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# Sensitivity and Specificity of Computerized Tomography Coronary Angiography for Evaluation of Coronary Stents of Variable Sizes and Sites

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## ABSTRACT

**Background:** Coronary artery stenting has become the most important non-surgical treatment for symptomatic coronary artery disease. However, in-stent restenosis occurs at a relatively high rate and this problem has led to the routine use of invasive angiography for assessing stent patency.

**Objective:** The aim of the study is to determine sensitivity and specificity of Computerized Topography Coronary Angiography (CTCA) for evaluation of coronary stent patency regarding its different sites and sizes.

**Patients and methods:** The study population consisted of 40 patients presented for follow up after previous coronary stent implantation within at least 6 months regardless presence or absence of symptoms suggestive of in-stent restenosis. It was carried out at Nasr City Police Hospital in the span of one year from June 2018 to June 2019. The study was approved by the medical ethics committee of Al-Azhar University Hospitals and a written informed consent was obtained from all patients. **Results:** The current study revealed a good diagnostic accuracy of the MSCT coronary angiography (91.2%). Sensitivity, specificity, PPV and NPV were 88.2%, 92%, 83.3% and 94.3% respectively. We also concluded the higher diagnostic accuracy of ISR in LAD compared to other vessels as well as higher diagnostic accuracy of ISR of proximal stents and stents of diameter > 3mm. **Conclusion:** It was concluded that the 320-slice CT coronary angiography is a robust test that can be used confidently to diagnose patients with coronary stents and more importantly to rule out significant coronary in-stent restenosis in patients with high likelihood of having significant ISR.

**Keywords:** Sensitivity, specificity, computerized tomography, coronary angiography, coronary stents.

## INTRODUCTION

Coronary artery disease (CAD) (including acute MI) is responsible for about half of cardiovascular deaths**.** Mortality from cardiovascular disease is expected to reach 23.4 million in 2030 [(1)].

The main non-surgical option for re-vascularization of the myocardium in patients suffering from obstructive coronary artery disease is coronary artery stenting [(2)]**.**

Coronary stents, which were first developed in the mid-1980s have ultimately replaced "plain old balloon angioplasty" (POBA) as the preferred method of performing percutaneous coronary intervention (PCI) after the observed improvements in angiographic and clinical outcomes seen with their use. Most PCI procedures involve a coronary stent, and therefore, interventional cardiologists are faced with a wide choice of coronary stents to implant. This choice ranges from conventional bare-metal stents (BMS) and drug-eluting stents (DES) that are widely used in contemporary practice to newer stents such as DES with biodegradable polymers, DES that are polymer-free, DES with novel coatings, dedicated bifurcation stents, self-expanding stents, and biodegradable stents [(3)]. Restenosis after angioplasty and stent implantation has been considered the most significant problem in coronary interventional treatment. Stent restenosis (ISR) is defined as a reduction in lumen diameter after (PCI). It is determined by an excessive tissue proliferation in the luminal vessel of the stent called "neo-intimal proliferation", or by a new-occurring atherosclerotic process called "neo-atherosclerosis" [(4)].

DES have dramatically reduced the rates of restenosis and target lesion revascularization (TLR) compared with BMS, However, a low rate of ISR after DES still exists, and its prevalence is not negligible because the population treated with DES is large [(5)]**.**

Stent thrombosis (ST) has complicated coronary artery stent implantation since its inception and is associated with considerable morbidity and mortality due to abrupt vessel closure. Several case reports and observational studies suggest that ST may occur unusually late in patients treated with DES, a phenomenon referred to as very late ST [(6)].

Conventional coronary angiography (CA) is considered the reference standard for evaluation of coronary artery stenosis, ISR, and the patency of coronary artery bypass grafts. However, the risk of potentially serious adverse effects and the costs associated with such effects have led to a search for noninvasive alternatives. Good diagnostic accuracy has been reported with the use of alternative coronary imaging modalities such as multi-slice computerized tomography (MSCT) and magnetic perfusion imaging (MRI) [(7)]. Non-invasive examination of coronary artery disease is an attractive and rapidly evolving possibility. Since the introduction of (MSCT), Computerized tomography coronary angiography (CTCA) has emerged as a new tool in the diagnosis and monitoring of coronary heart disease. Additionally, noninvasive assessment of coronary stents is an attractive potential application of MSCT technology [(8)].

There have been remarkable technological advances in cardiac computed tomography (CT) in recent years, and diagnostic cardiac catheterization has been used in conjunction with CTCA in many patients. CTCA exhibits a high negative predictive value (NPV), which is helpful in avoiding unnecessary catheterization procedures, Factors favoring the use of CTCA for the assessment of stent patency are the



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speed, robustness and cost-effectiveness of the technique and the increasingly widespread availability of MSCT scanners [9].

**AIM OF THE STUDY**

The aim of this study was to determine sensitivity and specificity of Computerized Topography coronary angiography (CTCA) for evaluation of coronary stent patency regarding its different sites and sizes.

**PATIENTS AND METHODS**

The study population consisted of 40 patients presented for follow up after previous coronary stent implantation within at least 6 months regardless presence or absence of symptoms suggestive of in-stent restenosis. It was carried out at Nasr City Police Hospital in the span of one year from June 2018 to June 2019.

**Ethical approval and written informed consent:**

**The study was approved by the medical ethics committee of Al-Azhar University Hospitals** and a written informed consent was obtained from all patients.

**Inclusion criteria:**

***This study included 40 patients with the following criteria:***

- History of coronary artery disease (CAD).
- History of previous PCI with coronary artery stent implantation.
- Recurrence of ischemic symptoms for evaluation.

**Exclusion Criteria:**

- Heart rate greater than 75 beats per minute despite therapy.
- Atrial fibrillation.
- Inability to hold breath adequately due to chest disease.
- Impaired renal function (creatinine > 1.8 or GFR < 30).
- History of allergic reaction to contrast material.
- Pregnancy.

***Preparation of Patients:***

- **History taking** with emphasis on risk factors for CAD, time, size, site of stent implantation, severe chest conditions precluding adequate breath hold and dye allergy.
- **Clinical examination:** with emphasis on blood pressure that should be controlled, heart rate (Resting) should be adequate, both were recorded and body mass index calculated by this equation weight/height (meters2). A normal BMI score is one that falls between 18.5 and 24.9. This indicates that a person is within the normal weight range for his or her height.
- **Chest condition:** patients with decompensated heart failure who cannot lie flat were excluded from the test and also patients with severe chest conditions preventing adequate breath hold were excluded from the test.
- **The patient's lab investigations** were reviewed and those with serum creatinine above 1.8mg/dl were excluded from the test.
- **CT scan:** All patients were instructed to remain fasting for about 4 hours before doing the scan. Metformin was stopped 48hours before the scan.
- Patients with **heart rate:** above 75 bpm were given 100mg of **Atenolol** orally, half to one hour before the procedure. Those with heart rate 70-75bpm were given 50mg of Atenolol, half to one hour before the procedure, patients with heart rate less than 70bpm didn't receive any beta blockers. A second dose of Atenolol was given one hour after the initial one if the heart rate was not satisfactory (above 75 bpm) up to a maximum 200mg. Some patients need additional bolus or intravenous **propranolol** (1_2mg), those were typically patients who showed an increased heart rate on the CT couch. All patients received an oral benzodiazepine, 1.5mg **bromazepam** 15-30min before the scan (patients were instructed not to drive back after the study) After controlling the heart rate, the patient was transferred to the scanning room where he was laid on the CT couch.
- The patient was then given a tablet of 5mg isosorbide dinitrate sublingually if there was chest pain or to improve scanning procedure. When the patient was ready and after doing breathing exercise and observing the heart rate response to the breath hold, the scan procedure was started.

***The scanning consisted of the following steps:***

- A topogram of the chest was done.
- On the topogram, the attempted scan volume was planned to start from just below the carina till the lower border of the cardiac silhouette (in a craniocaudal direction).
- ECG gated prospective sequential scans were done to evaluate the coronary calcification. Sequential scans were acquired at the diastolic intervals of the patient's ECG while the patient was holding a deep inspiration.
- **Contrast media** (10cc of iodinated or non-iodinated dye was injected into **antecubital vein** (Daiichi Pharmaceutical Co., Ltd., Tokyo, Japan). Based on the calculated scan time e.g. for a 12 seconds scan a 70ml of contrast was administered.
- Flushing with 20 to 50 ml saline. To reduce the incidence of adverse reaction, the sort of contrast media was selected for each patient considering previous usage. The proper amount of the contrast media and injection speed was determined.
- ECG gated reconstruction were done in the diastolic phase (75% of the R-R interval). The whole coronary tree was reviewed for motion artifacts, if there were any other phases of reconstruction were done as systolic phase (40%).

The datasets were reconstructed at a slice thickness of 0.6mm with 0.3mm increments. These datasets were then displayed and analyzed using several modes of presentation; axial images, MPR (multi-planar reformations), oblique MPR, curved MPR, MIP (maximum intensity projection) as well as VRT (volume rendering techniques) formats.

- One observer was blinded to angiographic and clinical findings but aware of previous cardiac history, evaluating the MSCT examinations using axial slices and multiplanar and curved reconstructions.
- **The stent** was judged to be **occluded (**significant ISR) when the lumen inside the stent was **darker** than the contrast-enhanced vessel before the stent and/or when **no run-off** could be visualized at the distal end of the stent.
- Significant ISR was considered when the lumen inside the stent showed a **darker rim** (eccentric or concentric) between the stent and the enhanced vessel lumen with a lumen reduction **>50%** (as compared with other portions of the stent).
- **Non-occlusive (**non-significant ISR) was considered when the lumen inside the stent showed a **darker rim** (eccentric or concentric) between the stent and the enhanced vessel lumen with a lumen reduction **<50%** (as compared with other portions of the stent).

  In addition, the presence of reduced run-off distal to the stent was taken into consideration; if **reduced distal run-off** observed, this is to be suggestive of significant **in-stent restenosis.**
- The presence of **distal run-off** was not used as a criterion for the absence of significant in-stent restenosis, because **collateral filling** may occur (which cannot be detected adequately by **MSCT**).

Invasive Coronary Angiography was performed selectively for left and right coronary arteries in different angiographic views according to conventional approach and evaluated by 1 observer blinded to the MSCT results. The lesion or ISR considered significant if more than 50% by CA.

The standard 15_segment AHA model of the coronary tree was employed**.** Segments were classified as being normal, atherosclerotic (with no significant stenosis), Stenotic (<50% luminal narrowing) or non-evaluable.

***Statistical analysis***

Data were collected and tabulated. The statistics were done using statistical package for social science (SPSS) version 20.0 statistical package. The current study included 29 patients; all of the patients had coronary CTA done followed by invasive coronary angiography within a time delay of 1-2 months as interval between both investigations.

- **Sensitivity**: the ability of the test to detect those who are truly diseased (true positive rate).
- **Specificity**: is the ability of the test to detect those who are free of disease (true negative rate).
- **PPV**: positive predictive value is the proportion of patients with an outcome or disease if the test is positive, is the percentage of true positive to all positive by the examined test.
- **NPV**: negative predictive value is the proportion of free cases in negative results.
- **Kappa**: Items such as physical exam findings, radiographic interpretations, or other diagnostic tests often rely on some degree of subjective interpretations of observers. Studies that measure the agreement between two or more observers should include a statistic that takes into account the fact that observers will sometimes agree or disagree simply by chance. The kappa statistic (or kappa coefficient) is the most commonly used statistic for this purpose. A Kappa of 1 indicates perfect agreement, whereas a kappa of 0 indicates agreement equivalent to chance. A limitation of kappa is that it is affected by the prevalence of the finding under observation.

**RESULTS**

The current study was performed to assess the diagnostic accuracy of Computed Tomography Coronary Angiography (CTCA) in diagnosing of in-stent restenosis. In the current study 53 coronary stent, of 40 patients, were scanned with CTCA.

**Baseline data of enrolled patients:**

**Table 1** shows baseline data of the studied patients. Mean age of those patients was 54.75 ± 8.19 year with range between 36 and 79 year and the majority (75%) of them were males. Range of body mass index (BMI) was between 19.69 and 36.09 kg/m$^2$ with mean BMI was 27.94 ± 4.63 kg/m$^2$. Hypertension, diabetes mellitus and family history of ischemic heart disease presented in 25 (62.5%), 28 (70%), and 20 (50%), respectively.

It was noticed that 36 stent of 23 patients were patent while 17 stent of 17 patients were re-stenosed based on angiography. It was noticed that age, BMI, and frequency of DM, HTN and family history of IHD were significantly higher in patients with re-stenosis.**Table (1):** Baseline data of studied patients

| Variables | N= 40 | With re-stenosis (n= 17) | Without re-stenosis (n= 23) | *P* |
|---|---|---|---|---|
| **Age** (years) | 54.75 ± 8.19 | 61.15 ± 10.33 | 44.95 ± 3.45 | 0.01 |
| **Sex**<br>Male<br>Female | <br>30 (75%)<br>10 (25%) | <br>12 (70.5%)<br>5 (29.5%) | <br>18 (78.2%)<br>5 (21.8%) | 0.09 |
| **BMI** (kg/m$^2$) | 27.94 ± 4.63 | 31.11 ± 2.76 | 23.45 ± 4.0 | 0.01 |
| **Hypertension** | 25 (62.5%) | 13 (76.5%) | 12 (52.2%) | 0.01 |
| **Diabetes mellitus** | 28 (70%) | 17 (100%) | 11 (47.8% | 0.01 |
| **Family IHD** | 20 (50%) | 10 (59%) | 10 (43.4% | 0.04 |

Data was expressed in the form of frequency (percentage), mean (SD), range. **IHD**; **ischaemic heart disease**

**Frequency of stent restenosis based on CT scanning and angiography:**

Based on CTCA, 18 (34%) stents were re-stenosed while 35 (66%) stents were patent but coronary angiography showed that 17 (32%) stents were re-stenosed while 36 (68%) stents were patent. So, CTCA had 88.2% sensitivity and 92% specificity in prediction of re-stenosed stent with area under curve was 0.80.

**Table (2):** Diagnostic performance of CTCA in diagnosis of re-stenosed stent.

| Indices | Value |
|---|---|
| **Sensitivity** | 88.2% |
| **Specificity** | 92% |
| **Positive predictive value** | 83.3% |
| **Negative predictive value** | 94.3% |
| **Accuracy** | 91% |
| **Area under curve** | 0.80 (> 0.50) |
| ***P* value** | 0.01 (< 0.05) |

*P* value was significant if < 0.05

**Frequency of stent restenosis based on CT scanning and angiography in case of proximal stent and distal stent:**

The study included 40 stents that were inserted proximally and based on CTCA, 16 (40%) of them were re-stenosed while 24 (60%) stents were patent but coronary angiography showed that 14 (35%) stents were re-stenosed while the other 26 (65%) stents were patent. So, CTCA had 100% sensitivity and 92.3% specificity in prediction of re-stenosed proximal stent with area under curve was 0.96. The study included 13 stents that were inserted distally and based on CTCA, 2 (15%) of them were re-stenosed while 11 (85%) stents were patent but coronary angiography showed that 3 (23%) stents were re-stenosed while 10 (77%) stents were patent. So, CTCA had 33.3% sensitivity and 90% specificity in prediction of re-stenosed distal stent with area under curve was 0.62.

**Table (3):** Diagnostic performance of CTCA in diagnosis of re-stenosed site stent.

| Indices | Proximal stent | Distal stent |
|---|---|---|
| **Sensitivity** | 100% | 33.3% |
| **Specificity** | 92.3% | 90% |
| **Positive predictive value** | 87.5% | 50% |
| **Negative predictive value** | 100% | 82% |
| **Accuracy** | 95% | 77% |
| **Area under curve** | 0.96 | 0.62 |
| ***P* value** | 0.01 | 0.01 |

*P* value was significant if < 0.05

**Frequency of stent restenosis based on CT scanning and angiography in case of LAD, RCA and LCx stenting:**

The study included 33 stents that were inserted in LAD and based on CTCA and angiography, 12 (36.4%) of them were re-stenosed while 21 (63.6%) stents were patent. So, CTCA had 100% sensitivity and 100% specificity in prediction of re-stenosed stent of LAD with area under curve was 1.

The study included 9 stents that were inserted in RCA and based on CTCA, 3 (33.3%) of them were re-stenosed while 6 (66.7%) stents were patent but coronary angiography showed that 2 (22.2%) stents were re-stenosed while 7 (77.8%) stents were patent. So, CTCA had 50% sensitivity and 71.4% specificity in prediction of re-stenosed stent within RCA with area under curve was 0.61.

The study included 11 stents that were inserted in LCx and based on CTCA and angiography, 3 (27%) of them were re-stenosed while 8 (73%) stents were patent. So, CTCA had 50% sensitivity and 71.4% specificity in prediction of re-stenosed stent within LCx with area under curve was 0.77.

**Table (4):** Performance of CTCA in diagnosis of re-stenosed based on vessels.

| Indices | LAD | RCA | LCx |
|---|---|---|---|
| **Sensitivity** | 100% | 50% | 66.7% |
| **Specificity** | 100% | 71.4% | 87.5% |
| **Positive predictive value** | 100% | 50% | 66.7% |
| **Negative predictive value** | 100% | 83.3% | 87.5%% |
| **Accuracy** | 100% | 66.7%% | 82% |
| **Area under curve** | 1 | 0.61 | 0.77 |
| ***P* value** | < 0.001 | 0.01 | 0.01 |

*P* value was significant if < 0.05

**Frequency of stent restenosis based on CT scanning and angiography in stent with length < 2.75, 2.75- 3.5 and > 3.5 cm:**

The study included 31 stents with length < 2.75 cm and based on CTCA, 11 (35%) of them were re-stenosed while 20 (65%) stents were patent but coronary angiography showed that 10 (32%) stents were re-stenosed while 21 (68%) stents were patent. So, CTCA had 90% sensitivity and 90.5% specificity in prediction of re-stenosed stent within RCA with area under curve was 0.90.

The study included 13 stents with length 2.75- 3.50 cm and based on CTCA, and angiography, 3 (23%) of them were re-stenosed while 10 (77%) stents were patent. So, CTCA had 66.7% sensitivity and 90% specificity in prediction of re-stenosed stent of length 2.75- 3.50 cm with area under curve was 0.78.T he study included 9 stents with length > 3.50 cm and based on CTCA, and angiography, 4 (44.4%) of them were re-stenosed while 5 (55.6%) stents were patent. So, CTCA had 100% sensitivity and 100% specificity in prediction of re-stenosed stent of length > 3.50 cm with area under curve was 1.

**Table (5):** Performance of CTCA in diagnosis of re-stenosed stent based on length.

| Indices | < 2.75 cm | 2.75- 3.5 cm | > 3.5 cm |
|---|---|---|---|
| **Sensitivity** | 90% | 66.7% | 100% |
| **Specificity** | 90.5% | 90% | 100% |
| **Positive predictive value** | 82% | 66.7% | 100% |
| **Negative predictive value** | 95% | 90% | 100% |
| **Accuracy** | 90.3% | 85% | 100% |
| **Area under curve** | 0.90 | 0.78 | 1 |
| ***P* value** | 0.01 | 0.01 | < 0.001 |

*P* value was significant if < 0.05

**Frequency of stent re-stenosis based on CT scanning and angiography in stent in obese and non- obese patients:**

The study included 41 stents in obese patients and based on CTCA, and angiography, 13 (31.7%) of them were re-stenosed while 28 (68.3%) stents were patent. So, CTCA had 84.6% sensitivity and 93% specificity in prediction of re-stenosed stent in obese patients with area under curve was 0.88.

The study included 12 stents in non- obese patients and based on CTCA and angiography, 5 (41.7%) of them were re-stenosed while 7(58.3%). So, CTCA had 100% sensitivity and 100% specificity in prediction of re-stenosis in non-obese patients with area under curve was 1.

**Table (6):** Performance of CTCA in diagnosis of re-stenosed stent based on obesity.

| Indices | Obese | Non- obese |
|---|---|---|
| **Sensitivity** | 84.6% | 100% |
| **Specificity** | 93% | 100% |
| **Positive predictive value** | 84.6% | 100% |
| **Negative predictive value** | 93% | 100% |
| **Accuracy** | 90 % | 100% |
| **Area under curve** | 0.88 | 1 |
| ***P* value** | < 0.001 | < 0.001 |

*P* value was significant if < 0.05

**Frequency of stent restenosis based on CT scanning and angiography in stent of diameter < 3 mm and > 3 mm:**

The study included 21 stents with diameter < 3 mm and based on CTCA, and angiography, 6 (28.5%) of them were re-stenosed while 15 (71.5%) stents were patent. So, CTCA had 75% sensitivity and 84.6% specificity in prediction of re-stenosed stent of diameter < 3 mm with area under curve was 80.

The study included 32 stents with diameter > 3 mm and based on CTCA, 10 (31.3%) of them were re-stenosed while 22 (68.7%) stents were patent while with angiography 9 (28%) stents were re-stenosed while 23 (72%) stents were patent. So, CTCA had 90% sensitivity and 95.6% specificity in prediction of re-stenosed stent of diameter > 3 mm with area under curve was 80.

**Table (7):** Performance of CTCA in diagnosis of re-stenosed stent based on diameter.

| Indices | < 3 mm | > 3 mm |
|---|---|---|
| **Sensitivity** | 75% | 90% |
| **Specificity** | 84.5% | 95.6% |
| **Positive predictive value** | 75% | 90% |
| **Negative predictive value** | 84.5% | 100% |
| **Accuracy** | 81% | 96.8% |
| **Area under curve** | 0.80 | 0.96 |
| ***P* value** | 0.01 | < 0.001 |

*P* value was significant if < 0.05

## DISCUSSION

The current study was conducted to evaluate the diagnostic accuracy of a rather new, non-invasive modality; 320-multislice CT coronary angiography versus the invasive coronary angiography which is the gold standard in evaluating the coronary stents.

The mean age of our studied patients was 54.75 ± 8.19 years old and most of them were males representing 75% of the study population.

These findings were revealed on stent bases analysis, by comparing the CT findings of each coronary stent with the invasive coronary angiography findings, this study involved 40 patients with 53 stents deployed in the coronary arteries.

This study showed that the 320-multislice CT has a good sensitivity and specificity for detecting significant in-stent re-stenosis (88.2%, 92 % respectively), with a good overall positive predictive value of 83.3 % and a negative predictive value of 94.3%. This is regarding all stents with no vessel discretion.

**These findings are consistent with several previously published reports.**

**De Graaf *et al.*** [10] also investigated the diagnostic value of CTCA, it showed sensitivity, specificity, PPV and NPV of 92%, 91%, 65%, 95 % respectively, these value are consistent with our study.

It is also consistent with previous studies investigating diagnostic accuracy of 64-multislice CT coronary angiography as **Cademartiri *et al.*** [11] who found sensitivity and specificity of 95%, 93% respectively.

**Zhang *et al.*** [12] who conducted a study on eighty-three patients with 171 coronary stents using 64-slice CT

scanner, showed that the negative predictive value was 100% despite of the stent's diameter. This goes with our study showing the importance of MSCT and its reliability to be used as a diagnostic tool to rule out in-stent restenosis.

Although the diagnostic accuracy of 320-row CTA may be similar to 64-row systems, a volumetric scanning approach has some advantages. First, volumetric scanning enables image acquisition of the entire heart in a single heart beat or gantry rotation, this approach reduced total scan time, thereby lowering the amount of contrast material and decreasing time of breath hold. In addition, single heart beat image acquisition reduces radiation burden by eliminating helical oversampling. Furthermore, the problem of stair-step artifacts, observed in imaging techniques requiring multiple beats to cover the entire heart, is eliminated. Therefore, 320-row CTA is possibly less prone to artifacts caused by irregular heart rhythm. Accordingly, the advantages of volumetric scanning may potentially expand the use of CTA to a broader general population, such as patients with increased heart rate variability.

However, the finding of interest is the persistently high NPV. This is of great value as this ensures the value of the MSCT as a rule out modality, this is consistent with **De Graaf *et al.*** [10] which had NPV at 98 %, **Cademartiri *et al.*** [11] which had NPV at 99%, and **Zhang *et al.*** [12] which had NPV of 100%.

By looking at the diagnostic accuracy per vessel, the sensitivity, specificity, PPV and NPV were 100%, 100%, 100% and 100% for the LAD, 66.7%, 87.5%, 66.7%, 87.5% for the LCX and 50%, 71.4%, 50% and 83.3% for the RCA respectively.

When the diagnostic accuracy of the MSCT coronary angiography per vessel was done without vessel discretion, high values were found and the diagnostic value in these vessels were 100% for LAD, 82% for LCX, 66.7% for RCA respectively.

These results are consistent with **Desbiolles *et al.*** [13] regarding MSCT per vessel assessment.

Regarding proximal stents, MSCT in our study tend to estimate ISR with sensitivity of 100%, specificity 92.3%, positive predictive value 87.5% and negative predictive value 100% and diagnostic accuracy of 95 %.

Regarding distal stents, MSCT in the present work tends to estimate ISR with sensitivity of 33.3%, specificity 90%, positive predictive value 50% and negative predictive value 82% and diagnostic accuracy of 77 %.

This is supported by the work of **Sheth *et al.*** [14] who found a higher diagnostic accuracy of the MSCT coronary angiography in evaluating the proximal coronary stents.

Regarding stents >3mm, MSCT in our study tends to estimate ISR with sensitivity of 90%, specificity 95.6%, positive predictive value 90% and negative predictive value 100% and diagnostic accuracy of 96.8 %.

**De Graaf *et al.*** [10] in their study regarding stent >3mm shows results that are consistent with our study with sensitivity, specificity, positive, and negative predictive values 91%, 90%, 63%, and 98%.

**Pflederer *et al.*** [15] in their work regarding stent >3mm shows results that are consistent with our results with sensitivity, specificity, positive, and negative predictive values of 89%, 93%, 67%, and 98%.

Regarding stents <3mm, MSCT in our study tends to estimate ISR with sensitivity of 75%, specificity 84.5%, positive predictive value 75 % and negative predictive value 84.5% and diagnostic accuracy of 81 %.

**Pflederer *et al.*** [15] shows results that are consistent with our study regarding stent diameter <3mm. with sensitivity, specificity, PPV, NPV which were 80%, 96%, 80%, 96% respectively.

However, **De Graaf *et al.*** [10] regarding stent diameter <3mm their study shows sensitivity, specificity, positive, and negative predictive values were 100%, 63%, 13%, and 100%, respectively. The main difference with our study is the high PPV compared to **De Graaf *et al.*** [10] (75% vs 13 %).

This observation may be explained by the fact that in case of a small diameter stents, high-density artifacts may obscure a large proportion of the stent lumen, thereby rendering the image un-interpretable. Accordingly, also in the present report, small stent diameter hampered stent assessment. Moreover, the current data showed that the diagnostic accuracy in stents with a diameter > 3.0 mm was significantly higher compared with stents with a diameter < 3.0 mm.

**Regarding stent length, the stents were divided into 3 groups as follows:**

First group had stents < 2.75 cm; the study showed sensitivity, specificity, PPV, & NPV of 90 %, 90.5 %, 82%, 95 % respectively.

Second group had stents from 2.75 cm to 3.5 cm; the study showed sensitivity, specificity, PPV, & NPV of 66.7 %, 90 %, 66.7%, 90 % respectively.

Third group had stents > 3.5 cm; the study showed sensitivity, specificity, PPV, & NPV of 100 %, 100 %, 100%, 100 % respectively.

Regarding BMI, the mean body mass index of the study population was 27.94 ± 4.63 kg/m$^2$. The obese group shows sensitivity, specificity, PPV and NPV of 84.6%, 93%, 84.6%, 93% respectively. while the non-obese group shows sensitivity, specificity, PPV and NPV of 100%, 100%, 100%, 100% respectively, thus these results shows no significant difference in results between obese and non-obese groups.

This neutral effect of obesity on the diagnostic accuracy of the CT in the study population is rather unexpected as the obesity is a known factor that negatively affects the CT quality. The CT image of obese patients are characterized by showing more noise and hence, less clear images and expectedly less diagnostic accuracy. This has been proved previously [16]. However, in this study there was no negative effect of obesity on the diagnostic accuracy of the CT in both groups.

This can be explained by the fact that while the calculated BMI is influenced by the whole-body obesity,

the cardiac CT is affected mainly by the obesity of the chest wall which cannot be reflected accurately by the total BMI.

## CONCLUSION AND RECOMMENDATIONS

It is concluded from this study that 320-MSCT coronary angiography is a very helpful test in diagnosing patients with coronary in-stent restenosis with sensitivity, specificity, PPV and NPV of 88.2%, 92%, 83.3% and 94.3% respectively. These values were reached when evaluating the MSCT results against invasive coronary angiography (per vessel analysis). These values were comparable to those found in a multitude of previous studies addressing the same issue.

This can put this test among the non-invasive armamentarium used to evaluate coronary in-stent restenosis.

The high negative predictive value (94.3%) can be utilized to rule out coronary in-stent restenosis in the clinical scenarios where no definite bedside diagnosis can be reached before sending the patient to invasive coronary angiography. This of course would minimize the burden and optimize the hospital performance and minimize the unnecessary risk in a substantial number of patients who had been otherwise sent to invasive coronary angiography.

Per vessel assessment of In-stent restenosis showed higher diagnostic accuracy of LAD compared to LCX and RCA.

Finally, In-stent restenosis can be evaluated with 320-slice MSCT with good diagnostic accuracy of 91% in this current study. A high negative predictive value of 94.3% was observed, indicating that 320-slice MSCT may be most valuable as a non-invasive method of excluding in-stent restenosis.

In view of the small number of the studied cases, further studies including larger number of patients and stents present in different vessels is highly recommended using the more advanced 320 rows multi-detector CT.

## REFERENCES


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