Diagnostic Accuracy of 128-Row Multidetector Computed Tomography Coronary Angiography in the Diagnosis of Significant Coronary Artery Stenosis

Narumol Chaosuwannakit MD*,
Songsak Kiatchoosakun MD**, Pattarapong Makarawate MD**

** Radiology Department, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand*
*** Cardiology Unit, Internal medicine Department, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand*

Objective: *To evaluate the diagnostic accuracy of 128-multi detector row computed tomography coronary angiography (MDCTCA) with that of invasive conventional coronary angiography (CCA) in the diagnosis of coronary artery disease (CAD).*
Material and Method: *Forty-two consecutive patients underwent both MDCTCA and CCA. All MDCTCA were evaluated for the presence of obstructive coronary stenosis by a blinded experts, and results were compared with quantitative CCA.*
Results: *Three vessels and five segments were uninterpretable on MDCTCA. Therefore, 123 vessels and 558 segments from 42 patients were analyzed. Sensitivity, specificity, and positive and negative predictive values of computed tomography for detecting detect > 50% luminal narrowing were 100%, 91%, 91%, and 100%, respectively, by patient, 98%, 98%, 96%, and 99%, respectively, by vessel, and 98%, 99%, 94%, and 99%, respectively, by segment. Moreover accuracy for detecting > 70% luminal narrowing were excellent by patient, vessel, and segment.*
Conclusion: *Noninvasive 128-detector row CT coronary angiography provides high diagnostic accuracy on per segment, vessel, and patient analysis.*

Keywords: *Multidetector computed tomography, Coronary angiography, Cardiac imaging*

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Cardiovascular disease is the leading cause of morbidity and mortality in the Western world. Early detection of coronary artery disease (CAD) is of vital importance as timely treatment may significantly reduce morbidity and mortality. Although invasive conventional coronary angiography (CCA) remains the standard of reference for the evaluation of CAD, the risk of adverse event is small, but serious and potentially life-threatening sequelae may occur, including arrhythmia, stroke, coronary artery dissection, and access site bleeding (total complication rate, 1.8%; mortality rate, 0.1%)[1,2]. Furthermore, catheterization induces some discomfort and mandates routine follow-up care. Therefore, CCA should be restricted to stringent clinical indications[1]. This situation constitutes the basis of the demand for a reliable gatekeeper or even noninvasive replacement. One recently developed modality that may potentially complement CCA is MDCT coronary angiography (MDCTCA), which may achieve a high level of reliability and accuracy in the visualization of the coronary tree[3-6]. This modality obviates much of the risk and discomfort associated with catheterization, although it retains the risks inherent in radiation exposure and use of contrast agents. Past studies have tested the sensitivity and specificity of MDCTCA versus CCA based on vessel segments and suggested that MDCTCA is highly accurate[3-6]. With sub-millimeter spatial resolution, this technique allows detailed visualization of luminal narrowing as well as atherosclerotic changes within the coronary vessel wall. Advances in multidetector computed tomography (MDCT) technology have led to continuous improvements in image quality as well as reduction in radiation dose and contrast material. Recently, 128-row MDCT systems were introduced, with enhanced craniocaudal volume coverage when compared with 64-row MDCT systems[7]. With this new generation MDCT scanners allows image acquisition of the entire

Correspondence to:
Chaosuwannakit N, Radiology Department, Faculty of Medicine, Khon Kaen University, Khon Kaen 40000, Thailand.
Phone: 084-646-4648, 081-661-4751
E-mail: docnaruchao@yahoo.com

heart within a single gantry rotation and few heart beats[7]. Accordingly, wide volume MDCTCA, in combination with prospective image acquisition, allows for a marked decrease in scan time and time of breath-hold, resulting in decreased radiation dose and contrast material when compared with retrospective helical imaging requiring multiple heart beats[7]. In addition, improved temporal resolution and scan time result in an overall reduction of cardiac motion artifacts and eliminate the problem of stair-step artifacts, observed during step-and-shoot acquisition techniques and helical imaging[7,8]. The diagnostic accuracy of 128-row MDCTCA in the evaluation of significant coronary artery stenosis has not been reported previously. Therefore, the purpose of the current study was to evaluate the diagnostic accuracy of 128-row MDCTCA in the identification of significant CAD, compared with CCA as the standard of reference.

Material and Method

Patient population

This retrospective study included 42 patients who underwent both MDCTCA and CCA, between December 2010 and December 2011. The indications for MDCTCA were an abnormal, equivocal, or non-diagnostic stress test, atypical chest pain, patients awaiting valvular surgery to detect or exclude associated coronary stenoses, as well as the evaluation of cardiac etiology of syncope. The above are considered appropriate indications for MDCTCA, based on the criteria of the American College of Cardiology (ACC)[9]. Exclusion criteria for MDCTCA included the presence of multiple ectopic beats, atrial fibrillation, pregnancy, renal failure, and a history of allergic reaction to iodine-containing contrast agents. The present study was approved by the Ethics Committee of the Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand, and informed consent was obtained from all patients.

MDCT coronary angiography (MDCTCA) scanning protocol

MDCTCA examinations were performed on a 128-slice MDCT (Brilliance 128, Philips Healthcare, Netherland) using prospective or retrospective electrocardiographic (ECG) gating with the following parameters: 128 x 0.6 collimation, 0.3 sec rotation time, pitch of 0.32, 120 kV tube voltage and 185 reference mAs. Patients with heart rates over 75 bpm with no contraindications to the use of beta-blockers received metoprolol orally 1 hour before the examination to reduce heart rate (n = 11). However, in the presence of contraindications for a beta-blocker or an unsatisfactory lowering of the heart rate, the scan was still performed, even at higher heart rates. Image acquisition was performed during inspiratory breath-hold. To familiarize the patient with the protocol, breath-holding was practiced before the examination. A contrast agent bolus of 80-100 mL was injected with a mean flow rate of 5 mL/s followed by a 50-mL saline flush. For timing purposes, an automated bolus-tracking software was used, starting the scan automatically 6 seconds after contrast agent density in the descending aorta reached a predefined threshold of 130 HU[10]. The entire volume of the heart was covered during one breath-hold in approximately 5 seconds with simultaneous recording of the ECG trace. Patients were scanned in the supine position twice, first without contrast medium to calculate the calcium score and secondly after contrast medium injection. Studies were acquired in the cranio-caudal direction from the level of the carina to just below the diaphragm. For optimal motion-free image quality, data sets were reconstructed in mid diastole (mean interval, 614 ± 175 ms after the R wave). All scans were performed with either prospective electrocardiographic (ECG) triggering using 60% to 100% phase window or, in patients with an indication for evaluation of cardiac function, full-beat retrospective ECG triggering using tube current modulation. Electrocardiographically gated datasets were reconstructed automatically to overlapping 0.5-mm slices in 0.25-mm intervals at 75% of the RR cycle length. Additional reconstruction windows were constructed after examination of initial datasets if motion or noise artifacts were present. This was done in 47.6% of the patients (n = 20).

MDCTCA image analysis

MDCTCA image analysis was performed by two cardiovascular and thoracic radiologists in consensus (with a respective 7 and 5 years of experience in examining cardiovascular and thoracic CT scans) and blinded to the clinical data and the results of CCA data. First, axial slices were visually examined for the presence of significant narrowing by determining the presence of > 50 and > 70% reduction of luminal diameter as recommended by the SCCT guidelines for the interpretation and reporting of CTA[11]. MDCTCA analysis was assisted by curved multiplanar reconstructions of all vessels. Subsequently, general information regarding the status and anatomy of the coronary arteries was obtained using three-dimensional volume-rendered reconstructions. Data were analyzed on a segmental, vessel, and patient basis. Coronary anatomy was assessed in a standardized manner by dividing the coronary artery tree into 15 segments according to a modified American Heart Association classification[12]. Each segment was determined interpretable or uninterpretable, and evaluated for the presence of > 50 and > 70% stenosis. Subsequently, vessel-based analysis was performed. If one segment was uninterpretable, an intention to diagnose strategy was applied. However, if more than one segment in a single vessel was deemed uninterpretable, the vessel was considered to be of non-diagnostic image quality. Finally, a patient-based analysis was performed using a similar approach. If one vessel was uninterpretable, an intention to diagnose strategy was applied. However, if more than one vessel was uninterpretable, the entire scan was considered to be of non-diagnostic image quality. Accordingly, diagnostic image quality, the presence of > 50% and the presence of > 70% stenosis were assessed on a segmental, vessel, and patient level.

Conventional coronary angiography (CCA)

CCA was performed according to standard techniques. Images were evaluated by an experienced cardiologist blinded to MDCTCA results. All segments visually scored as abnormal were quantified using a validated and dedicated quantitative coronary angiography (QCA) software package (CA-CMS, QAngioXA 6.0, Medis Medical Imaging Systems, Leiden, The Netherland). Each segment was evaluated for the presence of significant stenosis by determining the presence of > 50 and > 70% luminal diameter reduction in the angiographic view with most severe luminal narrowing.

Statistical analysis

Data were analyzed on a segmental, vessel, and patient basis. Sensitivity, specificity, and positive and negative predictive values, including 95% confidence intervals (CI), for the detection of > 50 and > 70% luminal narrowing on CCA were calculated. In an initial analysis, the diagnostic accuracy was determined excluding segments, vessels, or patients of non-diagnostic image quality. In a subsequent analysis, non-diagnostic segments, vessels, or patients were included in the analysis and were considered positive (> 50% luminal narrowing). Continuous data were expressed as mean ± SD. Statistical analyses were performed using SPSS software version 16 (SPSS, Inc., Chicago, IL, USA). A significance level of $p < 0.05$ was considered a statistically significant result and all reported p-values were two-sided.

Results

Patient clinical characteristics are presented in Table 1. Four-two patients (25 men, 17 women; mean age, 64 ± 10 years; range, 25 to 81 years) were included in this study over a period of 12 months. The mean time interval between MDCTCA and CCA was 3 ± 13 days (range, 0-25 days) and there were no clinical events between the two studies in any patient. In most patients (38/42), MDCTCA was performed before CCA, and in four patients, CCA was performed first. 37 (88%) investigations were initially performed in patients with chest pain, three (8%) in preoperative patients awaiting valvular surgery to detect or exclude associated coronary stenoses, one (2%) after an equivocal exercise stress test, and one (2%) in patients with dyspnea. Five patients received beta blocker prior to scanning due to high initial heart rate [75 to

Table 1. Patient characteristics (n = 42)

Characteristic	Value
Age (years), mean ± SD (range)	64 ± 10 (25-81)
Men	25 (59%)
Height (cm), mean ± SD	161.8 ± 13
Weight (kg), mean ± SD	59.8 ± 12
Body mass index (kg/m²), mean ± SD (range)	23.1 ± 6 (15-35)
Diabetes mellitus	11 (26%)
Hypertension*	21 (50%)
Hypercholesterolemia#	29 (69%)
Current smoker	11 (26%)
Obesity+	1 (2%)

* Blood pressure > 140/90 mmHg or treatment for hypertension
# Total cholesterol > 180 mg/dl or treatment for hyper-cholesterolemia
+ Body mass index > 30 kg/m²

Table 2. Distribution of Agaston calcium score

Total calcium score	n = 42 (%)
0	4 (9.5)
1-100	15 (35.7)
101-200	13 (30.9)
201-300	5 (11.9)
301-400	3 (7.2)
> 400	2 (4.8)

86 beats per minute (bpm)]. The mean heart rate during the MDCTCA scans was 61 ± 9 bpm (range, 42 to 72 bpm). The distribution of calcium score of all patients are shown in Table 2.

On a per segment basis, of 42 patients, 558 of 563 coronary artery segments were assessable (99.1%). Reasons for non-accessibility on a per segment basis were extensive calcifications [3 (60%)] and poor filling due to proximal stenosis or total occlusion [2 (40%)]. One uninterpretable segment was located in the left circumflex artery (segment 11)

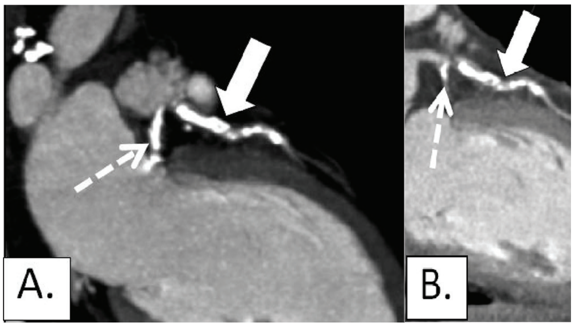

Fig. 1 High-attenuating artifact caused by extensive coronary calcification, oblique maximum intensity projection (A) and multiplanar reformatted (B) images showed extensive calcification at proximal LAD (arrow) and proximal LCX (dashed arrow), stenoses of proximal LAD and LCX cannot be evaluated

and four uninterpretable segments were located in the left anterior descending artery (segment 6, n = 1, segment 7, n = 1, segment 8, n = 1 and segment 9, n = 1) (Fig. 1). In the remaining 558 segments, MDCTCA analysis correctly ruled out significant stenosis in 509 segments (Fig. 2-3, true negative). In 45 segments, significant lesions were correctly identified on CTA (Fig. 4, true positive), whereas three segments deemed non-obstructive on CCA were incorrectly classified as obstructive by MDCTCA (Fig. 5). Consequently, the sensitivity and specificity for the detection of > 50% stenosis on a segment basis were 98 and 99%, respectively, and positive and negative predictive values were 94 and 99%, respectively. The diagnostic accuracy for the detection of > 50% luminal narrowing as well as the diagnostic performance for the detection of > 70% luminal narrowing are depicted in Table 2 and 3.

In 126 vessels evaluated, 44 significantly obstructed vessels were identified on CCA. Three vessels (2.3%) were rendered non-diagnostic on MDCTCA analysis due to extensive calcifications [2 (67%)] (Fig. 1) and poor filling due to proximal stenosis or total occlusion [1 (33%)]. In the remaining 123 vessels, MDCTCA correctly ruled out significant stenosis in 77 vessels. One or more significant lesions were correctly identified by MDCTCA in 43 vessels, whereas MDCTCA overestimated lesion size in two vessels. The absence of significant stenosis was

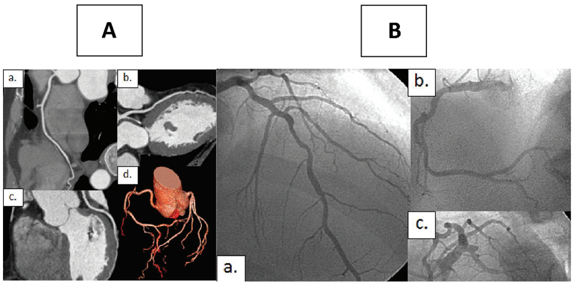

Fig. 2 Sample case in individual with nonstenosed coronary artery: Matched Negative Readings. A 68-year-old woman presenting with atypical chest pain referred for coronary CT angiography (CCTA). CCTA (A) Curved multiplanar reformation image of the RCA (a), LAD (b), LCX (c) and Volume rendering image (d) showed no coronary artery stenosis. Conventional coronary angiogram (B) confirms that no significant coronary artery stenosis in LAD (a), RCA (b) and LCX (c) (LAD: left anterior descending artery; RCA: right coronary artery, LCX: left circumflex artery)

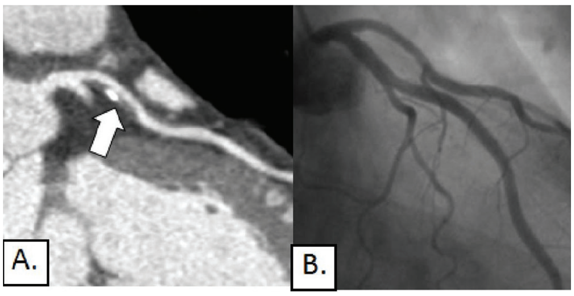

Fig. 3 Sample case in individual with nonstenosed coronary artery: Matched Negative Readings. A 52-year-old man presenting with atypical chest pain referred for coronary CT angiography (CCTA). CCTA Curved multiplanar reformation image of the LAD (A) showed mixed calcified and soft plaque at proximal LAD (arrow) does not induce significant lumen narrowing (< 50% diameter reduction). Conventional coronary angiogram (B) confirms that no significant coronary artery stenosis is found (LAD: left anterior descending artery)

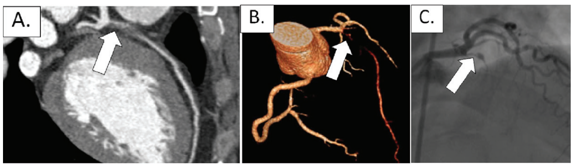

Fig. 4 Sample case in individual with stenosed coronary artery: Matched Positive Readings.CCTA Curved multiplanar reformation image of the LAD (A) and volume rendering technique image (B) showed soft plaque at proximal LAD (arrow) causing significant stenosis (> 70% diameter reduction). Conventional coronary angiogram (C) shows significant proximal LAD stenosis (LAD: left anterior descending artery)

incorrectly identified by MDCTCA in only one vessel resulting in a sensitivity and specificity of 98 and 98%, respectively, and positive and negative predictive values were 96 and 99%, respectively. The diagnostic accuracy for the detection of > 50% luminal narrowing as well as the diagnostic performance for the detection of > 70% luminal narrowing are depicted in Table 3 and 4.

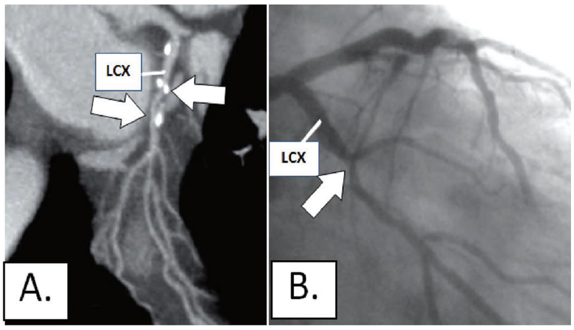

Fig. 5 False positive at LCX. CCTA Curved multiplanar reformation image of the LCX (A) showed calcified plaque at proximal LCX (arrows) which identified significant lumen narrowing. Conventional coronary angiogram (B) did not identify significant lumen narrowing (arrow) (LCX: left circumflex artery)

In patient analysis, out of 42 MDCTCA examinations, none of them was of non-diagnostic image quality. CCA identified 19 patients with obstructive CAD. All patients (100%) were correctly identified by MDCTCA. In addition, in 21 patients,

Table 3. Diagnostic accuracy of 128-row computed tomography coronary angiography for the detection of > 50% coronary artery stenosis

	Segment analysis	Vessel analysis	Patient analysis
Non-diagnosis	5/563, 0.9%	3/126, 2.3%	0/42, 0%
Sensitivity	45/46 (98%, 93-95%)	43/44 (98%, 88-100%)	19/19 (100%)
Specificity	509/512 (99%, 96-98%)	77/79 (98%, 96-100%)	21/23 (91%, 93-98%)
PPV	45/48 (94%, 80-95%)	43/45 (96%, 88-100%)	19/21 (91%, 95-99%)
NPV	509/510 (99%, 97-99%)	77/78 (99%, 96-100%)	21/21 (100%)
Diagnostic accuracy	554/558 (99%,95-98%)	120/123 (98%, 97-99%)	40/42 (95%, 95-100%)

Data are absolute values used to calculate percentages. Data in parentheses are percentages with 95% confidence intervals
NPV = negative predictive value; PPV = positive predictive value

Table 4. Diagnostic accuracy of 128-row computed tomography coronary angiography for the detection of > 70% coronary artery stenosis

	Segment analysis	Vessel analysis	Patient analysis
Non-diagnosis	5/563, 0.9%	3/126, 2.3%	0/42, 0%
Sensitivity	34/35 (97%, 88-99%)	32/33 (97%, 88-98%)	13/13 (100%)
Specificity	520/523 (99%, 98-100%)	88/90 (98%, 95-100%)	27/29 (93%, 90-98%)
PPV	34/37 (92%, 81-96%)	32/34 (94%, 88-98%)	13/15 (87%, 83-99%)
NPV	520/521 (99%, 97-100%)	88/89 (99%, 95-100%)	27/27 (100%)
Diagnostic accuracy	554/558 (99%,96-100%)	120/123 (98%, 96-100%)	40/42 (95%, 95-100%)

Data are absolute values used to calculate percentages. Data in parentheses are percentages with 95% confidence intervals
NPV = negative predictive value; PPV = positive predictive value

MDCTCA correctly ruled out the presence of significant CAD. Only two patients were incorrectly diagnosed with obstructive CAD on MDCTCA. In these patients, heavily calcified lesions were incorrectly classified as obstruction (LCX) (Fig. 5, false positive). Importantly, however, on a patient basis, no patients with significant CAD were missed by MDCTCA. Therefore, the sensitivity and specificity for the detection of > 50% stenosis on a patient basis was 100 and 91%, respectively. In addition, positive and negative predictive values were 91 and 100%, respectively. Table 3 and 4 present an overview of diagnostic accuracy for the detection of > 50% and > 70% coronary stenosis, respectively.

Discussion

The present study demonstrated excellent diagnostic accuracy for the assessment of obstructive CAD using 128-row MDCTCA. On a patient basis, a negative predictive value of 100% and a diagnostic accuracy of 95% were shown for the detection of > 50% and > 70% stenosis. Importantly, no patients with significant CAD were missed using 128-row MDCTCA. Furthermore, the excellent negative predictive value on a segmental, vessel, and patient basis suggests that MDCTCA might be particularly valuable in the exclusion of significant CAD. These results are in line with previous published data on the performance of 64-row CTA(13-16). Although diagnostic accuracy of 128-row MDCTCA may be comparable to the performance of 64-row scanners, advantages of this new technology lie in improved image acquisition compared with retrospectively gated 64-row CTA(7). Clinical progress by the development of MDCT technology beyond 16 slices can more likely be expected from increased temporal resolution, which reduces cardiac motion artifacts and increased spatial resolution rather than from only increase in the volume coverage speed. The limitations of earlier MDCT systems in the assessment of CAD are the consequence of partial volume effects and beam-hardening artifacts, which could be overcome by a higher isotropic spatial resolution. The total scanning time for a 128-row MDCTCA is shortened to approximately six seconds. Accordingly, faster image acquisition allows for a reducing the volume of contrast media and breath-hold time causing reducing respiratory motion artifacts, and making the technique more robust(17-19). Despite promising initial results, the present study has potential limitations. First, because our method of enrollment included some patients who underwent CCA because of MDCTCA results, selection bias in a proportion of patients may have overestimated the calculated sensitivity of CCTA. However, selection bias tends to underestimate specificity, which was still high in our study, and may have had minimal effect on PPV and NPV because patient enrollment after initial MDCTCA was independent of the actual true disease status on CCA. Secondly, the present result is limited by the number of significant stenotic lesions, therefore, the interpretation of sensitivity may be limited. Thirdly, our results represent a single-center experience, the generalizability of the present results is limited. Lastly, as MDCTCA and CCA analysis were performed blinded, differences in segment allocation may have occurred. Although differences in segment classification may have affected the results on a segment basis, the effect on a vessel, and particularly patient, basis may have been negligible.

In conclusion, 128-row MDCT coronary angiography provides a significantly increased spatial and temporal resolution compared with earlier MDCT systems. In a clinical setting, this technique may hold great promise for the reliable diagnosis or exclusion of significant CAD on a per patient basis and could give MDCTCA an important role in the stratification of patients with both known and suspected CAD. The appeal of MDCTCA compared with CCA is that it is noninvasive, avoiding most catheter-associated risks and discomforts with the exception of exposure to iodinated contrast agents and radiation. With rapidly improving technology, MDCTCA may well evolve from a useful complement to CCA to a clinically viable alternative.

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Potential conflicts of interest

None.

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ความแม่นยำในการวินิจฉัยโรคหลอดเลือดหัวใจตีบตันโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 128 สไลซ์

นฤมล เชาว์สุวรรณกิจ, ทรงศักดิ์ เกียรติชูสกุล, ภัทรพงษ์ มกรเวส

วัตถุประสงค์: *เพื่อศึกษาความแม่นยำของการตรวจหลอดเลือดหัวใจตีบตัน โดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 128 สไลซ์ เปรียบเทียบกับการฉีดสารทึบรังสีถ่ายภาพหลอดเลือดหัวใจโดยการสวนหัวใจ*
วัสดุและวิธีการ: *เป็นการศึกษาแบบตัดขวาง มีผู้ป่วย 42 ราย ที่ได้รับการตรวจหลอดเลือดหัวใจด้วยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 128 สไลซ์ และการสวนหัวใจ การประเมินการตีบตันของหลอดเลือดหัวใจทำโดยผู้ประเมิน 2 ราย ที่ไม่ทราบผลการสวนหัวใจ*
ผลการศึกษา: *หลอดเลือด 3 เส้น และ 5 segments ไม่สามารถวินิจฉัยรอยโรคได้ ดังนั้นจึงเหลือหลอดเลือดที่นำมาศึกษา 123 เส้น และ 558 segments จากผู้ป่วย 42 ราย พบว่าเมื่อประเมินหลอดเลือดหัวใจตีบมากกว่าร้อยละ 50 เครื่องเอกซเรย์คอมพิวเตอร์สามารถแสดงรอยโรคได้โดยมี ความไว ความจำเพาะ positive และ negative predictive value จากการประเมินในแง่ผู้ป่วย มีค่าร้อยละ 100, 91, 91, และ 100 ตามลำดับ เมื่อประเมินในแง่ของหลอดเลือด มีค่าร้อยละ 98, 98, 96, และ 99 ตามลำดับ และเมื่อประเมินในแง่ segment มีค่าร้อยละ 98, 99, 94, และ 99 ตามลำดับ ยิ่งไปกว่านั้นเมื่อประเมินหลอดเลือดหัวใจตีบมากกว่าร้อยละ 70 เครื่องเอกซเรย์คอมพิวเตอร์สามารถแสดงรอยโรคได้ผลแม่นยำมากเช่นกัน*
สรุป: *การวินิจฉัยโรคหลอดเลือดหัวใจตีบตันโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 128 สไลซ์ มีความแม่นยำมากทั้งในแง่ผู้ป่วย หลอดเลือดและในแง่ segment*