

Multi-Slice Computed Tomography in the Assessment of the Coronary Arteries

Essay

Submitted for Partial Fulfillment of Master Degree in
Radiodiagnosis

By

Mohamed Samir Abd El-Salam Youssef
(M.B., B.Ch)

Supervised by

Dr. Amany Mohamed Rashad Abdel-Aziz
Assistant Professor of Radiodiagnosis
Faculty of Medicine - Ain Shams University

Dr. Ahmad Mohammad Ghandour
Assistant Professor of Radiodiagnosis
Faculty of Medicine - Ain Shams University

Faculty of Medicine
Ain Shams University
2009



List of Contents

Title	Page
• Introduction	1
• Aim of the Work	3
• Review of Literature:	
○ Gross Anatomy of the Coronary Arteries	4
○ Pathology	23
○ Physics	37
○ Technique of the CT Coronary Angiography (CTCA)	70
○ Coronary Calcium Scoring	121
○ Other Non Invasive Imaging Modalities for the Coronaries	127
• Summary	134
• References	141
• Arabic Summary	--

List of Figures

Fig. No	Subjects	Page
1.	Recurrent course of the distal segment of the left anterior descending (LAD) artery reaching the interventricular posterior groove	1
2.	Left circumflex (LCx) artery ending at the (left) obtuse margin of the heart	6
3.	Normal anatomical variants of diagonal (Diag) branches	7
4.	Anatomy of the right coronary artery (RCA)	9
5.	Anatomy of the distal right coronary artery (RCA)	9
6.	Anatomical dominance of the left coronary system, with a posterior descending artery (PDA)	11
7.	Coronary artery anatomy at CT	12
8.	RCA	13
9.	Electron beam CT image shows mid RCA following right atrioventricular sulcus	14
10.	Proximal branches of right coronary artery (RCA)	15
11.	PDA	15
12.	Left main coronary artery	16
13.	Intermediate coronary artery	17
14.	LAD artery	17
15.	LCX artery	18
16.	Angiographic emulation(RCA) from the left sinus of Valsalva (blue arrows)	19

List of Figures (Cont.)

Fig. No	Subjects	Page
17.	Showing the Venous drainage of the heart	22
18.	Diagrams depicting the arrangement of detectors ...in adaptive (left) and fixed (right) modes of array	40
19.	Detector array designs for multiple row detector CT scanners that can yield 64 sections per gantry rotation	40
20.	Drawings show that relation of table movement with respect to gantry rotation is described by beam pitch.	42
21.	Graphs demonstrate the necessity for scanning at low pitch values during helical cardiac CT data acquisition	43
22.	Drawings show variable temporal resolution across image	45
23.	Diagram shows the range of diastolic regions for varying heart rates	50
24.	During the prospective ECG-triggered scan mode, the patient's ECG is continuously monitored but the x-rays are turned on at predetermined R-R intervals to acquire sufficient scan data for image reconstruction	52
25.	During the retrospective ECG-gated scan mode, the patient's ECG is continuously monitored and the patient table moves through the gantry	54
26.	Drawings show two types of retrospective reconstruction algorithms.....	56
27.	Differences between partial scan reconstruction versus multiple-segment reconstruction.....	57
28.	Effect of temporal resolution on reconstructed images from the same patient.....	59

List of Figures (Cont.)

Fig. No	Subjects	Page
29.	Contrast-enhanced retrospectively ECG-gated coronary CT angiograms.....	62
30.	Screenshots acquired from the scanner's main workstation (Navigator®) illustrating an axial-image-orientated test series in 5% steps (A–J) through the entire RR interval at mid ventricular level.....	63
31.	Contrast-enhanced retrospectively ECG-gated 64-section coronary CT angiography in 59-year-old man referred for noninvasive assessment of coronary artery stent patency	65
32.	Schematic illustration of the acquisition principle of dual-source CT by using two tubes (A and B) and two corresponding detectors.....	66
33.	Graphical description of an electrocardio-graphically gated spiral scan for high heart rates	67
34.	Contrast-enhanced retrospectively ECG-gated coronary CT angiography performed without saline chasing technique.....	75
35.	Contrast-enhanced retrospectively ECG-gated transverse coronary CT angiograms obtained at the level of the right atrium in three patients.....	76
36.	MPR images.....	78
37.	MIP images	79
38.	Contrast-enhanced retrospectively ECG-gated 64-section CT angiography in 55-year-old man with atypical chest pain and risk factors for coronary artery disease.....	81
39.	Occlusion of the left anterior descending coronary artery	84
40.	Coronary vessel analysis: left anterior descending stenosis in 2D long axis and short axis–soft plaque .	88

List of Figures (Cont.)

Fig. No	Subjects	Page
41.	Coronary vessel analysis: left circumflex stenosis on fibrous plaque in 2D long axis and short axis	89
42.	Coronary vessel analysis: main trunk stenosis on mixed plaque in 2D long axis and short axis	89
43.	Coronary vessel analysis: LAD stent restenosis in 2D LA and SA	90
44.	Volume-rendering 3D reconstruction of multiple venous bypass grafts.....	96
45.	Volume-rendering 3D reconstruction views of a single venous graft to the posterior descending artery in a patient with significant right coronary artery disease	96
46.	Source image showing the distal anastomosis site of a left internal mammary artery implantation to left anterior descending artery	98
47.	Source image with evidence of venous graft anastomosis to the second diagonal branch.....	99
48.	Axial visualization of a diseased venous graft on the left side of the pulmonary trunk in a patient with internal mammary artery implantation.....	100
49.	Axial image showing a completely occluded graft closer to a small patent right coronary artery and an occluded circumflex artery in the presence of patency of the corresponding graft.....	101
50.	Volume-rendering 3D reconstruction of a patent internal mammary artery graft implanted to left anterior descending artery	101
51.	Maximum intensity projection of a 16-row CT dataset	104

List of Figures (Cont.)

Fig. No	Subjects	Page
52.	Maximum intensity projection of a stent occlusion in the left anterior descending artery	105
53.	Multiplanar reformation 3D reconstruction of a patent stent for venous graft disease	106
54.	Blooming effect on follow-up images obtained with 64-section CT in a patient who underwent stent implantation in the left circumflex coronary artery .	107
55.	Variation in the severity of metal-related artifacts at 64-section CT with variations in metallic content, design, and luminal diameter of the stent.....	108
56.	Residual cardiac motion exacerbates metal-related artifacts at 64-section CT in a patient with a stent in the midportion of the right coronary artery and with a premature heartbeat recorded at ECG during scanning	110
57.	Visibility of low-contrast structures with different convolution filters	111
58.	Left anterior oblique (a) and anterior (b) MPR images show cardiac pulsation artifacts due to a rapid heartbeat.	113
59.	Stepladder artifact due to tachycardia.....	114
60.	Banding artifacts due to an increased heart rate from 51 to 69 beats per minute.....	115
61.	Artifacts due to incomplete breath holding.....	116
62.	Beam hardening effects caused by surgical clips.....	117
63.	Streak artifacts visible in the presence of a stent.....	118

List of Figures (Cont.)

Fig. No	Subjects	Page
64.	VR images obtained with different window width and level settings show the LAD artery and a diagonal branch (arrow).....	120
65.	Stepladder artifacts due to cardiac motion and inappropriate pitch selection	120
66.	A cross-sectional image through the aorta and the origin of the left coronary artery (dashed arrow). A moderate amount of calcification can be easily identified as bright signals	123
67.	A cross-sectional image through the aorta; a moderate amount of calcification can be easily identified as bright signals (arrows).....	123
68.	A cross-sectional image through the aorta (Ao), the left ventricle (LV) and the right atrium (RA)	124
69.	2D image in Fast GRE with filling of K-space in a spiral manner and fat subtraction.....	128
70.	Reformatted right coronary artery vessel wall images of 3 volunteers (A-F) Images were obtained with Cartesian (A-C) or radial (D-F) K-spac	131

List of Abbreviations

3D & 4D	Three and four dimensional
AHA	American Heart Association
ASA	Acetyl salicylic acid (Aspirin)
ASE	Agatston score equivalent
Bpm	Beat per minute
CABG	Coronary artery bypass graft
CAD	Coronary artery disease
CNR	Contract-to-noise ratio
CT	Computed tomography
CTA	Computed tomographic angiography
DSCT	Dual source computed tomography
EBCT	Electron beam computed tomography
ECG	Electrocardiogram
FOV	Field of view
GCV	Great cardiac vein
HR	Heart rate
HU	Hounsfield units
IVUS	Intra-vascular ultrasound
LAD	Left anterior descending artery
LCX	Left circumflex artery
LIMA	Left internal mammary artery
LMT	Left main (coronary) trunk
MRA	Magnetic resonance angiography
MRI	Magnetic resonance imaging

List of Abbreviations (Cont.)

MSEC	Millisecond
MSV	Milliseivert (unit for radiation measurement)
NPV	Negative predictive value
PCI	Per-cutaneous intervention
PDA	Posterior descending artery
PE	Pulmonary embolism
PET	Positron emission tomography
PL	Postero-lateral artery
PPV	Positive predictive value
RIMA	Right internal mammary artery
SNR	Signal-to-noise ratio
SVC	Superior vena cava
TECAB	Totally endoscopic coronary artery bypass
TEE	Trans esophageal echocardiography
LV	Left ventricle
MESA	Multi-ethnic study of atherosclerosis

Acknowledgement

*First and foremost, thanks to **GOD**, to whom I relate any success in my life as I owe Him for his great care, support and guidance.*

*Words do fail me when I come to express my sincere indebtedness, appreciation and profound gratitude to my **Professor Dr. Amany Mohamed Rashad**, Assistant Professor of Radiodiagnosis, Faculty of Medicine, Ain Shams University, for her moral support, valuable supervision, encouragement and resourceful knowledge which enabled me to fulfill this work,*

*Special thanks are due to **Prof. Dr. Ahmed Mohammad Ghandour**, Assistant Professor of Radiodiagnosis, Faculty of Medicine, Ain Shams University, for dedicating so much of his precious time and effort and for his willing assistance, constant guidance and continuous advice.*

Finally, I would like also to express my deepest gratitude to my family for their loving support and encouragement which pushed me forward in every step in my life and helped me throughout the hard times.

Mohamed Samir

O

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا
إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ
الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة الآية (32)

