



Essay

Submitted for partial fulfillment of master degree in radio diagnosis

Ву

Mohamed Abdel Wahhab Mohamed Ali

MB, B CH
Faculty of medicine
Cairo University

Supervised by

Dr. Suzan Bahige Ali

Professor of radio diagnosis
Faculty of medicine
Ain-shams University

Dr. Hosam Moussa Sakr

Lecturer of radio diagnosis
Faculty of medicine
Ain-shams University

Radio-diagnosis department Faculty of medicine Ain-shams University 2010

Acknowledgment

First of all, my prayerful gratitude should be submitted to **ALLAH**, the most gracious the merciful whose help I always seek, while I try humbly to lead on his path, and without his willing I will achieve nothing.

I wish to express my deepest gratitude and respect to Prof. *Dr. Suzan Bahige Ali*, professor of radio-diagnosis, Faculty of medicine, Ain Shams University for granting me the privilege of working under her supervision, and for her generous advices and support.

I also wish to express my great thanks and appreciation to *Dr. Hosam Moussa Sakr*, lecturer of radio-diagnosis, Faculty of medicine, Ain Shams University for his remarkable effort, kind support and great help through out this study.

I would also like to send my deepest love and gratitude to my parents and my family who had the patience to help me in whatever way they could.

بسم الله الرحمن الرحيم

وَعَلَّمَ ءَادَمَ ٱلْأَسْمَآءَ كُلَّهَا ثُمَّ عَرَضَهُمْ عَلَى ٱلْمَلَيْكَةِ فَقَالَ أَنْبِئُونِي بِأَسُمَآءِ هَنَوُلاَءِ إِن كُنتُمْ صَدِقِينَ شَقَالُواْ سُبْحَدنَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمُتَنَا أَ إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ شَ

صدق الله العظيم

Contents:

1. list of figures 5
2. list of tables 9
3. list of abbreviations 10
4. Introduction
5. Aim of the work
6. Gross and CT anatomy of coronary arteries 14
7. Pathology of coronary artery disease 37
8. Technique of MDCT coronary angiography 49
9. Manifestations of post interventional coronary artery
disease by MDCT 78
10. Summary and conclusion
11. References
12. Arabic summary.

List of figures

- Figures 1, 2, 3 Coronary anatomy; illustrated colored plates
- Figures 4,5 Coronary anatomy at different angiographic positions
- Figures 6,7 Angiographic anatomy of the coronary arteries
- **Figures 8, 9, 10** MIP CT images delineating the anatomy of the left and right coronary systems
- Figures 11 VR CT images delineating the anatomy of the left and right coronary systems
- Figure (12) Drawing shows examples of CABGs.
- Figure (13) Photograph shows a mechanical aortic connector
- Figure (14) Axial images and 3D reconstructions demonstrating SVG
- Figure (15) The coarse of internal thoracic arteries
- Figure (16) 3D reconstruction and curved MIP demonstrating LIMG anastomosis
- Figure (17) Radial artery grafts.
- Figure (18) 3D reconstruction and curved MIP demonstrating gastroepiploic artery anastomosis
- **Figure (19)** (a) Coronary bypass graft surgery(b) volume-rendered anterior view(c) anterolateral view; (d) lateral view LIMA on graft LAD, LIMA graft on right coronary artery (RCA)
- **Figure (20)** patent left internal mammary artery (LIMA) inserted into the left anterior descending coronary artery (LAD)
- Figure (21) coronary stent ing
- Fig. 22. 3D volume rendered image of a 62-year-old man with chest pain.
- **Fig. (23).** (A) Retrospectively ECG gated dual-source cardiac CT with 83 milliseconds temporal resolution (B) Curved multiplanar reformatted image of the LAD
- **Fig. (24)** Breathing-related motion artifacts

- **Fig. 25** (a) Continuous ECG tracing (b) Enlarged view of a single RR interval. (c) ECG-based tube current modulation or ECG pulsing
- **Fig. 26.** Time imaging window in ECG gating procedures.
- **Fig. 27 a, b.** Movement artifacts Image acquired at 75 bpm (a) and (b), afterwards, at 62 bpm, repeating the injection of contrast agent.
- Fig. 28 Patient positioning for cardiac CT
- Fig. 29 Positioning of ECG leads and planning of the scan
- Fig. 30. Contrast-agent power injector
- Fig. 31. High concentration of contrast agent in the left chambers of the heart
- Fig. 32 Different reconstruction techniques:(axial)
- **Fig. 33 a-c.** Planimetric analysis (multi-planar reformatting, MPR) during 3D imaging. (a) sagittal, (b) coronal, short axis, (c) axial, long axis
- Fig. 34 Reformatting along the curved planes shows the anatomy of the coronary artery
- Fig.35 "Ribbon" MPR image of a left anterior descending (LAD) artery stenosis (arrow
- **Fig 36** Maximum intensity projection (MIP): "Angiographic" MIP image of the coronary arteries
- Fig. 37 a-c. Examples of coronary vessels evaluated by means of volume-rendering technique
- Fig. 38 Virtual endoscopy of the coronary arteries
- Fig. 39 (a) Virtual endoscopy of the colon (b)a parietal 5-mm polyp is easily detected
- **Fig. 40 a, b**. Normal coronary artery evaluated using a bi-dimensional technique.
- Fig. 41 a-c. Marginal plaques (arrow)
- **Fig42 a, b.** Fibrolipidic marginal soft plaque of the left anterior descending artery (arrow) evaluated
- **Fig. 43 a, b.** Marginal fibrolipidic plaque (arrow) of the middle third of the left anterior descending artery (LAD), without significant caliber reduction.
- Fig. 44. Short segmental isolated plaque of the LAD. Blooming artifacts.

Fig. 45 a, b. Severe stenosis caused by a concentric plaque of the proximal segment of the right coronary artery.

Fig. 46 a, b. Vascular remodeling.

Fig. 47 a, b. Occlusion of the right coronary artery without distal re-vascularization and without collateral vessels.

Fig. 48 a, b. Occlusion of the right coronary artery, with evidence of collateral circulation providing flow distal to the occluded segment

Figure 49 Artifacts caused by a metal indicator

Fig.50 (A) Volume-rendered image. Patency of left internal mammary artery graft to mid-left anterior descending coronary artery (arrow) and saphenous vein grafts to the obtuse marginal branch (open arrow), first diagonal branch (arrowhead), and distal left anterior descending coronary artery (*) was demonstrated.(B) Curved multiplanar reformation of a saphenous graft

Figure 51 Occluded free arterial graft (right internal mammary artery) from the aorta to the posterolateral branch (RPL) of the right coronary artery.

Figure 52 (A) Volume-rendered images showing a patent left internal mammary artery (LIMA) inserted into the left anterior descending coronary artery (LAD). However, the presence of a surgical clip precludes reliable visualization of the anastomosis (arrow). Two occluded (Occl.) venous grafts are visualized as well as an occluded right coronary artery (RCA) (arrowheads). (B) Curved multiplanar reconstructed image showing the LIMA and distal filling of the LAD.

Figure 53 (C) Curved multiplanar reconstructed images of the occluded venous grafts (arrowheads) and collateral (Coll.) filling of the circumflex coronary artery (LCX) (upper panel) and right coronary artery (lower panel). (D) Curved multiplanar reconstructed images of the LAD (upper panel), LCX (middle panel), and RCA (lower panel).

Figure.54 Sequential venous graft with stenotic disease proximal and distal (arrows) to the anastomosis with a marginal branch (RM).

Figure.55Venous graft anastomosed to the left anterior descending coronary artery (LAD), containing two stents

Figure 56. Proximal RCA 50% stenosis diagnosed by coronary CTA and confirmed by conventional angiography.

Figure 57 Proximal left circumflex (LCX) artery with more than 50% stenosis diagnosed by coronary CTA and confirmed by conventional angiography.

Figure 58. Ongoing RCA greater than 50% stenosis diagnosed by coronary CTA and confirmed by conventional angiography.

Figure 59 Occlusion of a left internal mammary graft

Figure 60 Separate venous grafts have been anastomosed (arrows) to the left anterior descending coronary artery (SVG1, LAD) and a marginal branch (SVG2, RM).

Figure 61 Diffuse disease after coronary artery bypass graft.

Figure 62 (A) Volume-rendered CT image of a patient in whom 5 Bx velocity Cypher stents had been implanted to treat a catheter-induced dissection of the left main (LM) and left anterior descending (LAD) coronary artery. (B) Identical volumerendered CT image as in (a) but using different window level settings (1000 HU), (C) Invasive coronary angiogram of the LAD after 1-year follow-up. (D) Curved multiplanar CT image of the LAD. Only the lumen of the very proximal stent (3.5 mm in diameter) in the LM can be reliably assessed.

Fig. 63 Blooming artifact.

Fig. 64. Blooming. A volume-rendered image of the heart and coronary arteries

Fig. 65. Beam hardening.

Fig.66 a, b. Reconstruction kernel. Curved reformats showing a stent in the mid-LAD. Standard medium (a) smooth reconstruction .b) sharp kernel

Fig. 67a, b. Reconstruction kernel. Multi-planar images of three stents in an occluded saphenous vein graft (SVG) reconstructed with a standard smooth kernel (a) and a sharper kernel (b).

Figure.68 (A) Volume-rendered CT image showing an occlusion in the mid-part of the right coronary artery(RCA). (B) The corresponding invasive angiogram shows the entry point of the occlusion at the origin of the margo acutis. (C) Maximal intensity projection (D) multiplanar reconstruction of the RCA showing that the occlusion starts within a previously implanted stent .

Figure 69 a ,b, c, d ,e Example of a patient who underwent stenting of the left main coronary artery (LM).

Figure 70 (a) Invasive angiogram showing a significant stenosis in the proximal part of the right coronary artery (RCA). (b) Angiographic image post-stent implantation. (c) Maximal intensity projection showing the position of the stent in the RCA.

List of tables

- Table (1): Types of Grafts
- **Table (2)**; corresponding sites of myocardial lesions in the typical right dominant heart
- **Table. 3** Appropriate indications for coronary CT angiography
- **Table 4..** Steps in performing coronary CT angiography
- **Table. 5** CT challenges in postsurgical patients
- **Table. 6** Diagnostic accuracy of four-, 16-, and 64~slice CT
- **Table 7** Detection of coronary artery stenosis (>50%) by CT after coronary artery bypass graft
- **Table 8** Clinical applications of cardiac CT after bypass artery graft (CABG) surgery
- **Table 9.** Protocol for 64 slice single and dual-source MDCT: The typical protocol used in our institution for single-source and dual-source scanners in the evaluation of stents.
- **Table 10** Diagnostic performance of four- and 16-slice MSCT to detect coronary instent restenosis, with conventional angiography as the standard of reference
- **Table 11**Diagnostic performance of 64-slice MSCT to detect coronary in-stent restenosis, with conventional angiography as the standard of reference
- Table 12
 MSCT coronary stent assessment

List of abbreviations

AHA American heart association ASA Acetyl Salicylic Acid (Asprin) ASE Agatston score equivalent ATP Adinosine tri-phosphate bpm Beat per minute CABG Coronary artery bypass graft CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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	List of abbreviations		
ASA Acetyl Salicylic Acid (Asprin) ASE Agatston score equivalent ATP Adinosine tri-phosphate bpm Beat per minute CABG Coronary artery bypass graft CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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	3 D & 4 D	Three and four dimensional	
ASE Agatston score equivalent ATP Adinosine tri-phosphate bpm Beat per minute CABG Coronary artery bypass graft CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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			
ATP Adinosine tri-phosphate bpm Beat per minute CABG Coronary artery bypass graft CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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			
bpm Beat per minute CABG Coronary artery bypass graft CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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			
CABG Coronary artery bypass graft CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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	ATP		
CAD Coronary artery disease CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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	-		
CNR Contrast-to-noise ratio CT Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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		• • • • • • • • • • • • • • • • • • • •	
CTA Computed tomography CTA Computed tomographic angiography CTCA Computed tomographic coronary 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		· ·	
CTA Computed tomographic angiography CTCA Computed tomographic coronary 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	CNR	Contrast-to-noise ratio	
CTCA Computed tomographic coronary 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	CT	Computed tomography	
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		Computed tomographic angiography	
EBCT Electron beam computed tomography ECG Electrocardiogram FOV Field of view GCV Great cardiac vein HR Heart rate HU Hounsfield units	CTCA		
ECG Electrocardiogram FOV Field of view GCV Great cardiac vein HR Heart rate HU Hounsfield units	DSCT	Dual source computed tomography	
FOV Field of view GCV Great cardiac vein HR Heart rate HU Hounsfield units		Electron beam computed tomography	
GCV Great cardiac vein HR Heart rate HU Hounsfield units	ECG	Electrocardiogram	
HR Heart rate HU Hounsfield units	FOV	Field of view	
HU Hounsfield units	GCV	Great cardiac vein	
	HR	Heart rate	
TRACA T 1	HU	Hounsfield units	
IMA Internal mammary artery	IMA	Internal mammary artery	
IVUS Intra-vascular ultrasound	IVUS		
LAD Left anterior descending artery	LAD	Left anterior descending artery	
LCX Left circumflex artery	LCX	Left circumflex artery	
LIMA Left internal mammary artery	LIMA	Left internal mammary artery	
LMT Left main (coronary) trunk	LMT	Left main (coronary) trunk	
MRA Magnetic resonance angiography	MRA	Magnetic resonance angiography	
MRI Magnetic resonance imaging	MRI	Magnetic resonance imaging	
msec Millisecond	msec	Millisecond	
mSv Milliseiver (unit for radiation measurement)	mSv	Milliseiver (unit for radiation measurement)	
NPV Negative predictive value	NPV	Negative predictive value	
PCI Per-cutaneous intervention	PCI		
PDA Posterior descending artery	PDA	Posterior descending artery	
PE Pulmonary embolism	PE	Pulmonary embolism	
PET Positron emission tomography	PET	Positron emission tomography	
PL Postero-lateral artery	PL		
PPV Positive predictive value	PPV	Positive predictive value	
RIMA Right internal mammary artery	RIMA		
SNR Signal-to-noise ratio	SNR		
SVC Superior vena cava	SVC	Superior vena cava	
TECAB Totally endoscopic coronary artery bypass	TECAB		
US Ultrasound	US	Ultrasound	

INTRODUCTION

Recurrent ischemic symptoms in patients with previous coronary artery bypass graft (CABG) surgery for advanced coronary artery disease (CAD) is a common problem. Conventional coronary angiography (CCA) is currently the reference standard technique for evaluation of status of CABG and coronary arteries. CCA, however, is expensive and has a small risk of potentially life-threatening complications, including arrhythmia, stroke, coronary artery or graft dissection, embolic events, and myocardial infarction; the morbidity rate is 0% to 2%, and the mortality rate is 0.14% to 0.28%.

Therefore, a reliable noninvasive imaging modality is preferable for evaluation of patients suspected of having graft stenosis or occlusion. (Türkvatan A et al., 2009).

However, imaging of coronary artery stents is an important issue in cardiology because stenting is the predominant form of myocardial revascularization, with an estimated 664,000 angioplasty procedures have been performed in the United States in 2003. [Mühlenbruch G et al.,2007].

Computed tomography (CT) has been embraced as the premier non invasive modality for vascular imaging of the thorax and imaging of the heart, however, always been technically challenge because of the hearts continuous motion (Schoepf, 2004).

But the introduction of new generation MDCT scanner, with the ability to acquire up to 64 sub millimeter slices, provided more accurate detection of the vascular lumen with shorter scan time and fewer cardiac or respiratory artifacts, making it superior to conventional angiography in delineating the osteal origin and proximal path of an anomalous coronary artery .(Anders et al., 2006).

So that, MDCT permits non-invasive assessment of coronary artery bypass grafts with decreasing numbers of unevaluated graft segments. It is used to assess coronary artery bypass graft patency. (Nikolaou et al., 2006) especially with its sub-millimeter spatial resolution and premedication with oral beta-blockade (Herzog et al., 2004).

In addition, numerous studies comparing the accuracy of multidetector (64-row) computed tomography (64-MDCT) assessment of coronary graft

patency and stenosis with that of CAG have shown that 64-MDCT is a reliable diagnostic tool and less invasive than CAG. (Doi H et al.,2008).

In the other hand, making the diagnosis of in-stent restenosis by using multislice CT scanners with 16 or fewer detectors (1-7) is limited by such factors as blooming and streak artifacts. Sixty-four-detector row CT has recently been introduced for clinical use with its improved spatial and temporal resolution. The use of 64-detector row CT improves the visualization of the coronary stent lumen and the detection of in-stent stenosis. (Suzuki S et al., 2009).

MDCT may reduce the need of an invasive procedure. This may prove to be particularly beneficial in coronary CT angiography.

Aim of the work

The aim of this study is to highlight the manifestations of post interventional coronary artery disease by MDCT.

Gross & CT Anatomy of the coronary arteries