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ORIGINAL ARTICLE

Accuracy of Newer Generation Dual Source Multi-Detector Computerized Tomography for Detection of Coronary In-stent restenosis in Comparison with Invasive Coronary Angiography and Intravascular Ultrasound: A Comparative Cross-Sectional Study.

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ABSTRACT

Background: Previous studies have evaluated coronary artery in-stent diameter restenosis (ISDR) using the 64-slice multi-detector computed tomography coronary angiography (MDCT-CA) compared to invasive coronary angiography(ICA) as the gold standard. In our study, we aimed to compare the diagnostic precision of new generation dual source MDCT-CA and ICA with add on intravascular ultrasonography to evaluate ISDR.

Methods: One hundred patients with previously stented coronaries (n=110 stents) underwent MDCT-CA followed by ICA and IVUS within 24 hours. Specificities, Sensitivities, negative predictive values (NPV) and positive predictive values (PPV) of MDCT-CA and ICA for confirming or excluding ISDR by measuring in-stent area restenosis (ISAR) and minimal luminal area (MLA) ≤4.0 mm^2 of IVUS was taken as the standard reference standard.

Results: Newer generation dual source MDCT-CA and IVUS had a good sensitivity, specificity and accuracy in detection of ISDR. However, the patients have to be carefully selected. Consistent with previous MDCT-CA studies, our study observed significant effect of stent diameter on assessability, with 3 mm being a cutoff point below which the percentage of assessable stents is extremely low. When using IVUS MLA of 4.0 mm^2 as a reference method for identification of ISDR, no significant difference was detected between MDCT-CA and ICA in identification of ISDR.The higher NPV of MDCT-CA when compared with ICA and IVUS (100% and 100% respectively),therefore,MDCT-CA had an important role in exclusion of ISDR.

Conclusions: In conclusion,when evaluating the patency of stents,newer generation dual source MDCT-CA has the same performance as coronary angiography and IVUS and has the following advantages:non-invasiveness,low cost,and easy and convenient operation.

Keywords: Coronary angiography; in-stent restenosis; intravascular ultrasound; multi-detector computerized tomography; percutaneous coronary intervention.

INTRODUCTION

The conventional ICA is the most widely used imaging method to detect in-stent restenosis. However, the financial cost and the expected complications of ICA made it important to look for another non-invasive modality for assessment of in-stent restenosis **[1].**

The MDCT-CA is a good noninvasive, non-expensive, less complicated diagnostic modality for assessment of stent patency compared to conventional ICA. However, the development of 64-slice MDCT-CA not been proved reliable for assessment of in-stent restenosis probably due to partial volume effects and beam-hardening artifacts especially in stents with diameter 3 mm or less **[2–12]**. Also 64-slice MDCT-CA unlike older

version; can give information on morphology of coronary plaques and determine in-stent restenosis clearly almost the way IVUS can do **[13–15]**.

The newer generations of dual source MDCT-CA provides more accurate visualization of the stent and so, detection of any in-stent restenosis **[16].** So, our aim is to assess the diagnostic accuracy of dual source MDCT-CA compaired to ICA with IVUS in detection of coronary in-stent restenosis

METHODS

The present comparative cross-sectional study was conducted from January 2018 to January 2019 at our Hospital's Cardiology department. The protocol was approved by the Institutional Review Board, Faculty of Medicine, Zagazig University which confirmed that all methods were performed in accordance with in accordance in accordance with the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research. Informed written consent was obtained from all participants. The study group comprised 100 consecutive patients with suspected in-stent restenosis and referred for coronary angiography that fulfilled inclusion criteria.

Eligibility Criteria:

Inclusion criteria:

All patients with suspected in-stent restenosis (suspected by recurrent chest pain, wall motion abnormalities in ECHO, +ve stress ECG in patients with previous PCI). All of them were examined with newer generation dual source MDCT (SOMATOM Force Dual Source; Siemens Medical Solutions, Forchheim, Germany). Retrospectively electrocardiography (ECG)-gated contrast-enhanced dual source MDCT was performed ≤24 h prior to ICA. We only included patients, who are proved to have sinus rhythm and are clinically stable as well as received IVUS (2.9F; 40-MHz; single-element mechanical transducer; Boston Scientific, Natick, MA, USA) as a part of the catheterization procedure. Patients taking antihypertensive drugs or whose systolic blood pressure was ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg were considered to be hypertensive. Individuals who were taking anti-hyperlipidemic drugs or whose low-density lipoprotein cholesterol was ≥140 mg/dl and/or triglycerides ≥150 mg/dl and/or whose high-density lipoprotein cholesterol was <40 mg/dl were considered dyslipidemic. Diabetes mellitus was diagnosed according to the criteria of the World Health Organization **[17]**.

Exclusion criteria:

Patients with allergy to contrast medium, implanted a cardiac device of any type and mode, inability to perform breath hold, contraindication to administration of iodinated contrast agent, atrial fibrillation or other rhythm irregularity or arrhythmias or heart rate > 80 BPM, chronic kidney disease (serum creatinine >1.5 mg/dl or glomerular filtration rate <50 $ml \cdot min^{-1} \cdot 1.73\ m^{-2}$), patients with claustrophobia or unstable clinical conditions were not included.

Study Methodology:

Our 100 patients were done first ECG gated dual source MDCT whom performed interrelated image reconstruction. The study protocol included administration of propranolol (10 mg or higher) to have a target heart rate <65 bpm. The study population also received a single dose of 0.5 mg sublingual nitroglycerin 2 min prior to the MDCT scan.

The imaging protocol included the following steps. First, a non-contrast-enhanced coronal view of the chest was obtained to detect coronary calcification, the position of the heart, define the scan volume for further imaging. Then, a bolus of 70–80 mL of non-ionic contrast agent (Iopamiron, 370 mg iodine/ml, Bayer, Tokyo, Japan) was injected through ante-cubital vein with injection at a rate of 5 ml/sec. Followed by injection of 40 ml of saline via an 18-gauge catheter. Then, imaging was performed a bolus with regions of interest placed in the ascending aorta. Image reconstruction was done by Retrospective gating technique synchronized to an electrocardiogram, All the data obtained from the MDCT-CA were transferred to an offline workstation (Advantage Workstation Volume Share 4.4, GE Healthcare Technologies) for image analysis and all the images were observed by two experienced observers with more than 5 years' experience in MDCT-CA, blinded to the clinical data of the patients. The reconstructed images were viewed in multiple planes; the radiologist subjectively rated the overall image quality for in-stent diameter restenosis (ISDR) on a 5-point image quality score (Figure 1a): Score 1, superb image quality (with no artifacts); Score 2, good image quality (lesser artifacts); Score 3, adequate image quality (moderate artifacts); Score 4, Insufficient image quality; Score 5, poor or non-assessable image quality (with the highest artifacts). We included only patients with high- or moderate-quality images (Scores 1-3) of the stented segments.

Qualitative evaluation of ISDR was evaluated through the visual assessment of intraluminal contrast attenuation compared with the lumen of the vessel which graded (from 1 to 4) as follows: grade 1, non or minimal neointimal proliferation without narrowing; grade 2, moderate neointimal

proliferation with less than 50% luminal obstruction; grade 3, significant neointimal proliferation with luminal obstruction (no severe narrowing) more than 50%; grade 4, severe narrowing or total occlusion. In addition, a quantitative evaluation of ISDR by MDCT was performed on those stents without ISDR by either ICA or MDCT yielding positive for ISAR or minimal luminal area ≤4.0 mm^2 by IVUS (false negative). Diameters of the narrowest stent lumen, the distal and proximal reference segments were all measured in short axis views. Degree of luminal re-stenosis was quantified as diameter stenosis percentage by computing the stent and reference segments diameters ratio.

IVUS procedure was done to all patients. The images obtained for each site were analyzed similar to that of the MDCT as regard the size, pattern, and helped clearly delineate the vessel lumen, plaque and the surrounding tissue. All done by blinded experts in interventional cardiology. Recorded IVUS images started after initiating an automated pullback of the catheter at 0.5 mm/s. Measurements of area were performed at sites with lowest stent and lumen areas, and at distal and proximal reference sites. ISAR was defined as percent area stenosis ≥ 50% anywhere within the stent or within 5-mm segments distal or proximal to the stent edges. A significant lesion was defined as a MLA ≤ 6.0 mm^2 for the left main coronary arteries and a MLA ≤4.0 mm^2 for other epicardial coronaries.

ICA was performed according to the standard protocol after injection of intracoronary 200 µg of nitroglycerin. Multiple coronary projections were recorded and evaluated using QCA (Quantor QCA; Siemens Medical System, Forchheim, Germany) by an independent experienced cardiologist blinded to the image source. ISDR was defined as percent diameter stenosis ≥50% anywhere within the stent or within 5-mm segments distal or proximal to the stent edges.

Statistical Analysis:

For quantitative variables, the results were presented as a mean ± standard deviation, while categorical variables were summarized using absolute frequencies and percentages.

We measured the assessability of the MDCT-CA scan in identifying ISDR (the ratio of the number of assessable segments: total number of segments). We used ICA as the reference standard to evaluate the diagnostic accuracy of the dual source MDCT-CA in detecting ISDR with various degrees of luminal obstruction. Cross-tabulation was used to measure sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) for stenosis ≥50% and for less severe lesions (<50%). We used the IVUS as the reference standard to detect and quantify in-stent area restenosis (ISAR) and MLA ≤4.0 mm^2 which compared the capability of ICA and dual source MDCT-CA to detect and quantify ISDR. The differences in the precision and assessability of MDCT, and the standards were calculated using the chi-square test or Fisher's exact test. A 95% confidence interval was calculated from the binominal expression. A p value <0.05 was considered statistically significant.

RESULTS

A) Demographic data and risk factors: The baseline demographic and angiographic criteria of the patient population are all listed in (Tables 1 and 2). MDCT-CA was done ≤24 h prior to ICA and IVUS in the 100 patients with 110 stents (52 ISDR and 58 patent stents) (Table 3).

Age of the studied population ranged from 34 to 85 years with a mean of 57.41± 14.1 years. Male patients were 76 (76%), while females were 24 (24%).

B) Echocardiographic findings: Mean EF 57.05 ± 5.17, range was 45-65%. 51% of patients had SWMA in Echocardiography.

C) Stent diameter (Figure 1b): The stent diameters ranged from 2.5 to 3.5 mm. The study included 6 (5.8%) stents with 2.5 mm diameter, 15 (14.1%) with 2.75 mm diameter, 58 (52.9%) with 3.0 mm diameter, 31 (27%) stents with 3.5 mm diameter.

D) Results of MDCT-CA scanning (Figure 2a):A total of 110 stents were scanned by MDCT-CA. According to image quality of stents by MDCT-CA, 6 stents had poor image quality, 25 stents had adequate image quality, 43 stents had good image quality, and 36 stents had excellent image quality.

E) Results of invasive coronary angiography (Table 3 and Figure 2b):110 stents were evaluated for detection of in-stent restenosis (was defined as >50% luminal stenosis) and the results were as follows: 52 stents showed in-stent restenosis by ICA (47.3%) and 58 stents were patent by ICA (52.7%).

F) Results of intravascular ultrasound (IVUS) (Figure 3a): The results were as follows: 54 stents (49.09%) showed in-stent restenosis and 56 stents (50.9%) showed patent stents. Different mechanisms of in-stent restenosis were identified by IVUS.

G) Correlation between the results of MDCT-CA and ICA: According to stent diameter:

- **2.75 mm diameter:** 15 stents, 9 were patent by both MDCT-CA and coronary

angiography, 5 were occluded by MDCT-CA and coronary angiography, one stent was occluded by MDCT-CA and patent by coronary angiography (Figure 3b).

- **3.0 mm diameter:** 58 stents, 26 were patent by both MDCT-CA and coronary angiography, 30 were occluded by MDCT-CA and coronary angiography, 2 stents were occluded by MDCT-CA and patent by coronary angiography (Figure 3c).
- **3.5 mm diameter:** 31 stents, 13 were patent by both MDCT-CA and coronary angiography, 16 were occluded by MDCT-CA and coronary angiography, 2 stents were occluded by MDCT-CA and patent by coronary angiography (Figure 3d).

H) Correlation between the results of MDCT-CA, ICA and IVUS:

When compared with IVUS, no significant differences were found concerning in-stent restenosis identification by MDCT-CA or ICA. There were no differences in the diagnostic accuracy as regards to stent characteristics or index vessels between MDCT-CA and ICA, MDCT-CA and IVUS, or ICA and IVUS when the IVUS MLA ≤4.0 mm^2 method was used as a standard reference method. MDCT-CA has a higher sensitivity, NPV than ICA when compared with IVUS. ICA has a higher specificity, PPV than MDCT-CA when compared with IVUS (Tables 4 and 5).

The sensitivity, specificity, PPV, and NPV for in-stent restenosis identification by ICA were 92.4%, 94.1%, 94.2%, and 92.3%, respectively, when MLA 4.0 mm^2 was detected on IVUS. There was no difference in the diagnostic precision of MDCT-CA in identifying in-stent restenosis based on stent characteristics or index vessels (Table 6).

Table 1: Risk Factors among patients

		No.	%
HTN	Negative	45	45%
	Positive	55	55%
DM	Negative	55	55%
	Positive	45	45%
Dyslipidemia	Negative	47	47%
	Positive	53	53%
Family history of IHD	Negative	51	51%
	Positive	49	49%
Smoking	Negative	57	57%
	Positive	43	43%

HTN: hypertension; DM: Diabetes mellitus; IHD: ischemic heart disease

Table 2: Clinical Presentation of the patients:

	No.	%
Stable angina	28	28%
Unstable angina		
	62	62%
NSTEMI		
	5	5 %
STEMI	5	5%

NSTEMI: non-ST elevation myocardial infarction; STEMI: ST-elevation myocardial infarction

Table 3: ICA findings according to stent diameter

Stent diameter	2.5mm	2.75mm	3.0mm	3.5mm
Patent	6	9	28	15
Stenosis >50%	0	6	30	16
No.	6	15	58	31
%	5.8%	14.1%	52.9%	27%

Table 4: Accuracy and assessability of MDCT-CA to detect in-stent restenosis in comparison to ICA and in relation to stent characteristics and index vessel

	Stent no.	Evaluability	TP	TN	FP	FN	Specificity	Sensitivity	PPV	NPV	Accuracy
Segments Stented	110	94.5%	51	49	4	0	92.4%	100%	92.7%	100%	96.1%
Stented Vessel											
LAD	45	86%	19	18	2	0	90%	100%	92.5%	100%	94.8%
LCX	34	100%	16	17	1	0	94%	100%	94%	100%	97%
RCA	31	100%	16	14	1	0	93%	100%	90%	100%	96.7%
Stent Type											
DES	102	94%	47	45	4	0	91.4%	100%	92.1%	100%	95.8%
BMS	7	100%	4	4	0	0	100%	100%	100%	100%	100%
Stent Material											
Cobalt chromium	101	95%	46	46	4	0	92%	100%	92%	100%	95.8%
Stainless steel	9	88%	5	3	0	0	100%	100%	100%	100%	100%
Stent Diameter (mm)											
< 3.0mm	21	71%	5	10	1	0	90%	100%	85%	100%	93.7%
≥ 3.0mm	89	100%	46	39	3	0	92.8%	100%	93.8%	100%	95.5%

P value was not significant BMS: bare metal stent; DES: drug-eluting stent; FN: false-negative result; FP: false-positive result; NPV: negative predictive value; PPV: positive predictive value; TN: true-negative result; TP: true-positive result. LAD: left anterior descending coronary artery; LCX: left circumflex coronary artery; RCA: right coronary artery

Table 5: Accuracy of MDCT-CA to detect in-stent diameter restenosis in comparison to IVUS MLA and in relation to stent characteristics and index vessel

	Stent no.	Evaluability	TP	TN	FP	FN	Specificity	Sensitivity	PPV	NPV	Accuracy
Segments Stented	110	94.5%	53	47	3	1	92%	100%	92 %	100%	96.1%
Stented Vessel											
LAD	45	86%	21	14	3	0	82.3%	100%	87.5%	100%	92.1%
LCX	34	100%	17	17	0	1	100%	94%	94.4%	100%	97.1%
RCA	31	100%	15	16	0	0	100%	100%	100%	100%	100%
Stent Type											
DES	102	94%	47	46	3	1	93.8 %	97.9%	94%	98 %	95.8%
BMS	7	100	4	1	0	0	100%	100%	100%	100%	100%
Stent Material											
Cobalt chromium	101	95%	49	43	3	0	93.4%	100%	94.2%	100%	96.6%
Stainless steel	9	88%	4	4	0	1	100%	80%	100%	80%	88.8%
Stent Diameter(mm)											
< 3.0mm	21	71%	7	8	2	0	80%	100%	77.7%	100%	88.2%
≥ 3.0mm	89	100%	46	39	2	1	95.1%	97.8%	95.8%	97.5%	96.5%

P value was not significant

BMS: bare metal stent; DES: drug-eluting stent; FN: false-negative result; FP: false-positive result; NPV: negative predictive value; PPV: positive predictive value; TN: true-negative result; TP: true-positive result. LAD: left anterior descending coronary artery; LCX: left circumflex coronary artery; RCA: right coronary artery.

Table 6: Accuracy of CCA to detect in-stent diameter restenosis in comparison to IVUS MLA and in relation to stent characteristics and index vessel.

	Stent no.	Evaluability	TP	TN	FP	FN	Specificity	Sensitivity	PPV	NPV	Accuracy
Segments Stented	110	94.5%	49	48	3	4	94.1%	92.4%	94.2 %	92.3%	93.2%
Stented Vessel											
LAD	45	86%	19	16	3	1	82.3%	100%	87.5%	100%	89.7%
LCX	34	100%	16	15	0	3	100%	94%	94.4%	100%	91.1%
RCA	31	100%	14	17	0	0	100%	100%	100%	100%	100%
Stent Type											
DES	102	94%	46	46	3	2	93.8 %	95.8%	93.8%	95.8%	94.8%
BMS	7	100	3	2	0	2	100%	60%	100%	50%	71.3%
Stent Material											
Cobalt chromium	101	95%	46	44	3	2	93.6%	95.8%	93.8%	95.6%	94.7%
Stainless steel	9	88%	3	4	0	2	100%	60%	100%	66.6%	77.7%
Stent Diameter(mm)											
< 3.0mm	21	71%	7	7	1	3	87.5%	70%	87.5%	70%	77.7%
≥ 3.0mm	89	100%	42	41	2	1	95.3%	97.6%	95.4%	97.6%	96.4%

P value was not significant

BMS: bare metal stent; DES: drug-eluting stent; FN: false-negative result; FP: false-positive result; NPV: negative predictive value; PPV: positive predictive value; TN: true-negative result; TP: true-positive result. LAD: left anterior descending coronary artery; LCX: left circumflex coronary artery; RCA: right coronary artery.

Figure 1a: Grading of image quality score by MDCT-CA: 1–3, diagnostic; 4, 5, non-diagnostic images.

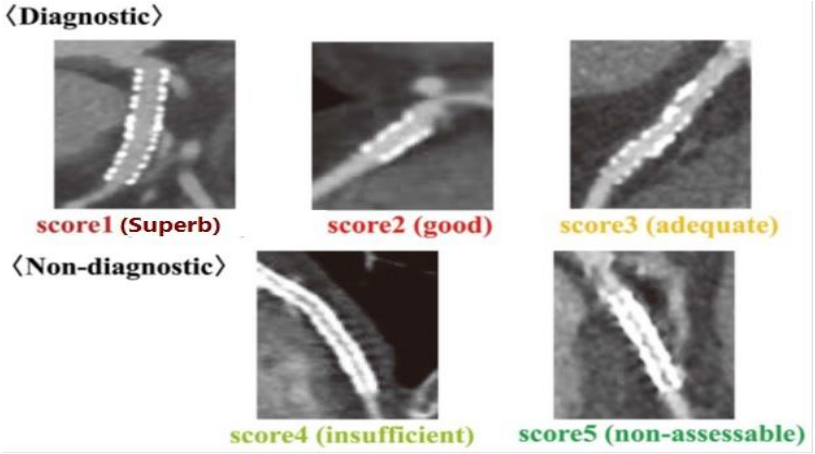


Figure 1b: Distribution of stent diameter

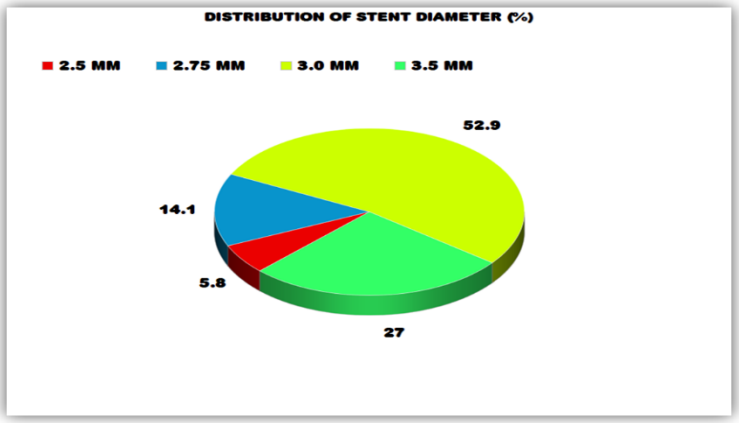


Figure 2a: Image quality by MDCT-CA

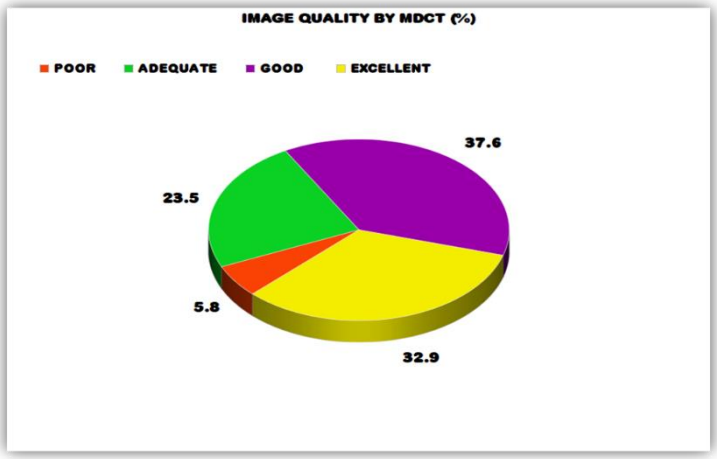


Figure 2b: (Case 1) A 78 years old male patient had a history of previous stenting to proximal LCX 23 months ago by DES 3.5×16 Cobalt chromium stent, and presented by unstable angina. ***Panel A:*** Coronal curved planar CT image showing suspected LCX in-stent stenosis (black shadow inside the stent), ***Panel B:*** Invasive coronary angiography showing LCX in-stent restenosis, ***Panel C:*** IVUS showing stent under expansion and ***Panel D:*** ECG at presentation shows inferolateral ischemia.

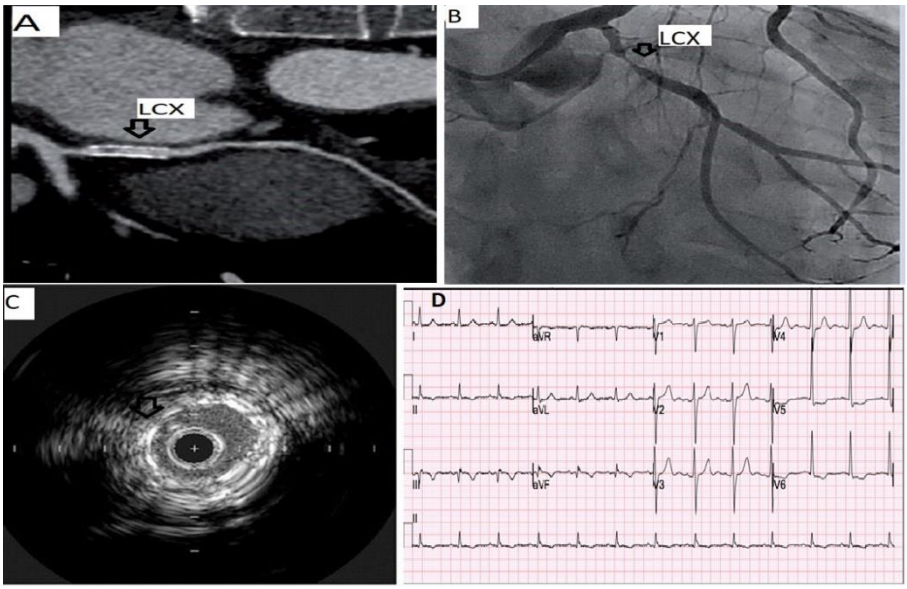


Figure 3a: Mechanisms of in-stent restenosis by IVUS

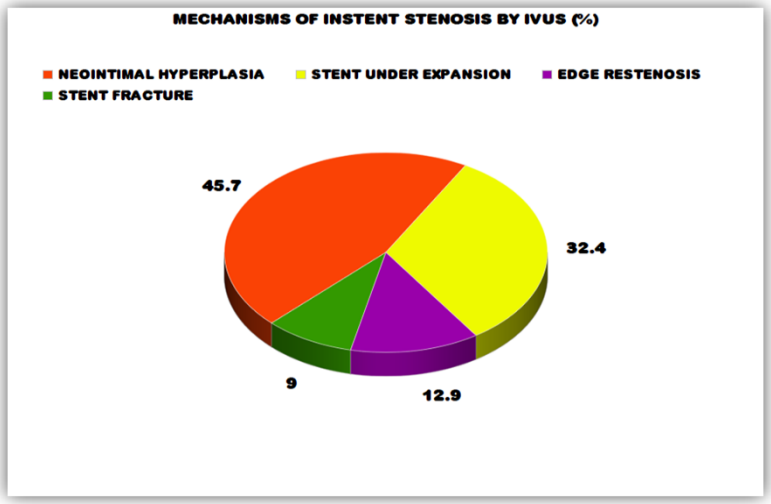


Figure 3b: Results among 2.75 mm diameter

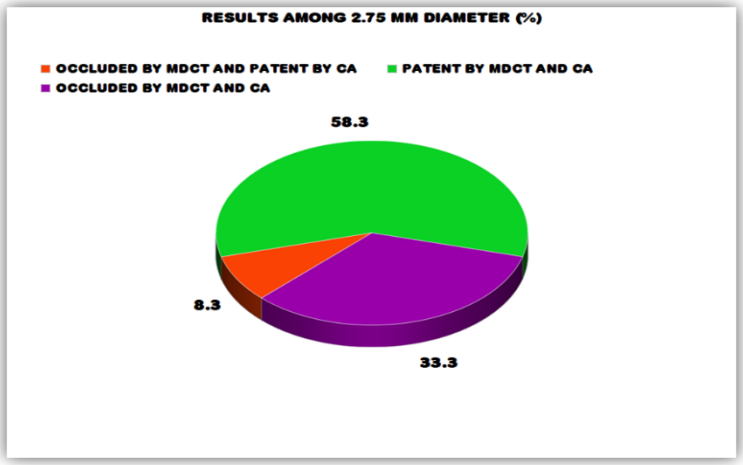


Figure 3c: Results among 3.0 mm diameter

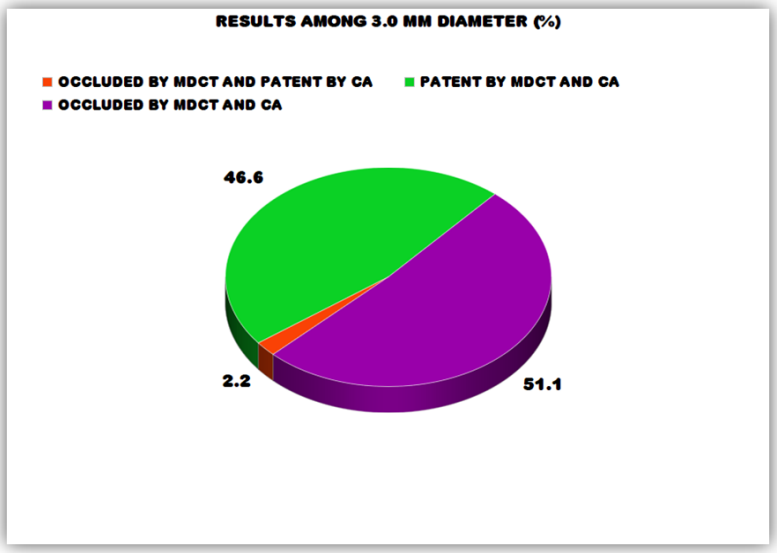
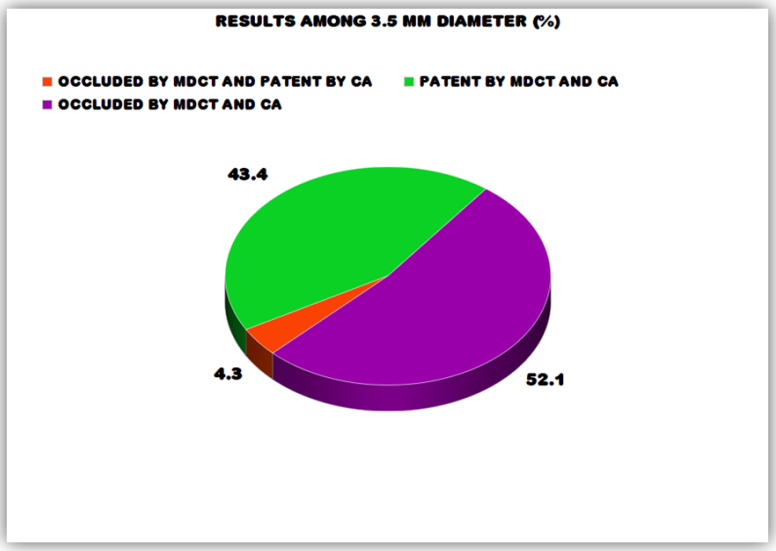


Figure 3d: Results among 3.5 mm diameter.



DISCUSSION

In our study, dual source MDCT-CA was performed less than one day prior to ICA, and IVUS was a part of the catheterization procedure in all the studied population. Only 104 stents were assessable for ISDR among the 110 stented segments using dual source MDCT-CA with an overall assessability of about 94.5%; this is in agreement with the results of the newly published studies **[8–12]**.

With the new advancement of dual source MDCT-CA in evaluation of plaque texture and coronary artery wall thickness, IVUS is meant to be the standard reference **[13–15, 19–23]**. Compared to recent techniques, IVUS is the best in identifying in-stent re-stenosis. Our study was the only study in English literature to assess in-stent restenosis using dual source MDCT and to use IVUS as an add on to the catheterization procedure. In agreement with the study done by Andreini et al., IVUS was done in all patients whose ICA showed moderate ISDR **[8]**. He observed a significant variation in area measurements between MDCT and IVUS, but suggested that this variation does not affect MDCT assessment of percent in-stent restenosis **[8]**. Joshi et al., concluded that absolute measurements of stenosis severity determined by MDCT correlated with those using ICA with IVUS (excluding ICA alone) in patients with intermediate grade lesions identified on ICA **[24]**. He found that, IVUS was used as the gold standard rather than ICA, MDCT appeared to be more accurate, and they suggested that the limitations of ICA as a reference standard need to be considered in studies evaluating the accuracy of MDCT **[24]**. In our study there were no differences in the diagnostic accuracy of stent characteristics or index vessels between ICA and IVUS, MDCT-CA and ICA, or MDCT-CA and IVUS in ISDR identifications when excluding non-assessable segments. When MLA $\leq$4.0 mm^2 was used as reference and non-assessable segments were excluded, dual source MDCT-CA had higher specificity and NPV for excluding ISDR rather than ICA. Therefore, dual source MDCT-CA is a reliable non-invasive tool for excluding ISDR. Our study revealed that dual source MDCT-CA, when compared with ICA had a good sensitivity and specificity to diagnose in-stent stenosis (100% and 92.4% respectively) with a remarkably good positive predictive value of 92.7% and a negative predictive value of 100% with accuracy of 96.1%. This was applied to all stents and different coronary vessels with no preference.

Also, this study revealed that dual source MDCT-CA, when compared with IVUS had a good sensitivity and specificity to diagnose in-stent stenosis (100% and 92% respectively) with a remarkably good positive predictive value of 92% and a negative predictive value of 100%. This was applied to all stents and different coronary vessels with no preference.Also, our study showed that MDCT-CA is comparable to coronary angiography in terms of assessing stent patency and in-stent restenosis. The negative predictive value and accuracy of MDCT-CA for in-stent restenosis are similar to those of coronary angiography. These results were in agreement with De Graaf et al. **[25]** who evaluated the diagnostic value of MDCT-CA and found that it has sensitivity, specificity, PPV, and NPV of 92 %, 91 %, 65 %, and 95 %, respectively, which is similar to our study findings**.** There are many technical issues affecting the visualization of coronary stents such as poor image quality, motion artifacts, stent strut artifacts, coronary artery calcification underlying the stents

and intravascular volume enhancement.In our study, 5.8% of the stents were non-assessable by MDCT-CA and had poor image quality and all of them were of small diameter (<3 mm diameter). A higher specificity, positive predictive value, and negative predictive value was found in stents with a diameter ≥3 mm in comparison with diameter <3 mm.Similar results were found by Pflederer et al. **[26]** in their study which showed that in stents >3mm diameter, MDCT-CA had a sensitivity, specificity, positive, and negative predictive values of 89%, 93%, 67%, and 98% in diagnosing in-stent restenosis**.**These findings might be explained by the facts that in case of a small diameter stents, high-density artifacts may distort a significant portion of the stent lumen, making the image of the stent lumen un-interpretable. As a result, limited stent diameter affected stent evaluation in the current study as well. Furthermore, the current results revealed that diagnosis performance in stents with diameters larger than 3.0 mm was slightly better than in stents with diameters smaller than 3.0 mm.

Heart rate reduction is also needed when using MDCT-CA, not only to achieve superb satisfactory images, but also help in reduction of radiation dose. Slower heart rate (65 bpm) increases temporal resolution and results in almost motionless images. It also allows for the use of prospective ECG-gating, Due to cardiac motion artifact, as higher rates will hinder the success in stent lumen evaluation and will make it difficult in image analysis **[27]**.The visibility of the stent lumen varies greatly depending on the stent type and diameter. Blooming is more evident in smaller coronary stents with thick struts, but it is less noticeable in larger stents. Stents with thicker struts and/or a narrower diameter are more likely to create non-interpretable images. The lumen visibility improves as the stent diameter exceeds 3 mm. According to stent material, Cobalt chromium and stainless steel drug eluting stents are better visualized than bare metal stents **[28]**.In our study, the main causes of inability to assess the stent lumen were higher heart rates, cardiac arrhythmias, thick struts and small stent diameter. In-stent restenosis quantification with Dual source MDCT-CA had low inter-observer variability, which was equivalent to invasive coronary angiography and IVUS.

Compared with invasive coronary angiography, dual source MDCT-CA is less costly, faster to perform, does not require the presence of an angiographic team to perform the study, widely available 24 h a day and can be performed as an outpatient procedure. It allows a wider range of manipulations of the volumetric data collection for image view and analysis in contrast to the limited projections obtained routinely during conventional angiography, and has less possible complications.

Limitations of the study

- **First**, the sample size was relatively small and there May Have been bias in the patient selection, affecting the overall results.so, larger prospective and randomized Controlled trials are needed to confirm the accuracy of dual source MDCT-CA in the evaluation of in-stent restenosis.
- **Second**, this study involved only stable patients with low heart rates, and a significant number of them received additional beta-blockers to further decrease heart rate. As a result, the current study's findings will not be applied to the general population, in addition to patients with smaller stents, patients with atrial fibrillation and contraindications to beta-blocking drugs were not included in the study.
- **Third,** a major disadvantage of dual source MDCT-CA is that it only provides anatomical information, so, the presence or absence of ischemia cannot be assessed from the MDCT-CA images. As a result, in patients with severe in-stent restenosis, functional testing is also required for further assessment of those patients.

Clinical implication:

According to the findings of this study, dual source MDCT-CA is a very relevant method to diagnose patients with coronary in-stent restenosis, with sensitivity, accuracy, PPV, and NPV of 100%, 96.1%, 92.7%, and 100%, respectively. When comparing MDCT-CA findings to invasive coronary angiography, these figures were found.As a noninvasive procedure, dual source MDCT-CA angiography may be used to evaluate in-stent restenosis, but patients must be carefully chosen. Patients with the capacity to hold their breath and maintain a low heart rate, as well as those with larger (> 3.0 mm) diameter and thin-strut stents, should be considered for a noninvasive evaluation of in-stent restenosis before undergoing invasive coronary angiography.

CONCLUSIONS

In conclusion, when evaluating the patency of stents, newer generation dual source MDCT-CA has the same performance as coronary angiography and IVUS and has the following advantages: non-invasiveness, low cost, and easy and convenient operation.

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