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Anatomical variations and anomalies of the coronary arteries: 64-slice CT angiographic appearance

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Abstract

Complex coronary arteries variant and anomalies may affect adversely myocardial perfusion, diagnosis of these variant and anomalies may help surgeon to operate safely. This study was design to identify the 64-slice CTA appearance of the anatomic variations and anomalies of the coronary arteries and determine their incidence in our population. A retrospective study including of 202 persons 114 (56%) males, 88(44%) females); age range 15-79 years who had underwent MDCT examination. The entire heart was scanned within a single breath-hold. MDCT coronary angiograms were carried out in Al Ameer Medical Diagnostic Center and Open Heart center in Al Sadder Medical City between the period of April 2010 and April 2011. Patients with coronary artery anomaly constituted the subject of study. The incidence of anomalies in females was 32.9% while in males was 38.6%. The prevalence of the RCA was dominant in 175 cases (86.8%), while the LCA was dominant in 24 cases (11.8%), and the incidence of co-dominance was observed in 3 cases (1.4%). The incidence of LMCA trifurcation was 35(17.32%) duplication anomalies were observed in one patient (0.5%) in which double LADA originated from LMCA. Variable number of diagonal branches arise from LADA where one diagonal in 67 patients (33.20%), two diagonal in 113(55.90%), three diagonal in 21(10.4%), no diagonal was observed in one patient (0.5%).

Keywords: Complex coronary arteries; CTA; LMCA; LADA

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Introduction

Computed tomography (CT) was discovered independently by a British engineer named Sir Godfrey Hounsfield and Dr. Alan Cormack. It has become a mainstay for diagnosing medical diseases. For their work, Hounsfield and Cormack were jointly awarded the Nobel Prize in 1979 [1].

In 1998, multi-detector computed tomography (MDCT) was introduced and since then, cardiac CT has played a major role in the evaluation of the coronary arteries. Before the introduction of this new technique, electron beam computed tomography (EBCT) had already been used to evaluate the heart, but because of the inferior spatial

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resolution compared with MDCT and the fact that it is not widely available, EBCT does not play a major role in cardiac imaging today With the advent of newer generations of CT scanners, the 64-slice MDCT, and more recently, the dual-source CT (DSCT), temporal and spatial resolution have improved dramatically, due to a higher gantry rotation speed. Consequently, image quality has improved and the number of motion artifacts have substantially decreased compared to earlier scanner generations. As a result of these developments, evaluation of the coronary artery tree is increasingly performed with CT [2].

In MDCT, the coronary anatomy is shown in axial slices, as in all other radiological studies. But besides these axial slices, coronary anatomy can also be evaluated using a three-dimensional visualization derived from these axial slices. With current software, oblique multiplanar reconstructions, curved multiplanar reconstructions, three- and four-dimensional volume rendering can be achieved without extensive manual manipulation necessary [3]. Excellent image acquisition required a normal resting sinus rhythm with a targeted rate of less than 65 beats per minute during the scan. Cardiac motion with higher diastolic interval was desirable for acquisition of nearly motion-free images. This was achieved by administering beta blocker agent 2 h before the examination [4].

Classification of coronary artery anomalies (CAA) was performed according to anatomical criteria of origin and course, intrinsic anatomy, and termination. These anomalies may be pathophysiologically classified as benign and malignant with hemodynamical significance. The hemodynamically significant anomalies seen in the study included: anomalous origin of coronary artery from pulmonary artery, anomalous interarterial course between aorta and pulmonary artery, anomalous LMCA origin from RCA and myocardial bridging. The hemodynamically signifycant anomalies are responsible for perfusion anomalies with high risk of myocardial ischemia and sudden death. Surgery is generally recommended for malignant course. The prevalence of life threatening coronary artery anomaly causing sudden death is approximately less than one percent [5].

Coronary artery anomalies [6-14]

1- Anomalies of the origin and course:

a. Multiple Ostia

b. Single coronary artery

c. High takeoff of coronaries

d. Anomalous origin of coronary artery from pulmonary artery

e. Origin from non-coronary cusp.

f. Origin from opposite or noncoronary sinus and anomalous course (retroaortic, inter-arterial prepulmonic and septal)

g. Duplication of arteries Anomalous left main from RCA.

2-Anomalies of termination

a. Coronary artery fistula

b. Coronary arcade

c. Extra cardiac termination

Materials and methods

CT data of 202 patients (114 males, 88 females; age range, 15-79 (Years) **table (4)** who underwent 64-slice coronary CTA in and Al Ameer Medial Diagnostic Center and Open Heart center in Al

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Sadder Medical City were retrospectively reviewed to identify the coronary anatomy and determine anatomic variants and anomalies. Patients were referred for coronary CTA because of known or suspected coronary artery disease (CAD).

CT scan

All CT examinations were performed by a 64-slice CT scanner (Aquillon 64, V4.51 ER 010, Toshiba Medical Systems, Tochigi, Japan) with retrospective ECG gating (scan protocol is given in **Table 4**). Patients with a heart rate greater than 70 beats/min were premedicated with an oral dose of beta blocker like 40 mg propranolol or 50 mg Metoprolol one hour before the scan. For venous access, an upper extremity vein (antecubital vein of the right arm) and a 20-gauge IV cannula was used. A total of 80–85 mL of ominopaque 350 mg/mL was injected with a flow rate of 5-6 mL/s, Followed by a 30 mL normal saline 3 ml/s. The scan timing was determined with automated bolus tracking technique by placing the region of interest over the proximal descending aorta and setting the trigger threshold to 180 HU. Raw spiral CT data were reconstructed in various phases of the cardiac cycle to obtain images with the highest quality (without motion artifact). Reconstruction performed at four segments 40-75% of R-R interval.

Image analysis

Images reconstructed at the optimal phase were transferred to another workstation (Vitrea 2 workstation, Vital Images Inc., Plymouth, Minne-sota, USA), where image analysis was performed. All images were reviewed first in axial projection, then with post processing tools such as multiplanar reconstructions (MPR), curved planar reformat (CPR), thin-slab maximum intensity projection (thin MIP), and volume-rendering technique (VRT) with transparent background display. All CT examinations were reviewed by two radiologists experienced in cardiovascular radiology. After determining the dominance of the coronary artery system, the origin, course, and caliber of the major coronary arteries and their branches were evaluated. Dominance of the coronary artery system was determined according to the origin of the posterior descending artery. Coronary artery systems with PDA originating from the right coronary artery were defined as right dominant, and those with PDA originating from the left main coronary artery were defined as left dominant. Coronary artery systems where PDA was supplied by the RCA and significant portion of the posterior wall of the left ventricle was supplied by postero-lateral branches (PLB) from the circumflex artery (Cx) were termed as co-dominant [15].

Coronary artery anomalies were classified according to the classification system by Angelini *et al* [14] as anomalies of origination and course, anomalies of intrinsic coronary artery anatomy, and anomalies of termination. The small dimensions and rapid movement of coronary arteries have made their evaluation with computed tomography (CT) challenging.

However, because of the dramatic development of multislice CT (MSCT) technology in the last decade, coronary CT angiography (CTA) has become an

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increasingly important noninvasive modality in the diagnosis of coronary artery diseases. High temporal and spatial resolution capabilities of MSCT scanners enable detailed 3D visualize-ation of complex coronary artery anato-my without motion artifact.

To be able to interpret the coronary CTA correctly, radiologists should be familiar with normal anatomy, anatomic variants, and anomalies of the coronary arteries and their cross-sectional appea-rances [16].

Results

Distribution of study sample according to the gender and age

The total no. of our patients was 202 patients, males (114, 56%), females (88, 44%).The male age range 20-77years, mean 49.4±11.7, female age range15-79 years, mean 55.8 ±10. In this study the no. of anomalies in 88 female was 29 (32.9%) while the no. of anomalies in 114 males was 44 (38.6%) so there is no significant effect of gender on the result (P-value =0.4) **Table (6)**.

Dominancy

Of 202 patients the RCA was dominant in 175 cases (86.8%) while the LCA was dominant in 24 cases (11.8%) and in 3 cases (1.4%) co dominance **Table (7)**.

RCA

The conus artery was the first branch of the RCA in 192(95.06%) cases, it originated from the right sinus of Valsalva with a separate ostium in 5 cases (2.47%), not detected in 5 cases (2.47%) **Table (8).**

LCA

In 35 cases (17.32%) the LMCA trifurcated and give ramus intermedius **Fig. 1**. The LMCA was absent in 3 cases (1.48%) in which the LAD and Cx originated from the left sinus of Valsalva with separate Ostia, 1case (0.44%) LMCA origin from non-coronary sinus. The LMCA trunk presented with variable length, <1 cm was seen in 8 patients (3.9%), 1–2 cm was seen in 182 patients (90%), and >2 cm was seen in 12 patients (5.6%) **Fig. 2**.

A variable number of diagonal bran-ches were observed: one diagonal branch in 67(33.20%) cases, two diago-nal branches in 113 cases (55.9%), and more than two in 21 cases (10.4%) **Fig. 3**. No diagonal branches were visualized just in one case (0.44%). Myocardial bridging was seen in 11 cases (5.4%) 10 cases of myocardial bridging seen in LAD **Fig. 4** and one case (0.5%) seen in LCX, in 4 cases (1.98%) LCX originate from RT. coronary sinus **Fig. 5**, one case (0.49%) double LAD originate from LMA.

Dominence	
Right	532(67%)
Left	64 (9.1%)
Co-dominence	104(14%)
Conus artey	
From RCA	544(78%)
With separate ostium	154(22%)
With two separate ostium	2(0.2%)
Sinus node artery	
From RCA	554(79%)
From CX	140(20%)
From LMCA	3(0.4%)
Separate ostium	3(0.4%)
Ramus intermedius	221(31%)

Table 1.
Prevalence of anatomic variants of the coronary arteries.

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Anomalies of origin &course	
Absent LMCA	3(0.4%)
Absent LCX	1(0.1%)
High take off	6(0.8%)
Of RCA	1(0.1%)
Of LMCA	5(0.7%)
Anomalous origin from opposite sinus	
RCA originating from Lt.Coronary Sinus	4(0.5%)
LMCA originating from Rt.coronary sinus	2(0.2%)
LCX orginating from Rt.coronary sinus	1(0.1%)
Anomalies of intrinsic coronary arterial anatomy	
Myocardial bridging	259(37%)

Table 2.
Prevalence anomalies of origin &course of the coronary arteries, number and (%).

variant		Patient % (No.)
Conus arery	From proximal RCA	64.1(348)
	From ostial RCA	22.3(121)
	From aorta	11.6(63)
	ND	2(11)
Sinus node artery	From LCX	16.6(90)
	From RCA	65.4(355)
	From RCA&LCX	9.2(50)
	From LCX &pumonary artery	0.2(1)
	From aorta	0.2(1)
	ND	8.4(46)
LMCA length	<1cm	41.6(226)
	1-2cm	47.3(257)
	>2cm	7(38)
Absent		4.1(22)
Intermediate branch		21.9(119)
Diagonal branches from LADA	ND	1.3(7)
	1	25(136)
	2	24.7(270)
	>2	24(130)

Table 3.
Normal variant of coronary arteries.

Gender	No. (%)	Range/year	(Mean± SD)
Male	114(56%)	20-77	49.4±11.7
Female	88(44%)	15-79	55.8±10
Total No.	202		

Table 4.
Distribution of study sample according to the gender and age.

Tube current	400mAs
Tube voltage	120 KV
Tube rotation time	400 ms
Section thickness	0,5 mm
Increment	0.3

Table 5.
Scan protocol of 64-slice coronary CT angiography Scan protocol (Toshiba Aquillon 64).

gender	No.	No. of anomalies	Percentage (%)
female	88	29	32.9
male	114	44	38.6
Total	202	73	36.2
P-value = 0.4			

Table 6.
Prevalence of anatomic variants of the coronary arteries, n (%) regarding gender.

Dominance	Number(n)	Percentage (%)
Right dominance	175	86.8
Left dominance	24	11.8
Co -dominance	3	1.4
Total	202	100%

Table 7.
Prevalence of anatomic variants of the coronary arteries dominancy n (%).

Origin &course	From Rt. coronary sinus No. (%)		From LT. coronary sinus NO. (%)	Total
	202(100%)		0	202
Conus branch	From RCA.	From aorta.	Not detected	
	No (%)	No (%)	No. (%)	
	192 (95.06%)	5 (2.47%)	5 (2.47%)	202
Bridging	Present no. (%)		Not present no. (%)	
	0 (0%)		202 (100%)	202

Table 8.
Prevalence of anatomic variants of the RCA.

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Variant	Number (n)	Percentage (%)
Trifurcation (ramus intermedius)	35	17.32
left main artery (LMA): length:		
<10mm	8	3.9
10-20mm	182	90.2
>20mm	12	5.9
Absent	3	1.48
Origin		
From Lt coronary sinus	201	95.5
From non-coronary sinus	1	0.50
bridging	0	0
Lt anterior descending artery (LAD):		
Double LAD	1	0.50
Myocardial bridging	10	4.95
No. of diagonal (D):		
D1	67	33.20
D2	113	55.90
D3	21	10.4
no diagonal	1	0.50
abnormal origin	0	0
abnormal course	0	0
LT. circumflex (LCX):		
LCX originate from RT. Coronary sinus	4	1.98
Myocardial bridging	1	0.50

Table 9.
Prevalence of anatomic variants of the LCA.

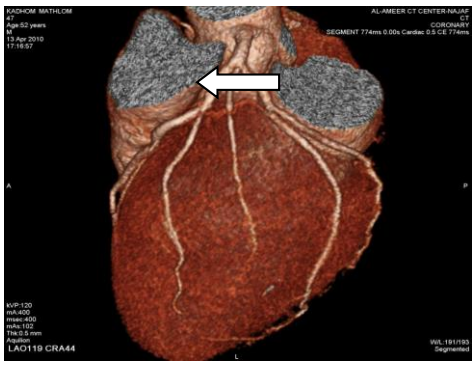

Figure 1.
3-D VR CTA demonstrate ramus intermedius (arrow).

Figure 2.
3D VR CTA image demonstrate short LMCA.

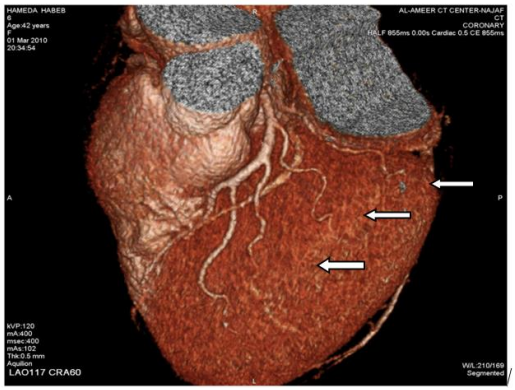

Figure 3.
3-D VR CTA demonstrate 3 diagonal branches from LAD (arrows).

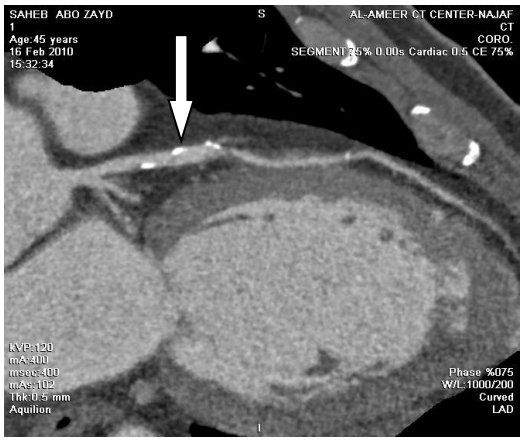

Figure 4.
MIP CTA demonstrate myocardial bridging of LADA (arrow).

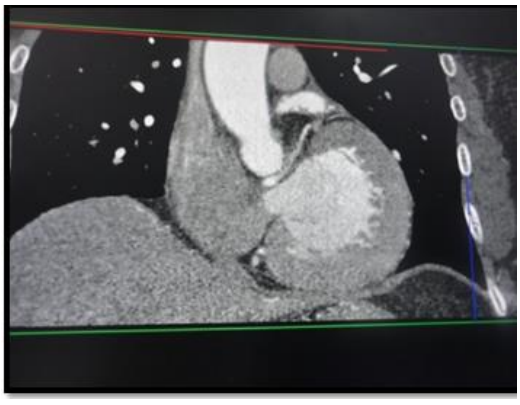

Figure 5.
3-D MIP CT A demonstrate LCX origin from RT. Coronary sinus.

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Discussion

Conventional coronary angiography (CCA) has been the technique of choice for visualization of the coronary artery system for several decades. Despite its common use, alternative methods of visualizing the coronary arterial system are desired; in addition to being invasive, CCA has disadvantages in detecting coronary artery anomalies because of the limited number of 2D projection images obtained during catheterization and because of the absence of soft tissue information. Over the last decade, substantial advances have been made in noninvasive cardiac imaging. New technological modalities include coronary MR angiography, electron beam CT (EBCT), and coronary CTA. Coronary CTA has an increasingly important role in the diagnosis of coronary artery disease. Cardiac CT applications were limited to the myocardium, cardiac chambers, and gross coronary calcifications with conventional CT scanners [5, 17].

In our study RCA was dominant 86.8%while the LCA was dominant in 11.8% these results are similar to the study done by Kini *et al*. 2007 [12] who reported the RCA was dominant in (80% -85%) and LCA was dominant in (15%-20%) but higher than result of Koşar *et al*. 2009 [6] who reported that RCA was dominant in (67%) while LCA was dominant in (64%). The current study shows low prevalence of co-dominant (1.4%) compare to high result of Koşar *et al*. 2009 [6] reported the incidence of co dominant was (14%). In our study the origin of RCA from right sinus of Valsalva in (100%) &the anomalous origin of RCA from left sinus of Valsalva (0%) which is lower than result reported by Koşar *et al*. 2009 [6] (0.5%), Bunce NH *et al* 2003 [10] (0.3% to 0.17%).

Our result of conus artery originated from proximal RCA was (95.06%) which is higher than the incidence reported by F Cademartiri *et al* 2006 [7] (64.1) & the incidence of conus artery originate from aorta in our study was (2.49%) this result lower than incidence reported by F Cademartiri *et al* 2006 [7] (11.6). The current study showed the conus was undetected in (2.49%) similar to the result of F Cademartiri *et al* 2006 (7) (2%).

In the current study the length of LMA <10mm in (4%) and >20mm was (6%) these result greatly lower than the result reported by F. Cademartiri *et al* 2006 [7] and the incidence of 10-20 mm length of LMA was (90%) in our presented study higher than result of F. Cademartiri *et al* 2006 [7].

The LMCA bifurcates to the LAD and Cx. Occasionally the LMCA trifurcates. In our result ramus intermedius present in (17%) which is lower than result of KOSAR *et al* [6] (31%).

Occasionally the LMCA was absent in 3 cases (1.48%), this result lower than the result performed by Cademartiri *et al* 2006 but higher than result of (Kosar et *al*) [6] and Duran C, Kantarci M, Subasi Durur I, *et al* 2006 [9].

In our study the incidence of anomalous origin of LMCA was observed in one patient (0.5%) who arises from non-coronary sinus. The origin of LMCA origin from Rt.

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coronary sinus in our study is (0%) which is similar to the result reported by Bunce NH et al 2003 [10] (0.09% to 0.11%). The LAD has two groups of branches, referred to as septal perforators and diagonals. In our study variable numbers of diagonal arteries were observed no diagonal branch observed in one case (0.5%) which lower than result of F. Cademartiri *et al* (2006) [7] while one diagonal in (33.2%), two diagonal in (55.9%) these two result higher than the result of (F. Cademartiri *et al* (2006) (7), the incidence of three diagonal observed in (10.40%) which is lower than study performed by (F. Cademartiri *et al* 2006) [7]. In our study the double LADA was founded in one case (0.5%) no available literature mentions the incidence of this anomaly. The current study showed high prevalence of LCX origin from RT. Coronary sinus (1.96%) this is comparable to KOSAR *et al* [6] study who reported incidence of (1%) LCX origin from RCA.

In present study the incidence of myocardial bridging was 5.4% lower than result reported by Kosar *et al* (37%) [6]. The difference between our result &these of other investigators may be related to selection of patients their no. and age.

In conclusions, complex anatomy of the coronary artery system can accurately be depicted by 64-slice CTA. This modality is useful in detecting coronary artery variants and anomalies and is a valid alternative to conventional coronary angiography in their diagnosis.

Competing interests

Author declare no competing interests.

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