

**Role of multidetector computed tomography angiography in
evaluation of anatomical variations in the coronary arteries**

Thesis

**Submitted for Partial Fulfillment of master degree in
Radiodiagnosis**

By

Nahla Deyaa El Deen Mostafa

M.B.B.Ch (Faculty of Medicine- Cairo University)

Supervised by

Prof. Dr. Magdy Ibrahim Bassiouny

Professor of Radiology

Cairo University

Dr. Mohamed Ali Salem, MD

Lecturer of Radiology

Cairo University

Faculty of Medicine

Cairo University

2015

Abstract

Although the majority of these anomalies were detected incidentally during coronary CT angiography, awareness of them is clinically important for the appropriate management of cardiac patients.

Multidetector CT with rapid coverage, thin collimation, faster gantry rotation, overlapping reconstructions with ECG gating and advanced postprocessing techniques enables perfect noninvasive delineation of complex coronary artery anatomy, variations and congenital anomalies of coronary arteries. That's why CCTA has gained much a wider application area in the field of cardiovascular imaging after improvement of the radiation dose and is now the primary imaging modality for the evaluation and diagnosis of CAAs..

The objective of this study was to assess the prevalence of the different types of coronary artery anatomical variants and primary congenital anomalies using the multislice CT coronary angiography as a non invasive imaging tool.

We studied 1000 patients referred to us to detect or exclude coronary artery disease by using multislice computed tomography evaluation of the coronary arteries.

Our study showed that the incidence of these variations and anomalies in our population is close to that reported in other populations and that coronary artery anatomical variations are almost benign entities with no haemodynamic significance, while some congenital anomalies may interfere with adequate myocardial blood supply causing variable ischemic symptoms.

Keywords: CCTA-CT-ECG-CAAS- ALCAPA

ACKNOWLEDGEMENTS

Praise be to Allah, the creator and sustainer of the world. It is but with His help that this piece of work could come to life.

*Foremost; I would like to express my deepest gratitude to **Prof. Dr. Magdy Ibrahim Bassiouny**, professor of radiology, faculty of medicine, Cairo University; for choosing this interesting topic and for his guidance, encouragement and continuous support that were of great value throughout the work. .*

*My deepest appreciation to **Dr. Mohammed Ali Salem**, lecturer of Radiodiagnosis, Cairo University, for his encouragement, support, guidance, kind advice and help throughout supervising this work.*

*I am extremely grateful to **Dr. Maha Mohamed El Taher** for her endless support, encouragement, continuous help and kind advice throughout the work.*

*I have to thank **Prof. Dr. Amr Osama**, professor of Radiodiagnosis, the technologists and nurse staff in Alfa scan radiology centre and the department of radiology in Kasr Al Aini educational hospital, for their cooperation, dedication and the help they showed throughout the work.*

*I am also thankful to **Prof. Dr. Mohamed Mohamed Eltoukhy**, former head, and **Prof. Dr. Ashraf Salah Selim**, current head of the radiology department, faculty of medicine, Cairo University.*

*And last, but definitely not least, I deeply thank my **family** for their endless support, care and encouragement to complete this work.*

CONTENTS

List of Figures	I
List of Tables	XII
List of Abbreviations	XIII
Introduction	1
Aim of the work	2
Review of literature	
 I] Anatomy of the coronary arteries	
• Gross anatomy of the coronary arteries	3
• LV segmental anatomy	8
• Coronary artery territories	12
• Angiographic anatomy	13
• CT anatomy of coronary arteries	21
• The coronary venous system	24
 II] Anatomical variations and anomalies	28
• Anomalies of origination and course	29
• Anomalies of intrinsic coronary arterial anatomy	35
• Anomalies of coronary termination	38
 III] Multislice CT (physical& technical principles)	
• Evolution of computed tomography	41
• Multislice CT; technical principles	45

IV] Multislice CT coronary angiography	53
• Requirements for CTCA	54
• Radiation dose	70
• Technique of CT coronary angiography	73
• Pitfalls, artifacts and limitations of CTCA	84
Patients and methods	91
Results	102
Case presentation	115
Discussion	150
Summary and conclusion	158
References	160
Arabic summary	168

List of Figures

Fig. number		Page
	Review of literature	
Fig.1	Axial MIP image showing left coronary (LC), right coronary (RC) and posterior non-coronary (NC) cusp	3
Fig.2	An overview of the coronary arteries in the anterior projection showing Left Main or left coronary artery (LCA) and Right coronary artery with their branches.	6
Fig.3	An overview of the coronary arteries in the right anterior oblique projection showing Left Main or left coronary artery (LCA) and Right coronary artery with their branches.	7
Fig.4	An overview of the coronary arteries in the lateral projection showing Left Main or left coronary artery (LCA) and Right coronary artery with their branches.	7
Fig.5	(A) VR image of right dominance (B) VR image of left dominance	8
Fig.6	LV segmentation in horizontal and long vertical and horizontal axes	9
Fig.7	LV segmentation in short axis	10
Fig.8	LV territorial supply, (A) in short axis at base, mid body and apex, (B) in horizontal and vertical long axis	12
Fig.9	Planes of epicardial tree	13
Fig.10	CCA of RCA in LAO cranial projection	16
Fig.11	CCA of RCA in left lateral projection	16

Fig.12	CCA of RCA in AP cranial projection	16
Fig.13	CCA of LCX in RAO projection	20
Fig.14	CCA of LAD in LAO cranial projection	20
Fig.15	CCA of LMT in LAO caudal (spider) projection	20
Fig.16	Normal origin of coronary arteries in axial CT cuts	21
Fig.17	Axial CT showing normal anatomy of the coronary arteries	22
Fig.18	CT angiography curved reformatted MIP images showing normal anatomy of the coronary arteries	23
Fig.19	CT angiography VR images before and after subtraction of the heart showing normal coronary anatomy	24
Fig.20	VR images showing the coronary veins	26
Fig.21	Interarterial LCA Axial MIP and VR images of a patient with an anomalous origin of the LCA from the right sinus of Valsalva and coursing between the aorta and pulmonary artery	31
Fig.22	<ul style="list-style-type: none"> • The illustration in the left upper corner is the most common and clinically significant anomaly. • There is an anomalous origin of the LCA from the right sinus of Valsalva and the LCA courses between the aorta and pulmonary artery. • This interarterial course can lead to compression of the LCA (yellow arrows) resulting in myocardial ischemia. 	31

	The other anomalies in the figure on the left are not hemodynamically significant	
Fig.23	Axial and VR images of ALCAPA	33
Fig.24	Axial MIP and VR images of Myocardial bridging	36
Fig.25	Axial and VR images of Fistula	39
Fig.26	Single slice, single helix, Multislice and four interleaved helices CT	43
Fig.27	Single vs Multidetector CT geometry	44
Fig.28	Dual source CT tube opened and closed	44
Fig.29	Detector array designs for multiple-row detector CT scanners that can yield 64 sections per gantry rotation	46
Fig.30	Flexible use of detectors in 4-slice MSCT scanners.	47
Fig.31	Drawings show that relation of table movement with respect to gantry rotation is described by beam pitch.	49
Fig.32	Graphs demonstrate the necessity for scanning at low pitch values during helical cardiac CT data acquisition.	50
Fig.33	Drawings show variable temporal resolution across image.	51
Fig.34	Diagram shows the range of diastolic regions for varying heart rates.	56
Fig.35	Prospective ECG-triggering with X-ray beam on during a portion of cardiac cycle, while in the remaining cardiac phase, the X-ray beam is turned off	59
Fig.36	Conventional retrospective ECG-gated coronary CT angiography. X-ray beam is turned on during the entire cardiac cycle	59

Fig.37	CPR MIP CT image of prospective ECG-triggered coronary CT angiography shows presence of misalignment, affecting visualization of the right coronary artery	60
Fig.38	Drawings show two types of retrospective reconstruction algorithms.	62
Fig.39	Differences between partial scan reconstruction versus multiple-segment reconstruction.	62
Fig.40	Coronary CTA images acquired with the most recent CT hardware. (A) A 320-slice CT, (B) high-pitch spiral acquisition with dual-source CT	65
Fig.41	Six representative transverse sections were reconstructed, at the same z-axis position at the level of the aortic valve at different cardiac phases.	67
Fig.42	Reconstructions of the data set with (A, B) a routine algorithm and (C, D) a more edge-enhancing algorithm.	69
Fig.43	Coronary CT angiography performed without saline chasing technique showing streak artifact.	78
Fig.44	Coronary CT angiograms obtained at the level of the right atrium showing difference between monophasic, biphasic and triphasic injections	78
Fig.45	64 MDCT angiography reveals moderate stenosis (arrow) of the proximal LAD due to a mixed, partially non-calcified plaque seen with different advanced visualization techniques.	83

Fig.46	CCA and CCTA showing pulsation artifacts.	86
Fig.47	CCTA showing stepladder artifacts due to cardiac motion.	86
Fig.48	CCTA showing artifacts due to increased heart rate (arrows).	87
Fig.49	Stepladder artifact due to respiratory motion. Sagittal MIP image shows a severe respiration related artifact in the anterior chest wall (arrows)	87
Fig.50	(A) MPR image, (B) Axial image showing beam hardening artifact.	88
Fig.51	Beam Hardening artifact owing to heavy calcifications.	88
Fig.52	VR images obtained with different window width and level settings show the LAD artery and a diagonal branch.	90
Fig.53	Difficulties due to overlapping contrast-filled vascular structures	90
	Patients and methods	
Fig.54	Segmental anatomy of right coronary artery (RCA) (lateral view), and left coronary artery (right anterior oblique view) with left main trunk (LMT), left anterior descending (LAD), and left circumflex (LCX) according to American Heart Association (AHA)	98
	Results	
Fig.55	Pie chart displaying the gender of patients	102
Fig.56	Pie chart displaying coronary dominance	103
Fig.57	Pie chart displaying the LAD type	104

Fig.58	Bar chart displaying the number of diagonal branches	105
Fig.59	Bar chart displaying the number of OM branches	106
Fig.60	Pie chart displaying prevalence of ramus branches and their number	107
Fig.61	Pie chart displaying the prevalence of HL branches and their number	108
Fig.62	Pie chart displaying the origin of conus branch	109
Fig.63	Pie chart displaying the origin of SA nodal branch	110
Fig.64	Pie chart showing the incidence of the different congenital anomalies	111
	Case presentation	
Fig.65 Case 1	Single coronary artery A: CPR MIP image showing the LMT>>>LAD B: CPR MIP image showing LMT>>>LCX>>>OM1 C: CPR MIP image showing continuation of the LCX in the Rt AV groove D: VR image showing LMT branching into LAD (giving diagonals), Ramus intermedius and LCX (which gives a long PL branch) E: VR image showing the continuation of LCX in the Rt AV groove	116- 117
Fig.66 Case 2	Ectopic origin of LMT from NCS A: CPR MIP image showing LMT>>> LCX>>OM B: CPR MIP image of the LMT>>>LAD C: CPR MIP image of the RCA>>>PDA	118- 119

	<p>D: axial MIP image showing the origin of the LMT from the non coronary sinus</p> <p>E: VR image showing the LMT originating from the posterior non coronary sinus and branching into LAD and LCX branches</p> <p>F: VR image of the heart showing the RCA, LAD and LCX</p>	
Fig.67 Case 3	<p>Single coronary artery</p> <p>A: VR image showing LMT arising from proximal RCA</p> <p>B: CPR MIP image of RCA>>>LAD</p> <p>C: CPR MIP image of RCA>>>LAD>>>D</p> <p>D: CPR image of RCA>>>PL</p> <p>E: CPR image of RCA>>>LMT>>>LCX>>>OM</p> <p>F, G, H: axial MIP images showing origin of LCA from proximal RCA</p>	120- 121- 122
Fig.68 Case 4	<p>Ectopic origin of RCA from LCS</p> <p>A: VR image showing the origin of RCA from LS, anterior to the LMT, and runs in an interarterial course</p> <p>B: CPR MIP image of LMT>>>LAD</p> <p>C: CPR MIP image of LMT>>>LAD>>>D</p> <p>D: CPR MIP image of RCA>>>PDA</p> <p>E: VR image showing RCA originating from LS and running interarterially to continue normally in the right AV groove</p>	123- 124
Fig.69 Case 5	<p>Ectopic origin of LMT from RCS</p> <p>A: CPR MIP image of LMT>>>LAD</p>	126

	<p>B: CPR MIP image of the RCA>>>PDA</p> <p>C: VR image showing RCA>>>PL</p> <p>D: VR image showing LMT arising from RS and runs prepulmonic then divides into LAD and LCX</p>	
Fig.70 Case 6	<p>Coronary fistula</p> <p>A, B and C: CPR MIP images showing fistulous communication between the RCA and the Rt atrium</p> <p>D and E: Coronal oblique MIP images for the fistula</p> <p>F: sagittal oblique image for the fistulous communication between the RCA and the Rt atrium</p>	128- 129
Fig.71 Case 7	<p>ALCAPA</p> <p>A, B, C and D: sagittal oblique MIP images showing anomalous origin of the left coronary artwry from the pulmonary artery ALCAPA</p> <p>E: CPR MIP image showing LAD continuation of the LMT which is originating anomalously from the pulmonary artery</p> <p>F: CPR MIP image of LMT>>>LCX</p>	130- 131
Fig. 72 Case 8	<p>High take off of RCA</p> <p>A: VR image showing origin of LMT from LS and its bifurcation into LAD and LCX</p> <p>B: CPR MIP image of LMT>>>LAD</p> <p>C: CPR MIP image of LMT>>>LCX</p> <p>D: CPR MIP image of RCA>>>PDA</p> <p>E: VR image showing RCA originating from above RS and running in the Rt AV groove</p>	132- 133

Fig.73 Case 9	High take off of RCA A: VR image showing LMT arising from LS and dividing into LAD and LCX B: CPR MIP image of LMT>>>LAD C: CPR MIP image of LMT>>>LCX D: CPR MIP image of RCA E: VR image showing RCA arising from tubular aorta and running interarterially between pulmonary artery and ascending aorta	134- 135
Fig.74 Case 10	Separate ostia for LAD and LCX A: CPR image showing LCX arising directly from LS B: CPR MIP image showing separate ostia fro LAD and LCX from LS C: CPR MIP image showing LAD arising directly from LS D: VR image showing separate origins of LAD and LCX from LS	136- 137
Fig.75 Case 11	Separate ostia for LAD and LCX A: VR image showing separate ostia for the LCX and LAD from LS B: VR image showing origin of RCA from RS C: CPR MIP image of LAD arising directly from LS D: CPR MIP image of LCX arising directly from LS	139
Fig.76 Case 12	Co-dminance A: CPR MIP image of LMT>>>LAD B: CPR MIP image of LMT>>>LCX>>>PDA	140- 141

	<p>C: CPR MIP image of RCA>>>PDA</p> <p>D: VR image showing origin of LMT from LS and dividing into LAD and LCX which gives a PDA branch</p> <p>E: VR image showing RCA arising from RS and giving a PDA branch</p>	
<p>Fig.77 Case 13</p>	<p>Single coronary artery</p> <p>A, B, C: axial MIP images showing the anomalous single coronary artery arising from tubular aorta and dividing into two branches</p> <p>D: CPR image of LMT>>>LAD</p> <p>E: CPR image of LMT>>>LCX>>>PL</p> <p>F: CPR image of RCA>>>PL</p> <p>G: CPR image of RCA>>>PDA</p> <p>H: VR image showing anomalous single coronary artery arising from tubular aorta and dividing into RCA and LMT</p>	<p>143- 144</p>
<p>Fig.78 Case 14</p>	<p>Single coronary artery</p> <p>A, B, C axial MIP images showing LMT dividing into LCX and LAD which gives origin to RCA that runs in a prepulmonic course</p> <p>D: CPR MIP image of LMT>>>LAD>>>RCA</p> <p>E: CPR MIP image of LMT>>>LAD</p> <p>F,G: VR images showing the origin of RCA from LAD and runs in a prepulmonic course</p>	<p>145- 146</p>
<p>Fig.79 Case 15</p>	<p>Ectopic origin of RCA from LCS</p> <p>A, B, C and D axial MIP images showing RCA arising</p>	<p>147- 148-</p>