Role of Multi-slice computed tomography using contrast in Evaluation of Coronary Artery Stents

Mohamed Farouk Agag, M.D., Mohamed Salah Tafeek Elfeshawy, M.D., Mohamed Hafez Ahmed Abbass, M.Sc

Radiodiagnosis Departments, Faculty of Medicine (For Boys), Al-Azhar University, Cairo, Egypt
mst1200@yahoo.com

Abstract: Background and Objective: Coronary artery stenting has become an established treatment for symptomatic coronary artery disease. One of the most important variables that determine the successful clinical outcome of coronary artery stent application is the short- and long-term patency rate of the stents. The Aim of this study: The aim of this study was to evaluate multi-detector row CT angiography as a less invasive technique in the assessment of the patency of the coronary arteries stents without involvement of much more invasive techniques (e.g. conventional angiography) to assess the patency of their stents. **Patients and methods:** A total number of 50 patients were enrolled for multi-detector row CT angiography of the coronary arteries between May 2015 and May 2017. Twenty two patients underwent both conventional coronary angiography and MDCT coronary angiography. Both examinations were done within a month. The patients who did not perform the conventional angiography were mostly due to the decision made by the referring physicians as there is increased confidence in the results of MSCT angiography, so those patients were referred for conservative medical treatment. **Results:** CT angiography compared to the conventional angiography as a gold standard technique gave us a sensitivity of 100%, a specificity of about 83.8 %, an accuracy of about 87.1%, PPV is 61.5% and NPV is 100% in the assessment of the patency of the coronary artery stents, taking into consideration proper standard CT angiography techniques in all cases included in the final results with exclusion of all cases that experienced inevitable conditions that may hinder proper stent lumen evaluation as sudden rise of the heart rate during scanning time or unexpected cardiac arrhythmias. **Conclusion:** our study helps to identify factors that influence the assess ability of coronary artery stents by 64-, 128- dual source and 256-slice CT scanners, namely, stent type and diameter. It shows that under certain conditions, the detection of in-stent restenosis might be possible with an accuracy that could permit clinical applications, but that the relatively high rate of unevaluable stents currently does not allow to use MDCT for coronary angiography in unselected patients with implanted stents in coronary arteries or bypass grafts.

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Key words: Multi-detector row CT, Multi-slice CT, CT angiography, coronary artery stents, Non-invasive vascular imaging

1. Introduction

Over the past 25 years, catheter-based intervention has become the dominant form of coronary revascularization, Percutaneous coronary interventions are increasingly performed instead of coronary artery bypass graft surgery, even in patients with three-vessel disease or left main coronary artery disease. The most important advance in the field of percutaneous coronary interventions was the introduction of coronary stent implantation in the 1990s, which led to reductions in both the risk of acute major complications and the incidence of restenosis, compared with the risks after balloon angioplasty **(Fischman DL. et al., 1994)..**

Although the use of recently introduced drug-eluting stents has resulted in even further reductions in the occurrence of restenosis, in-stent thrombosis and neointimal hyperplasia may still occur and cause artial or complete obstruction. **(F. Pugliese, et al., 2006).**

Whereas the clinical diagnosis of stent occlusion due to thrombosis is usually straightforward in patients with a recent stent implantation and with a subsequent onset of acute myocardial ischemia leading to acute myocardial infarction, the assessment of in-stent restenosis is more challenging. Restenosis occurs in approximately 10%– 20% of patients with complex lesion characteristics **(Sharma SK. et al., 2004).**

Conventional coronary angiography is still the technique of choice for the diagnosis of in-stent restenosis, although cardiac catheterization may involve major complications and is associated with moderate to high costs. Magnetic resonance (MR) angiography also can depict the coronary anatomy and help detect stenoses in the proximal segments of coronary arteries **(Kim WY et al., 2001).**

However, metallic stents cause magnetic susceptibility artifacts that may prevent visualization of the lumen **(Hug J. et al., 2000).**

Electron-beam CT is the modality with the shortest image acquisition times, namely 100 msec for a 3-mm-thick section suitable for morphologic interpretation and 50 msec for an 8-mm-thick section used for flow analysis without direct visualization of the in-stent lumen. However, image noise is extremely high with the first technique, and only severe, flow-limiting stenoses can be detected byusing the flow technique. Thus, the occurrence of non obstructiveneointimal hyperplasia remains unnoticed at electron-beam CT. In addition, patients who undergo percutaneous coronary intervention may experience a progression of atherosclerosis in native coronary vessels without a stent implant, but electron-beam CT is suboptimal for monitoring such progression, because it requires the sequential triggered acquisition of multiple 3-mm-thick sections **(F.Pugliese et al., 2006).**

Hence, the latest generation of multidetector (multisection) CT scanners, which offer a smaller voxel size, faster gantry rotation speed, and reconstruction per gantry rotation, provide an appealing alternative for noninvasive luminal assessment in patients with chest pain after coronary stent placement **(Schuijf JD. et al., 2004).** Hence, the latest generation of multidetector (multisection) CT scanners, which offer a smaller voxel size, faster gantry rotation speed, and reconstruction per gantry rotation, provide an appealing alternative for noninvasive luminal assessment in patients with chest pain after coronary stent placement **(Schuijf JD. et al., 2004).**

The improved hardware configuration of multidetector CT scanners allows direct visualization of the stent struts and lumen for a more reliable assessment of instent patency than is allowed by the visualization of distal runoff. In symptomatic patients, multidetector CT may be used as a complement or a substitute for treadmill testing; because the latter lacks specificity, additional noninvasive investigations such as stress echocardiography and scintigraphy often are required before cardiac catheterization is undertaken. Multidetector CT also can be useful to assess the condition of the whole coronary tree, as it provides information about the number, severity, and location of coronary lesions. In the follow-up of asymptomatic patients after stent implantation, multidetector CT might help overcome the limited accuracy of treadmill testing to rule out restenosis and thus enable a reduction in the number of further examinations (ie, stress echocardiography, scintigraphy) needed because of a positive or inconclusive test result. **(F.Pugliese et al., 2006).**

Improvements in CT hardware technology, such as high x-ray output, isotropic voxel size of 0.4 x 0.4 x 0.4 mm, acquisition times of 6–14 seconds, and the capability of rendering 64 sections per rotation, can play a valuable role also in the evaluationof the intra–coronary artery stent lumen. Indeed, advances in multidetector CT technology mean that thinner sections can be obtained in a shorter time, with resultantincreased spatial resolution along the z-axis and with almost motion-free data sets **(Nakanishi T, et al., 2005).**

Temporal resolution depends primarily on a gantry rotation speed faster than those available with earlier scanners. The reduced breath-holding time is better tolerated by patients and contributes to the minimization of motion-related artifacts. Coupled with these improvements in hardware design, lectrocardiography (ECG)-based gating techniques and specialized methods of image reconstruction are used. Depending on the patient's heart rate, data acquired during one cardiac cycle (monosegmental) or multiple cardiac cycles (multisegmental) can be used for section reconstruction. With these combined advantages, current64-section CT systems provide better spatial and temporal resolution than do earlier generations of multidetector CT scanners, and higher spatial resolution and a better signal-to-noise ratio than do electron-beam CT scanners **(Maintz D. et al., 2001).**

In the clinical evaluation of coronary stents, better delineation of the graft struts and of the presence of instent restenosis is possible with 64-section CT technology. A luminal diameter reduction of more than 50% due to neointimal hyperplasia is consistent with hemodynamically significant stent restenosis. **(Cademartiri F, et al., 2005) .**

The accuracy of coronary CT angiography was better for stents with 50% or more reduction of in-stent luminal diameter However, the accuracy of coronary CT angiography was inferior for stents with less than 50% reduction in luminal diameter, Although early neointimal hyperplasia causing less than 50% restenosis with definite in-stent hypointense focal defects may not change the clinical course of patients, it indicates higher sensitivity of the scanner in detecting such early pathologic findings Until recently, the assessment of the stent lumen for nonocclusive stent restenosis due to neointimal hyperplasia was a challenging task. With the improved isotropic resolution of the present generation of CT, more of these early defects may be detected and an early surveillance may be initiated before progression into a significant lesion. **(K.M.Das. et al., 2007).**

2. Stent Imaging with Multidetector CT:

A.General Issues:

In addition to the specifications of scanner hardware, scanning technique, and dedicated post processing (ie, convolution filter), variables such as stent diameter, material, and design as well as patient characteristics may heavily affect the visibility of the in-stent lumen. The earliest experiments to assess the feasibility of coronary stent imaging with multidetector CT were performed in vitro with varying collimations, contrast material concentrations, stent calibers, and stent positions within the gantry **(Mahnken AH. et al., 2004).**

B. Optimization of Contrast Enhancement:

Prominent contrast enhancement in the lumen is a prerequisite for robust coronary CT angiography which is achieved not only by optimizing the contrast material injection parameters (ie, using a high-concentration contrast agent and a fast injection rate) but also by accurately synchronizing the CT data acquisition with the passage of the contrast agent by means of bolus tracking or a test bolus. Edge-enhancing convolution filters, which may be used for better delineation of stents, have the drawback of producing noisier data sets. If such a convolution filter is used, the assessability of the in-stent lumen particularly benefits from the presence of a high degree of intraluminal contrast enhancement, which somewhat compensates for the kernel-related noise. A high degree of intraluminal enhancement is recommended especially for the investigation of stent patency in vessels that have a small diameter and thus contain less blood **(F.Pugliese. et al., 2006).**

C. Residual Cardiac Motion:

Residual cardiac motion is of the utmostimportance as acause of vessel non-assessability at multi-detector CTcoronary angiography. Residual cardiac motion also playsa role in exacerbating metal-related artifacts suchas beam hardening and partial volume averaging effects (Fig 1). The use of high gantry rotation speeds, multi-segmental reconstruction techniques, and B blockers tolower the heart rate consistently improves the interpretability of multidetector CT coronaryangiograms. ECG-based editing techniques allow animprovement of image quality for patients with mildirregularities in sinus rhythm, such as premature beats, and for those with bundle-branch block **(F.Pugliese. et al., 2006).**

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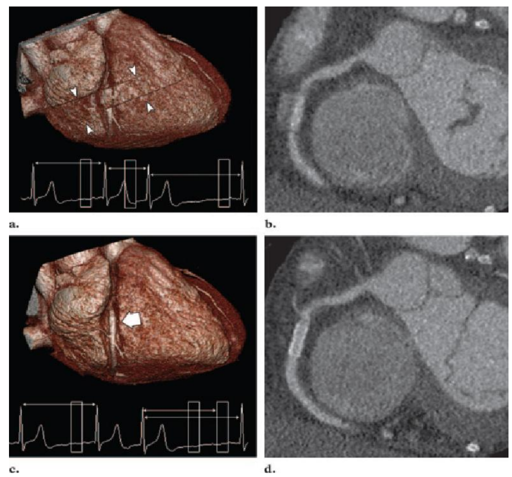

Figure (1): Residual cardiac motion exacerbates metal-related artifacts at 64-section CT in a patient with a stent in the midportion of the right coronary artery and with a premature heartbeat recorded at ECG during scanning. (a, b) Images obtained from data acquired during gating with the original ECG tracing. On the volume-rendered image (a), a stepladder artifact (arrowheads) is visible at the level of the midportion of the right coronary artery. On the multiplanar reformatted image (b), a blurring of contours is visible. (c, d) Images obtained with cardiac gating after editing of the ECG tracing. To avoid a gap in the image data, the reconstruction window during the premature heartbeat was deleted and another was added to the subsequent cardiac cycle. This step eliminated the abrupt heart rate change related to the premature beat and allowed a more coherent reconstruction of the data set. On the volume-rendered image (c), the appearance of the stent (arrow) is unaffected by motion artifacts. Likewise, the in-stent lumen is well depicted on the multiplanar reformatted image (d) **(F.Pugliese. et al., 2006).**

3. Patients and Methods

A total number of 50 patients were enrolled for multi-detector row CT angiography of the coronary arteries between May 2015 and May 2017. Twenty two patients underwent both conventional coronary angiography and MDCT coronary angiography. Both examinations were done within a month. The patients who did not perform the conventional angiography were mostly due to the decision made by the referring physicians as there is increased confidence in the results of MSCT angiography, so those patients were referred for conservative medical treatment.

40 of our patients (80%) presented with recurrent chest pain (defined as a retro-sternal or precordial diffuse burning, heaviness, or squeezing sensation that may radiate to the left arm, neck or lower jaw and is precipitated by effort & relived by rest or nitrates) or suspected progression of known coronary artery disease. While the remaining 10 patient's (20%) came for regular follow up to assess the patency of previously deployed coronary stents by MSCT. The total patients mean age was 58 years old, ranging between 39 and 73 years old. There were a total number of 38 males and 12 females. The average heart rate was 62 beats/min.

Inclusion criteria:

- patients with previous history of coronary stent insertion in need to:
  - Assess the patency of their stents.
  - Assess the progression of the disease in the native arteries.

Exclusion criteria:

- Arrhythmias.
- Heart rate above 80 /min not responding to medical preparation.
- Clinically unfit patients (unable to stop breathing during the examination).

Methods:-

Patient Preparation:

- Patients were asked to fast 4-6 hours prior to the examination. Medications are not to be discontinued.
- The heart rate was evaluated before the examination. The examination was done if the heart rate is below 65 beats per minute.
- Patients with heart rates above 70 beats per minute were given cardio-selective beta-blocker; 100 mg of Metoprolol or atenolol orally 1 hour before the study to obtain a stable low heart rate, provided that contra-indications to β-blockers are excluded.
- Nitroglycerine was not administrated prior to the study because, in spite of its coronary-dilator effect that enhances visualization; the drug has the potentiality to increase the heart rate and also falsely increases the estimated diameter reduction of the stenotic lesions.
- The steps of the study were explained in details for each patient. To evaluate patients ability of breath-withholding; they were required to perform a deep inspiration and to continue to hold their breath without pushing (i.e., Valsalva maneuver). During this trial, the patient was observed for compliance and the electrocardiogram for significant changes.

Contrast Material:

A bolus of 70-80 ml of water soluble non-ionic contrast (Ultravist 370 mg Schering, Berlin, Germany) was injected through 18 gauge canula into an upper limb vein (right antecubital vein in all our cases to reduce left sided artifacts) with a flow rate of 5 to 5.5 mL/sec. This injection was automatically followed by injection of about 40-50 cc of saline at a flow rate of 4 ml/sec using a programmed dual head power injector pump (MedRad; USA) to maintain good opacification of the coronary vessels with wash out of contrast material from the SVC and right side of the heart that may cause artifacts.

Scan Protocol:

CT angiographic examinations were performed by several CT scanners namely: Definition 128- Dual source MDCT (Seimens Medical Systems, Germany) in Dar El-Foad and Cairoscan as well as Aquilion 64 (Toshiba Medical Systems, Tokyo, Japan) and Brilliance iCT 256 SP (Philips Medical Systems, Netherlands) in Alfascan.

Patients were positioned supine on the CT table. ECG leads were fixed on the chest wall. All reconstructions are performed using the retrospective ECG gating. For this technique; an ECG must be recorded simultaneously through out the duration of the scanning.

A scanogram was taken that presented an AP and lateral views of the examined region. It was used to position the imaging volume of the coronary arteries that extends from the level of tracheal bifurcation down to about 1 cm below diaphragm. In case of post CABG status the imaging volume should extend from the level of the root of the neck down to about 1 cm below diaphragm to include the entire course of the arterial or venous grafts.

The center of the field of view is 2 cm to the left of the dorsal spine on the AP scout and at the level of the hilum on the lateral scout.

No calcium scoring was done for our patients due to the presence of radiopaque coronary stents that would lead to false high scores.

Then, automated determination of the starting time using the "Bolus-tracing technique" was done. It entails injection of the whole volume of the utilized contrast material as a one bolus at the pre-determined rate. After a delay of about 10 seconds from the start of injection (time estimated for the contrast to reach the great vessels of the chest, being variable according to the site of the canula, rate of injection, body built and heart rate); series of axial images at the level of the origin of the left main coronary artery is acquired with an interval of 1 second between subsequent images. The density within the descending aorta is monitored in each axial image on a real time base while the region of interest (ROI) carefully avoiding the athermanous calcifications.

Time-attenuation curves were generated. When the density within the descending aorta exceeds 120 HU (i.e. the contrast started to arrive), the scanning is triggered with a delay of further 3 seconds (time needed for the table movement to the cranial start position while the patient is instructed to hold breathing). This time delay also allows for increase in the contrast concentration at the ascending aorta and coronary arteries. It is to be noted that the axial images taken at the "Bolus-tracing technique" are of low radiation dose with a 120 KV and 40 mAs (not of diagnostic value). This is to reduce the radiation exposure.

And then the volume data set was taken in a spiral mode with simultaneous acquisition of at least 64 parallel slices at certain scan parameters. During the helical scan; the ECG signal was recorded digitally. Patients were automatically instructed to maintain an inspiratory breath hold while the CT data and the ECG trace were acquired.

No adverse reactions were noted due to contrast material. Despite that the CT scan is completed within minutes; the total examination time was around 10-15 minutes.

Image Reconstruction:

For most patients, the grafts and the native arteries were best visualized at 75% and 40% of the cardiac cycle. If these images were not satisfying, further phases of the cardiac cycle were used to visualize the different coronary segments.

In patient with some motion artifacts; 4 data sets were created during different time instants of the cardiac cycle (50%, 60%, 70% and 80% of the R wave to R wave interval); the data set containing the fewest motion artifacts (on the bases of cross sectional images) was used for further creation of the reconstructed images and evaluation of the coronary artery. The average time of the study was 10 minutes. Another 60 minutes were spent for result evaluation at the workstation.

Data Evaluation:

The reconstructed axial images at different points of the cardiac cycles are sent to an off-line workstation where detailed reconstruction was made to each data set to get the data.

Visibility of the stent was considered "good" when there is sharp delineation from the surrounding structures, with less blurring artifacts. Visualization was considered "adequate" in presence of image-degrading artifact that didn't interfere with evaluation with moderate confidence and "poor" in the presence of image-degrading artifacts when the evaluation is possible yet only with low confidence. The examined stent was considered "nonassessable" when the image-degrading artifacts were severe enough to prevent differentiation between the significant stenosis and occlusion on one hand and the normal segment or mildly stenotic lesions on the other hand. These stents were usually of narrow caliber (2.5 mm or less) with thick struts and marked blooming artifacts which indicates further confirmation by conventional diagnostic angiography.

In evaluable stents, presence or absence of a significant stenosis (≥ 50% reduction in diameter) was identified and located.

Multi-planner (specially the curved planes) reconstructions were more suitable for assessment of the stent lumens. Volume-rendered reconstructions were used for three dimensional orientations and global presentation of results.

As regard to the composition of the plaque, a distinction was made between calcified and non-calcified plaques. Plaques with a mean attenuation of 130 HU or greater were graded as calcified, whereas plaques with a mean attenuation of less than 130 HU were graded as non-calcified. Calcified plaques were identified on non-enhanced scans, and non-calcified plaques were identified on contrast-enhanced scans.

The axial as well as the reconstructed images including the multi-planer reformatted (MPR), thin slab maximum intensity projection (MIP) and the volume rendered (VR) images are all used in combination to evaluate the coronary artery disease. MIP was the modality that used to identify the coronary lesions while the degree of stenosis was evaluated primary on the axial scans and MPR (specially the curved reformatted images) using the software and scale calibration, automatic determination of the degree of stenosis was available with possible manual editing when necessary.

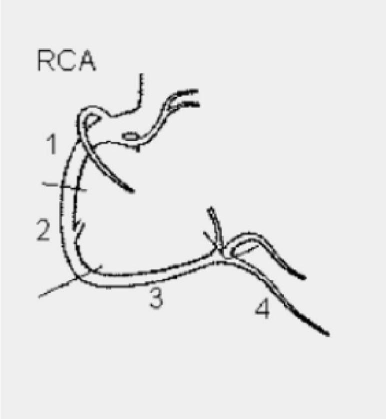

Figure (2) Segmental anatomy of right coronary artery (RCA) (lateral view), according to American Heart Association (AHA) ***(Kopp AF. et al., 2002)***

Identification of coronary artery segments was based on the model suggested by the American Heart Association (AHA), where the RCA (Figure 2) shows proximal (1), middle (2) and distal (3) segments and the PDA branch (4).

The left coronary system (Figure 3) is formed by the left main trunk; LMT (5) that bifurcates to LAD and left circumflex. The LAD has proximal (6), middle (7) and distal (8) segments. It gives off at least two sizable diagonal branches (9) and (10). The left circumflex artery has proximal segment (11) before it gives off the first obtuse marginal artery (12). The distal segment (13) turns on the inferior surface of the heart. LCX may give additional obtuse marginal branches (14) and (15) that are not included in statistics owing to their small size.

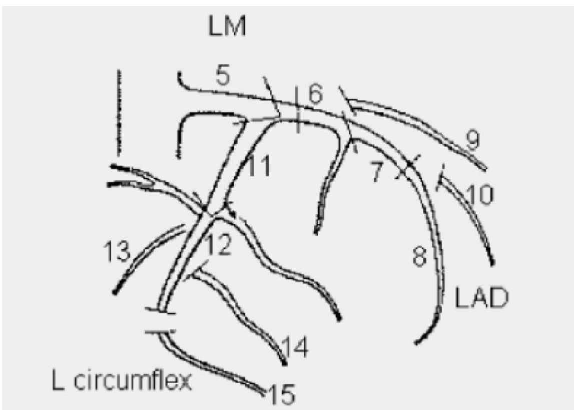

Figure (3) Segmental anatomy of the left coronary artery (right anterior oblique view) with left main trunk (LMT), left anterior descending (LAD), and left circumflex (LCX) according to American Heart Association (AHA) ***(Kopp AF. et al., 2002)***

The coronary artery segments are further classified into proximal [RCA 1, LMT 5, LAD 6], middle [RCA 2, LAD 7, LCX 11], distal [RCA 3, LAD 8, LCX 13] and branches [including the diagonals of LAD (9 & 10), obtuse marginal of the left circumflex (12) and posterior descending artery (4)].

4. Results

This study included 50 patients with prior coronary stent deployment, 22 of them (44%) underwent conventional angiography as a gold standard for evaluation of the patency of the coronary stents. The indications of conventional angiography were unstable angina in 10 cases out of the 22 cases (45.45 %), while the rest were performed to assess stent patency after suspected instent re-stenosis or failure of evaluation by multislice CT coronary study in 12 cases out of 22 (54.54 %).

The mean age of the included patients was 58 with an age range between 39 and 73 years. Male patients were 44 (88 %) while females were 6 (12 %).

Out of them; 25 (50%) had positive family history for premature coronary artery disease, 28 (56 %) had diabetes mellitus, 43 (86 %) had hypertension, 39 (78 %) were smokers, 37 (74 %) had dyslipidemia. Mean time from stent deployment was 30 months with a range between 15 months and 7 years.

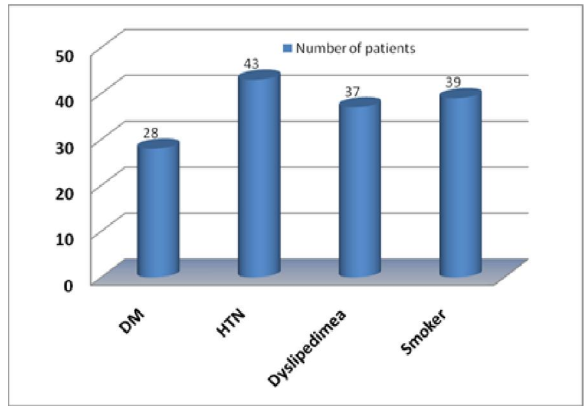

Figure (4)3D chart showing the number of patients with risk factors, and their distribution among the population of the study.

The rest of 28 cases their CT show minor findings which are accepted by the physician and not necessitate further investigations especially that they are improved on medical treatment.

A total of 95 coronary artery stents deployed within 50 patients were included in this study; and assessed by MSCT for follow up of their patency, 42 stents in 22 cases (44.2 % of the total included stents) underwent conventional coronary angiography and after correlation of the MSCT with the conventional coronary angiography, they were classified as follows:

- 3 stents were non-evaluable by MSCT due to heavy stent struts and narrow caliber [all of them are (2.5 mm) in caliber] and proved to be patent stents by conventional angiography.
- Within the 39 evaluable stents the following results were found:

1) 4 stents: were reported to be totally occluded by MSCT and proved their occlusion by conventional coronary angiography [their calibers are: one stent of (3.5 mm), two of (3 mm) and one of (2.5 mm)].

2) 9 stents: were reported to have suspected instent restenosis by MSCT and the conventional coronary angiography revealed that 4 of them have instent re-stenosis [their calibers are: two stents of (2.5 mm) and two of (2.75 mm)] while 5 stents proved to be patent by angiography [two of (3 mm), two of (2.5 mm) and one of (2.75mm) in cliber].

3) 26 stents: were reported to be patent by MSCT and proved their patency by conventional coronary

angiography after re-checking due to clinical conditions recommending so in the form recurrent chest pain and unstable angina [their calibers are: 10 of (3 mm), 7 of (3.5 mm), 7 of (2.75 mm) and 2 of (2.5 mm)].

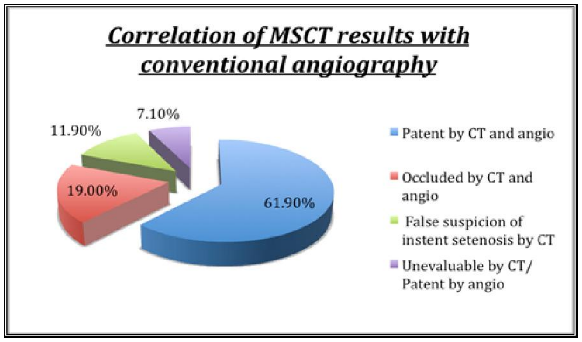

Figure (5): 3D pie chart showing the relation between the results of MSCT and conventional coronary angiography in the evaluated 22 cases.

The calibers of the deployed coronary stents in our study ranging from 2.5 up to 3.5 mm and so if we classify our results of the evaluated 42 stents by both MSCT and conventional angiography in correlation to the caliber of the deployed stents, the results will be as follows:

8 stents of 3.5 mm in caliber show: 7 stents (87.5%) are patent by both CT and catheter angiography, 1 stent (12.5 %) is occluded by CT and angiography.

14 stents of 3mm in caliber show: 10 stents (71.4%) are patent by both CT and catheter angiography, 2 stents (14.2 %) are occluded by CT and angiography and 2 stents (14.2%) are suspected to be re-stenosed by CT but not proved by angiography.

11 stents of 2.75 mm in caliber show: 7 stents (63.6%) are patent by both CT and catheter angiography, 1 stent (9 %) is occluded by CT and angiography and 3 stents (27.2 %) are suspected to be re-stenosed by CT two of them (18.1%) proved to have actual restenosis by conventional angiography while the other one (9%) proved to be patent by conventional angiography.

9 stents of 2.5 mm in caliber show: 2 stents (22.2%) are patent by both CT and catheter angiography, 3 stent (33.3 %) were non-evaluable by CT due to thick stent struts and narrow caliber and proved their patency by conventional angiography and 4 stents (44.4 %) are suspected to be re-stenosed by CT but two of them (22.2%) proved to be actually patent by angiography and the other two stents (22.2%) proved to have actual instent restenosis.

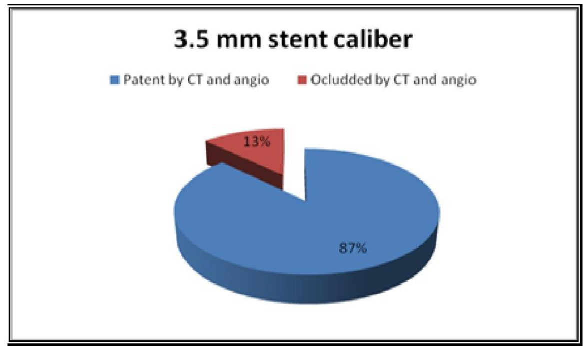

Figure (6): 3D chart showing variable CT and angiographic results within 3.5 mm coronary stent caliber

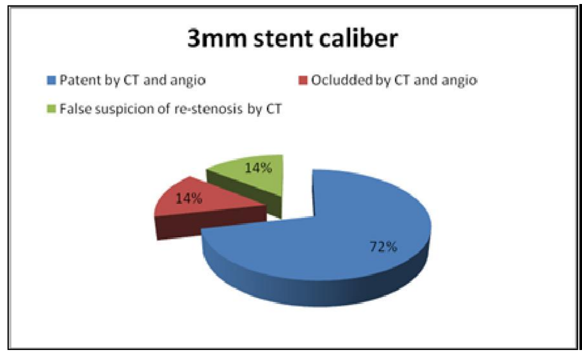

Figure (7): 3D chart showing variable CT and angiographic results within 3 mm coronary stent caliber

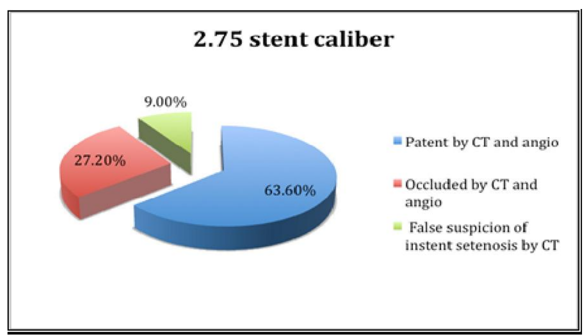

Figure (8): 3D chart showing variable CT and angiographic results within 2.75 mm coronary stent caliber

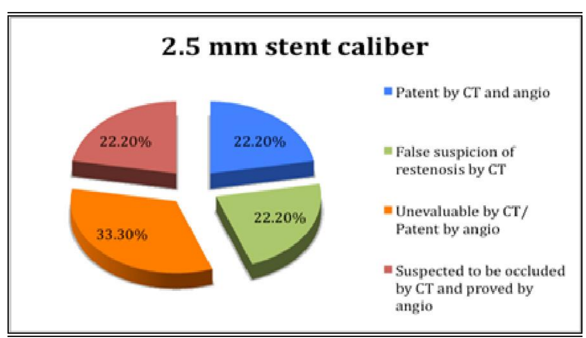

Figure (9): 3D chart showing variable CT and angiographic results within 2.5 mm coronary stent caliber.

In an overall view, CT angiography compared to the conventional angiography as a gold standard technique gave us a sensitivity of 100%, a specificity of about 83.8 %, an accuracy of about 87.1%, PPV is 61.5% and NPV is 100% in the assessment of the patency of the coronary artery stents, taking into consideration proper standard CT angiography techniques in all cases included in the final results with exclusion of all cases that experienced inevitable conditions that may hinder proper stent lumen evaluation as sudden rise of the heart rate during scanning time or unexpected cardiac arrhythmias.

5. Selected cases:

Case No 1.

A 61 years old male patient, ex-smoker and dys-lipidemic. 4 years ago, he developed acute anterior myocardial infarction and was admitted at CCU. Diagnostic coronary angiography was done and a (Multilink Tetra) stent 3.0/38 mm was applied at the middle segment of LAD.

At the end of 2015, he started to complain again by compressing retro-sternal chest pain, precipitated by effort and relieved by rest and nitrates. He was referred for MSCT coronary angiography to evaluate the coronary stent patency and to assess the condition of the native arteries.

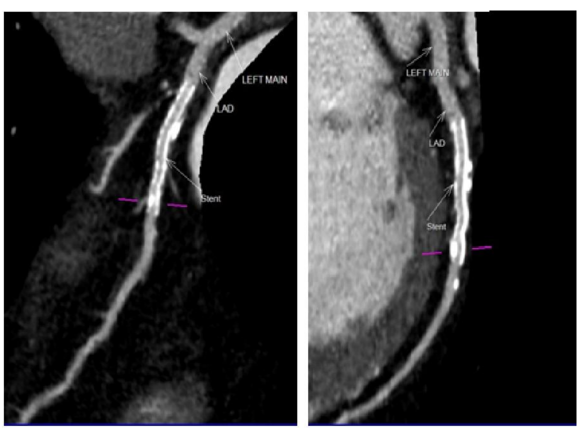

Figure (10A): Curved MPR images of the LAD showing fair luminal opacification of its mid segment applied stent suggestive of its patency. The LAD afterwards shows good filling with normal patency and no visible significant stenosis there after.

Case No 2

A 59 years old male patient, smoker, diabetic, dys-lipidemic and hypertensive. In 2015, he developed acute chest pain with history of previously applied coronary stents.

MSCT coronary angiography was done to evaluate the coronary stent patency and to assess the condition of the native coronary arteries, which reports that the previously applied stents are un-evaluable due to thick stent struts.

Diagnostic coronary angiography was done to assess the state of the coronary stents and native arteries.

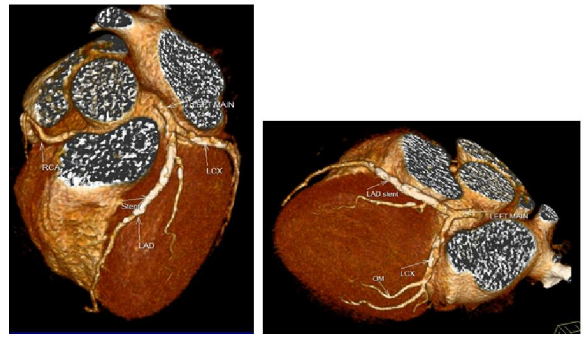

Figure (10B) VR images of the LAD showing shows good filling of its post stent segment with normal patency and no visible significant stenosis there after

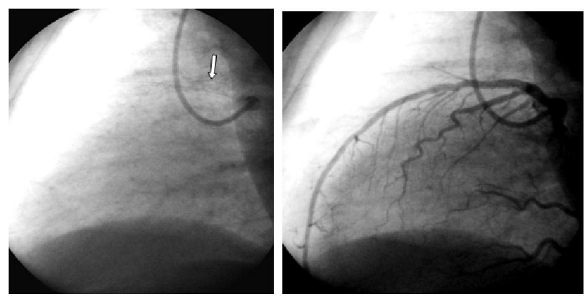

Figure (10C): Conventional angiography of the coronary arteries showing faint stent struts before injection of contrast (arrow) with patent stent lumen and rest of the LAD artery down to its distal segments.

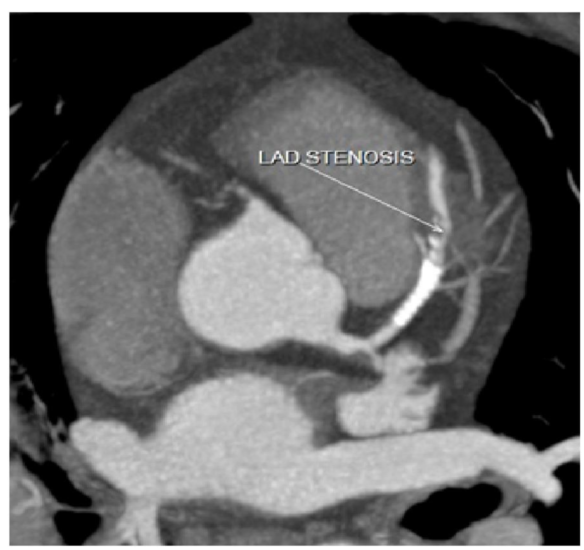

Figure (11A) Curved MPR images of the LAD showing non-evaluable proximal stent (due to thick stent struts) with severe mid LAD stenosis.

Figure (11B) Curved MPR images of the OM shows non evaluable mid segment stent (due to thick stent struts) with severe stenosis immediately after the stent followed by patent average calibered distal segment

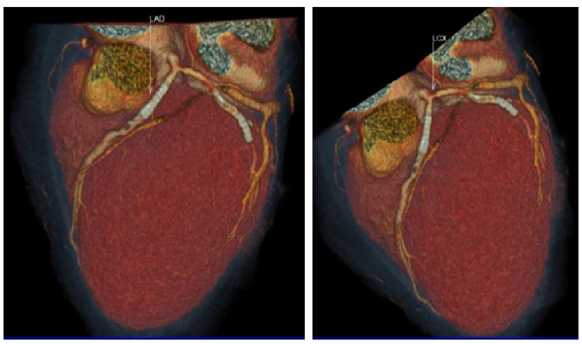

Figure (11C) VR images of the proximal LAD and mid OM stents with severe mid LAD and OM stenosis.

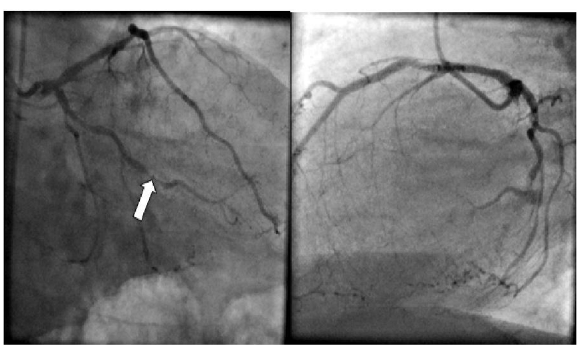

Figure (11D) Conventional angiography of the coronary arteries showing patent proximal LAD and mid OM stents followed by mild mid LAD and severe distal OM stenosis (arrow).

__Case No 3__

A 44 years old male patient, non-smoker, diabetic, hypertensive, dys-lipidemic with unstable angina. In 2014, he developed acute chest pain and was admitted at CCU. Diagnostic coronary angiography was done and was found to have severe proximal LAD stenosis with coronary arterial stent insertion.

In 2016, he started to complain again by retro-sternal chest pain, precipitated by effort and relieved by rest and nitrates. This pain started to increase in the last month. He was referred for MSCT coronary angiography to evaluate the LAD stent and to assess the condition of the rest of coronary arteries.

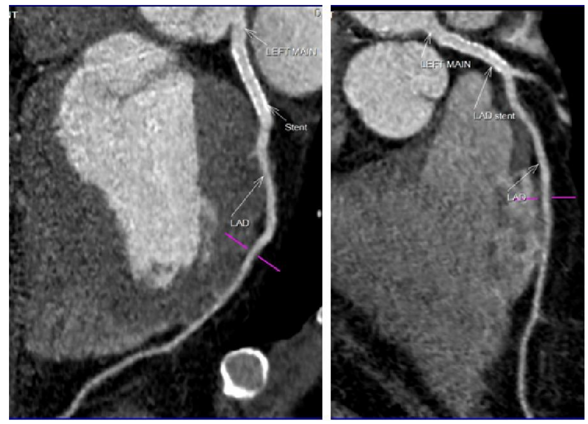

Figure (12A) Curved MPR images of the LAD showing patent proximal stent

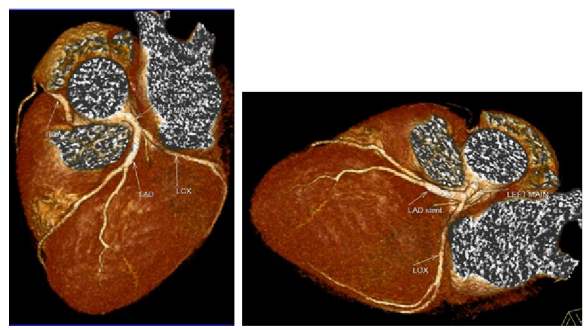

Figure (12B) VR images of the LAD showing proximal stent with average caliber of distal segment of the LAD artery

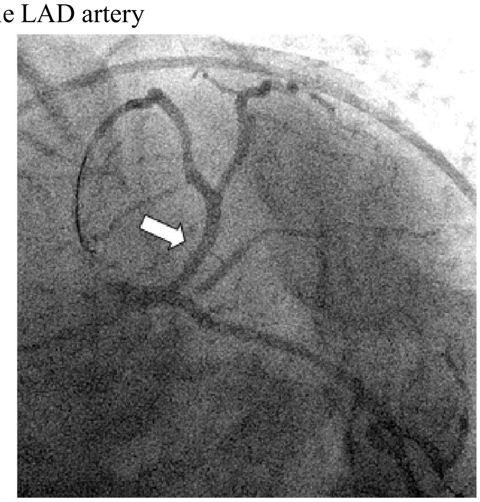

Figure (12C) Conventional angiography of the coronary arteries showing patent proximal LAD stent.

Case (4):

A 66 years old female patient, non-smoker, hypertensive with unstable angina. In 2014, she developed acute chest pain and was admitted at CCU. Diagnostic coronary angiography was done and was found to have atherosclerotic CAD with eccentric atheromatous plaque in proximal LAD and eccentric atheromatous plaque in proximal ramus intermedius where PCI was done with coronary stent application [(2.5 x 28mm) XIENCE-V stent in proximal ramus intermedius and (3.5 x 9 mm) Driver stent in proximal LAD].

In 2016, she started to complain again by retro-sternal chest pain, precipitated by effort and relieved by rest and nitrates. She was referred for MSCT coronary angiography to evaluate the coronary stents and rest of coronary arteries.

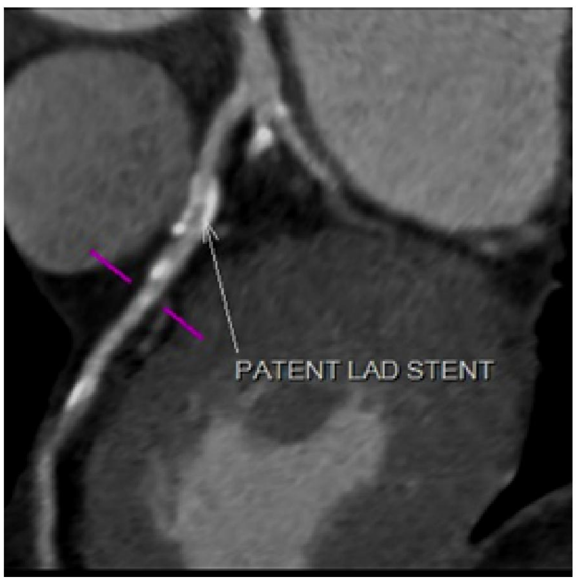

Figure (13A) Curved MPR images shows patent proximal LAD stent.

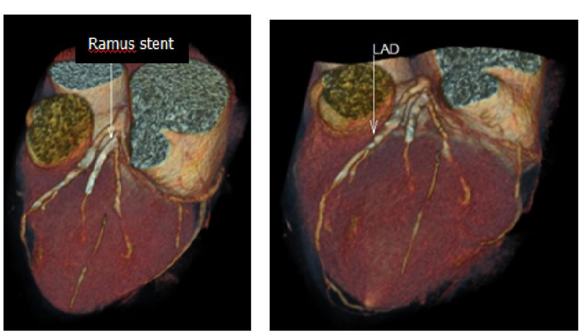

Figure (13B) Curved MPR images showing patent proximal LAD stent with non-evaluable ramus intermedius stent.

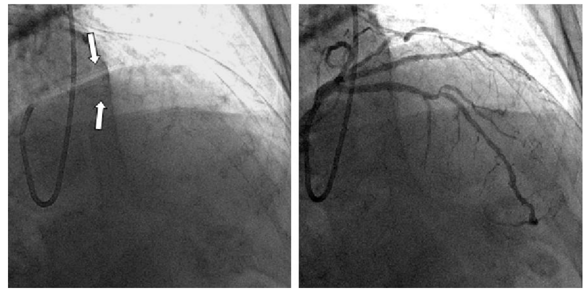

Figure (13C) Conventional angiography of the coronary arteries showing patent proximal LAD and proximal ramus intermedius stents (arrows in pre-contrast images).

Case (5):

A 49 years old male patient, hypertensive and dys-lipidemic. 2 years ago, he developed acute chest pain and performed diagnostic coronary angiography with multiple coronary arterial stents were applied as follows:

- Three LAD stents (the distal one is Liberte 2.75 x 24 mm).
- One OM1 stent (Zeta 3.0 x 33 mm).
- Two RCA stents (the distal one is Vision 3.0 x 23 mm).

During the last month, he started to complain again by compressing retro-sternal chest pain, precipitated by effort and relieved by rest and nitrates. He was referred for MSCT coronary angiography to evaluate the coronary stent patency and to assess the condition of the native arteries.

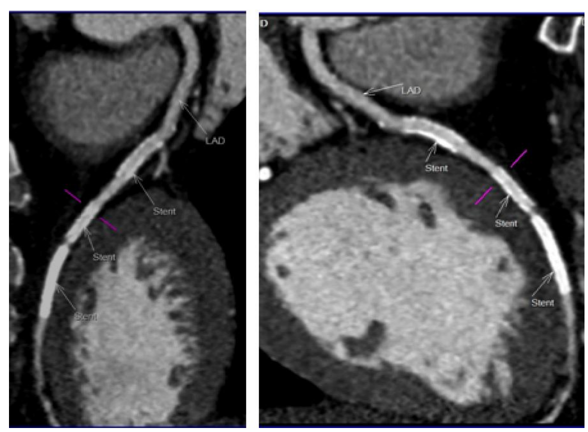

Figure (14A) Curved MPR images of the LAD showing fair luminal opacification of its proximal and mid segment applied stents suggestive of their patency, while its distal longest stent has dense struts, narrower caliber and non evaluable lumen. Patent average caliber of the distal part of the LAD down to the apex of the heart.

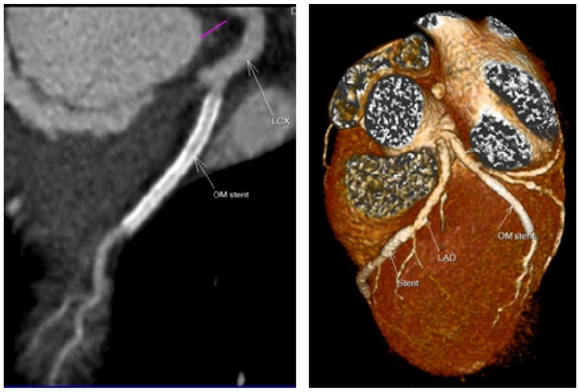

Figure (14B) Curved MPR image (on the left side) showing fair luminal opacification of the OM1 applied stent suggestive of its patency. VR image (on the right side) showing LAD and OM1 stents with patent average caliber of the arteries all through their course.

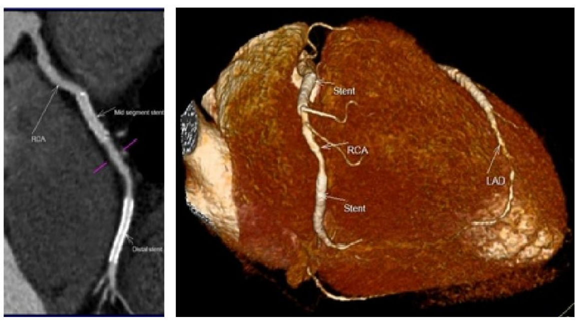

Figure (14C) Curved MPR and VR images of the RCA showing shows good luminal opacification of its proximal and distal stents indicating their patency.

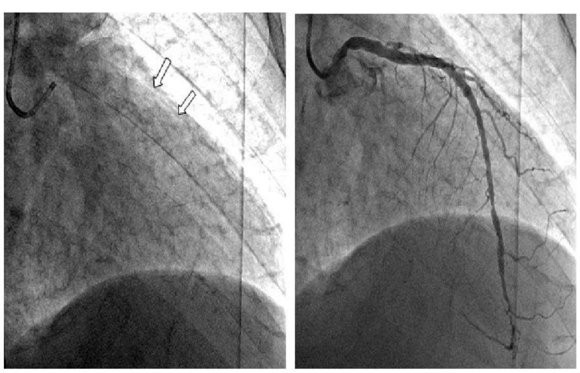

Figure (14D) Conventional angiography of the LAD showing faint stent struts before injection of contrast (arrows) with patent stents lumen and rest of the LAD artery all through its course

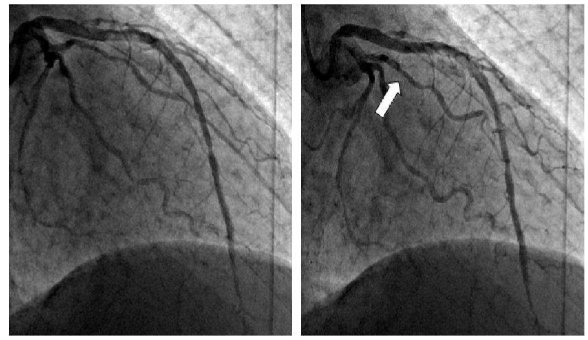

Figure (14E) Conventional angiography of the LCX showing patent OM1 stent lumen (arrow).

Figure (14 F) Conventional angiography of the RCA showing faint stents struts before injection of contrast (arrow) with patent stents lumen and rest of the RCA artery all through its course.

6. Discussion

So far, conventional coronary angiography has been considered the standard of reference for evaluation of the patency and luminal stenosis of coronary artery stents. However, the main drawbacks of conventional coronary angiography for this purpose include invasiveness, patient discomfort, and risk of complications. A less invasive imaging modality is desirable for evaluation of patients suspected of having stent re-stenosis or occlusion.

Symptomatic patients who have undergone coronary stenting often pose a challenging diagnostic problem to the angiographer. The calcified, tortuous, and diffusely diseased coronary arteries complicate precise delineation of the lesions. High-quality angiographic images and thorough knowledge of the coronary anatomy are required in order to adequately determine revascularization options. Performing this angiographic evaluation in a noninvasive fashion is even more challenging. Noninvasive imaging techniques are hampered by specific limitations.

The major improvements of the recently developed 64- section or higher and Dual Source CT machines compared with the old four-section scanners, include improved temporal resolution due to shorter gantry rotation time, better spatial resolution owing to sub-millimeter collimation, and considerably reduced scan acquisition times. Despite the recent technical advances, the 64-detector row CT coronary angiography is still sensitive to arrhythmia. Persistent irregular cardiac rhythm such as atrial fibrillation and frequent extra-systoles preclude MDCT coronary angiography. However, motion artifacts owing to mild arrhythmia (e.g. single ventricular extra-systole) can be diminished by manual repositioning the reconstruction windows.

The use of multi–detector row CT is gaining increasing acceptance for noninvasive cardiac imaging. Several studies have demonstrated successful application of multi–detector row CT angiography for assessment of coronary artery disease and evaluation of cardiac valves.

Carbone et al. evaluated the ability of 64-detector row CT to assess the coronary artery stent patency on fifty-five consecutive patients (age range 45–80 years) with 97 previously implanted coronary artery stents the sensitivity, specificity, positive predictive value and negative predictive value were 75, 86, 71 and 89%, respectively. However, nine of the 12 stented segments of 2.5-mm diameter and 10 of the 23 stented segments of 2.75-mm diameter were excluded from the analysis since these segments were considered as nonevaluable due to blooming artifact. **(Carbone I, et al.,2008).**

In another recent study by Oncel et al. on thirty patients (27 men, three women; mean age, 58.2 years; range, 42–67 years) with 39 coronary stents were examined with 64-section multidetector CT. At conventional angiography, nine of the 39 stents were shown to be totally occluded. All of the occluded stents were correctly diagnosed with CT angiography. Nineteen of 20 patent stents were correctly demonstrated with CT angiography. Ten stents had in-stent restenosis; eight were correctly diagnosed with CT. The sensitivity, specificity, positive predictive value and negative predictive value were 89, 95, 94 and 90%, respectively. However, the stents with a diameter ≤ 2.5 mm were excluded from their analyses and the average stent diameter was 3.1 ± 0.4 mm. **(D. Oncel, et al., 2007).**

In another recent study by Rist et al., on twenty five patients with 46 applied stents underwent 64SCT of the coronary arteries and quantitative x-ray coronary angiography (QCA) after coronary artery stent placement. Significant in-stent restenosis or occlusion was detected on QCA in 8/45 cases (>/=50% stenosis = 6; occlusion = 2). Both of the two occluded coronary stents were correctly identified, while two of the six stents with nonocclusivestenoses were misdiagnosed as patent. The diameters of these two misdiagnosed stents were 2.5 and 3.0 mm, respectively. These findings indicated that nonocclusive in-stent stenoses were undetected in some cases, and especially for stents with a smaller diameter, even with using 64-detector row CT. **(Rist C, et al., 2006).**

Seifarth et al. reported that the artificial lumen narrowing due to blooming artifact was about 40% for stents with a 3-mm diameter and with using 64-detector row CT. **(Seifarth H, et al., 2006).**

Another study by Mahnken et al. showed that the average visible lumen was about 53% for stents with a 3-mm diameter and with using 64-detector row CT. **(Mahnken AH, et al,. 2006).**

Stent lumen visibility varies largely depending on stent type and diameter. The blooming effect is more disturbing in smaller coronary stents with thicker struts and is less disturbing in larger stents. Un-interpretable images tend to be obtained in stents that have thicker struts and/or a smaller diameter. When the lumen diameter is more than 3 mm, lumen visibility is better. Regarding the type of stent, gold or goldcoated stents, along with tantalum made stents, cause the most severe artifacts, while stainless steel and cobalt stents are better visualized **(D. Oncel, et al.,2007).**

Early feasibility studies confirmed the technical capability of dual-source CT to produce diagnostic-quality images of the coronary arteries in patients with high heart rates **(Pugliese F, et al., 2008).**

A study by **(Pugliese F, et al., 2008)** showed high diagnostic performance of dual-source CT in the detection of in-stent restenosis with no dependence on heart rate., only smaller stents (< 2.75 mm) caused diagnostic problems. high temporal resolution of dual-source CT makes it helpful for visualization of the lumens of coronary stents without heart rate control .

Six studies (with 482 patients and 682 stents) that have compared 64-slice CT and dual-source CT with invasive angiography for the detection of in-stent stenosis are currently available. On average, 88% of stents were interpretable. Interpretable stents could be evaluated with fairly high diagnostic accuracy; weighted mean sensitivities and specificities were 91% (95% CI 85–96) and 94% (95% CI 91–95), respectively. While the negative predictive value was uniformly high [90–99%, mean 98% (95% CI 96–99)], positive predictive values were as low as 63% [in mean 76% (95% CI 68–83)]. For all scanner generations, the stent diameter has been identified as a major predictor of stent evaluability, with particularly low rates of evaluable stents for diameters ≤ 3.0 mm. Patient weight, which determines image noise, and heart rate may also influence stent assessability. **(S. Schroeder, et al., 2008).**

Although in single, carefully selected cases (e.g. large diameter stents in a proximal vessel segment, low and stable heart rate, and absence of excessive image noise) coronary CT angiography may be a possibility to rule out in-stent restenosis, routine application of CT to assess patients with coronary stents can currently not be recommended. Visualization of the stent lumen is often affected by artifacts, and especially the positive predictive value is low. **(S. Schroeder, et al., 2008).**

New technical developments are bringing to the market CT scanners with increased performance. For many years technology in this field developed following the law of “more slices = better images”. Some manufacturers are developing in this direction (Siemens Medical with 128 slices, Philips Medical with 256 slices and Toshiba Medical with 320 slices). Others are developing into higher spatial resolution (i.e. new detector hardware) technology (GE medical). Others are developing into higher temporal resolution (Siemens Medical with Dual Source technology). Others are developing also into concomitant Dual Energy platforms (GE Medical and Siemens Medical). It is not clear at the moment weather one development will prevail on the others. We know for sure that current benchmark (i.e. 64- slice CT-CA) is already performing very well in experienced hands. **(F. Cademartiri, et al., 2010).**

The advantages of more slices (between 128 and 320slices) are inherent to the very short scan time (1-2s) and to potential for myocardial perfusion. The “price”might be related to constraints in temporal resolution and an increased radiation dose. The advantages of high resolution technology are inherent to better image quality with the same radiation dose or to the same image quality with a lower radiation dose.

The advantages of higher temporal resolution are inherent to a reduced use of beta-blockers administration or to better image quality while keeping the heart rate below 65bpm. The advantages of a dual energy platform are inherent to totally unexplored spectral imaging capabilities**. (F. Cademartiri, et al., 2010).**

Although diagnostic accuracy of 320-row CTA may be comparable to the performance of 64-row scanners, advantages of this new technology lie in improved image acquisition as well as reduced radiation dose compared with retrospectively gated 64-row CTA. For the first time, since the introduction of CTA technology, 16 cm volumetric data acquisition within a single gantry rotation has become possible, allowing full cardiac imaging within a single gantry rotation, even in patients with an enlarged heart. Accordingly, single heart beat image acquisition allows for a significant reduction of contrast material and breath-hold time (with a total breath-hold time of 5 s) when compared with CTA systems requiring multiple heart beats to image the entire heart. **(F. R. de Graaf, et al., 2010).**

Furthermore, 320-row systems have increased temporal resolution (350 ms per gantry rotation) which reduces cardiac motion artefacts. Although certain types of 64-row systems have a slightly higher temporal resolution (330 ms per gantry rotation), these systems can only cover a small volume (3.2 cm) in a single heart beat. Similarly, dual-source systems, with even superior temporal resolution (83 ms), allow limited craniocaudal coverage per rotation. In contrast, 320-row CTA allows volumetric data acquisition with full cardiac coverage in a single rotation, eliminating the problem of stair-step artefacts associated with helical and step-and-shoot scanning techniques. **(F. R. de Graaf, et al., 2010).**

Recently, several new approaches have been developed to reduce CTA radiation dose. First, dose modulation was introduced, allowing tube current modulation throughout the cardiac cycle, decreasing radiation exposure at the cost of increased image noise during low tube current. Subsequently, prospective ECG triggering became available, allowing data acquisition during a narrow pre-defined portion of the R-R interval (usually enddiastolic phase when the heart is relatively motion-free), resulting in a substantial reduction in radiation dose. Importantly, volumetric data acquisition used by 320-row CTA may further reduce radiation exposure by eliminating helical oversampling. Therefore, compared with retrospectively gated 64-row CTA, prospectively gated 320-row CTA may considerably reduce radiation exposure to the patient, while maintaining good image quality. Of note, even lower mean radiation doses have been reported recently in studies using new-generation 64-row CTA with prospectively ECG triggered step-and-shoot technology. These studies however were performed using maximal dose reduction by using tube voltages with a maximum of 100 or 120 kV as well as performing image acquisition during a minimal phase window of only 75% of the cardiac cycle. Other technical advances, such as adaptive collimation and highpitch spiral acquisition, may also allow significant radiation reduction using scanning techniques requiring multiple heart beats. **(F. R. de Graaf, et al., 2010).**

Wykrzykowska, et al, found that 64-MDCT evaluation of the stents was limited because of beam-hardening and stent-strut artifacts—that is, the blooming effect. It is particularly problematic with early stent designs where the strut thickness is greater and metals such as tantalum and gold were used. Newer stents have much thinner struts and are made predominantly of stainless steel, cobalt chromium, and nitinol. In addition, recent advances in MDCT technology, such as improvement in the z-resolution, faster tube rotation, and the development of special dedicated kernels for stent evaluation, have the potential to improve the ability of MDCT to accurately detect in-stent restenosis. **(J.J. Wykrzykowska, et al.,**

2010).

There was no correlation between poor quality image or misdiagnosis and type of stent. There was no significant difference inthe results for bare metal and drug-eluting stents. There also was no correlation with location of the stent in terms of right or left side of the circulation. Image quality and misdiagnoses, however, were strongly related to stent size. Images of all of the misidentified stents were of poor quality, and all of these stents were 3 mm or less in diameter and therefore located in small segments of the coronary vasculature. **(D. Oncel, et al., 2008).**

D. Andreini, et al., study reported that slice misalignment due to inadequate heart rate control was another influential factor in ability to evaluate stents. MDCT feasibility was significantly lower in patients with heart rates ≥60 beats/min compared with <60 beats/min. The study reported a significant difference in the feasibility between the right coronary artery and the left coronary artery. Slice misalignment was more likely to occur in the right coronary artery due to the spatial distribution of this vessel, which may explain this finding. **(D. Andreini, et al.,2009).**

D. Andreini, et al. study found that 64-slice multidetector computed tomography detects in-stent re-stenosis (ISRs) in assessable coronary stents with high accuracy and specificity compared with invasive coronary angiography. An incorrect diagnosis of ISR was made by multidetector computed tomography in 3 of 131 stents deemed free of obstruction by invasive coronary angiography. Stent diameter is a fundamental parameter affecting stent lumen assessment by multidetector computed tomography. Accordingly, significantly higher specificity, positive predictive value, and negative predictive value were found in stents with a diameter ≥3 mm compared with a diameter <3 mm. Stent strut thickness was another determining factor for lumen interpretation. All accuracy parameters were higher and positive predictive value was significantly higher in stents with a thickness <100 μm. A significantly higher positive predictive value was also found in bare metal stents compared with drug-eluting stents. This was likely due to the thicker struts of most drug-eluting stents implanted in the study. **(D. Andreini, et al.,2009).**

Owing to the artifacts caused by metal, visualization of the coronary lumen within stents by CTA is more challenging than evaluation of the native coronary arteries. The limited spatial resolution of CT, the type of stent and, especially, stent diameter (< 3 mm being associated with the highest number of partial lumen visualization and non diagnostic scans) contribute to limited clinical results. Our study confirms that even with improved scanner technology, evaluation of implanted coronary artery stents remains challenging.

Similar to the previous studies performed by 64-slice MDCT, our study also found a significant influence of stent diameter on evaluability, with 3 mm being a threshold below which the rate of evaluable stents is very low. The question of patency can be answered with MSCT, but often only indirectly by the demonstration of filling with contrast medium both proximally and distally to the stent. A stent lumen of diameter 3 mm or less may not be directly evaluable by MSCT, and the technique typically underestimates the internal stent diameter. The nature of the stent also has an important influence on the results of MSCT imaging, because artifacts due to the stent material can make the stent lumen difficult to assess, and the difficulty is only heightened if the stents contain additional radio-opaque markers. Solving this problem requires higher spatial resolution, which, however, cannot be obtained at present without excessive radiation exposure.

Our study found that among the main causes of stent lumen un-evaluation by 64-, 128- or 256-slice CT scanners, are the uncontrolled high heart rates, cardiac arrythmias, large body mass index, thick stent struts and narrow stent calibers.

By the aforementioned analysis of the calibers of the involved coronary stents within our study the results proves the direct relation between the caliber of the deployed stent and the right CT assessment of its patency with adequate CT visualization of the wide calibered stents, while increased suspicion of in-stent re-stenosis and failure of evaluation in small calibered stents.

After exclusion of all unevaluable stents, sensitivity for the detection of in-stent restenosis in our study was 100% and this could be due to the relatively small number of cases (with a specificity of 83.8%, accuracy of 87.1%, PPV is 61.5 % and NPV is 100%), which indicates that clinical applications might be possible if the problem of stent evaluability was solved. However, the frequency of cases with un-interpretable image quality - an overall rate of 7.14 % in our study (representing 33.3% in patients with stents of 2.5 mm diameter) precludes the application of MDCT for coronary angiography in unselected patients with implanted coronary artery stents.

Further improvements in spatial resolution using novel detector designs as well as better reconstruction algorithms may increase the utility of CT for the assessment of stents in the near future. Until then, patients must be carefully selected before undergoing MDCT evaluation for in-stent restenosis. Patients with a low BMI and the ability to breath-hold and achieve low heart rates as well as patients with large (> 3.0 mm) thin-strut, recently implanted stents and low calcium scores should be considered for noninvasive assessment of in-stent restenosis rather than being sent directly to cardiac catheterization.

Coronary artery stenting has become an established treatment for symptomatic coronary artery disease. One of the most important variables that determine the successful clinical outcome of coronary artery stent application is the short- and long-term patency rate of the stents.

So far, conventional coronary angiography has been considered the standard of reference for evaluation of the patency and luminal stenosis of coronary artery stents. However, the main drawbacks of conventional coronary angiography for this purpose include invasiveness, patient discomfort, and risk of complications. A less invasive imaging modality is desirable for evaluation of patients suspected of having instent stenosis or occlusion.

The use of multi–detector row CT is gaining increasing acceptance for noninvasive cardiac imaging. Recent years with the new emerging machines have demonstrated successful application of multi–detector row CT angiography for the less invasive assessment of coronary artery disease and the evaluation of coronary artery stents.

The aim of this study was to evaluate multi-detector row CT angiography as a less invasive technique in the assessment of the patency of the coronary arteries stents without involvement of much more invasive techniques (e.g. conventional angiography) to assess the patency of their stents.

This study included 50 patients with prior coronary artery stent application, 22 of them underwent conventional angiography as a gold standard for evaluation of the coronary artery stents. The indications of angiography were unstable angina in 10 cases (45.45%) while the rest were performed to assess stent patency after suspected instent re-stenosis or failure of evaluation by multislice CT coronary study in 12 cases out of 22 (54.54 %). The mean age of the included patients was 58 with an age range between 39 and 73 years. Male patients were 44 (88 %) while females were 6 (12 %).

A total of 95 coronary artery stents deployed within 50 patients were included in this study; and assessed by MSCT for follow up of their patency, 42 stents in 22 cases (44.2 % of the total included stents) underwent conventional coronary angiography. The patients who did not perform the conventional angiography were mostly due to the decision made by the referring physicians as there is increased confidence in the results of MSCT angiography, so those patients were referred for either conservative medical treatment or for angioplasty.

Conventional angiography was considered the gold standard technique after correlation of the MSCT with the conventional coronary angiography, 3 stents (7.14%) were non-evaluable by MSCT due to heavy stent struts and narrow caliber [all of them are (2.5 mm) in caliber] and proved to be patent stents by conventional angiography, while the rest of 39 evaluable stents the following results were found:

1) 4 stents: (10.25%) were reported to be totally occluded by MSCT and proved their occlusion by conventional coronary angiography.

2) 9 stents: (23%) were reported to have suspected instent restenosis by MSCT and the conventional coronary angiography revealed that 4 (10.25%) of them have instent re-stenosis while 5 (12.8 %) stents proved to be patent by angiography .

3) 26 stents: (66.66%) were reported to be patent by MSCT and proved their patency by conventional coronary angiography after re-checking due to clinical conditions recommending so in the form recurrent chest pain and unstable angina.

CT angiography compared to the conventional angiography as a gold standard technique gave us a sensitivity of 100%, a specificity of about 83.8 %, an accuracy of about 87.1 %, PPV of 61.5 % and NPV of 100% in the assessment of any type of coronary artery stents.

The latest multi-detector row CT scanners show a potential to become a first-line tool for the noninvasive evaluation of patients with suspected instent restenosis. Conventional angiography may be spared for patients who needs an intervention e.g. angioplasty within placed stents or within a native coronary artery.

In conclusion, our study helps to identify factors that influence the assess ability of coronary artery stents by 64-, 128- dual source and 256-slice CT scanners, namely, stent type and diameter. It shows that under certain conditions, the detection of in-stent restenosis might be possible with an accuracy that could permit clinical applications, but that the relatively high rate of unevaluable stents currently does not allow to use MDCT for coronary angiography in unselected patients with implanted stents in coronary arteries or bypass grafts.

References

1. Cademartiri F, Mollet N, Lemos PA, et al. (Usefulness of multislice computed tomographic coronary angiography to assess in-stent restenosis.) Am J Cardiol 2005;96:799–802.
2. Cademartiri F, Mollet NR, van der Lugt A, et al. (Intravenous contrast material administration at helical 16-detector row CT coronary angiography: effect of iodine concentration on vascular attenuation.) Radiology 236:661–665, 2005.
3. Carbone I, Francone M, Algeri E, Granatelli A, Napoli A, Kirchin MA, et al. (Non-invasive evaluation of coronary artery stent patency with retrospectively ECG-gated 64-slice CT angiography.) Eur Radiol 2008;18:234-243.

4. Daniele Andreini, Gianluca Pontone, Antonio L. Bartorelli, Daniela Trabattoni, Saima Mushtaq, Erika Bertella, Andrea Annoni, Alberto Formenti, Sarah Cortinovis, Piero Montorsi, Fabrizio Veglia, Giovanni Ballerini, and Mauro Pepi. (Comparison of Feasibility and Diagnostic Accuracy of 64-Slice Multidetector Computed Tomographic Coronary Angiography Versus Invasive Coronary Angiography Versus Intravascular Ultrasound for Evaluation of In-Stent Restenosis) (Am J Cardiol 2009;103:1349 –1358).
5. Dilek Oncel, Guray Oncel, Ahmet Tastan, Batuhan Tamci (Evaluation of Coronary Stent Patency and In-Stent Restenosis with Dual-Source CT Coronary Angiography Without Heart Rate Control) AJR 2008; 191:56–63.
6. Dilek Oncel, Guray Oncel, Mustafa Karaca. (Coronary Stent Patency and In-Stent Restenosis: Determination with 64-Section Multidetector CT Coronary Angiography—Initial Experience) Radiology: Volume 242: Number 2—February 2007, P:403-409.
7. Filippo Cademartiri, Erica Maffei, Alessandro Palumbo, Chiara Martini, Annachiara Aldrovandi, Diego Ardissino, Valerio Brambilla, Paolo Coruzzi, Nico R. Mollet, Gabriel P. Krestin, Pim J de Feyter (CT Coronary Angiography for the follow-up of coronary stent) ACTA BIOMED 2010; 81: 87-93.
8. Fischman DL, Leon MB, Baim DS, et al. (A randomized comparison of coronary-stent placement and balloon angioplasty in the treatment of coronary artery disease.) Stent Restenosis Study Investigators. N Engl J Med 1994;331:496–501.
9. Fleur R. de Graaf, Joanne D. Schuijf, Joe¨ lla E. van Velzen, Lucia J. Kroft, Albert de Roos, Johannes H.C. Reiber, Eric Boersma, Martin J. Schalij, Fabrizio Spano´, J. Wouter Jukema, Ernst E. van der Wall, and Jeroen J. Bax (Diagnostic accuracy of 320-row multidetector computed tomography coronary angiography in the non-invasive evaluation of significant coronary artery disease) European Heart Journal (2010) 31, 1908–1915.
10. Francesca Pugliese, Filippo Cademartiri, Carlos van Mieghem, Willem B. Meijboom, Patrizia Malagutti, Nico R. A. Mollet, Carlo Martinoli, Pim J. de Feyter, Gabriel P. Krestin. (Multidetector CT for Visualization of Coronary Stents) Radio Graphics 2006; 26:887–904.
11. Hug J, Nagel E, Bornstedt A, Schnackenburg B, Oswald H, Fleck E. (Coronary arterial stents: safety and artifacts during MR imaging.) Radiology 2000;216: 781–787.
12. Joanna J. Wykrzykowska, Armin Arbab-Zadeh, Gustavo Godoy, Julie M. Miller, Shezhang Lin, Andrea Vavere, Narinder Paul, Hiroyuki Niinuma, John Hoe, Jeffrey Brinker, Faisal Khosa, Sheryar Sarwar, Joao Lima, Melvin E. Clouse. (Assessment of In-Stent Restenosis Using 64-MDCT: Analysis of the CORE-64 Multicenter International Trial) AJR 2010; 194:85–92 .
13. Kim WY, Danias PG, Stuber M, et al. (Coronary magnetic resonance angiography for the detection of coronary stenoses.) N Engl J Med 2001;345:1863–1869.
14. K. M. Das, Ayman A. El-Menyar, Amar M. Salam, Rajvir Singh, Wafer Amin K. Dabdoob, Hajar A. Albinali, Jassim Al Suwaidi (Contrast-enhanced 64-Section Coronary Multidetector CT Angiography versus Conventional Coronary Angiography for Stent Assessment) Radiology: Volume 245: Number 2—November 2007 P:424-432.
15. Kopp AF, Schroeder S, Kuettner A. et al. (Non invasive coronary angiography with high resolution multi-detector row computed tomography.) Eur Heart J, 23; 1714, 2002.
16. Mahnken AH, Buecker A, Wildberger JE, et al. (Coronary artery stents in multislice computed tomography: in vitro artifact evaluation.) Invest Radiol 2004;39:27–33.
17. Mahnken AH, Mu ¨hlenbruch G, Seyfarth T, Flohr T, Stanzel S, Wildberger JE, et al. (64-slice computed tomography assessment of coronary artery stents: a phantom study.) Acta Radiol 2006;47:36-42.
18. Maintz D, Fischbach R, Juergens KU, Allkemper T, Wessling J, Heindel W. (Multislice CT angiography of the iliac arteries in the presence of various stents: in vitro evaluation of artifacts and lumen visibility.) Invest Radiol 2001;36:699–704.
19. Nakanishi T, Kayashima Y, Inoue R, Sumii K, Gomyo Y. (Pitfalls in 16–detector row CT of the coronary arteries.) Radio Graphics 2005;25:425–438.
20. Rist C, von Ziegler F, Nikolaou K, Kirchin MA, Wintersperger BJ, Johnson TR, et al. (Assessment of coronary artery stent patency and restenosis using 64-slice computed tomography.) Acad Radiol 2006;13:1465-1473.
21. Schuijf JD, Bax JJ, Jukema JW, et al. (Feasibility of assessment of coronary stent patency using 16-slice computed tomography.) Am J Cardiol 2004;94:427–430.
22. Seifarth H, Ozgu ¨n M, Raupach R, Flohr T, Heindel W, Fischbach R, et al. (64- versus 16-slice CT angiography for coronary artery stent assessment: in vitro experience.) Invest Radiol 2006;41:22-27.
23. Sharma SK, Choudhury A, Lee J, et al. (Simultaneous kissing stents (SKS) technique for treating bifurcation lesions in medium-to-large size coronary arteries.) Am J Cardiol 2004;94:913–917.
24. Stephen Schroeder, Stephan Achenbach, Frank Bengel, Christof Burgstahler, Filippo Cademartiri, Pim de Feyter, Richard George, Philipp Kaufmann, Andreas F. Kopp, Juhani Knuuti, Dieter Ropers, Joanne Schuijf, Laurens F. Tops, and Jeroen J. Bax (Cardiac computed tomography: indications, applications, limitations, and training requirements) European Heart Journal (2008) 29, 531–556.

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