between 90º- 100º in 78.57% of cases , 14.29% of cases the range 100º-110º and in 7.14% the range is 120º-130º. [47]

2)Situation of the coronary orifices:

The situation of the coronary orifices in the aortic sinuses varies in both cross sectional plane and frontal plane . [43,47]

***The cross sectional plane*:** the left coronary orifice may originates from the mid third of left coronary sinus in 87% , from the posterior third in 10% and from the anterior third in 3% . While the right coronary orifice originates from the mid third of right coronary sinus in 40% , from the posterior third in 59% and from the anterior third in 1% [47] .

***The frontal plane*:** the position of the coronary orifices according to their relation to the sin-tubular junction. The levels of the ostia are observed above the sinu-tubular junction by 10mm it is called " high take off" and if below the sinu-tubular junction it is called "low take off". The clinical significant of high left coronary orifice is usually associated with a long left coronary artery which injured during surgery either by the low clamping of aorta or an incision of aortic wall during valvular replacement .(47)

Most haemodynamists agree that the high and low coronary orifices represent an additional difficulty in coronary angiography . (47,51, 52) ***3)Presence of multiple coronary orifices :***

- ***Right aortic sinus :*** normally has RCA orifice but the most frequent variation is an accessory orifice for the conal artery 23-51%.(8,9,11,12,20,47,51) Less frequent independent orifice presents for sinus node artery . (47)
- ***Left aortic sinus :*** normally has LCA orifice but the most frequent variation is absence of LCA that's mean the left anterior descending artery and left circumflex artery have existence of two separate orifices known as "shotgun orifice " this range between (0.5 -1%) .(47)
- ***Multiple orifices in both aortic sinuses :*** there may be combinations of these Multiple orifices giving rise to the presence of 4 or 5 independent orifices .(47)

B)Variations in the length and distribution of coronary arteries :

The left coronary artery if the length above 15mm is called long LCA but if its length below 5mm is called short LCA .This short LCA is clinically relevant especially when a coronary angiography is performed because incomplete imaging of the area when introducing the catheter in to one of terminal branches. The short common trunk has a potential risk as the absence of common trunk. The short LCA reported a risk factor for the development of coronary atherosclerosis . (47,53 - 55)

In general the LMS divided into left anterior descending artery and left circumflex artery but in 25-40% the LMS divided to left anterior descending artery, left circumflex artery and median artery (intermediate artery). The median artery originates in between the angle formed by the main terminal arteries of the left coronary artery . The median artery possesses a substantial caliber may be similar to that of the left anterior descending artery or greater than caliber of the left circumflex artery .The median artery has an area of distribution extending half way down to the free wall follows an oblique route via the sternocostal surface of the left ventricle frequently reaching the midpoint between the cardiac base and the apex . But it may reach the apex itself until reaching the diaphragmatic surface of the left ventricle.(47,56)

For this reason unlike certain hemodynamists we should not focus our angiographic examination only on the searching for lesions in the left anterior descending artery and circumflex arteries since the involvement of the median artery because of its distribution may be dangerous as the involvement of the two arteries. The median artery may play an important role as a collateral vessel in the deprivation of the coronary circulation.(47)

***Left anterior descending artery**:* this artery may end either before reaching the apex, in the apex itself and more frequently pass around the apex and reaches the posterior interventricular groove . The length at this level is variable in some cases it may be longer reaching half of the posterior interventricular groove. The portion of the artery that is lodged in the posterior interventricular groove is known as the "posterior recurrent interventricular artery". It appears to have a relation between the length of this artery and that of the posterior interventricular artery or posterior descending artery (branches from the right coronary artery or the circumflex artery) .On the occasion of the recurrent artery may entirely substitute the posterior interventricular artery in this case the circulation of the interventricular wall depends entirely on the anterior interventricular artery. However these two arteries may be anatomized. (47,57)

Left circumflex artery: it is one of the three main coronary arteries. the circumflex artery has the greatest variability in terms of length and distribution. . Two points are generally used to situate the termination of the circumflex artery the obtuse marginal artery or the posterior descending artery . (47,58)

Right coronary artery :The length of the right coronary artery is highly variable. In more than 70% of cases the right coronary artery goes beyond the crux cordis (47,59,60)

C)Variations in the origin of significant collateral arteries :

1) Sinoatrial artery :

The sinus node artery was most frequently a large atrial branch of the RCA arising at a mean distance of 1.2 cm (range 0.2 - 2.2 cm) from RCA beginning . Similarly in a computed tomography study SAN artery was originating from the proximal 40 mm of the RCA and from the proximal 35mm of the left circumflex artery (61,62,63) . SAN artery observed as a single branch which arised from the right coronary artery in 50- 54%, from the circumflex artery in 42-44%(47,61,64) as in **Figure 1.12.** Two sinus node arteries arised from both right coronary artery and circumflex artery found in 2-4%(In the case of double blood supply one of the arteries always has a greater caliber).(47) The length of sinus node artery is longer if originated from left side than that from right side . In all cases the SAN artery provided a collateral branch to atrium and /or auricle of same side of origin and /or the opposite side . (47,64)

The origin and course of SAN artery may provide a safe approach to interventional cardiologist and cardiac surgeon and we should be careful because compensation the single SAN artery is not possible in the case of its being cut or occluded which later lead to atrial arrhythmias including sinus bradycardia , sinoatrial block so as a result the dual blood supply may be a protective factor to patients from arrhythmic events.(61,64)

Figure 1.12. Sinus node artery originating in the posterior portion of the circumflex artery. The artery presents the characteristic S-shape (Ao: aorta; LCX: circumflex artery; LAA: left atrial appendage; SA: sinoatrial artery; SVC: superior vena cava). (47)

2)Atrioventricular node artery:

The atrioventricular node artery may originate from the right coronary artery in 86% , from the circumflex artery in 12% and from both arteries in 2% .Habitually, the atrioventricular node is irrigated by the artery that reaches the crux cordis and gives the posterior interventricular artery. Although as noted coronary dominance does not automatically reflect the origin of the AV node artery and that explains in 17% of cases the AV node artery originated from LCX and the posterior interventricular artery originates from RCA . Double AVN arteries was encountered with the upper artery larger and passed between the right and left atria and the lower artery smaller and crossed the space adjacent to the right ventricle.(47,65)

3)Posterior interventricular artery:

It originates from the RCA near the acute margin of the heart and adopts an oblique path on the posterior wall of the right ventricle to reach the middle third of posterior interventricular groove contributing to the irrigation of the diaphragmatic heart surface. The posterior interventricular artery also may originate from the left circumflex artery or both(the right coronary artery , left circumflex artery). It may regard as a collateral or a terminal branch and its origin is one of the parameters of cardiac arterial circulation dominancy. The right dominant in 50-60% , left dominant in 10-15% and the Co-dominance in 10%. (47, 54)

4)Conal artery or third coronary artery:

Firstly described by Schlesinger (1949).(66) It supplies the infundibulum (conu) of the right ventricle , variable parts of the anterior wall of the right ventricle and the interventricular septum. Sometimes the ischemic changes do not detect in these regions because of the collateral blood flow by the conal artery therefore its important in the progress and extent of myocardial infarction and in cardiac surgery. (43,58 ,67 ,68) The separate orifices for the TCA and the RCA had been explained by insufficient union of these two vessels during their growth towards the ascending aorta (69) .

1.15. Aims of study :

1) To know the incidence of each anatomical variations of human coronary arteries among people in Basrah governorate .
2) To evaluate by angiographical examination the anatomical and morphometric analysis of each coronary artery.

Chapter Two

Materials and Methods

2.1. The study setting :

This angiographical prospective study was carried out in the cardiac catheterization center at Al Sadder Teaching Hospital ,Basrah governorate during the period extended from 5th of October 2012 to the end of June 2013 . The patients who attended this center had age range from twenty to eighty five years old.

2.2. Sampling design and sample size :

The sample included all patients who lived in Basrah and attended the center during the study period .The patients with history of congenital heart diseases and angiographical findings as ischemic arterial changes or congenital coronary arteries anomalies were excluded from the study .

The sample size was three handered fifteen cases (315) , the cases selected randomly in age and sex (the male cases were 212 while female 103) with normal angiographical and anatomical findings of coronary arteries were collected from the cardiac catheterization center at Al Sadder Teaching Hospital ,Basrah governorate **.**

2.3. Development of questionnaires and data collections :

A structural questionnaires formula was developed and designed for the purpose of the study after being discussed with experts . All 315 cases were interviewed , the interview and data collections was carried out after taken a verbal permission from the patient to participate in this study . The questionnaires form and data collections included the following informations :

- Socio demographic characters of the patients which included : age , sex ,residency, history of chronic diseases (diabetes mellitus , hypertension , bronchial asthma ..etc) .
- Data collections from calculating system of conventional angiographic computed device were using quantitive coronary angiography QCA (after end of angiographical study to patients) included the measurements of coronary arteries length, caliber, origin, number of branches of each coronary artery, type of coronary circulation (dominancy), etc …

2.4. Catheterization Equipments :

The catheterization equipments used in cardiac catheterization center at Al Sadder Teaching Hospital were :

1) Phillips angiographic equipment : which used in the center since 2008 and manufactured in Holland .
2) General Electrical angiographic equipment : : which used in the center since 2012 and manufactured in USA.

Both equipments consisted of same parts and the only difference was in the criteria of image quality and radiation adjustment. The equipments consisted of optical system, video camera, video cassette recorder , analog to digital converter , and heamodynamic monitors. The x-ray tube was the source of the x-ray beam which passed superiorly through the patient as shown in **Figure 2.1**. The angiographic equipment room also had D.C shock apparatus and sectors to the catheters and sheaths , emergency drugs, intravenous fluids and sector to the contrast dyes.

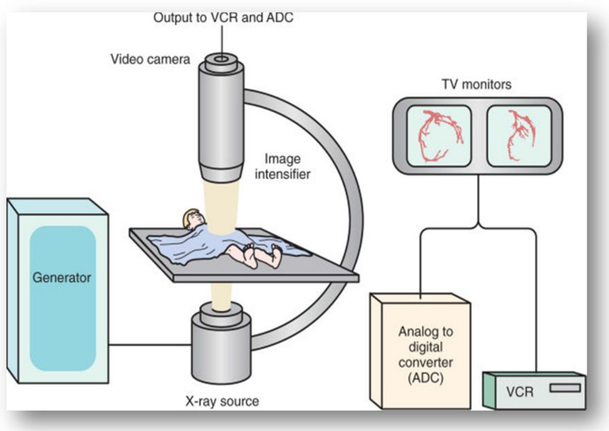


Figure 2.1. angiographic equipment. The major components include a generator, x-ray tube, image intensifier attached to a position such as optical system, video camera, videocassette recorder (VCR), analog to digital converter (ADC), and television monitors. (23)

2.5. Standard angiographic views :

The angiographic anatomical landmarks formed by the spine, catheter and diaphragm provided information to discern which tomographic view from which the image is obtained. In the LAO view the catheter and spine are seen on the right side of the image as in **Figure 2.2A**, while in the RAO they are

found on the left side of the image as in **Figure 2.2B** . PA imaging these landmarks placed in the center of the image as in **Figure 2.2C** . The projection is referred to "the cranial view" if the image intensifier is tilted toward the head of the patient .The projection is referred to "the caudal view" if the image intensifier is tilted down toward the feet of the patient or in other word the cranial angulation can usually be distinguished from caudal angulation by the presence of the diaphragm.

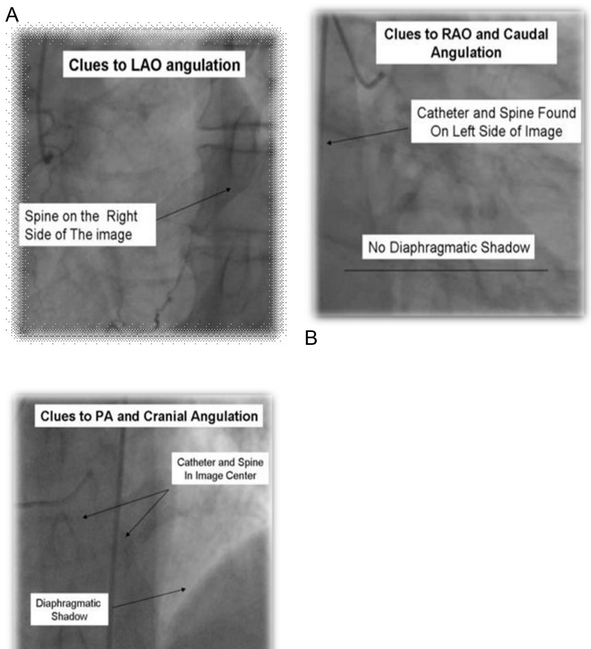


Figure 2.2. A,B,C Show the angiographic views in relation to anatomical landmarks. [23]

There are no rules in which tomographic views are most useful, but generally for left circumflex artery and proximal epicardial visualization the caudal views are most useful as in **Figure 2.3 A** , LAD and LAD/diagonal visualization the cranial views are most useful as in **Figure 2.3 B** and for left main stem visualization the LAO caudal or spider view as in **Figure 2.3 C** are useful.

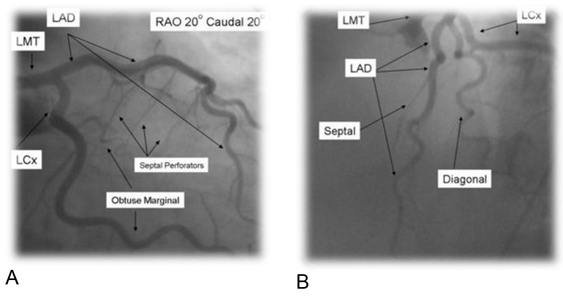


Figure 2.3. A the RAO caudal show the left circumflex artery and it's obtuse marginal branches, B the LAO cranial show LAD and it's branches but C show the left main stem . [23]

The right coronary artery is engaged in the LAO position, the initial angiographic imaging of the RCA in this view LAO gives the best view of significant ostial and proximal RCA disease. The mid RCA is best visualized in the straight RAO position but the bifurcation of the distal RCA and right PDA is best seen in the PA cranial view with a small breath in as seen in **Figure 2.4.**

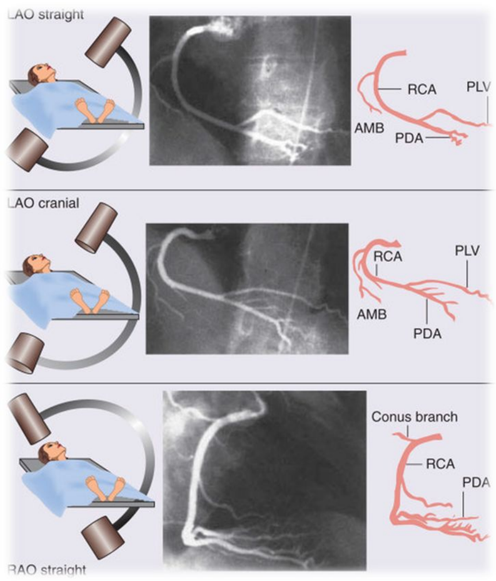


Figure 2.4. Angiographic views of the right coronary artery (RCA). The approximate positions of the x-ray tube and image intensifier are shown for each of the commonly used angiographic views. left anterior oblique view (LAO straight) shows the proximal and mid-portions of the RCA as well as the acute marginal branches (AMB) and termination of the RCA in the posterior left ventricular branches (PLV). The left anterior oblique view with of cranial angulation (LAO cranial) shows the mid-portion of the RCA and the origin and course of the posterior descending artery (PDA). The right anterior oblique view (RAO) shows the mid-portion of the RCA, the conus branch, and the course of the PDA . [23]

2.6. Technique of coronary angiography :

2.6.1. Preparation of the patient :

Elective coronary angiography should be performed alone or in conjugation with contrast left ventriculography when co morbid conditions exist such as congestive heart failure .

The patient came fasting, he didn't administer the morning dose of aspirin and if he was diabetic no hypoglycemic drugs should be taken that morning only the antihypertensive drugs .

The patient should be stable at time of conventional angiographical study , each patient should have done the following tests : the baseline ECG, electrolytes , renal function tests, complete blood cell count and coagulation test should be reviewed before coronary angiography because the patient at increased risk for systemic thromboembolism on withdrawal of warfarin specially those with atrial fibrillation , mitral valve disease and previous history of systemic thromboembolism.

2.6.2. Drugs Used During Coronary Angiography :

1) Sedation:

The goal of its use is to achieve a state of conscious sedation as a minimally depressed level of consciousness that allows a patient to respond appropriately to verbal commands and to maintain a patent airway. Several different sedation regimens are recommended but the most common drug used was diazepam 5 - 10 mg intramuscularly , patients undergoing conscious sedation should have a continuous hemodynamic and electrocardiographic monitoring .

2.Anticoagulants:

Heparinized saline is still required during routine coronary arteriography specially for patients at increased risk for the thromboembolic complications including those with severe aortic stenosis or atrial fibrillation. Frequent flushing of all diagnostic and guiding catheters with heparinized saline prevents the formation of micro thrombi within the catheter tip. A continuous flush through the arterial access sheath may also lower the occurrence of distal thromboembolism.

3.Other drugs according to the patient conditions:

These drugs included: intravenous fluid, adrenaline, atropine, hydrocortisone , antihypertensive drugs or hypoglycemic drugs according to measurement of blood pressure or the level of fasting blood sugar .

4. contrast dye :

All radiographic contrast agents contain iodine, which effectively absorbs x-rays in the energy range of the angiographic imaging system. Radiographic contrast agents currently used for coronary arteriography may also produce a number of adverse effect on the hemodynamic, electrophysiological and renal system. The frequency of these side effects varies among the different radio contrast agents because of differences in their ionic content, osmolality and viscosity . The most used dye was Ominipaque contrast media 350mg /1cc , the vial contain 100 cc given according to body weight. The Ominipaque was a brand name to the Iohexol, it's osmolality is 844 mosmol/kg , it's viscosity at 37 ° is10.4 . It contains 350mg /ml of iodine while the amount of sodium is 5meq /liter. The additive substances with Ominipaque are : Tromethamine ,calcium , EDTA. The Ominipaque was the preferable dye because of its low side effect profile .

2.7. Vascular accesses:

A variety of vascular approaches available for coronary arteriography and the selection of the vascular access depends on the operator , patient condition and the presence of peripheral vascular disease. There are different arterial approaches to angiography:

1)Common femoral arterial access: it is the most common arterial access for performing left heart catheterization.

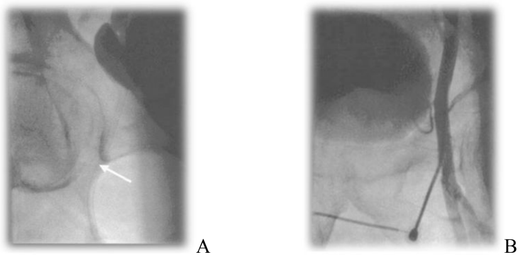
2) Brachial access: it is the original catheterization procedure , this site is still commonly used in patients with lower extremity peripheral access issues.

3) Radial artery access: it is also used commonly in some practice settings. Before radial access is performed the competence of the radial artery arch should be assessed with the Allen test [76] or used the pulse oximetry that can facilitate interpretation of the test.

2.7.1.Femoral Artery Approach:

The right or left femoral arteries accesses are the most commonly used for coronary arteriography. The common femoral artery coursed medially to the head of femur which can be localized by fluoroscopy before arterial puncture as in **Figure 2.5 A**. The anterior wall of the common femoral artery should

be punctured few centimeters below the inguinal ligament but proximal to the bifurcation of the superficial femoral and profunda femoral arterial branches see **Figure 2.5 B**. If the puncture site is proximal to the inguinal ligament the hemostasis after the procedure may be difficult with manual compression, leading to an increased risk of retroperitoneal hemorrhage. If the puncture site is distal to the femoral bifurcation, there is a higher risk of pseudoanuerysm formation after femoral sheath removal.



A B

Figure2.5. Radiographic landmarks can be used to identify the course of the common femoral artery. A, The middle third of the right femoral head identifies the usual course of the common femoral artery (arrow). B, The arterial sheath is shown placed proximally to the bifurcation of the superficial femoral artery and the profunda femoris .(23)

2.7.2. Radial and brachial artery approaches:

Although Sones (24) firstly introduced the cut down approach to the brachial artery for coronary arteriography (23,24) but the access to the brachial and radial arteries is now most often obtained percutaneously. These approaches are preferred on the femoral approach in the presence of severe peripheral vascular diseases and morbid obesity. The radial artery access is generally preferred than brachial catheterization because its more easy for introducing and removal of catheter , also the size of catheter was differ in brachial artery than the radial artery . Before radial artery access attempted the Allen test should be carried out to ensure that the ulnar artery is patent. Systemic anticoagulation with intravenous heparin is used for both approaches to prevent catheter thrombosis and administration of intra arterial Verapamil and nitroglycerin reduce the occurrence of radial artery spasm, although rare episodes of radial artery trauma and avulsion had occurred .

2.8. Catheters in angiography :

Diagnostic catheters developed for coronary arteriography are generally constructed from polyethylene or polyurethane with a fine braided wire within the wall to allow advancement and directional control and to prevent kinking. The most widely used the Judkin catheter as in **Figure 2.6** which the outer diameter size of the catheters ranged from 4 to 8F, but 4 and 6F catheters are used most commonly for diagnostic arteriography. Other catheters such as Amplatz catheters can be used in engagement of the left main stem or anomalous arteries.

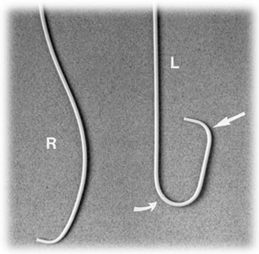


Figure 2.6. Showing the right and left Judkin catheters used commonly for diagnostic arteriography. (23)

2.9. Technique :

After the administration of subcutaneous anesthesia , the Cook needle is used to puncture the front wall of the femoral artery this technique known as the Seldinger technique and it prevented posterior arterial bleeding or venous communication from the puncture.

Once access is obtained the Cook needle is steadied while the artery is accessed with a wire through the lumen of the Cook needle. The Cook needle is then removed and a sheath is inserted into the artery. Under fluoroscopy view , catheters are then introduced using an J-tipped guide wire into the aortic root. The catheters are then attached to a three way manifold . This manifold used to allow for continuous pressure monitoring, saline flush instillation and contrast administration through the catheter tip. The catheter selection for a routine left heart catheterization is generally straight forward. The Judkin left generally engaged the left coronary artery in most patients with relative ease as in **Figure 2.7** .

For the right coronary artery a Judkin right is most often used with slow clockwise rotation of the catheter in the aortic root would be engaged the ostium of the RCA as in **Figure 2.8**

Once the artery is engaged it was important to examine the pressure wave form. Normally the waveform should mimic to the aortic root pressure but the dampening or ventricularization of the pressure waveform indicated over engagement of the catheter . Extreme care should be taken before instillation of contrast medium without normal pressure waveforms

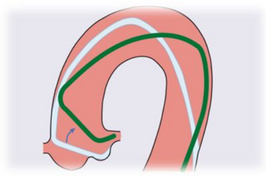


Figure 2.7. Push-pull technique for catheterizing the left coronary artery with the Judkin left catheter.

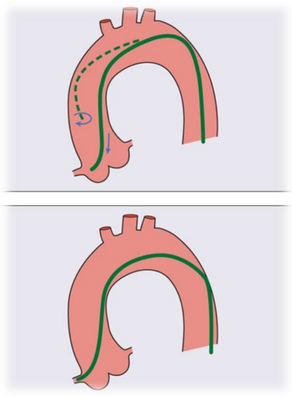


Figure 2.8. Cannulation of the right coronary artery using the Judkin right catheter. A, the tip of the catheter facing rightward and then the catheter is rotated clockwise slightly. B, Sudden rightward and downward movement of the catheter tip signifies the entry into the right coronary ostium. (23)

2.10.Statistical analysis :

Statistical analysis was used to evaluate anatomical variations of coronary arteries and correlate them with others , the SSPS system (version 15) was used . The relation between parameters was determined using t- test and ANOVA test . The Statistical significance was defined as **p - value < 0.05 .**

Chapter Three

Results

3.1. Socio-demographic characteristics of studying cases:

This angiographical prospective study was carried out in the cardiac catheterization center during the period from 5th of October 2012 to the end of June 2013 . Sample size was three handered fifteen cases (315) chosen randomly, the male patients were 212 (67.3%) and the female patients were 103 (32.7%) as in **Diagram 3.1**. The age of patients ranged between 20 – 85 years old with average age 56±10.4 years there was no significant difference between sexes and between rural and urban areas (p> 0.05) see **Table 3.1**.

Diagram 3.1: Distribution of cases according to gender:

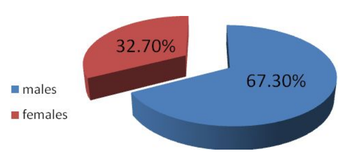


Table 3.1.Analysis of variance according to gender and residency:

Subjects	Degree of freedom	Mean square	Significant (p- value)
Male	1	0.006	0.638
Female	2	0.008	0.955
Urban	2	40.4	0.499
Rural	1	74.4	0.258

3.2. Dominancy of cardiac arterial circulation:

The pattern of coronary arterial circulation among our population was right dominant in 81%, the co-dominant in 9.8% and the left dominant in 9.2% as shown in **Table3.2 , Figure 3.1a,b.**

Table3.2. Distribution of cases according to Dominancy:

Dominancy	Frequency	Percent %
Right	255	81 %
Left	29	9.2 %
Co dominant	31	9.8 %
Total	315	100 %

3.3. Left coronary artery or left main stem:

3.3.1. LMS presentation :

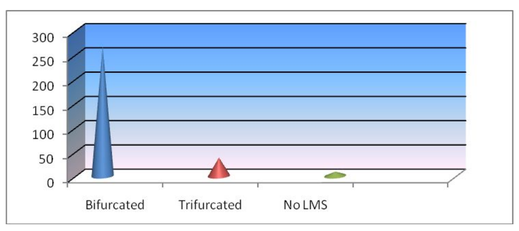
The left coronary artery was presented in 97.8% of cases and absent in 2.85% of cases see **Table 3.3.1, Figure 3.2a,b.**

Table3.3.1. Distribution of cases according to Left main stem presentation:

Left main stem	Frequency	Percent %
Present	308	97.8 %
Absent	9	2.85 %
Total	315	100 %

3.3.2. LMS Furcation :

The left coronary artery bifurcated to the anterior descending artery and left circumflex artery in 85.1%of cases or trifurcated to the left descending artery , left circumflex artery and the ramus intermedius in 12.1% of cases but in 2.85% there was already no left coronary artery. See **Diagram 3.3.2** , **Figure 3.2b, Figure3.3.** **Diagram.3.3.2. Distribution of cases according to Left main stem Furcation**:



3.3.3. LMS length and caliber :

The mean length of left coronary artery was 9.38 ± 4.65 mm on the other hand the caliber of left coronary artery was 4.69 ± 1.310 mm as in **Table 3.3.3**.

Table 3.3.3 .Left main stem measurements :

Variables		Mean (mm)	Std. Deviation
Left main stem	Length	9.38	4.65
	Caliber	4.69	1.310

3.4. Left anterior descending artery, Left circumflex artery and Right coronary artery :

The ***LAD*** was the first branch of left coronary artery, its length was 128.20 ± 30.27 mm and its caliber was 3.79 ± 2.563 mm . The ***LCX*** was the second branch of the left coronary artery, its length was 103.36 ± 26.29 mm and its caliber was 3.59±0.96 mm . ***RCA*** was the second coronary artery its length was 101.93 ±24.11mm and its caliber was 3.74±1.94 mm as shown in **Table 3.4**, **Figure3.4a , b.**

The measurements of the distances between the RCA ostia and RCA branches were the following :

Distance from ostia to conal artery was 4.11±8.06mm .

Distance from ostia to sinoatrial node artery was 6.58 ± 7.53mm.

Distance from ostia to RVB artery was 38.04 ± 21.30mm .

Distance from ostia to AM branch was 54.93 ± 17.95mm .

Distance from RVB to RCA bifurcations was 63.78 ± 21.39mm .

Table 3.4. Measurements of Left anterior descending artery, Left circumflex artery and Right coronary artery :

Variables		Mean (mm)	Std. Deviation
LAD	Length	128.20	30.27
	Caliber	3.79	2.563
LCX	Length	103.36	26.29
	Caliber	3.59	0.96
RCA	Length	101.93	24.11

	Caliber	3.74	1.94
	Distance from ostia to conal artery	4.11	8.06
	Distance from ostia to SA node artery	6.58	7.53
	Distance from ostia to RVB	38.04	21.30
	Distance from ostia to AM branch	54.93	17.95
	Distance from RVB to RCA bifurcation	63.78	21.39

3.5. Variations in the origin of coronary arteries :

3.5.1. Variations of left circumflex artery origin :

This study revealed that the LCX artery originated from LMS in 97.1% , the origin from left coronary sinus in 1.9% as shown in **Table 3.5.1, Figure 3.2a, Figure 3.3, Figure3.5**.

Table3.5.1. Distribution of cases according to left circumflex artery origin:

left circumflex artery origin	Frequency	Percent %
From left main stem	306	97.1 %
From left coronary sinus	6	1.9 %

3.5.2. Variations of sinoatrial nodal artery origin:

The SA Node artery originated from RCA artery in 68.6% while its origin from LCX in 31.4 % as in **Table 3.5.2** ,**Figure 3.6.**

Table3.5.2. Distribution of cases according to Sinoatrial nodal artery origin:

Sinoatrial node artery origin	Frequency	Percent %
From Right Coronary artery	216	68.6 %
From Left circumflex artery	99	31.4 %
Total	315	100 %

3.5.3. Variations of Conal artery origin:

The Conal artery originated from Right coronary artery in 60.6 %, its origin from left circumflex artery in 32.7% and its origin from right aortic sinus in 6.7% as in **Table 3.5.3,Figure 3.4a, Figure 3.7.**

Table. 3.5.3 : Distribution of cases according to Conal artery origin

Conal artery origin	Frequency	Percent
From Right coronary artery	191	60.6 %
From left circumflex artery	103	32.7 %
From Right coronary sinus	21	6.7 %
Total	315	100 %

3.6.Variations of the collateral branches according to its number:

3.6.1. Variations of the diagonal branches number :

A variable number of diagonal branches originated from the left anterior descending artery: number of diagonal branch was one in 19% ,two diagonal branches in 41.6 %, three or more diagonal branches in 0.63-26 % see **Table 3.6.1 , Figure 3.8, Figure 3.9.**

3.6.2. Variations of the septal branches :

The septal arteries originated from left anterior descending artery: one LAD septal branches in 23.4 % , two septal branches in 28.9% and three or more septal branches in 0.3-20.6% see **Table 3.6.2.**, **Figure 3.8, Figure 3.9.**

Table3.6.1. Distribution of cases according to diagonal branches:

No. of Diagonal branches	Frequency	Percent %
1	60	19 %
2	131	41.6 %
3	82	26 %
4	34	10.8 %
5	6	1.9 %
7	2	0.63%
Total	315	100 %

Table3.6.2. Distribution of cases according to left anterior descending septal branches:

No. of septal branches	Frequency	Percent %
1	74	23.4 %
2	91	28.9 %
3	65	20.6 %
4	39	12.4 %
5	27	8.6 %
6	11	3.5 %
8	2	0.6 %
9	1	0.3 %
10	3	1 %
11	2	0.6 %
Total	315	100 %

3.6.3.Variations of Left obtuse marginal branches :

Obtuse marginal artery branched from left circumflex artery and it was variable in number : obtuse marginal branch was one in 25.7%, two in 40.3% and three or more in 0.3 -24.1% see **Table3.6.3, Figure 3.10.**

Table3.6.3.Distribution of cases according to left obtuse marginal branches:

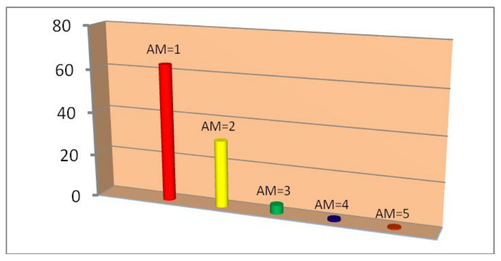
No. of obtuse marginal branches	Frequency	Percent
1	81	25.7%

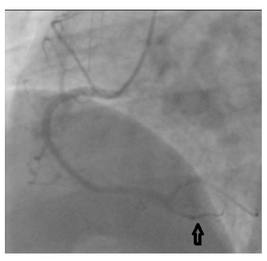
2	127	40.3 %
3	76	24.1 %
4	18	5.7 %
5	11	3.5 %
7	1	0.3 %
8	1	0.3 %
Total	315	100 %

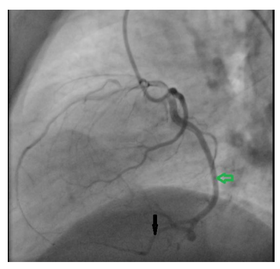
3.6.4. Variations of right acute marginal branches :

The inferior margin of the heart toward apex was supplied by acute marginal artery. In this study observed a variability in number :The number of acute marginal branch was one in 63.5 %, two in 30.8% and three or more in 0.6-4.1% see **Diagram 3.6.4**

Diagram 3.6.4 : Distribution of cases according to right acute marginal branches

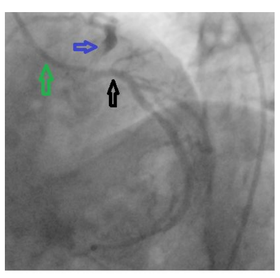


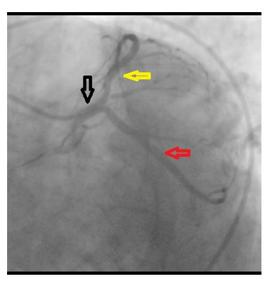




a b

Figure 3.1 a) LAO cranial where the right dominant circulation, black arrow referred to posterior descending artery arised from right coronary artery .b) LAO cranial view where left dominant circulation the posterior descending artery(black arrow) arised from left circumflex artery(green arrow).





a b

Figure 3.2 a) LAO caudal view: the catheter (green arrow) in LCS where the anterior descending artery(blue arrow) and left circumflex artery(black arrow) arised directly from LCS, (b) LAO caudal view: left coronary artery(black arrow) branched to anterior descending artery(yellow arrow) and left circumflex artery (red arrow).

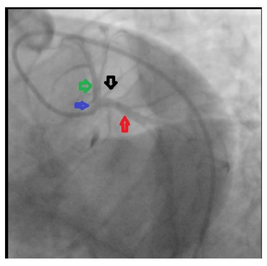
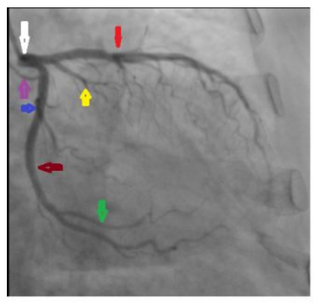
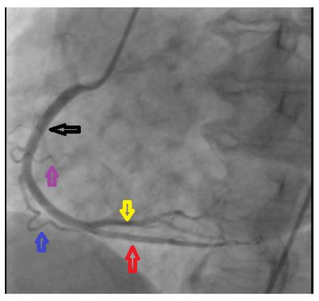


Figure 3.3. LAO caudal view where the left coronary artery(blue arrow) trifurcated to 3 branches: anterior descending artery(green arrow) , left circumflex artery(red arrow) and median artery(black arrow).



a



b

Figure 3.4.(a) RAO view where the left coronary artery(white arrow) bifurcated to left anterior descending artery(red arrow) which its branched to diagonal artery(yellow arrow) and septal artery . Left circumflex artery(brown arrow) which branched to septal artery (blue arrow), obtuse marginal artery (green arrow) and conal artery (pink arrow). (B) RAO view where right coronary artery(black arrow) and its terminal branches: right ventricular branch (pink arrow) , acute marginal(blue arrow), posterior descending(red arrow) and posterior right ventricle (yellow arrow) .

/

Figure 3.5. LAO view where the left circumflex artery (black arrow) arised from right coronary sinus (blue arrow) same as right coronary artery (red arrow).

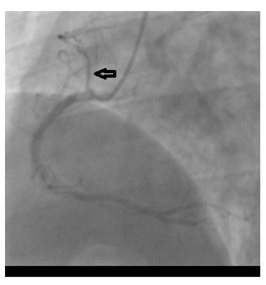


Figure 3.6. RAO view where the SA Node artery (black arrow) originated from right coronary artery.

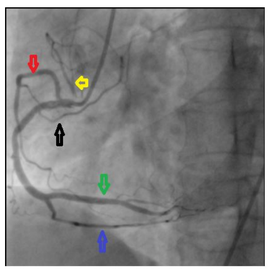


Figure 3.7. LAO view where the Conal artery (black arrow) originated from Right coronary artery, sinoatrial artery (yellow arrow), right ventricular branch (red arrow) , posterior descending(blue arrow) and posterior right ventricle (green arrow) .

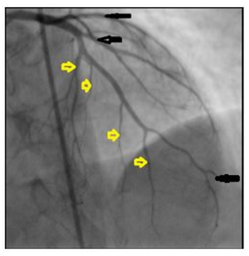


Figure 3.8. LAO cranial view where the diagonal branches(black arrow) numbers are three and the septal branches (yellow arrow)are four .

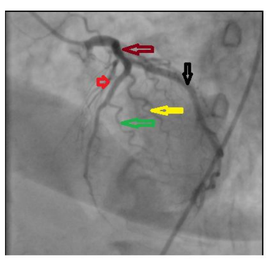


Figure 3.9. LAO cranial view where anterior descending artery(brown arrow) with its terminal branches: diagonal artery D1,D2 (yellow and green arrow) and septal arteryS1 (red arrow) .

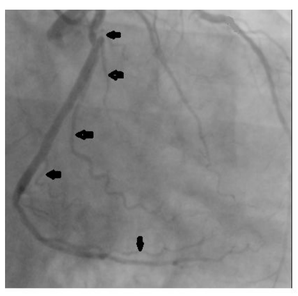


Figure 3.10. RAO caudal view where the obtuse marginal branches (black arrow) are five

Chapter Four

Discussion

The numbers of cases in this study was 315 (67.3% males and 32.7% females) who attended to cardiac catheterization center at Al- Sadder Teaching Hospital in Basrah governorate . The patients age ranged between 20 – 85 years with average age of 56 ± 10.4 years old, there was no significant difference between both sexes and between rural and urban areas ($p > 0.05$) even when they exposed to different socio economic levels .

4.1. Dominancy of arterial circulation of heart:

Among our population the most dominant cardiac arterial circulation was the right dominant in 81% while the Left dominant in 9.2% and the co- dominant in 9.8% . The results of the present study are in agreement with Cadmartiri *et al.*, 2008; Nordon *et al.,* 2012; El-Maasarany *et al.,* 2009; Pınar Kosar *et al.,* 2009 and Abdellah *et al.,* 2009.[14,51,65,70,71] PDA supplied the posterior wall of right and left ventricles adjacent to the posterior interventricular groove and this has a great effect in case of inferior myocardial infarction, this fact emphasizes the importance of knowing the type of cardiac arterial circulation in otherword the heart with a co- dominant circulation is less likely to be affected by the medical diseases as diabetes mellitus and hypertension, while the left dominate is most likely affected by these diseases because the left circumflex artery has small caliber when compared with the right coronary artery .

4.2. Left main stem presentation :

In this study the LMS presented in 97.8 % and absent in 2.85%.The absence of LMS is due to split of the origin of LMS into LAD and LCX .[14] these results were agreed with Kalpana, 2003 and Cadmartiri *et al*., 2008.[14,54]

4.3. LMS divisions:

In our study the LMS bifurcated in 85.1% and trifurcated in 12.1% where this disagreed with other studies; Bhimalli *et al*., 2011; Cadmartiri *et al*., 2008; Fazliogullari *et al*., 2010 and Kalpana, 2003. [14,38,40,54] This variations may be due to geographical and genetic basis differences [49].

4.4. LMS length and caliber :

In our study LMS length was 9.38± 4.65mm and its caliber was4.69± 1.310mm these results agreed with other studies as Fazliogullari *et al*., 2010, Reig Vilallonga , 2003 and Fiss, 2007 .[38,42,47]

The short LMS may be clinically relevant especially when a coronary angiography is performed because of incomplete imaging of the left coronary artery this may be seen when introducing the catheter into only one of the terminal branches . The studies observed that a short LMS presents the same potential risk as the absence of the LMS [53,54] .Other authors reported that the existence of a short LMS is a risk factor for the development of coronary arteriosclerosis or as a cause of blockage in the left branch of the bundle of His.[47] These findings may suggest that in cases with a short left coronary artery the atherosclerotic lesions in the anterior descending and left circumflex branches appear earlier, progress faster at higher levels of severity and lead more frequently to myocardial infarction when compared with the cases with a long left coronary artery trunk. In patients with the age of 50 years, it was shown that the degree of atherosclerosis in the left anterior descending and left circumflex branches was inversely related to the length of the main left coronary artery.[53,54,55]

4.5. Left anterior descending artery , left circumflex artery and right coronary artery :

Different researches performed to study these coronary arteries either together or separately .The results of our study were the LAD length 128.2 ± 30.27mm and its caliber 3.79 ± 2.56 mm , LCX length 103.36 ± 26.29 mm and its caliber 3.59 ± 0.96 mm , RCA length 101.93 ± 24.11 mm and its caliber 3.74 ± 1.94 mm which agreed with Vathsala *et al*., 2011; Kosar *et al*., 2009 and Fiss, 2007.[42,51,72] There is no similar study concerned with measurement of the left circumflex length . Our results of RCA length and caliber agreed with Vathsala *et al.,* 2011; Fazliogullari *et al.,*2010; Ballesteros *et al*.,2011 and Stankovic *et al*., 2004.[38,67,72]

According to Vathsala *et al*.,2011 the caliber of RCA equal to the caliber of LAD[72] and that findings are similar to our study results (RCA caliber 3.74 ± 1.94 mm and LAD caliber 3.79 ± 2.56 mm) .

4.6. Distances of RCA branches :

4.6.1. Distance of SA nodal artery from Ostia:

The present study result was 6.58±7.53 mm which agreed with the findings of Ortale *et al*., 2006.[64]

4.6.2.Distance of the conal artery from Ostia:

The results of this study showed that the distance of conal artery from ostia was 4.11 ± 8.06 mm, there was no similar study for the measurement of the distance of right conal artery origin from ostia .A heamodynamic analysis of the coronary blood flow should be based on the measurements of branching pattern and vascular geometry of the coronary vasculature when this later help to overcome the potential difficulty in cardiosurgical procedures such as reinsertion of the coronary arteries [37,52]

4.6.3. Distances of right ventricular branch , right acute marginal artery from Ostia:

In this study the distance of right ventricular branch from ostia was 38.04±21.3 mm and the distance of right acute marginal artery from ostia was 54.93 ±17.95 mm. There were no similar studies related to the measurement of these distances.

4.6.4. Distance from the right ventricular branch to RCA bifurcations :

In our study the distance from the right ventricular branch to RCA bifurcations was 63.78±21.39 mm and there was no similar study related to measurement of this distance.

The measurements of the distances of RCA branches are valuable in explanations of the site of occlusion or thrombosis in case of right ventricular infarction .

4.7.Variations in the left circumflex artery origin:

The present study showed that the left circumflex artery originated from LMS in 97% , the origin from left coronary sinus in 1.9%. These results were in agreement with Fazliogullari *et al*., 2010; Abdellah *et al*., 2009 and Sohrab *et al*., 2010.[38,70,73]

4.8.Variations in the sinoatrial nodal artery origin :

The SA nodal artery originated from RCA in 68.6% and originated from LCX in 31.4%. Our study agreed with Vathsala *et al*., 2011; Ballesteros *et al*., 2011 and Kalpana, 2003.[54,60,72]

4.9.Variations in the conal artery origin :

The origin of conal artery from RCA in 60.6 % , from LCX in 32.7% and the origin from RCS in 6.7% . The results of the present study was in agreement with Sankari *et al*.,2011 and Ballesteros *et al*.,2011.[43,60] The result related the origin of conal artery from RCS was in agreement with Kurjia *et al*.,1986 [74]. There is no similar study mention the origin of the conal artery from left circumflex artery .

Stankovic *et al.,*2004 and Sankari *et al*.,2011 explained the multiple openings in anterior right aortic sinus could be due to the folding of the heart resulting in bulbous cordis being absorbed into both ventricles. The folding of the heart results in opening of existing peritruncal capillaries at the conotruncal circle either directly into the newly formed aorta resulting in multiple ostia or secondarily attached to the existing blood vessels surrounding the atrioventricular circle resulting in the right conus artery arising from right coronary artery.[43, 67] The percentage of the origin of the conal artery from RCS in our study was less when compared this result with other studies results that was supported the suggestion of ethnic variability due to geographical and genetic basis differences .[43,49]

The existence of right conus artery bridges was important in the collateral circulation between the right and left coronary arteries [43,67] which is really significant in ischemic changes of the heart. [43] The vascularization area of the conal artery did not depend on the origin of the artery but depended on the length to determined its physiological significance [67].

4.10.Number of left anterior descending diagonal branches :

The diagonal branch was one in 19%, two diagonal branches in 41.6% and three or more diagonal branches in 0.63-26 %. These results were agreed with Cadmartiri *et al*., 2008.[14] The diagonal branches originated from LAD at acute angles and extend over the left ventricle in a diagonal fashion toward the acute margin and the apex, they run parallel to each other and are variable in number (2 to 9), if the ramus intermediate artery is present the diagonal vessels are less prominent [42]but in this study the frequency of median artery was less when compared with other studies and accordingly the diagonal branches are more prominent in supplying the left ventricle .

4.11.Number of left anterior descending septal branches:

The results revealed that the septal branch was one in 23.4%, two septal branches in 28.9% and three or more septal branches in 0.3-20.6 % . There was no similar study concerned with the number of LAD septal branches.

Possatti,2005 explained that the anterior interventricular septal branches emerging from the proximal segments of the left anterior descending artery are supplying blood to the septomarginal trabecula which bears the distal portion of the right branch of the atrioventricular bundle and supplying blood to the anterior papillary muscle of the right ventricle. The interventricular septum divided into two areas, had different blood supplies **(the upper portion** had the atrioventricular node, the atrioventricular bundle and the proximal segment of the two main bundle branches all these supplied by a branch of the right coronary artery, **The lower portion** comprised a greater mass of the septum including most of two main bundle branches and the Purkinje arborization of the septum supplied mainly by anterior interventricular septal branches **)** [57] . Fiss ,2007 suggested that the anterior septal perforators have mechanically immobilization of LAD , fixing it to the heart , limiting its motion and preventing buckling of the artery during systole.[42]

4.12.Number of left obtuse marginal branches :

The obtuse marginal branches of the left circumflex artery was one in 25.7%, two in 40.3% and three or more in 0.3 -24.1%. The results were in agreement with Cadmartiri *et al*., 2008. [14]

4.13.Number of right acute marginal branches :

The acute marginal branches arised from the RCA and supplied the anterior right ventricular wall .[75] The present study explained the distribution of the right acute marginal branches : the number of acute marginal branch was one in 63.5 %, two in 30.8% and three or more in 0.6-4.1% . There was no similar study concerned with the number of right acute marginal branches .

Chapter Five

5.1.Conclusions :

1) The results revealed that the incidence of median artery was less prominent in our population and accordingly the diagonal branches are responsible for supplying most of the left ventricle, therefore the coronary angiography of patient with anterior MI must not concentrate only on the main arteries examination but also looking for their branches .
2) The left coronary artery among our population less affected by chronic diseases as hypertension and diabetes mellitus because the LCA length and caliber act as a protected factors , the therapeutic procedures in patients with these LCA measurements are better in compared with other patients have short LCA .
3) The awareness of the origin and course of variants SAN artery may provide a safe approach to interventional cardiologist and cardiac surgeon during surgical coronary and atrial interventions**.**
4) The existence of right conus artery bridges recorded its important as a collateral circulation between the right and left coronary system which is really significant in ischemic changes of heart **.**

5.2. Recommendations :

❖This study serve as a pilot study for further studies in Basrah city and other governorates with additional researches are needed especially in anatomical and morphometric analysis of the anatomical variations of each coronary artery by utilization of CT angiography which is a valid alternative method to CCA .

❖Study the effect of chronic diseases with details in people with these anatomical variations of the coronary arteries .

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Appendix

Angiographic study of Anatomical variations of coronary arteries among people in Basrah

Name:

Age:

Sex:

residency:

Job:

Chronic diseases:

DM Ht Asthma

Habits:

Smoking alcoholic sports

Left main stem artery :

Length caliber

Anterior origin

Posterior origin

Originate from Lt

From Rt

Bifuricated : trifuricated:

No LMS

Left descending artery

Length

Caliber

Normal origin

Abnormal origin

No. of Digonal branch No. of septal branch

Left circumflex dominant non-dominant

Length

Caliber

Normal origin

Abnormal origin

No. of OM branches No . of septal branches

RT coronary artery dominant Non dominant

Length caliber

normal origin

NO .of marginal branch

Distance from ostium to SA node artery

Distance from ostium to conal artery

Distance from ostium to R.V.B

Distance from ostium to acute marginal branch

Distance from R.V.B. to bifurcate of R.C.A

SA Node artery origin:

RCA LCX

Conal artery origin:

RCA LCX RCS

الخلاصة :

إن التغيرات التشريحية في الدورة الدموية التاجية شائعة. وفي الوقت الحاضر غيرت هذه الاختلافات الشائعة لمرضى الأمراض المزمنة على القلب وكون الى دور في تفسير الإجراءات العلاجية في مجال جراحة القلب والأوعية الدموية ونسبة حدوث التغيرات التشريحية في الشرايين التاجية هي 1% الى كن من الفصل إيضاح أهميتها السريرية. إن هذه الدراسة هي دراسة استطلاعية للتصوير الوعائي للشرايين التاجية التي أجريت على 315 مريض ذوي شرايين تاجية سليمة في مركز قرطبة للقلب في مستشفى البصرة التعليمي خلال الفترة الممتدة من الخامس من تشرين الأول 2012 وحتى الثاني من حزيران 2013.

وقد أظهرت نتائج الدراسة إن حدوث التغيرات التشريحية للشرايين التاجية لدى سكان مدينة البصرة كالتالي: نمط الدورة الدموية التاجية اليمنى السائدة في 81 % , نمط الدورة الدموية التاجية اليسرى السائدة في 9.2 % ونمط الدورة الدموية التاجية المشترك في 9.8 % . إن الشريان التاجي الرئيسي الأيسر وهو أكبر شريان تاجي وجد بنسبة 97.8 % من سكان مدينة البصرة وغير موجود بنسبة 2.85%. وكان طول الشريان التاجي الرئيسي الأيسر 9.38 ± 4.65 ملم وقطره 4.69 ± 1.31ملم. اذا الشريان ينتهي عادة إلى شريانين (الشريان الأمامي الأيسر النازل والشريان الأيسر المنعطف) بنسبة 85.1 % و ينتهي إلى ثلاثة شرايين بنسبة 12.1 % من سكان البصرة.

إن الشريان الأمامي الأيسر النازل يعتبر الفرع الأول للشريان التاجي الرئيسي الأيسر ويبلغ طوله 128.20 ±30.27 ملم و قطره 3.79 ± 2.563 ملم ولوحظ وجود عدد متغير من الفروع الى هذا الشريان: فرع قطري واحد في 19% ، فرعين قطريين في 41.6 % , ثلاثة وأكثر من الفروع القطرية في 0.63 - 26 % , فرع حاجزي واحد في 23.4 % ، فرعين حاجزيين في 28.9 % و ثلاثة وأكثر في 0.3- 20.6 %.

وقد وجد طول الشريان الأيسر المنعطف 103.36 ±26.29 ملم و قطره 3.59 ± 0.96 ملم. أظهرت الدراسة تغير في منشأ هذا الشريان حيث يتفرع الشريان الأيسر المنعطف من الشريان التاجي الأيسر في 97.1% و يتفرع من الجيب الأبهري الأيسر في 1.9 % . الفروع الهامشية المنفرجة من الشريان المنعطف كان عددها واحد في 25.7 % اثنان في 40.3% , ثلاثة وأكثر في 0.3 -24.1 % .

إن الشريان التاجي الأيمن يعتبر الشريان التاجي الثاني للقلب وطوله 101.93 ± 24.11 ملم و قطره 3.74 ± 1.94 ملم . تضمنت نتائج هذه الدراسة قياس المسافة من منشأ الشريان التاجي الأيمن إلى شريان العقدة الجيبية الأذينية 6.58 ± 7.53ملم وكانت المسافة من المنشأ إلى الخروط الشرياني 4.11 ± 8.06 ملم ، مسافة من المنشأ إلى الشريان البطيني الأيمن 38.04 ± 21.30 ملم ، المسافة من المنشأ إلى الشريان الهامشي الحاد 54.93 ± 17.95 ملم والمسافة من الشريان البطيني الأيمن إلى تفرع الشريان التاجي الأيمن هي 63.78 ± 21.39 ملم . إن هذه المسافات مهمة في تحديد مكان النزداد أو الجلطة الوعائية في حالة الجلطة الطبيعية للبطين. إن الحالة الأقوى للقلب لعبت دورا في الشريان الهامشي الحاد وان عدد الفروع الهامشية الحادة هي: فرع هامشي حاد واحد في 63.5 % ، اثنين في 30.8% وثلاثة وأكثر في 0.6-4.1 % .

شريان العقدة الجيبية الأذينية من الشريان التاجي الأيمن في 68.6 % و من الشريان المنعطف الأيسر في 31.4 % ويتفرع المخروط الشرياني من الشريان التاجي الأيمن في 60.6 % ، من الشريان المنعطف الأيسر في 32.7 % من الجيب الأبهري الأيمن في 6.7 % . نوصي بإجراء دراسات أخرى للتغيرات التشريحية في شرايين القلب التاجية باستخدام التصوير الوعائي المقطعي ودراسة تأثير الأمراض المزمنة على التغيرات التشريحية.

التصوير الوعائي التشريحي للشرايين التاجية كتجربة أولى في مدينة البصرة

أطروحة مقدمة إلى كلية الطب – جامعة البصرة كجزء من

متطلبات نيل شهادة الماجستير في التشريح البشري

من قبل

علي محمود عيسى

بكالوريوس طب و جراحة عامة

2013

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