Assessment of Coronary Artery Stenosis with 16 Slices Multidetector CT

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ABSTRACT

Objective: To investigate the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of noninvasive coronary computer tomography (CT) for assessment of coronary arteries.
Methods: The total of 330 patients who were suspected to have coronary artery disease underwent noninvasive coronary CT angiography. The 26 patients (male 14: female 12) had consecutively undergone a 16 slices multi-detector row CT, as well as invasive coronary angiography, within a 3 months period. The coronary CT angiography was retrospectively reviewed by two radiologists. The degree of coronary stenosis was compared with invasive conventional angiography.
Results: The coronary CT angiography of 306 segments in 26 patients was evaluated. The 306 segments were divided into proximal 155 branches and distal 151 branches. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of coronary CT angiography for coronary artery stenosis were 76.9%, 91.7%, 65.6%, 95.1%, and 89.2% respectively. The sensitivity and specificity of proximal coronary artery stenosis 155 segments were 85.7%, and 90.8%, respectively. The sensitivity and specificity for 151 distal branches were 58.8% and 92.5%, respectively.
Conclusion: Coronary CT angiography using 16 slices multi-detector row CT allows for the reliable detection of coronary artery stenoses with a high diagnostic accuracy.

Keywords: Coronary artery, multidetector CT, cardiac imaging, CT angiography

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Myocardial ischemia and myocardial infarction are leading causes of death in Thailand and worldwide[1] that result from stenosis or occlusion of coronary arteries supplying the myocardium. Clinical diagnosis of coronary arterial disease requires history taking, symptom9s0, sign(s), electrocardiogram and laboratory findings. Computed tomography (CT) has become a clinically important noninvasive diagnostic technique in cardiac gating.[1,2] Accurate imaging is needed for therapeutic planning such as percutaneous coronary intervention and coronary arterial bypass graft.

The gold standard for studying coronary images is conventional coronary angiography by percutaneous catheter insertion with contrast medium injection via femoral or radial arteries passing into the thoracic aorta and placed at the origin of the coronary arteries. The conventional coronary angiography is an invasive technique for coronary imaging that requires experienced medial staff. Complications may occur during the procedure. There is also cardiac magnetic resonance imaging which has many advantages such as non-radiation, non contrast technique, ability to evaluate cardiac function, contractility, perfusion and viability.[2] The disadvantages for magnetic resonance imaging are the high cost of study, it is not available at many hospitals, a long time for examination and cannot visualize calcium.

The current development of multi-detector row CT (MDCT) is becoming available for coronary imaging. It can be done with cardiac triggering and temporal resolution in less than 400 milliseconds. The advantages of MDCT for coronary images are faster study and higher temporal resolution. The imaging quality is enough for analysis of small vessels as well as 1.5 millimeters vessels.[2]

The purpose of this study was to investigate the

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sensitivity, specificity, positive predictive value, negative predictive value and accuracy of noninvasive coronary imaging for assessment of coronary arteries.

MATERIALS AND METHODS

A total of 330 patients who were suspected to have coronary artery disease were investigated by noninvasive coronary CT angiography in Siriraj Hospital from September 2003 to May 2005. This study protocol was approved by the Institution Ethics Committee (Certificate of approval no. Si 216/2005). Twenty six patients (male 14 : female 12) who had consecutively undergone multi-detector row CT, as well as invasive coronary angiography, within 3 months period were retrospectively reviewed. The average time between the two examinations was 33 ± 26 Days (range, 1-90 days), and the mean patient age was 65.3 years (range 42-93 years). Patients who had received coronary artery bypass were excluded from this study. The mean patient heart rate was 63.6 ± 7.4 beats per minute (bpm) (range 52-80 bpm). Patients with cardiac arrhythmia, irregular heart beats, heart beat faster than 80 bpm, or previous coronary artery bypass graft (CABG) were excluded from the study. (The last clause is a repeat of previous statement 4 lines above.) All patients received 100 mg of metoprolol orally 1 hour before the scan if the heart rate was more than 70 bpm.

All CT examinations were performed with a 16 slices multi-detector row CT scanner (Lightspeed CT; GE medical systems). The following scanning protocol was used: 16 X 0.625 mm collimation (simultaneous acquisition of sixteen 0.625 mm-thick sections per rotation); automatically adjusted heart rate according to heart rate; 500 msec rotation time; 120 kV and 440 mA; To calculate the scanning delay, a test bolus of 20 ml of contrast material at a flow rate 4 ml per second was used. The arrival time at the ascending aorta was calculated by measuring the peak CT attenuation at the ascending aorta plus 2 seconds. The contrast injection was 120 ml bolus of nonionic contrast material (350-370 mg of iodine per milliliter) by a single syringe power injector at 300 PSI. The ECG monitoring was simultaneously triggered with the CT scan.

CT scans were performed at the level of the aortic root just below the carina about 1 cm to the bottom of heart. Patients were instructed to briefly hyperventilate 3 times and hold their breath about 20 seconds for scanning. The field of view was as small as possible for the area of the heart.

An algorithm was used to reconstruct the image data.[1] A conventional single-sector algorithm was used when the heart rate was slower than 70 beats per minute. For heart rates of 70 beats per minute or faster, two sectors were used for reconstruction.[2] The image reconstructions were retrospectively performed at 35%, 45%, 55%, 65%, 75% and 85% of the cardiac cycle. The best image quality in these phases was selected for analysis. The reconstructed section thickness was 0.625 mm, and the image increment was 0.625 mm. The image data from each of these reconstructions were transferred to a computer workstation (Advantage workstation; GE medical systems). The three-dimensional volume rendered with curved reformatted post-processing was used for image analysis.

Coronary CT angiography was performed in all patients without complications. The mean scanning time with breath holding was 20 seconds. The mean heart rate was 63.6 ± 7.4 bpm.

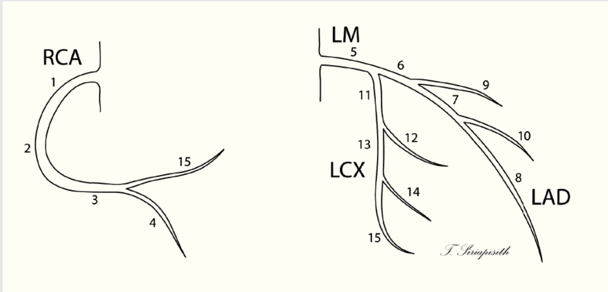

Fig 1. Diagram of coronary anatomy divided into 15 segments according to American heart association (RCA: right coronary artery, LM: left main coronary artery, LAD: left anterior descending artery, LCX: left circumflex coronary artery). (Modified from Kopp AF, et al. Coronary Arteries: Retrospectively ECG-gated Multi-Detector Row CT Angiography with Selective Optimization of the Image Reconstruction Window. Radiology 2001;221:683-8.)

Two reviewers visually assessed the three-dimensional volume rendered and curved reformatted images interactively by consensus on the workstation. The coronary arteries were divided into 15 segments (Fig 1) according to the standard American Heart Association.[3] Each reader assessed segments 1-4 (right coronary artery), segment 5 (left main coronary artery), segments 6-10 (left anterior descending artery), and segments 11-15 (left circumflex artery). The images were descriptively analyzed in 5 aspects, degree of stenosis, amount of calcification, type of plaque and stent. The degree of stenosis was graded into 4 grades: 1 - mild stenosis (<50%); 2 - moderate stenosis (50-74%); 3 - severe stenosis (75-99%); and 4 - occlusion (100%) (Fig 2). The amount of calcification was graded in 3 levels: 1 - mild calcification; 2 - moderate calcification; and 3 - severe calcification. The type of plaque was divided into soft, calcific and mixed plaque.

The conventional angiogram was analyzed by an experienced interventional cardiologist for coronary stenosis in each segment. The degree of stenosis greater than 50% indicates significant stenosis.

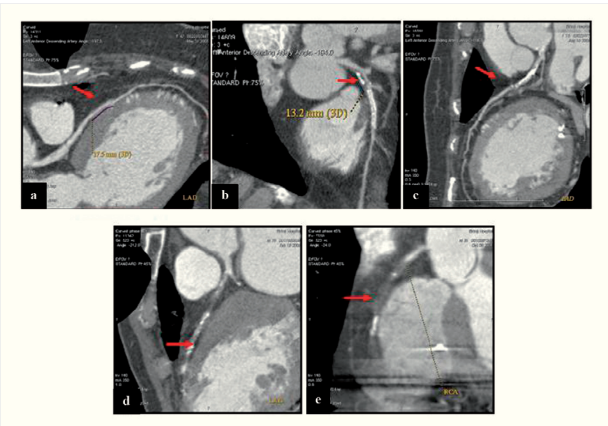

Fig 2. Curved reformatted images of normal and stenosis (arrow) of coronary arteries. a) no stenosis b) grade 1, mild stenosis c) grade 2, moderate stenosis d) grade 3, severe stenosis e) grade 4, occlusion.

TABLE 1. Correlation between coronary CT Angiography and invasive conventional angiogram for 15 segments of coronary arteries. The significant stenosis is greater than 50% stenosis.

Coronary CT Angiography	Invasive conventional angiogram: No significant stenosis	Significant stenosis	Total
No significant stenosis	233	12	245 (80.1%)
Significant stenosis	21	40	61 (19.9%)
Total	254	52	306

We calculated the accuracy, sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) to determine coronary CT angiography for assessing stenosis using conventional coronary artery angiography as the reference standard.

RESULTS

Twenty six patients were included in this study (male 14: female 12), whose age ranged from 42 to 93 years (mean 65.3 ± 14.1 years). The average time between the two studies was about 33 ± 26 days. Twenty four out of 26 patients (92.3%) had coronary CT angiography performed before invasive conventional angiography. The remaining 2 patients had coronary CT angiography performed after invasive conventional angiography.

An interventional cardiologist evaluated the 355 invasive conventional angiogram segments and two radiologists evaluated the 306 coronary CT angiography segments in the 26 patients. Forty nine segments could not be detected by coronary CT angiography which included small branches which were composed of obtuse marginal branch (segment 14) for 22 segments (44.9%), and 2nd diagonal branch (segment 10) for 14 segments (28.6%). The 306 segments were divided into proximal 155 branches and distal 151 branches. The results for both radiologists are listed in the Table 1. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy for coronary artery stenosis were 76.9%, 91.7%, 65.6%, 95.1%, and 89.2% respectively. The sensitivity and specificity of proximal coronary artery stenosis 155 segments were 85.7%, and 90.8%, respectively. The sensitivity and specificity for distal branches were 58.8% and 92.5%, respectively.

Analysis of 33 segments which revealed stent placement had a sensitivity and specificity for stenosis of 80% and 100%, respectively. The remaining 273 non-stent segments revealed a lower sensitivity and specificity 75.7% and 91.1%, respectively.

The plaque found in 63 segments was composed of calcific plaque in 43 segments (68%), mixed plaque in 13 segments (21%) and soft plaque in 7 segments (11%).

TABLE 2. Sensitivity and specificity for diagnosis coronary artery stenosis in different degree of calcification in these segments.

Degree of calcification	Number of segment	Sensitivity	Specificity
No-calcification	198 (64.7%)	58% (11/19)	97% (174/179)
Mild	77 (25.2%)	84% (16/19)	90% (52/58)
Moderate	24 (7.8%)	91% (10/11)	46% (6/13)
Severe	7 (2.3%)	100% (3/3)	25% (1/4)

The degree of calcification interferes with the sensitivity and specificity for diagnosis of coronary artery stenosis. Severe calcification in a coronary segment had the highest sensitivity for coronary artery stenosis 100% (3 of 3 segments). The moderate, mid and no calcification in coronary segments showed sensitivities of 91%, 84%, 58%, respectively. However, the highest specificity for coronary artery stenosis was the non-calcified segment 97% (174 of 179 segments). The mild, moderate and severe calcification in coronary segments showed specificities of 90%, 46% and 25%, respec-tively. (Table 2)

DISCUSSION

Multidector CT has an important role for depiction of morphological and functional analysis of the heart. The 16 slices MDCT is a famous tool for the diagnosis of coronary artery stenosis which has many advantages such as less invasive, less complication, less cost and short study time.

Our study found the sensitivity, specificity, positive predictive value, negative predictive value and accuracy for coronary artery stenosis were 76.9%, 91.7%, 65.6%, 95.1%, and 89.2%, respectively. There is a high negative predictive value of coronary artery stenosis in coronary CT angiography (95.1%) similar to many studies[4,6,11], so most patients refused to undergo invasive conventional coronary angiography. The high negative predictive value was an indicator of the patients excluded from invasive study, if patients had a negative result in the non-invasive study. However, the limitation of coronary CT angiography is marked calcification, motion artifact from inadequate breath holding and some irregular heart rates producing more stenotic lesions or psuedostenotic lesions or non-assessable segments[6,9,10,11] which resulted in a low positive predictive value (65.6%). We recommend that a positive segment should be confirmed by invasive coronary angiography because of the low positive predictive value.

Subgroup analysis of the proximal segment found a higher accuracy (sensitivity, 86%; specificity, 91%) for assessment of coronary stenosis than the distal segment (sensitivity, 77%; specificity, 92%). The results were similar to many studies. Fortunately, the atherosclerosis was likely to involve the proximal segment more than the distal segment, so the overall accuracy was high. The proximal part of the coronary arteries with a diameter of greater than 2 mm raises the diagnosis accuracy greater than for the overall group.[12] and the distal segment was significantly smaller than the proximal segment that may have had a more partial volume averaging effect.

Many investigations analyzed coronary artery stenosis in coronary CT angiography compared with conventional angiography.[4,5,6,7] They found the sensitivity and specificity for diagnosis of coronary artery stenosis ranged from 82-95% and 86-97%, respectively.[8] There are many factors interfering with the image quality of coronary CT angiography[9,10,11] such as betablocker controlled heart rate, nitrate dilated coronary artery, heart rate during CT scan-ning, breath holding, amount of coronary calcification and type of coronary stent that affects the image interpretation of coronary CT angiography. Furthermore, the specific thresholds seem to be useful to raise the diagnostic accuracy of coronary CT angiography.[5]

The most plaque that can be found in coronary arteries was calcific plaque (68%). Subgroup analysis found a higher sensitivity (87.9%) in calcific segments and lower specificity (78.7%) in calcific segments than all groups (sensitivity, 76.9%; specificity, 91.7%), because of the very high attenuation of calcification produced a partial volume averaging effect and blooming artifact. The calcication may lead to overestimation of vascular stenoses.[6,9,10,11] Assessment of the coronary artery lumen on CT is difficult when severely calcified lesions are present.[5] which produces a lower accuracy for coronary stenosis (sensitivity, 100%; specificity, 25%) compared with non-calcified segments (sensitivity, 58%; specificity, 97%). The poor differentiation between contrast-enhanced vessel lumens and high-density calcified plaques may lead to misinterpretation of stenotic lesions and may make some vascular segments unassessable.[5]

Hoffmann et al.[13] found motion-free depiction and accessibility of 97% of coronary artery segments in all patients with a heart rate of less than 80 beats per minute. The patients did not require a beta-blocker to slow the heart rate. The four-detector row CT scanners indicate that patients must have a heart rate of no more than 65 beats per minute to obtain motion-free images.[14] The optimal diagnostic image quality with 16-detector row CT scanners were achievable at heart rates of up to 75 beats per minute.[14] However the maximization of diagnostic image quality with 16-detector row CT scanners did not seem to differ from those with four-detector row scanners

Our limitation in this study was that it was a retrospective study. The population in this study is only 26 patients (all 330 patients had undergone coronary CT angiography but one criteria of the study is the patient in the population who had undergone both coronary CT angiogram and invasive coronary angiogram within 3 months) who had a significant stenosis segment or non-assessable coronary arteries. The patient with negative coronary CT angiography refused further invasive coronary angiography.

CONCLUSION

Coronary CT angiography using 16 slices multidetector row CT allows the reliable detection of coronary artery stenosis with a high diagnostic accuracy in appropriate patients. Moderate and severe coronary calcifications may affect the diagnostic accuracy of coronary CT angiography. The high negative predictive value indicates that coronary CT angiography may be a suitable tool to rule out coronary artery disease.

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