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ORIGINAL ARTICLE

Role of CT Coronary Angiography in Delineating the Anatomic Variations of the Coronary Arteries.

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ABSTRACT

Background: Multi-slice computed tomography of the coronary arteries have been shown promising results, regarding the detection of coronary artery disease, as well as an alternative tool for interventional coronary procedures, Multi-slice computed tomography of the coronary arteries is currently considered the ideal tool to three-dimensionally visualize the complex and tortuous anatomy of coronary arteries.
Before coronary revascularization procedures, precise evaluation and description of the coronary artery tree is greatly needed by Multi-slice computed tomography of the coronary arteries

Aim : To assess the role of multi-detector computed tomography (MDCT) coronary angiography with multi-planar reformation (MPR) and three-dimensional (3D) reconstruction in the evaluation of anatomic variations of coronary arteries.

Method: this study was cross-sectional and was carried out at the radiodiagnosis department, Zagazig university hospitals, A total number of 87 patients with normal heart rates were scheduled for elective multi-detector computed tomography of coronary angiography in the period from June 2018 to February 2019.

Result: Our study reported coronary dominance was found to be right-sided in 83.3 %, left-sided in 6.7 %, and co-dominant in 10 % of our study group. And left main coronary artery branching pattern shows that type IV of the left anterior descending artery (36.7%) was the commonest variant and also a variable number of diagonals were observed.
On the other hand, the right coronary artery branching pattern shows that one acute marginal branch was been in 73.3%, Regarding the second variant of the right coronary artery shepherd's crook coronary artery is noted in 3.3% of cases, and also conus artery originated from proximal right coronary artery seen in (58.3%).

Conclusion: This study has shown that computed tomography of coronary angiography is an excellent non-invasive modality in the diagnosis and delineation of coronary arteries and can offer valuable information about the coronary arterial system regarding its normal variants.

Keywords: MSCT- CCA: Multi-slice CT coronary angiography, ECG: Electrocardiography, ECHO: Echocardiography, HR: Heart Rate, MDCT: Multi-Detector Computed Tomography.

INTRODUCTION

Since the beginning of the 1990s, a variety of non-invasive techniques are introduced to coronary artery imaging in an attempt to replace conventional coronary artery angiography (CCA) **[1].**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 widely available in the territory **[2].**

The introduction of multi-slice computed tomography coronary angiography allowed the detection of coronary artery disease. The improved performance of 128-slice CT equipment provided a valid alternative to CCA in selected patient populations. MSCT-CA is currently considered the ideal tool to three-dimensionally visualize the complex and tortuous anatomy of coronary arteries **[3].** For a long time, conventional angiography (CCA) has been the gold standard for assessing coronary arteries. Unawareness of the atypical location of the vessel orifice by the operator can make selective coronary catheterization and its assessment so difficult in CCA. it also doesn't provide three-dimensional images for detailing the coronary anatomy **[4].**

Screening of coronary variants in the population is becoming viable with MDCT angiography, it

developed as a non-invasive tool in diagnosing coronary artery anatomic variations and anomalies. Being of high temporal and spatial resolution enables visualization of the detailed anatomy of the coronary arteries **[4].** Before coronary revascularization procedures, precise evaluation and description of the coronary artery tree are greatly needed. To report possible coronary variations and anomalies that may cause technical difficulties during coronary interventional procedures and end in catastrophic complications for the patient **[5].**The study aimed to assess the role of multidetector computed tomography (MDCT) coronary angiography with multiplanar reformation (MPR) and three-dimensional (3D) reconstruction in the evaluation of anatomic variations of coronary arteries.

METHODS

This study was carried out at the Radio-diagnosis department, at Zagazig university hospitals. A total number of 87 patients with normal heart rates were scheduled for elective MDCT coronary angiography in the period from June 2018 to February 2019. 27 patients (neonates and infants) were excluded from the study with poor image quality hindering detailed assessment of the coronaries along their whole course. Finally, 60 patients were enrolled in the study, 43 male (71.7 %) and 17 female (28.3 %), their ages ranged from 1 to 68 years (mean: 48.3 ± 13.9). The commonest age group of the selected patients was 50 - 60 years of age (66 %).

Full history was taken regarding risk factors for coronary artery disease, chest pain, cyanosis, or revascularization surgery. Revision of previous laboratory and other cardiac investigations was done before the MDCT examination.

Any patient with suspected coronary heart disease was included in the study. Patient exclusion criteria were either absolute contraindications **(**Patients with creatinine ≥ 1.5 mg/d, allergy to contrast media, Pregnancy, morbid obesity) or relative contraindications (hemodynamic instability**,** Inability to hold breathes for 8-10 sec, poor image quality).Written informed consent was obtained from all participants; the study was approved by the research ethics committee of the Faculty of Medicine, Zagazig University, the study was done according to the code of ethics of the world medical association (Declaration of Helsinki) for studies involving humans.

Patient preparation :Fasting for 4 hours before the examination but medications are not to be discontinued (apart from metformin is stopped 48 hours before examination), HR control to be kept about 65 beats per minute (Beta – blockers administered one day before examination), Respiration training to hold breath for 12 seconds then I.V route in right ante-cubital vein. Sedation by an anesthesiologist for children below 8 years.

Image acquisition

A retrospective ECG gated CTA during a single breath hold technique was performed using 128 multi-detectors (Ingenuity Phillips health care, best, Netherlands) scanner as follows: Scanogram Scan parameters of Scanogram: kV 120 kV Tube Current 30 mA FOV 220 mm Matrix 512 Slice Thickness 0.6 - 0.8 Increment -0.4, followed by Calcium score calculation (examination is terminated if Agatston's score exceeds 1000) then contrast media is administrated using bolus tracing technique. Image acquisition started from the carina till 1cm below the diaphragm.

Post-procedural evaluation of patient

The patient is kept under observation for 15 minutes after the procedure to check the vital signs (pulse and blood pressure).

Image reconstruction and interpretation

Cases were revised and interpreted by two radiologists using axial images (as source images), and reconstructed images (including MPR (curved and oblique), MIP, and volume rendering techniques) on an advanced Philips workstation.

STATISTICAL ANALYSIS

Data was collected through a 128-slice MDCT scanner (ingenuity Philips health care, best, Netherlands and outcome measures were coded, entered, and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. Qualitative data were represented as numbers and percentages, quantitative data were represented by mean ± SD. Differences between quantitative paired groups were tested by paired t-test for significance, the P value was set at <0.05 for significant results & <0.001 for highly significant results.

RESULTS

Coronary dominance Coronary dominance was found to be right-sided in 83.3 %, left-sided in 6.7 %, and co-dominant in 10 % of our study group (**Table 1**).

Left main artery (LMA) variants : Regarding LMA branches, our study reported bifurcation into LAD and LCX in about 66.7 % and trifurcation into LAD, Ramus intermedius (RI), and LCX in 33.3% of our patients (**Table 2**).

Left anterior descending artery (LAD) variants

Type IV LAD (36.7%) was the commonest variant. The variable number of diagonals was observed: one diagonal branch (45%), two diagonals (48.3%), and three diagonals (6.7%) (**Table 2**).

Left circumflex artery (LCX) variants: While obtuse marginal arteries were not identified in 3.3 %; one artery was identified in 80 % and two obtuse marginal arteries in 16.7 % (**Table 2**).

Right coronary artery branching pattern : One AM branch was seen in 73.3%, two AM branches in 13.3%, and was not identified in 13.3% of our G population; shepherd's crook coronary artery was the second detected variant of RCA (3.3%) of cases. Conus artery origin from proximal RCA was seen in (58.3%) and from the right coronary sinus by a separate ostium in (30%) (**Table 3**).

Table 1: Coronary artery dominance.

		N	%
Dominant	**Co-dominant**	6	10.0
	Left	4	6.7
	Right	50	83.3
Total		60	100.0

Table 2: Left main coronary artery branching pattern.

			N	%
LAD	**Types**	**I**	9	15
		II	12	20
		III	17	28.3
		IV	22	36.7
	Diagonals Number	**D1**	27	45
		D1&2	29	48.3
		D1&2&3	4	6.7
Obtuse marginal (OM) number		**Not identified**	2	3.3
		OM1	48	80
		OM1&OM2	10	16.7
LMA branches		**Bifurcates into LAD & LCX**	40	66.7
		Trifurcates into LAD & RI & LCX	20	33.3
Total			60	100.0

Table 3: Right coronary artery branching pattern**.**

			N	%
Acute marginal (AM) number		**Not identified**	8	13.3
		AM1	44	73.3
		AM1&AM2	8	13.3
Pseudo narrowing in RCA (kink)(Sheperd's crook)		**-ve**	58	96.6
		+ve	2	3.3
Early posterior descending artery (PDA) take off from RCA			1	1.6
Conus artery		**Not identified**	7	11.7
		RCA branch	35	58.3
		Separate ostium	18	30
SAN artery	**Origin**	**Not identified**	21	35
		From LCX	12	20
		From RCA	27	45
	Course	**Pre-caval**	18	46.2
		Retro-caval	21	53.8
Total			60	100.0

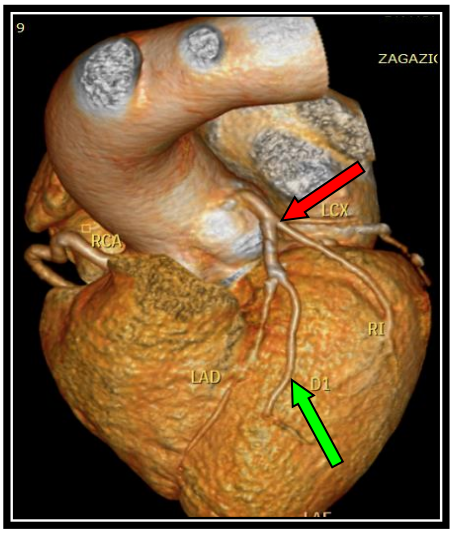

Figure 1: This figure is three dimensions volume-rendered image (anterior view) showing trifurcation of the left main artery (LMA) into left circumflex (LCX), Ramus intermedius (RI), and left anterior descending (LAD) (Red arrow) giving rise to one Diagonal branch (D1) (Green arrow

Figure 2: This figure shows the Axial Maximum Intensity Projection image showing the Sinoatrial nodal artery arising from the right coronary artery with a retro-caval course (Green arrow).

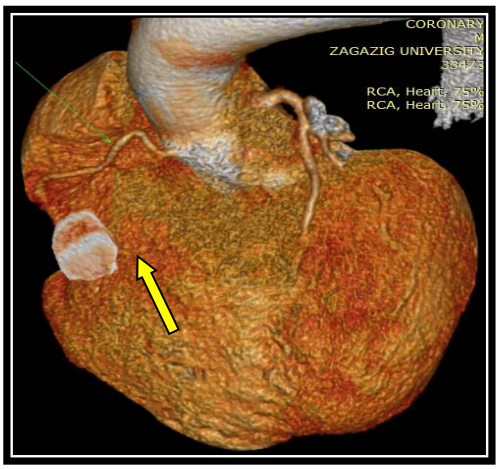

Figure 3: This figure Curved Multi-planner Reformat and three dimensions volume rendered images showing upward curvature of proximal right coronary artery just distal to its origin with apparent kink (Shepherd Crook anomaly) (Yellow arrows).

DISCUSSION

The wrong evaluation of coronary variants or anomalies might cause technical difficulties during revascularization procedures or lead to clinical misdiagnosis or catastrophic complications during coronary interventional procedures. Accurate anatomical evaluation of the coronary artery tree is a must before angioplasty **[6 & 7].**

Coronary arteries can be anatomically categorized into three groups based on their anatomical features: normal coronary anatomy, anatomic variations of the coronary artery, and coronary artery anomalies (CAAs) [**8].**Angelini introduced the concept of a normal variant based on a statistical definition of what constitutes the normal range (coronary pattern observed in 99% of an unselected population) **[8&9].** In the current study on sixty patients, there was no statistically significant difference regarding gender and prevalence of anatomic variants (P value = 0.481). Coronary artery dominance is defined by the vessel which gives rise to the posterior descending artery (PDA), which supplies the myocardium of the inferior 1/3rd of the posterior inter-ventricular septum. Our results were in agreement with multiple studies performed by **Namrumol chaosuwannakit [10]**, **Rao et al [11], and Eldin [12**] who reported incidence rates of right dominance in (75 %, 77 %, 79%), left dominance in (13%, 12%, 11%) and co-dominance in (12%, 11%, 10%) respectively. while other studies reported higher right dominance incidence and much lower co-dominance incidence such as **kultida chaiyagool** [13]**, Abdelrahman et al** [14]**, Mehta and Agarwal** [2] **and Erol and Seker** [15] who reported incidence rate of right dominance in (91.4%, 88.7%, 85%, 86.6%), left dominance in (7.2%, 9.9 %,12%, 9.6%) and co- dominance in (1.4%, 1.4, 2.8%, 3.8%) of the cases respectively.

Considering left coronary system variants, starting with the LMA branching pattern; in most populations, it bifurcates to the LAD and LCX. Trifurcation into Ramus intermedius between LAD and LCX is the most common anatomic variation observed in the left coronary system and its prevalence in our results is 33%, our results come in agreement with **Abdelrahman et al** [14] **Koşar et al.** [6] who reported ramus in (31.2% & 31%) of their population, but our results are lower than those reported by **kultida chaiyagool** [13]who reported ramus in 68.8 %; and higher than **Rao et al** [11] who reported ramus in 21.8 %. this could be attributed to different races and larger sample sizes.

The Diagonals of LAD usually come in a variable number from one to three, we have found two diagonals in 48.3%, one diagonal branch in 45%, and three diagonals in 6.7%, these results were in agreement with **Rao et al** [11] **Eldin.** [12]who found two diagonals in (56.1%, 60 %), one diagonal in (35.2%, 20%), and three diagonals in (7.2%,17 %), also **Bazzocchi et al.** [16]reported that one or two diagonal branches were seen in > 90% of their patients, while in partial agreement with **Abdelrahman et al** [14]**,** who reported one or two diagonal branches in78.3% and three diagonals in 21.7%. The second LAD variant is its types, it has four types; type I is LAD not supplying apex, type II is LAD is partially supplying apex, type III is supping apex and type IV is wrapping around apex [14]. In our study the commonest type is type IV which represents 36.7% followed by type III 28.3% then type II in 20% and type I in 15% of cases, these results disagree with **Abdelrahman et al** [14]who reported that the commonest type is type III in 77.4% followed by type IV in 16.4%, then type II in 4.2% and type I in 2%, while **Mehta and Agarwal** [2]found that the commonest type of LAD is type II in 34.9% then type I in 24.5% followed by type III in 23.5% and type IV in 16.9%, and this could be attributed to that we used 128 MSCT scanner that allowed better evaluation of the distal LAD segment compared to 64 MSCT used by **Abdelrahman et al** [14]and **Mehta and Agarwal** [2].

Concerning LCX variants, One obtuse marginal branch (OM1) was found in 80% and two OMs branches in 16.7% while it couldn't be identified in 3.3% of our patients, Our results agreed with **Rao et al** [11]**, Eldin** [12]and **Abdelrahman et al** [14] who reported one OM branch in (46.2%, 80%, 59.9%) and two OM branches in (35.8%,10%, 31.7%) of their study population.

Regarding RCA variants, in our study, we reported one acute marginal branch (AM1) branch in 73.3%, and two AM branches in 13.3% while it was not identified in 13.3% of our population.

The second variant of RCA is shepherd's crook RCA where it takes a tortuous and high course immediately after it originates from the right coronary sinus. Our study showed a 3.3% prevalence of shepherd's crook RCA while **Shriki et al.** [7] reported a 5% prevalence of this variant.

The conus artery is a small early branch from RCA that supplies the conus of the main pulmonary artery. In our study conus artery originated from proximal RCA in (58.3%) and right coronary sinus by a separate ostium in (30%), these finding was in partial agreement with **Eldin** [12]**, Rao et al** [11]and **Abdelrahman et al** [14]who reported that conus artery arises from RCA in (77%, 65.1%, 47%) and RT coronary sinus by separate ostium in (16 %, 16.8%, 14%). Higher results were reported by **kultida chaiyagool** [13] who reported that the conus artery arises from RCA in 95% and RT coronary sinus by separate ostium in 5% of their population.

The sinoatrial nodal artery (SANA) is a small branch supplying the SA node, In our study, the SAN artery originated from RCA in (45%), from

LCx in (20%), and was not identified in (35%), It takes a pre-caval course in 46.2% and retro-caval course in 53.8%, these findings were in partial agreement with **kultida chaiyagool** [13], **Rao et al** [11], **Eldin** [12]**and Abdelrahman et al** [14]who reported that SAN artery arises from RCA in (55.6%,62.5%,65%,54%), from LCX in (32.6%,12.2%,22%,21.8%) and not identified in (11.1%,16.9%,3%,)**,** while **Kosar et al.** [6] reported that SAN artery arises from RCA in 79%, from LCX 20%. The high rate of unidentification of the SAN artery could be attributed to some technical fallacies like its small caliber that is sometimes beyond the capability of the machine or used protocol.

There were some limitations to this study. First, this is a single-central study and involved a relatively small sample size thus requires confirmation by involving larger multi-central studies and larger sample sizes. Second, the exclusion of 27 patients with the poor image quality from the study may represent a source of selective bias. Finally, lack of reference standards to calculate the diagnostic performance of coronary CTA in delineating the coronary variants.

In conclusion, MDCT coronary angiography is an excellent non-invasive modality in the delineation of coronary arteries and can offer valuable information about the coronary arterial system regarding its normal variants; thus in turn shall help greatly in planning coronary revascularization procedures. We recommend using coronary CTA as a routine preliminary investigation before any coronary interventional or revascularization procedure.

Conflict of interest: no

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