Preliminary Report

Detection of Coronary Stenoses in Chronic Stable Angina by Multi-Detector CT Coronary Angiography

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Objective: *To assess the accuracy for detection of coronary stenoses in chronic stable angina patients.*
Material and Method: *Twenty-four chronic stable angina patients, referred for conventional coronary angiography by the indication of positive stress tests or clinical highly suspicion of coronary artery disease were enrolled. MDCT coronary angiography (MDCTCA) and conventional coronary angiography (144 coronary vessels) were performed within one month. Accuracy of MDCTCA for predicting significant coronary artery stenoses was analyzed.*
Results: *Five patients were excluded due to the total Agaston calcium score more than 500. Therefore, 114 vessels or 209 segments from 19 patients (9 males and 10 females) were available for analysis, and 186 segments were assessable (89%). Of all assessable segments, 13 from 20 significant lesions (65%) and 158 from 167 normal or non-significant lesions (95%) were correctly detected by MDCTCA. The sensitivity, specificity, positive and negative predictive values to detect significant coronary artery stenoses in terms of vessel are 82%, 96%, 79%, and 97% respectively.*
Conclusion: *Coronary CT angiography provides accurate assessment of coronary luminal artery narrowing and shows the ability to exclude significant coronary artery stenoses in patients with chronic stable angina.*

Keywords: *Coronary CTA, Chronic stable angina, Coronary stenosis, Accuracy*

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Chronic ischemic heart disease or chronic stable angina is the most frequent clinical syndrome in the patients who have coronary artery disease[1]. Detection of myocardial ischemia or the extent of coronary artery stenoses are important for diagnosis and risk stratification. The conventional coronary angiography (CCA) is considered the gold standard and utilized for evaluation of the extent of coronary artery stenoses. Although it is a safe procedure with only a small risk with experienced physicians, the CCA is an invasive procedure and risk for potentially serious adverse effects and the costs associated with such effects have led to search for noninvasive alternative.

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Since 1998, multi-detector computed tomography (MDCT) with four detector arrays and a minimum rotation time of 500 milliseconds were introduced[2] and its utilization for coronary artery imaging has progressed rapidly. The diagnostic accuracy has been shown to be improved with the latest generation of MDCT. In literature, it was found that at least 16-slice or 16-row MDCT was needed to obtain accurate detection of coronary artery stenoses[3].

The objective of the present study is to assess the accuracy of MDCT coronary angiography (MDCTCA) for detection of coronary artery stenoses in chronic stable angina patients comparing to the CCA.

Material and Method

The authors enrolled 24-chronic stable angina patients who underwent MDCTCA and CCA with duration within one month apart. The present study was approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. Chronic stable angina patients were defined by patient discomfort in the chest, jaw, shoulder, back, or arm, less than 20 minutes in duration, typically aggravated by exercise or emotional stress and relieved by rest or nitroglycerine. The following inclusion criteria included positive or equivocal non-invasive tests (exercise stress test, myocardial scintigraphy, or echocardiography) or clinical highly suggestive coronary artery disease, regular heart rate**,** creatinine level equal or less than 1.5 mmol/L and stable clinical condition. Patients with atrial fibrillation, multifocal atrial tachycardia, uncontrolled arrhythmia, creatinine level above 1.5 mmol/L, decompensated heart failure, or calcium score > 500 were excluded.

Coronary CT imaging

MDCTCA was performed with ECG gated on a Somatom Sensation 16, Siemens CT scanner (Germany) during intravenous injection of non-ionic contrast agent (300 mgI/mL, 80-90 mL at a flow rate of 3.5-4 mL/sec, 250 PSI with a chaser bolus of 50 mL of normal saline). The following scanning protocol was used: 16 x 0.75 mm collimation, 3.4-mm table feet/rotation, 420-msec gantry rotation time, and 600-mAs at 120-kV tube voltage. For each patient, the phase of image reconstruction was selected from the preview image of each phase from 10% to 90% and the data containing the fewest motion artifacts was used for further evaluation of each coronary artery.

On the basis of the cross-sectional images, thin-slab maximum-intensity projections, multi-planar reconstruction and volume rendering images, the coronary arteries were classified as assessable and non-assessable. In the assessable arteries, the presence of significant stenosis (equal or more than 50% luminal reduction) was assessed using visual estimation. The results were documented separately for 4 major coronary arteries (right coronary artery, left main, left anterior descending and left circumflex artery) and 2 minor coronary arteries (posterior descending and posterolateral artery). The subdivision of coronary arteries into 11 segments was performed according to AHA classification(4) except segment 9 (first diagonal), 10 (second diagonal) and 12 (obtuse marginal) were excluded. The MDCTCA analysis depended on consensus of two interpretators (one cardiologist and one radiologist).

***Conventional coronary angiography* (CCA)** was performed within one-month and blind MDCTCA interpretation performed by a cardiologist.

Statistical analysis

Comparing coronary arteries imaging between MDCTCA and CCA by using sensitivity, specificity, positive predictive value, negative predictive value for diagnosis of coronary stenoses in terms of vessel and segment as defined,

1. Agreement in terms of vessel means any significant stenoses in the same vessel could be correctly detected by MDCTCA whether in the same segment or not

2. Agreement in terms of segment means significant stenoses in the same segment of the vessel could be correctly detected by MDCTCA

Factors affecting coronary artery assessment from MDCTCA were analyzed by using Fisher's Exact test. A p-value of less than 0.05 was considered significant (SPSS statistical package version 11.5).

Table 1. Distribution of Agatston calcium score

Total calcium score	n = 19 (%)
0	4 (21)
0-100	12 (63)
101-200	0 (0)
201-300	2 (11)
301-400	0 (0)
401-500	1 (5)

Table 2. Patient basic characteristics (n = 19)

Demographic data	
Age, yrs	59.0 ± 6.7
Gender, M	9 (47%)
Body weight, kg	69.4 ± 9.2
Height, cm	159.9 ± 6.6
Medical history	
DM	6 (32%)
Hypertenstion	12 (63%)
Dyslipidemia	9 (47%)
Others	3 (16%)

Data presented as the mean value ± SD or number of patients, Fourteen patients had risk factor, Nine patients had more than one risk factor

Results

Of the twenty-four patients who underwent both MDCTCA and CCA, five patients were excluded due to the total Agatston calcium score more than 500. The distribution of calcium score of all patients are shown in Table 1. Baseline characteristics of the 19-enrolled patients are demonstrated in Table 2.

The median time between MDCTCA and CCA was 7 days (range 2-27 days). During the MDCTCA study, no severe complication occurred. One patient had chest discomfort after the first intravenous contrast injection, which was relieved with 1 tablet sublingual nitroglycerine. Five patients received beta blocker prior to scanning due to high initial heart rate (68-76 beats per minute-bpm). Heart rates during scanning in all patients ranged from 48-65 bpm.

Of 19 patients, 114 coronary vessels or 209 segments were available for total analysis and after exclusion of non-assessable segments, 186 segments were assessable (89%) (Table 3).

Extensive calcification and cardiac motion artifact were the major causes of non-assessable segments in this study (Fig. 1, 2).

The reasons why 22 segments (10.5%) could not be assessed are shown in Table 4. Twenty from twenty-six significant lesions were demonstrated in assessable segments from MDCTCA (77%). Of 186 assessable segments, 13 from 20 significant lesions (65%) and 158 from 167 normal or non-significant lesions (95%) were correctly detected by MDCTCA. The diagnostic accuracy of MDCTCA to detect significant coronary artery stenoses in each coronary artery is shown in Table 5.

The average diameter of RCA = 3.4 mm, LMA = 3.5 mm, LAD = 2.8 mm, LCX = 2.6 mm, PDA = 1.3 mm, PL = 1.4 mm. The measured point was within 5 mm from the origin of each vessel.

Table 3. Number of assessable segments in 19 patients (209 segments)

Segment	Number assessable/total
Right coronary artery	
Proximal	18/19(95%)
Middle	17/19 (90%)
Distal	17/19 (90%)
Left main artery	19 (100%)
Left anterior descending artery	
Proximal	16/19 (84%)
Middle	16/19 (84%)
Distal	15/19 (79%)
Left circumflex artery	
Proximal	18/19 (95%)
Middle	18/19 (95%)
Posterior descending artery	15/19 (79%)
Posterolateral artery	17/19 (90%)
Total	186/209 (89%)

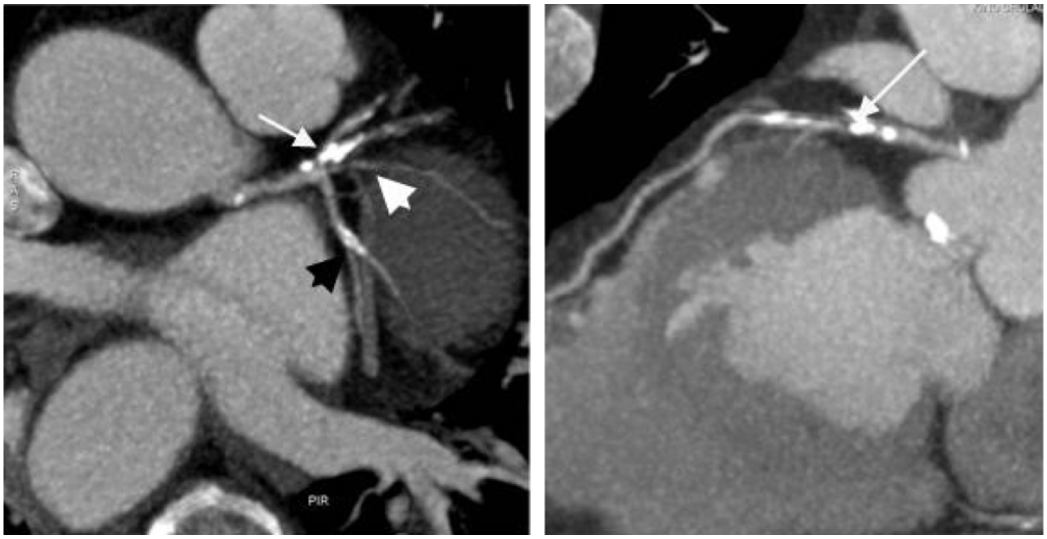
Table 4. Reasons for non-asssessable segments in 19 patients (209 segments)

Causes	Number (segments)
Respiratory motion artifact	1
Cardiac motion artifact	6 ($p<0.05$)
Extensive calcification	6 ($p<0.05$)
Poor filling (Technique)	2
Poor filling (Proximal stenoses or total occlusion)	4
Small vessel	2 ($p<0.01$)
Dense adjacent contrast-filled structures	1
Total	22

Table 5. Sensitivity, specificity, positive predictive value and negative predictive value analyzed in each coronary artery

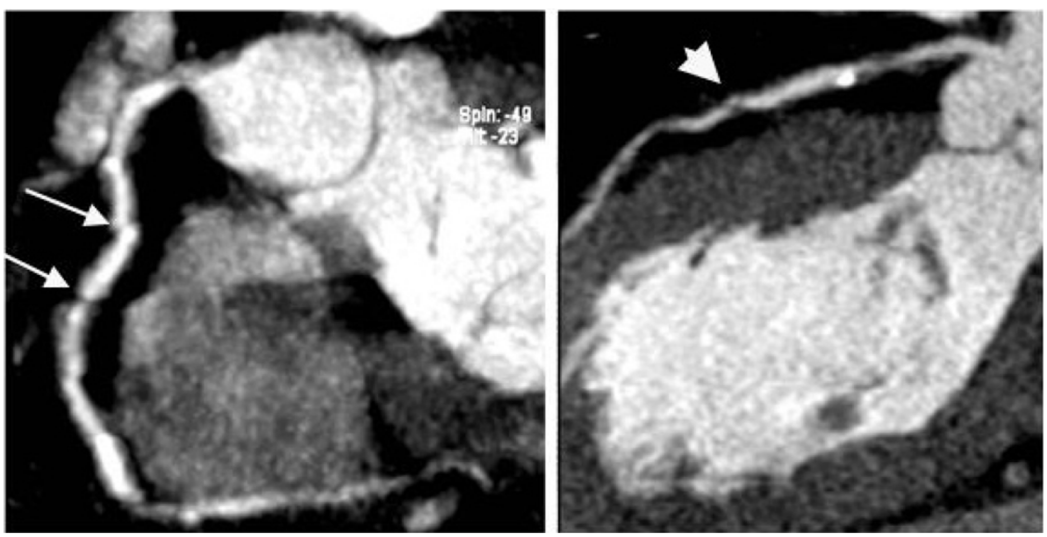
	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
RCA	100	100	100	100
LMA	-	100	-	100
LAD	90	90	89	95
LCX	50	87	67	87
PDA	-	94	-	100
PL	-	100	-	100

- could not be analyzed due to the number of true positive = 0 (zero)



A B

Fig. 1 High-attenuating artifact caused by extensive coronary calcification, (A) axial oblique maximum intensity projection and (B) multiplanar reformatted images show extensive calcification at proximal left anterior descending artery-LAD (arrow) and at the bifurcation of left circumflex and 1st obtuse marginal branch (black arrow head), stenoses of proximal LAD and ramus intermedius (white arrow head) cannot be evaluated

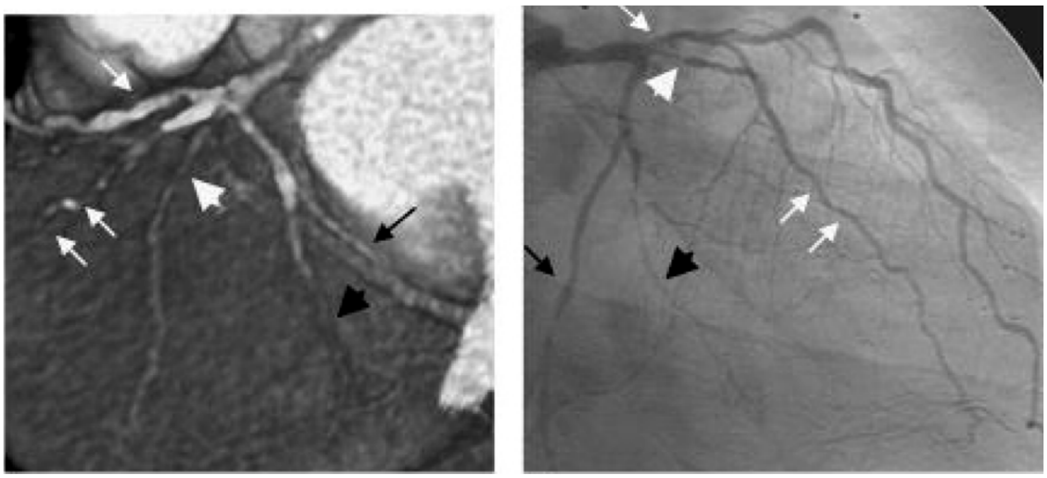


A B

Fig. 2 Step ladder cardiac motion artifact, (A, B) multiplanar reformatted images show step ladder cardiac motion artifact affects right coronary artery (arrow) more than left anterior descending artery (arrow head)

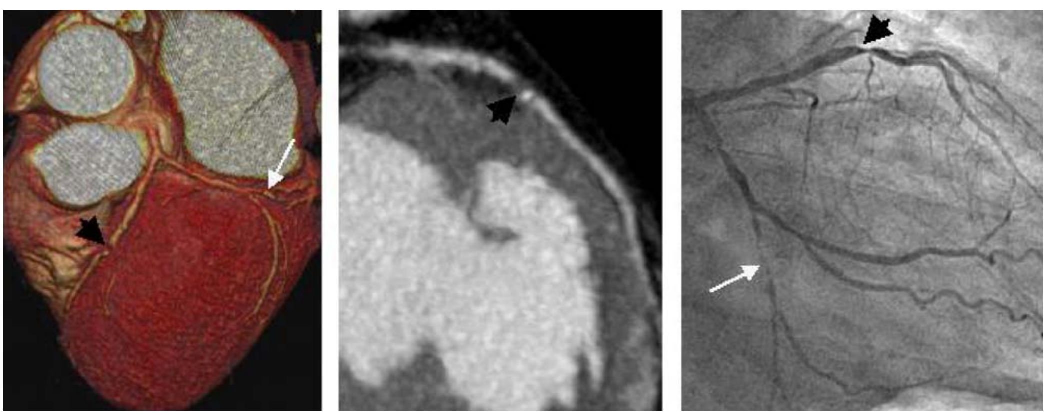
The causes affecting non-assessable coronary vessels were analyzed by using Fisher's Exact test were cardiac motion artifact ($p < 0.05$), extensive calcification ($p < 0.05$), proximal stenoses ($p <= 0.05$) and small size vessel ($p < 0.01$).

The final diagnosis from CCA showed single vessel disease in two patients, double vessel disease in five patients, triple vessel disease in two patients and normal coronary artery in 10 patients. Twenty-six significant lesions were found. There was no compli-



A B

Fig. 3 False negative at left circumflex artery-LCX, the same patient in Fig. 1, (A) volume rendering image shows heavy calcification at proximal LAD (white arrow) and first diagonal branch (double arrows) and mild irregular narrowing at ramus intermedius (white arrow head) and OM1 (black arrow head) with subsequently confirmed stenoses in CCA (B), however, mild stenosis at mid LCX (black arrow) was not shown in MDCTCA



A B C

Fig. 4 False negative at mid left circumflex-LCX, (A) volume rendering and (B) multiplanar reconstruction images show partial calcific plaque caused significant stenosis at mid left anterior descending artery-LAD (black arrow head) compared to CCA (C) while another significant stenosis at mid left circumflex artery-LCX (white arrow) was not shown in MDCTCA

cation during and after the CCA procedures.

The causes of misinterpretation are small vessels, calcified plaque and soft plaque. The false negative interpretation was occurred in the LCX (Fig. 3, 4) and LAD, which resulted from small vessels and calcification. The sensitivity and specificity including positive and negative predictive values to detect significant stenoses in terms of vessel and segment are shown in Table 6.

Calcific plaque caused stenoses in five segments and non-calcific plaque (lipid or fibrous or clot) was the cause of stenoses in eight segments (Fig. 5).

Discussion

The present study has shown that 16-slice MDCTCA is an excellent technique to exclude significant coronary artery stenosis in the group of chronic stable angina.

A B C

Fig. 5 Soft plaque at proximal left anterior descending artery-LAD (white arrow) and ramus intermedius (black arrow head) caused significant stenoses, (A) maximum intensity projection and (B) volume rendered-images show soft plaque at proximal LAD (white arrow) and ramus intermedius (black arrow head) caused significant stenoses compared to CCA (C) mild stenoses at left circumflex artery-LCX (black arrow) was also noted

Table 6. Sensitivity and specificity analyzed in terms of vessel and segment

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Vessel	83	96	79	97
Segment	65	95	62	96

Previous studies have shown that the sensitivity to detect coronary artery stenosis increasing from 4-slice to 64-slice resulted from increased spatial resolution, temporal resolution, and less artifacts from less scanning time. However, these scanners have been consistent in the ability to exclude significant coronary artery stenosis, which demonstrated by the excellent negative predictive value in the range of 95-100%[5-12]. The present study has also shown the negative predictive valve of 97%.

The prevalence of coronary calcification is increasing with aging and the presence of coronary atherosclerosis, which somewhat limits the diagnostic capability due to blooming artifact. Sometimes calcification is focal, MDCTCA is still useful because it may detect significant lesions in other segments.

The present result is limited by the number of significant stenotic lesions, therefore, the interpretation of sensitivity may be limited. In the literature, the sensitivity was in the range of 63-95%[5-10] in 16-slice MDCT system. On current 64-slice MDCT system, the sensitivity is in the range of 73-97%[11-13] and the next generation of MDCT may be able to improve further on diagnostic accuracy, radiation exposure reduction, and contrast material minimization.

Concerning clinical applications, most of the patients with chronic stable angina will see physicians and frequently will have exercise stress testing performed. Patients with abnormal stress test may undergo CCA, which is invasive. Furthermore, 30-50% of the studies are normal or minimal luminal narrowing of coronary arteries. With excellent negative predictive value of MDCTCA, patients with equivocal stress test will benefit from the study to exclude coronary artery stenosis and unnecessary invasive procedure exposure.

Conclusion

Coronary CT angiography provides accurate assessment of coronary luminal artery narrowing and shows the ability to exclude significant coronary artery stenoses in patients with chronic stable angina.

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การวินิจฉัยหลอดเลือดหัวใจอุดตันโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิดมัลติดีเทคเตอร์ในผู้ป่วย
chronic stable angina

เมลิสสา พันธุ์เมธิศร์, สมใจ หวังศุภชาติ, ไพโรจน์ ฤกษ์พัฒนาพิพัฒน์, สุพจน์ ศรีมหาโชตะ, วศิน พุทธารี, วีรนุช กิจสุขจิต

***วัตถุประสงค์**: เพื่อประเมินความแม่นยำในการตรวจหลอดเลือดหัวใจอุดตัน โดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิดมัลติดีเทคเตอร์ ในผู้ป่วย chronic stable angina เปรียบเทียบกับการฉีดสารทึบรังสีถ่ายภาพเอกซเรย์หลอดเลือดหัวใจโคโรนารี*

***วัสดุและวิธีการ**: เป็นการวิจัยแบบไปข้างหน้าในผู้ป่วย chronic stable angina จำนวน 24 คน จำนวน 144 หลอดเลือดหัวใจที่มีความจำเป็นในการตรวจฉีดสารทึบรังสีผ่านสายสวนถ่ายภาพเอกซเรย์หลอดเลือดหัวใจโคโรนารี ซึ่งได้รับการตรวจด้วยเครื่องเอกซเรย์คอมพิวเตอร์ชนิดมัลติดีเทคเตอร์ ในระยะเวลาห่างกันไม่เกิน 1 เดือน จากนั้นวิเคราะห์ความแม่นยำในการแสดงหลอดเลือดอุดตันที่มีความสำคัญทางคลินิก จากการตรวจโดยเครื่องเอกซเรย์คอมพิวเตอร์เปรียบเทียบกับการฉีดสารทึบรังสีผ่านสายสวนถ่ายภาพเอกซเรย์หลอดเลือดหัวใจโคโรนารี*

***ผลการศึกษา**: ผู้ป่วย 5 รายได้ถูกตัดออกจากการวิจัยเนื่องจาก Agaston calcium score มากกว่า 500 การตรวจด้วยเครื่องเอกซเรย์คอมพิวเตอร์สามารถประเมินหลอดเลือดหัวใจได้ 186 segments จากทั้งหมด 209 segments ในผู้ป่วย19 ราย คิดเป็นร้อยละ 89 สามารถแสดงรอยโรคหลอดเลือดหัวใจอุดตันได้ถูกต้อง 13 จาก 20 รอยโรค (ร้อยละ 65) และแสดงหลอดเลือดที่ตีบน้อยหรือปกติได้ถูกต้อง 158 จาก 167 segments (ร้อยละ 95) ความไว ความจำเพาะ positive และ negative predictive value จากการประเมินในแง่ของหลอดเลือดมีค่า ร้อยละ 82, 96, 79 และ 97 ตามลำดับ*

***สรุป**: การตรวจหลอดเลือดหัวใจอุดตัน โดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิดมัลติดีเทคเตอร์ให้ผลแม่นยำในระดับที่น่าพอใจ สามารถคัดแยกหลอดเลือดหัวใจอุดตันที่มีความสำคัญทางคลินิกในผู้ป่วย chronic stable angina ได้ถูกต้องเกือบทั้งหมด*