Accuracy of Sixteen-Slice CT Scanners in Detected Coronary Artery Disease

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Background: *The coronary artery disease, now, the incidence is increasing in both developed and developing countries. The investigation is evoluted and non-invasive multislice CT scanners have been used more frequently, although the gold standard is still the coronary angiography.*
Objective: *To investigate the accuracy in detected coronary artery disease by using 16-slice CT scanners compared to the conventional coronary angiography.*
Material and Method: *Fifty-five patients were 43 males, 12 females, median aged 62 years (43-82 years), and average heart rates 67 beats/minute (46-147 beats/minute) had the ECG-gated CT angiography followed by coronary angiography in 3 months. The ECG-gated CT angiography was performed by using16-slice MSCT detector (0.42-s rotation time, 16 x 0.75-mm detector collimation).*
Results: *All patients were classified into two major groups; one was significant coronary artery stenosis which was designed by stenosis at least 50% and the other was non-significant stenosis which was designed by normal or stenosis less than 50%. The site having blooming artifact due to calcification that causes complete obliteration of the lumen or having significant motional artifacts was ruled out. There were 285 evaluable sites in 19 patients with high heart rates, more than 70 beats/ minute. The sensitivity, specificity, and accuracy in significant stenosis were 72.9%, 99.6%, and 94.0% respectively. In 36 patients with a lower heart rate, there were 563 evaluable sites, the sensitivity was 86.5%, specificity was 98.5%, and accuracy was 96.6%. The overall showed 81.1% of sensitivity, 98.9% of specificity, and 95.8% of accuracy.*
Conclusion*: The accuracy of the 16-slice CT angiography for patients suspected of having coronary artery disease was high. However, blooming artifacts from the calcium, respiratory artifacts, and small size of the distal and branching artery still caused limited luminal assessment. These problems have challenged the new coming generation of MDCT.*

Keywords: *CT angiography, Coronary angiography, Coronary disease*

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Cardiovascular diseases are the leading causes of death and disability worldwide in both developed and developing countries. Most recently, the diseases contributed to a third of global deaths and 78% were low and middle-income countries. These are due to economic transition; urbanisation, industrialisation, and globalisation, causing a life style change and then promoting heart disease[1].

The coronary artery disease is the predominant type of cardiovascular disease encountered in most countries. The gold standard method for diagnosis has still been the coronary angiography. This technique has limitations as a result of its invasive nature with a small procedure-related mortality (0.15%) and morbidity (1.5%) rates and relatively high cost. Attempts have been made to image the coronary artery lumen with noninvasive methods. Those are CT and MR angiography.

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The conventional CT scanner has so far not been sufficient to visualize native coronary arteries due to low temporal resolution. During the past years, electron-beam CT has been used to visualize the coronary arteries. The CT scanner has been developed with multidetector rows used with retrospective ECG gating. So, the cardiac CT imaging can be performed with short time of data acquisition with high temporal resolution.

The present study was done to investigate the accuracy of 16-slice CT scanner with ECG-gated image reconstruction algorithm compared to the invasive coronary angiography.

Material and Method

Study population

Fifty-five consecutive patients (42 men and 13 women; median age, 62 years; range, 43 to 82 years) were investigated. All patients who were suspected of having coronary artery disease had CT angiography performed followed by invasive coronary angiography in 3 months, were included in the present study. The coronary site that presented the clump-calcified plaque causing obliteration of the lumen or had significant motional artifacts was ruled out. All patients had sinus rhythm (heart rate, 46 to 147 bpm; mean, 67 bpm) and were in a clinically stable condition. They gave written informed consent, and the departmental board approved the study protocol.

Protocol of CT Angiography

CT angiography was performed with using 16-slice CT scanner (Mx 8000 IDT, Phillips Medical Systems, Best, the Netherlands). All image acquisitions were performed in inspiratory breathhold. First, a non-contrast localization scan was performed that yielded an anteroposterior view of the chest in which the field was extended from the carina to 1 cm below the diaphragmal face of the heart and then non-contrast study for calcium score was done by using 75% phase of cardiac cycle. The second step, the same field was used to position the imaging volume for contrast coronary artery imaging. In this step, the locator was placed in the ascending thoracic aorta, just above the aortic root, and then bolus of 80-120 ml of contrast agent (Iopromide, Ultravist 370, Schering AG) followed by 50 ml of normal saline chaser was injected intravenously at 4 ml/s via an 18-gauge needle catheter placed in the cubital vein. In the third step, CT scan was initiated when the peak of density in the ascending thoracic aorta reached the default setting, 200 Hounsfield units. The volume data set for coronary artery visualization was acquired in spiral mode, with simultaneous acquisition of all 16 parallel slices with 0.75-mm collimation each. The gantry rotation time was 0.42 second with 0.238 pitch. The tube voltage was 140 kV and current was 400-450 mAs. During the scanning, the patient's ECG was digitized and continuously recorded.

Image Reconstruction

The raw data of the contrast study was reconstructed into 8 phases (0, 12.5, 25, 37.5, 50, 62.5, 75, and 87.5 percent) of cardiac cycles. All derived data was transferred to an offline, PC-based workstation.

The calcium score was firstly calculated, using vendor software, based on the Agatston system.

Then the images were reconstructed into three-dimensional and four-dimensional volume rendering and multiplanar reformation were performed by choosing the data in the cardiac phase with the least artifacts.

The final step, left ventricular motion at the apex, mid, and base and left ventricular function analysis were performed, using the cardiac review program.

Quantitative Coronary Angiography

The study was performed following the CT angiography within 3 months. A single observer classified the stenosis of the each coronary segment by using QCA algorithm (Prucka Mac-Lab 2000/4000/7000, GE Medical Systems, USA.) and according to the American Heart Association classification[2].

Data Evaluation

All data, axial, multiplanar reformatted, three-dimensional, and four-dimensional images, was used to evaluate the luminal stenosis. The length of the vessel segments that were visually judged to be free of motion artifacts was determined and the segment that showed significant motional artifacts and obliteration by the extensive calcified plaque was ruled out. The evaluable segments were classified into significant (at least 50% stenosis) and non-significant stenosis (less than 50% stenosis). Two blinded observers evaluated all data.

Statistical analysis

The sensitivity, specificity, positive and negative predictive value, and accuracy of 16-slice MDCT were obtained with setting coronary angiography as the standard of reference.

Results

Fifty-five patients had both conventional and MSCT coronary angiography performed without complication were included in the present study. There were 43 male and 12 female patients. The mean age was 61.2 years (43-82 years) and the mean heart rate was 67 bpm (46-147 bpm). Total segments of coronary arteries were 880 sites, divided to 848 evaluable segments and 32 nonevaluable segments. The cause of nonevaluability was motional artifacts in 31 sites and both motional and heavily calcified blooming artifacts in 1 site (Fig. 1, 2).

In 848 evaluable segments, conventional angiography demonstrated 148 segments of significant stenosis and 700 segments of non-significant stenosis. CT angiography could demonstrate 128 significant stenotic segments and 720 non-significant stenotic segments but 120 significant and 692 non-significant segments were compatible with the results of conventional coronary angiography respectively (sensitivity

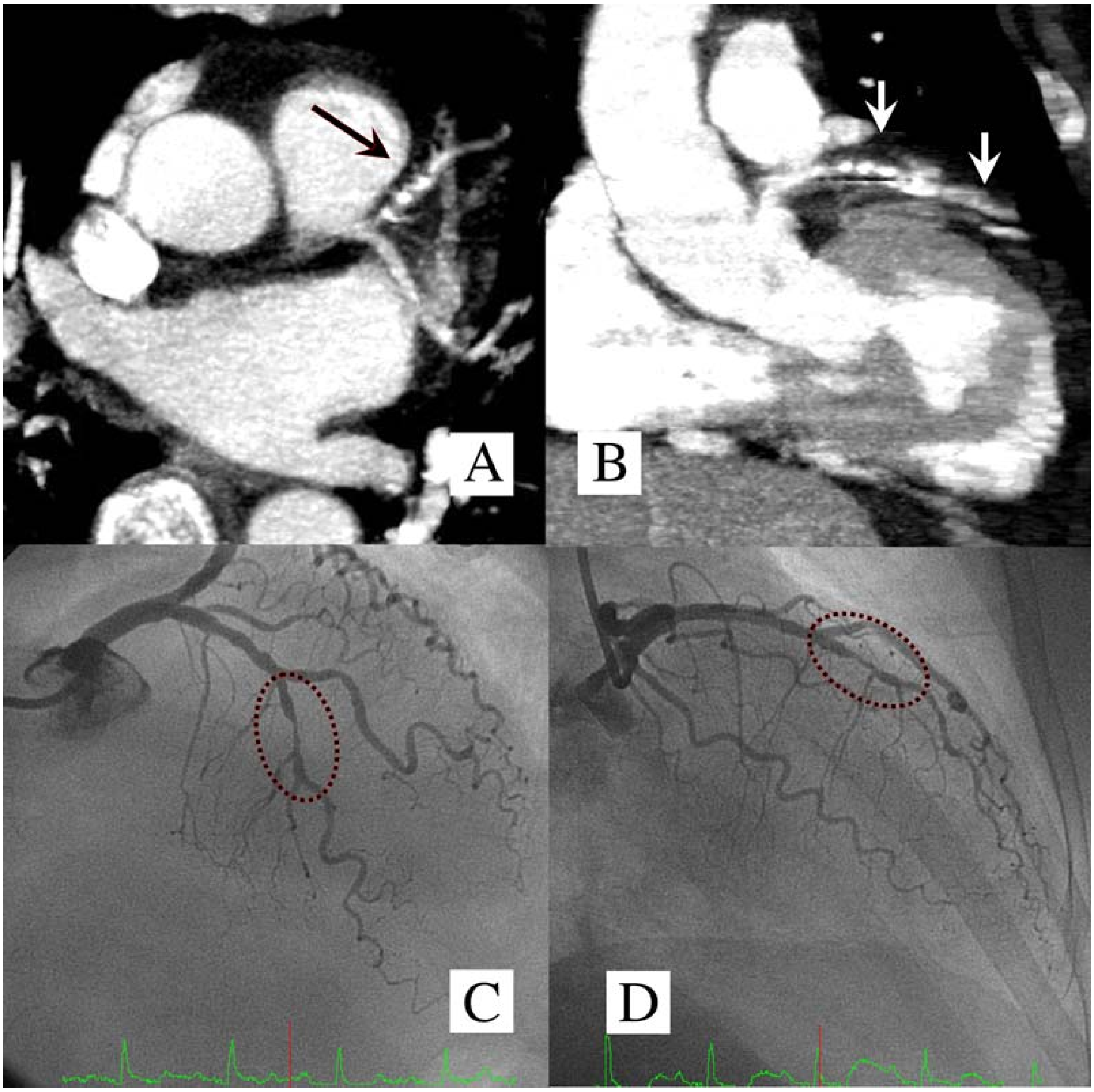

Fig. 1 A 77-year-old female presented with dyspnea. **A and B** show calcium and respiratory artifacts seen at the proximal and mid LAD on CT angiogram. These effects limit in evaluation of the luminal stenosis. **C and D**, coronary angiogram, show no stenosis at the proximal LAD but there is short segmental severe stenosis at the middle LAD

Fig. 2 There are calcified plaques at the proximal LAD, partial obliterating the lumen. This causes limitation for accurate luminal assessment. The coronary angiogram shows no luminal stenosis

81.1% and specificity 98.9%). The positive predictive value (PPV) is 94%, negative predictive value (NPV) is 96%, and accuracy is 95.8%. The detailed data is shown in Table 1.

If the patients were divided into two groups; 36 patients had a lower heart rate ($\leq$ 70 bpm) and the rest had a higher heart rate (> 70 bpm). The first one showed 563 evaluable sites with 86.5% of sensitivity,

Table 1. Sensitivity, Specificity, and Accuracy in All Patients

Coronary Segments	Evaluable segment	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
All	848	120	692	8	28	81.1	98.9	94.0	96.0	95.8
LMA	54	1	53	0	0	100.0	100.0	100.0	100.0	100.0
LAD	271	70	185	6	11	86.4	96.9	92.0	94.0	93.7
Proximal	54	28	22	4	0	100.0	84.6	88.0	100.0	92.6
Middle	54	25	27	1	1	96.2	96.4	96.0	96.0	96.3
Distal	54	7	46	0	1	87.5	100.0	100.0	98.0	98.1
Branches	109	10	89	1	9	52.6	98.9	91.0	91.0	90.8
LCx	268	18	237	1	12	60.0	99.6	95.0	95.0	95.1
Proximal	53	7	44	1	1	87.5	97.8	88.0	98.0	96.2
Middle	53	8	43	0	2	80.0	100.0	100	96.0	96.2
Distal	52	1	49	0	2	33.3	100.0	100	96.0	96.2
Branches	110	2	101	0	7	22.2	100.0	100	94.0	97.6
RCA	255	31	218	1	5	86.1	99.5	97	98	98.1
Proximal	51	9	40	1	1	90.0	97.6	90	98	96.1
Middle	48	13	35	0	0	100.0	100.0	100	100	100.0
Distal	48	6	42	0	0	100.0	100.0	100	100	100.0
Branches	108	3	101	0	4	42.9	100.0	100	96	96.3

TP = True positive, TN = True negative, FP = False positive, FN = False negative, PPV = Positive predictive value, NPV = Negative predictive value

Table 2. Comparison of sensitivity, specificity, and accuracy in patients with low and high heart rate

Heart rate	Evaluable segment	Sensitivity	Specificity	PPV	NPV	Accuracy
Low (≤ 70 bpm)	563	86.5	98.5	91.7	97.5	96.6
High (> 70 bpm)	285	72.9	99.6	97.7	93.4	94.0

98.5% of specificity, 91.7% of PPV, 97.5% of NPV, and 96.6% of accuracy. The latter showed 285 evaluable sites with 72.9% of sensitivity, 99.6% of specificity, 97.7% of PPV, 93.4% of NPV, and 94.0% of accuracy. The compared data is shown in Table 2.

Comparison of lesion by lesion in low heart rate patient

There were 7 false positive sites; 4 at the proximal LAD and each one at middle LAD, proximal LCx, and proximal RCA, and there were 12 false negative sites; 4 at the first diagonal branch, 3 at the second diagonal branch, and each one at middle and distal LAD, proximal LCx, second obtuse marginal branch, and PL branch. The sensitivity was least at the second obtuse marginal branch, 0%. The maximal sensitivity was 100% at LMA, proximal LAD, mid and distal LCx, and entire RCA. The specificity was 100% in almost all segments except for 95% at the middle LAD, 97% at proximal LCx and proximal RCA, and least at proximal LAD, 78%. The detailed data is shown in Table 3.

Comparison of lesion by lesion in high heart rate patient

There was only one false positive site; at the first diagonal branch, but there were 16 false negative sites; 4 at the first obtuse marginal branch, two at the first diagonal branch, mid and distal LCx, second obtuse marginal branch, and PL branch, and 1 at proximal RCA and PDA. The sensitivity was least at distal LCx and the second obtuse marginal branch, 0%. The maximal sensitivity was 100% at the entire LAD, proximal LCx, and mid and distal RCA. The specificity was 100% in almost all segments except for the first diagonal branch, 93%. The details are shown in Table 3.

Discussion

Until now, conventional coronary angiography is still the gold standard for detection of coronary artery disease. Because the present study was invasive, had a minimal morbidity rate, and the patients had to be admitted to the hospital. The non-invasive imaging methods, Computed tomography and Magnetic resonance imaging, were developed.

Recently, a pooled study in the literature[3] presented 87% sensitivity and 91% specificity in significant coronary stenosis by using the electron-beam CT scanner and 59% sensitivity and 89% specificity by using a multisliced CT scanner. However, the study time and number of the patients were limited.

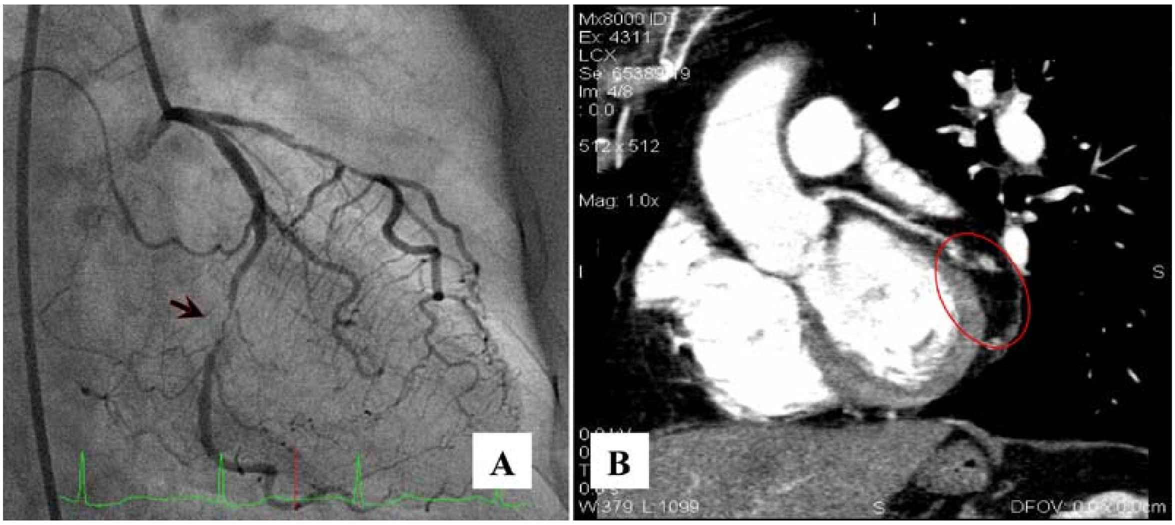

Fig. 3 A shows severe stenosis at the mid LCx on CAG but cannot demonstrate this segment of the vessel on CTA, due to small size

Table 3. Details of sensitivity, specificity, and accuracy in low and high heart rate patients groups

Coronary segments	Evaluable segment		TP		TN		FP		FN		Sensitivity		Specificity		PPV		NPV		Accuracy	
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
All	563	285	77	43	467	225	7	1	12	16	86.5	72.9	98.5	99.6	91.7	97.7	97.5	93.4	96.6	94.0
LMA	35	19	1	0	34	19	0	0	0	0	100.0	NA	100.0	100.0	100.0	NA	100.0	100.0	100.0	100.0
LAD	176	95	45	25	117	67	5	1	9	2	83.3	92.6	95.9	98.5	90.0	96.2	92.9	97.1	92.0	96.8
Proximal	35	19	17	11	14	8	4	0	0	0	100.0	100.0	78.0	100.0	81.0	100.0	100.0	100.0	89.0	100.0
Middle	35	19	15	10	18	9	1	0	1	0	94.0	100.0	95.0	100.0	93.8	100.0	95	100.0	94.0	100.0
Distal	35	19	6	1	28	18	0	0	1	0	86.0	100.0	100.0	100.0	100.0	100.0	97	100.0	97.0	100.0
Branches	71	38	7	3	57	32	0	1	7	2	50.0	60.0	100.0	97.0	100.0	75.0	89.1	94.1	90.1	92.1
LCx	180	88	12	6	165	72	1	0	2	10	85.7	37.5	99.4	100.0	92.3	100.0	98.8	87.8	98.3	88.6
Proximal	36	17	3	4	31	13	1	0	1	0	75.0	100.0	97.0	100.0	75.0	100.0	97.0	100.0	94.0	100.0
Middle	37	16	7	1	30	13	0	0	0	2	100.0	33.0	100.0	100.0	100.0	100.0	100.0	87.0	100.0	88.0
Distal	35	17	1	0	34	15	0	0	0	2	100.0	0.0	100.0	100.0	100.0	NA	100.0	88.0	100.0	88.0
Branches	72	38	1	1	70	31	0	0	1	6	50.0	14.3	100.0	100.0	100.0	100.0	98.6	83.8	98.6	97.0
RCA	172	83	19	12	151	67	1	0	1	4	95.0	75.0	99.3	100.0	95.0	100.0	99.3	94.4	98.8	95.2
Proximal	35	16	5	4	29	11	1	0	0	1	100.0	80.0	96.7	100.0	83.3	100.0	100.0	92.0	97.1	94.0
Middle	34	14	9	4	25	10	0	0	0	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Distal	33	15	4	2	29	13	0	0	0	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Branches	70	38	1	2	68	33	0	0	1	3	50.0	40.0	100.0	100.0	100.0	100.0	98.6	91.7	98.6	92.1

L = low heart rate group, H = high heart rate group

Table 4. Comparison of sensitivity and specificity in each study

STUDY	Sensitivity (%)	Specificity (%)
4-slice By Eugenio M et al (No. =416)	65	98.0
4-slice By Auchenbach S et al (No. = 174)	85	76.0
8-slice By Matsuo et al (No. = 94)	75	96.0
16-slice (using12-detector) By Nieman K et al.(No. = 231)	95	86.0
16-slice By Mollet RN et al (No. = 1384)	92	95.0
16-slice In this study (No. = 848)	81	98.9

No. = Number of the evaluable segments

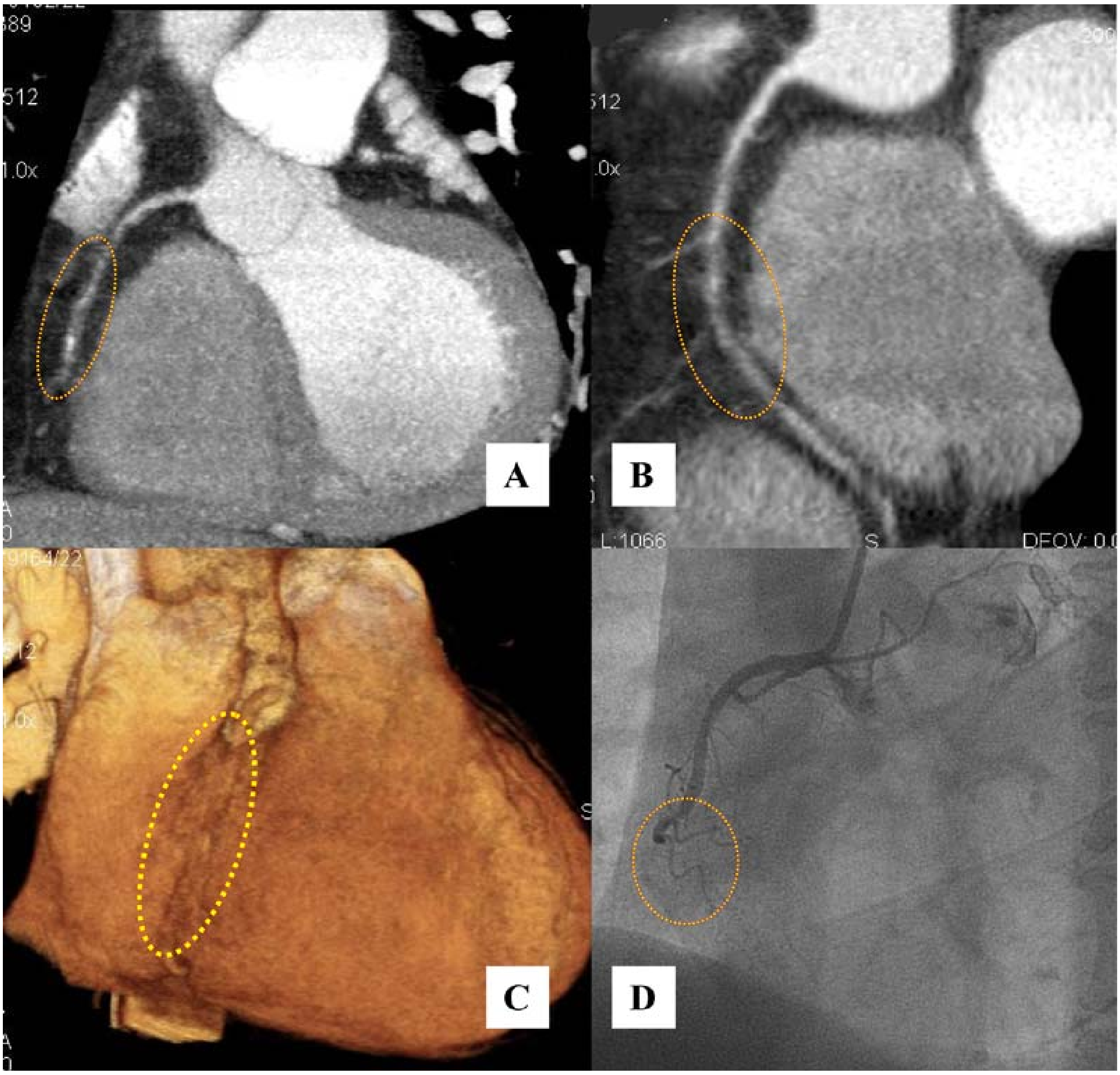

Fig. 4 A 49-year-old man was present with dyspnea on exertion. **A-C** show severe stenosis at the middle segment of the RCA in CT angiogram. **D** presents complete occlusion at this site by conventional coronary angiogram

The present study used a sixteen-sliced CT scanner in the patients suspected to have coronary artery disease. The overall result showed high in both sensitivity and specificity, 81.1% and 98.9% respectively. In comparison to a previous study (Table 4) by using a four-sliced CT scanner of Eugenio M et al[4] and Auchenbach S et al[5] and using an eight-sliced CT scanner in the study of Matsuo et al[6], these previous studies showed 65%/98%, 85%/76%, and 75%/ 96% of sensitivity / specificity respectively. In the study using 16-sliced MDCT (using 12 detectors) by Nieman K et al[7], the overall sensitivity and specificity were 95% and 86% respectively. Most recently, the study by using sixteen-sliced CT scanner of Mollet RN et al[8] showed 92% in sensitivity and 95% in specificity. The present study had less sensitivity, may be resulting from uncontrolled heart rate of the included patients.

This suspected cause was proved by dividing the patients into low ($\leq$ 70 bpm) and high (> 70 bpm) heart rate groups. Significantly decreased sensitivity was seen in the high heart rate group, 72.9% and definitely increased in the low heart rate group, 86.5%.

Pitfalls, overestimation was mostly seen in the proximal LAD (4 in 8 sites) and missed lesions (Fig. 3) were mostly in the distal segment of the left circumflex artery and branching vessels (22 in 31 sites). The latter pitfall similar to the study of Mollet RN et al suggested that the sixteen-sliced CT for coronary artery is still limited in evaluation of the small distal artery and side branches.

The overall positive and negative predictive values were also high, 94% and 96% respectively. The accuracy was 95.8%. These were not significantly different between high and low heart rate groups (Table 2).

Conclusion

The accuracy of the 16-slice CT angiography for patients suspected of having coronary artery disease is high. However, blooming artifacts from the calcium, respiratory artifacts, and small size of the distal and branching artery have still caused limited luminal assessment. These problems have challenged the new coming generation of MDCT.

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ความแม่นยำในการตรวจหาโรคหลอดเลือดหัวใจตีบด้วยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 16-slice

พัชรี ไพจิตรประภาภรณ์, สุทธิพงษ์ จงจิระศิริ, ลออพร ตั้งประกาศิต, จิรพร เหล่าธรรมทัศน์, องค์การ เรืองรัตนอัมพร, นิธิ มหานนท์

วัตถุประสงค์: *เพื่อประเมินความแม่นยำในการตรวจหาโรคหลอดเลือดหัวใจตีบด้วยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 16-slice*

วัสดุและวิธีการ: *ผู้ป่วยทั้งหมด 55 ราย (ผู้ชาย 43 ราย หญิง 12 ราย) อายุเฉลี่ย 62 ปี (43-82 ปี) มีอัตราการเต้นของหัวใจสม่ำเสมอ เฉลี่ย 67 ครั้งต่อนาที (46-147 ครั้งต่อนาที) และทุกรายมี Hemodynamic stable ได้ทำการตรวจหาโรคหลอดเลือดหัวใจตีบด้วยเอกซเรย์คอมพิวเตอร์ชนิด 16 slice (0.42-s rotation time, 16x0.75-mm detector collimation) และได้รับการตรวจซ้ำด้วยวิธีการสวนหัวใจผ่านทางหลอดเลือดแดง ภายในระยะเวลาไม่เกิน 3 เดือน ส่วนของหลอดเลือดที่พบว่ามีแคลเซียมขนาดใหญ่บัง และมี artifact จากการขยับหรือกลั้นลมหายใจได้ไม่ดีของผู้ป่วยจะถูกคัดออกจากการศึกษานี้ (ส่วนของหลอดเลือดที่สามารถนำมาศึกษาได้มี 848 ส่วน และไม่สามารถนำมาศึกษามี 32 ส่วน)*

ผลการศึกษา: *พบว่าการตรวจด้วยเอกซเรย์คอมพิวเตอร์ ในผู้ป่วยที่มีหลอดเลือดหัวใจตีบมากชัดเจน (significant คือตีบตั้งแต่ 50% ขึ้นไป) มี sensitivity 81.1%, specificity 98.9%, และ accuracy 95.8% โดยถ้าแบ่งผู้ป่วยตามอัตราการเต้นของหัวใจ จะพบว่าผู้ป่วยที่มีอัตราการเต้นของหัวใจเร็ว (มากกว่า 70 ครั้งต่อนาที ทั้งหมด 19 ราย) จะมี sensitivity 72.9%, specificity 99.6%, และ accuracy 94.0% และในผู้ป่วยที่มีอัตราการเต้นของหัวใจช้า (ไม่เกิน 70 ครั้งต่อนาที ทั้งหมด 36 ราย) พบว่ามี sensitivity 86.5%, specificity 98.5%, และ accuracy 96.6%*

สรุป: *ความแม่นยำในการตรวจโรคหลอดเลือดหัวใจตีบด้วยเครื่องเอกซเรย์คอมพิวเตอร์ 16-slice นั้นมีสูง แต่ยังคงมีข้อจำกัดอยู่ในกรณีที่มีแคลเซียมขนาดใหญ่บังหลอดเลือด ผู้ป่วยขยับหรือกลั้นลมหายใจได้ไม่ดีระหว่างทำการตรวจ และบริเวณหลอดเลือดส่วนปลาย หรือ side branch ที่มีขนาดเล็ก*