Diagnostic accuracy of 64-slice computed tomography in patients with suspected or proven coronary artery disease

Şüpheli veya kanıtlanmış koroner arter hastalıklı olgularda 64 kesitli bilgisayarlı tomografinin tanısal doğruluğu

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Objectives: Multislice computed tomography (MSCT) is a promising noninvasive method of detecting coronary artery disease. However, most data have been obtained in selected series of patients. The purpose of this study was to investigate the accuracy of 64-slice CT in consecutive patients with suspected or proven coronary artery disease.

Study design: Seventy-three consecutive patients (57 males, 16 females; mean age 59±9 years; range 33 to 83 years) were examined by 64-slice CT before coronary angiography (CA). Eight patients had a history of percutaneous coronary intervention and stenting and five patients had a history of coronary artery bypass grafting. Sensitivity, specificity, and positive (PPV) and negative (NPV) predictive values of MSCT for the detection of significant stenosis were calculated on a segmental, vessel, and patient basis.

Results: Sixty-one patients were diagnosed as having at least one significant stenosis with CA. Of these, MSCT identified 58 patients correctly. Two patients were incorrectly diagnosed as having one-vessel disease by MSCT. Patient-based sensitivity, specificity, NPV, and PPV of MSCT were 95.1%, 83.3%, 76.9%, and 96.7%, respectively. Of 1065 segments evaluated, CA detected 141 significant stenoses. On MSCT, significant stenoses were correctly diagnosed in 116 segments. Twenty-four nonsignificant lesions were overestimated by MSCT. In segment-based analysis, the overall sensitivity was 82.3%, specificity was 97.4%, NPV was 97.3%, and PPV was 82.9%. The accuracy of MSCT was in full agreement with CA in the evaluation of stent and graft patency.

Conclusion: Our findings show that 64-slice CT is highly accurate for the detection of significant coronary artery disease in an unselected patient population and can be used as a noninvasive technique.

Key words: Coronary angiography; coronary artery disease/diagnosis/radiography; coronary stenosis/diagnosis; sensitivity and specificity; tomography, X-ray computed.

Amaç: Çokkesitli bilgisayarlı tomografi (ÇKBT) koroner arter hastalığının saptanmasında gelecek vaat eden, invaziv olmayan bir yöntemdir. Ancak, bilgilerin çoğu seçilmiş hasta serilerinden elde edilmiştir. Bu çalışmada, şüpheli veya kanıtlanmış koroner arter hastalığı bulunan ardışık hasta grubunda 64 kesitli BT'nin tanısal doğruluğu araştırıldı.

Çalışma planı: Çalışmaya, koroner anjiyografiden önce 64 kesitli BT ile incelenen 73 ardışık hasta (57 erkek, 16 kadın; ort. yaş 59±9; dağılım 33-83) alındı. Sekiz hastaya daha önce perkütan koroner girişim ile birlikte stent yerleştirilmiş, beş hastaya ise koroner arter baypas ameliyatı yapılmıştı. Önemli koroner arter darlığının saptanmasında ÇKBT'nin duyarlığı, özgüllüğü, negatif ve pozitif öngörü değerleri segment, damar ve hasta temelinde hesaplandı.

Bulgular: Koroner anjiyografide 61 hastada en az bir damarda önemli darlık saptandı. Bu hastaların 58'inde ÇKBT koroner anjiyografi ile uyumluydu. İki hastada ÇKBT yanlış olarak tek damar hastalığı gösterdi. Hasta temelli değerlendirmede ÇKBT'nin duyarlığı, özgüllüğü, negatif ve pozitif öngörü değerleri sırasıyla %95.1, %83.3, %76.9 ve %96.7 bulundu. Değerlendirilen 1065 segmentin 141'inde koroner anjiyografi ile önemli darlık gösterildi. Bu segmentlerin 116'sında ÇKBT koroner anjiyografi ile uyumluydu; 24 segmentte ise ÇKBT ile yanlışlıkla önemli darlık değerlendirilmesi yapıldı. Segment temelli değerlendirmede ÇKBT'nin duyarlığı, özgüllüğü, negatif ve pozitif öngörü değerleri sırasıyla %82.3, %97.4, %97.3 ve %82.9 bulundu. Stentli ve greftli hastalarda ÇKBT koroner anjiyografi ile tam uyum gösterdi.

Sonuç: Bulgularımız, ÇKBT'nin seçilmemiş koroner arter hastalarında önemli koroner darlığı saptamada yüksek doğruluğa sahip olduğunu ve invaziv olmayan bir yöntem olarak kullanılabileceğini göstermektedir.

Anahtar sözcükler: Koroner anjiyografi; koroner arter hastalığı/tanı/radyografi; koroner darlık/tanı; duyarlık ve özgüllük; bilgisayarlı tomografi.

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Conventional coronary angiography (CCA) is regarded as the standard reference method for the assessment of coronary artery stenosis. However, it is an invasive and expensive procedure with associated morbidity and mortality.[1] Furthermore, approximately 40% to 50% of all coronary angiograms are performed to exclude significant stenosis without the need for an intervention.[2] Therefore, a noninvasive technique for imaging of coronary artery disease is highly desirable.

Noninvasive coronary imaging techniques have undergone rapid developments, but only multislice computed tomography (MSCT) has been found suitable for routine clinical use.[3,4] However, the diagnostic value of 4- and 16-slice computed tomography angiography is still limited and has not achieved the accuracy of CCA. Currently, 64-slice CT angiography offers improved image quality and resolution compared to 4- and 16-slice systems.[5-8]

The aim of this study was to investigate the diagnostic performance of 64-slice CT for assessing significant stenoses of coronary arteries in comparison with CCA.

PATIENTS AND METHODS

Study population. During the period between February 2008 and September 2008, 80 consecutive patients who were scheduled for elective or emergency coronary angiography for suspected coronary artery disease were examined by 64-slice CT coronary angiography within 60 days before the procedure. Exclusion criteria for MSCT examination were the presence of the following: irregular heart rate, known allergic reaction to iodinated contrast material, renal insufficiency (serum creatinine ≥1.5 mg/dl), severe congestive heart failure (NYHA class IV), and inability to follow breath-hold commands. After exclusion of seven patients, 73 patients (57 males, 16 females; mean age 59±9 years; range 33 to 83 years) were found to be eligible for the study. Indications for CCA were atypical chest pain (n=25), stable angina pectoris (n=35), and unstable angina pectoris (n=13). There were eight patients with a history of percutaneous coronary intervention (PCI) and stent implantation and five patients with a history of coronary artery bypass grafting (CABG). All patients gave written informed consent, and the study was approved by the local ethics committee.

One hour before MSCT, patients with a heart rate exceeding 70 beats/min received 100 mg oral metoprolol. If necessary, an additional intravenous dose of 5 mg was administered just before CT examination. Patients with a heart rate above 65 beats/min during acquisition were not excluded. A few minutes before the scan, patients received sublingual isosorbide dinitrate.

MSCT protocol and image reconstruction. All MSCT scans were performed using the Philips Brilliance 64-slice CT system (Philips Medical Systems, Eindhoven, Netherlands) with a pitch of 0.2, tube voltage of 120 kV, and tube current of 1050 mAs. A bolus of 80-100 ml nonionic contrast material (Iomeron 400, Bracco SpA., Milan, Italy) was injected into the antecubital vein at a flow rate of 6 ml/sec, followed by a 50 ml saline chasing bolus. The start delay was automatically defined using the bolus tracing software included on the scanner. The region of interest was placed within the descending aorta and the scan was started when the CT density was 120 Hounsfield units higher than that of the baseline. All data sets were reconstructed using retrospective electrocardiographic-gating at 40%, 75%, and 80% of the RR interval. Raw data were obtained with an effective slice thickness of 0.625 mm. During postprocessing and reconstruction, slice thicknesses of 0.625 mm and 0.9 mm were used. Data sets were transferred to a dedicated workstation (EBW, Philips Medical Systems).

Conventional coronary angiography. Coronary angiograms were obtained according to the standard techniques and multiple views were stored on a CD-ROM. A single observer, unaware of the MSCT findings, identified the coronary segments by using a 17-segment classification system modified from that proposed by the American Heart Association.[9] All segments, regardless of diameter, were included in comparison with MSCT coronary angiography except for those that were not visualized in CCA because of anatomic variation (absence of intermediate branch) or proximal total occlusion. Segments were classified as having nonsignificant stenosis (normal or with wall irregularities or with <50% lumen reduction) or significant stenosis (≥50% lumen reduction). Coronary stenoses were quantified in two orthogonal projections by using a validated algorithm for coronary quantitative analysis (Allura Xper QCA Program, Philips Medical Systems).

Evaluation of MSCT coronary angiography images. All scans were independently analyzed by two observers blinded to the CCA findings. Total calcium score was calculated with dedicated software and expressed as the Agatston score.[10] All available coronary segments were assessed for the presence of significant stenosis. In the axial images, maximum intensity projections were used to identify coronary lesions and multiplanar projections were used to classify stenoses as significant or nonsignificant. Disagreement between observers was resolved by consensus. Image quality was assessed in each segment and classified as good (no motion artifacts or severe calcification), adequate (presence of artifacts degrading the image but allowing evaluation with moderate confidence), or poor (artifacts not allowing proper image evaluation resulting in low diagnostic confidence).

Statistical analysis. The sensitivity, specificity, and positive (PPV) and negative (NPV) predictive values (including 95% confidence intervals) of MSCT for the detection of significant stenosis were calculated on a patient, vessel, and segmental basis. A patient or vessel was classified as positive if the presence of any stenosis was identified correctly by MSCT. Quantitative variables were expressed as mean±standard deviation. The sensitivity, specificity, PPV and NPV for 64-slice CT for detecting significant stenoses in all coronary arteries were calculated with the chi-square test using the contingency tables, and 95% confidence intervals (CI) were calculated with binomial expansion. All statistical analyses were performed using the SPSS software (version 11.5).

RESULTS

The mean interval between MSCT and CCA was 18±18 days (range 1 to 60 days). The mean heart rate was 80±11 bpm. Beta-blocker therapy was administered to 67 patients (91.8%). Patient characteristics are shown in Table 1.

Table 1. Clinical characteristics of the patients

	n	%	Mean±SD
Age (years)			59±9
Sex			
Men	57	78.1	
Women	16	21.9	
Hypertension	56	76.7	
Hypercholesterolemia	60	82.2	
Diabetes	26	35.6	
Smoking	34	46.6	
Previous coronary artery bypass	5	6.9	
Previous coronary angioplasty	8	11.0	
Previous myocardial infarction	2	2.7	
Calcium score (Agatston)			
Mean			230±388
Normal coronary artery			54±61

The mean coronary calcium score was 230±388 Agatston units (range 0-2450). Image quality on a per-segment basis was classified as good in 66 cases (90.4%), moderate in six cases (8.2%), and poor in one case (1.4%).

In the patient-based analysis, 61 patients were diagnosed as having at least one significant stenosis with CCA. Of these, MSCT identified 58 patients correctly (Fig. 1), but failed to show significant stenosis in three patients with single-vessel disease (1 left anterior descending artery, 2 diagonal arteries). Two patients who were found to have noncritical lesions

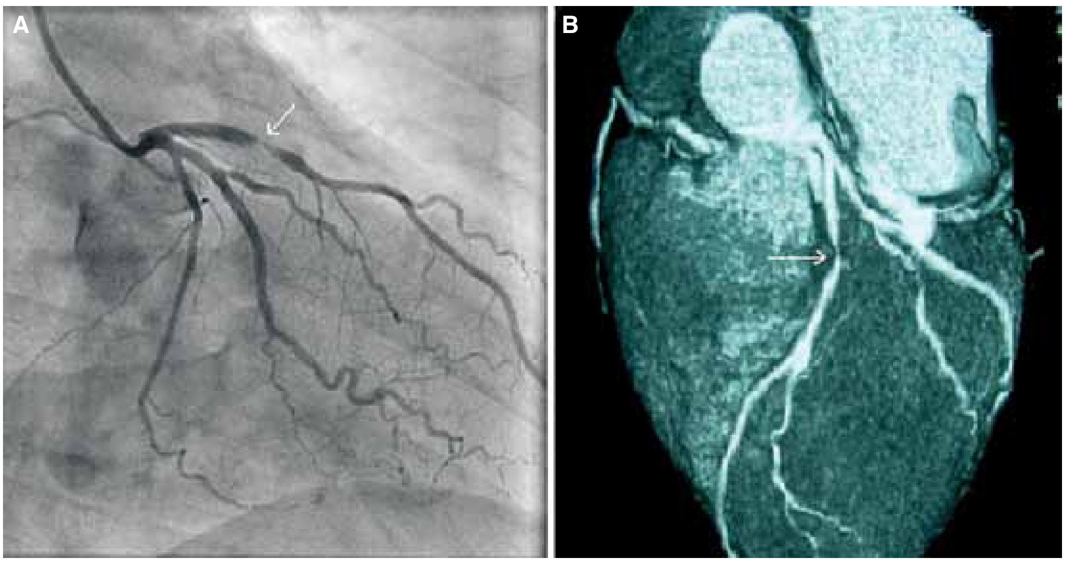

Figure 1. (A) Conventional coronary angiography and **(B)** three-dimensional, volume-rendered 64-slice computed tomography angiography images of a 54-year-old man with unstable angina pectoris, showing a significant stenosis of the left anterior descending coronary artery.

Table 2. Diagnostic accuracy of 64-slice computed tomography

	n	Sensitivity (%, 95% CI)*		Specificity (%, 95% CI)		Positive predictive value (%, 95% CI)		Negative predictive value (%, 95% CI)	
Segment-based	1065	82.3	(74-88)	97.4	(96-98)	82.9	(75-88)	97.3	(96-98)
Left main trunk	72	100.0	(4-100)	100.0	(98-100)	100.0	(4-100)	100.0	(98-100)
Left anterior descending artery	73	91.1	(83-95)	75.0	(62-82)	85.4	(78-89)	84.0	(70-92)
Left circumflex artery	73	65.4	(53-70)	95.7	(88-98)	89.5	(72-96)	83.3	(77-86)
Right coronary artery	73	95.5	(81-99)	86.3	(80-87)	75.0	(64-77)	97.8	(91-99)
Patient-based	73	95.1	(86-98)	83.3	(51-97)	96.7	(88-99)	76.9	(46-94)

*95% confidence intervals calculated with binomial expansion.

in the left anterior descending artery by CCA were incorrectly diagnosed as having one-vessel disease by MSCT. Both patients had low coronary artery calcium scores (4 and 77 Agatston units). The patient-based sensitivity and specificity rates of MSCT to detect significant coronary artery disease were 95.1% and 83.3%, respectively, with NPV of 76.9% and PPV of 96.7%. Sensitivity and specificity rates were 83% and 75% in female patients, and 98% and 85% in male patients, respectively.

Seventeen segments per patient were available for analysis (a total of 1241 segments). Among these, 162 segments were not visualized with CCA and 14 segments (2 distal left anterior descending, 2 left circumflex middle and distal, 6 obtuse marginal, and 4 diagonal arteries) were uninterpretable with MSCT. The left main coronary artery was not visualized by both CCA and MSCT in one patient because of anatomic variation. A total 1065 segments were included for comparison with CCA. Conventional coronary angiography detected 141 significant stenoses, showing 924 segments free of significant stenosis. On MSCT, the presence of significant stenosis was correctly diagnosed in 116 of 141 segments (Fig. 1). The localization of 25 segments that MSCT failed to show significant stenosis were as follows: the left anterior descending artery (n=2), diagonal artery (n=7), left circumflex artery (n=3), obtuse marginal artery (n=8), intermediate artery (n=1), right coronary artery (n=1), posterolateral artery (n=1), and posterodescending artery (n=2). Of these unidentified lesions, one was in the proximal segment, and the remaining 24 were in the middle or distal segments. Twenty-four nonsignificant lesions were overestimated by MSCT, leading to a false positive result. These segments were in the left anterior descending artery (n=8), diagonal artery (n=1), left circumflex artery (n=4), right coronary artery (n=10), and posterior descending artery (n=1). Of these overestimated lesions, 11 were in the proximal segments, and the remaining 13 were in the middle or distal segments. In the segment-based analysis, the overall sensitivity was 82.3%, specificity was 97.4%, NPV was 97.3%, and PPV was 82.9%. The diagnostic accuracy of MSCT for detecting significant lesions by segment, vessel, and patient is shown in Table 2.

In eight patients with a history of PCI and stent implantation (3 left circumflex artery, 3 left anterior descending artery, 2 right coronary artery), six and two segments were correctly identified as patent and occluded by MSCT, respectively.

In five patients with a history of CABG, four left internal mammary artery grafts and 11 saphenous vein grafts were used. Identification of all these grafts was correctly made by MSCT, which showed occlusion in three saphenous vein grafts and patency in the remaining.

DISCUSSION

The standard of reference for diagnosis of coronary artery disease is still CCA, with the advantage of high spatial resolution and temporal resolution. However, it is an invasive and expensive procedure with associated morbidity and mortality. Therefore, a noninvasive technique for imaging of coronary artery disease is highly desirable. The technique of MSCT angiography in cardiac imaging is evolving rapidly. It has become a promising technique with the increase of detector rows from 4-slice to 16-slice and 64-slice scanners.[11-18] Increasing MSCT detector rows enable subsequent improvements in image quality. Other advantages of 64-slice CT include decreased total scan time and lower amounts of contrast media. These improvements facilitate breath-holding and reduce the risk for contrast nephropathy.[19]

In our study of 73 unselected patients, 64-slice CT was able to detect significant coronary artery stenosis on a segmental basis with a sensitivity of 82.3%, specificity of 97.4%, PPV of 82.9%, and NPV of 97.3%. In the segment-based analysis, our findings were similar to those reported by Ong et al.[20] (sensitivity 85%, specificity 98%) and Herzog et al.[21] (sensitivity 82%, specificity 97%). On the other hand, the segment-based sensitivity of 82.3% is still below clinical expectations. This may be explained by the fact that we included all segments for the analysis irrespective of vessel size and only 14 segments with insufficient image quality were excluded. False negative results were obtained in small vessels. The diagnostic accuracy of MSCT in coronary artery disease was lower in the middle and distal artery branches compared to proximal branches. Segment-based sensitivity of 16-slice CT in segments >2 mm vessel size has been reported between 53% and 95%.[15,16] More coronary segments can be assessed with 64-slice CT, with the percentage of assessable segments being higher compared to 16-slice scanners.[15,16]

The diagnostic accuracy of 64-slice CT has been reported by various investigators.[6,7,20-23] Pooled estimates and 95% confidence intervals of patient-based sensitivity, specificity, PPV, and NPV were found as 97% (94%-99%), 88% (79% and 97%), 94% (91%-97%), and 95% (90%-99%), respectively.[24] Our findings on the patient-based assessment were similar with the exception of a lower NPV because two patients (left anterior descending artery lesions) with noncritical lesions on CCA were incorrectly diagnosed as having one-vessel disease. In one of these patients, MSCT showed a severe distal lesion in the left anterior descending artery. A review on published studies on the accuracy parameters of MSCT reported that low coronary artery calcium scores were associated with higher sensitivity and NPV versus high coronary artery calcium scores (sensitivity and NPV: 92% and 99% *vs*. 77% and 89%, respectively).[24] The Agatston score appears to be much higher in our patient population.

Multislice computed tomography is a convenient diagnostic tool for triage of patients with acute coronary syndrome (ACS) in the emergency department. Sato et al.[25] showed that MSCT could identify ACS with sensitivity and specificity of 95.5% and 88.9%, respectively. The number of patients with unstable angina pectoris was low in our study, but MSCT showed a false negative result in a patient with unstable angina pectoris. We observed that all false positive results of MSCT were obtained in patients with atypical chest pain. Our results suggest that the sensitivity of MSCT seems to increase as true incidence of significant disease increases.

Overall, there is considerable heterogeneity in the patient population of our study, in that we included patients who had undergone PCI or CABG. The sensitivity and NPV of MSCT in examining coronary artery bypass grafts and intracoronary stents were reported as 97% and 97% for graft occlusion or stenosis, and 71% and 93% for in-stent restenosis, respectively.[24] In our study, PCI- or CABG-based analyses of MSCT showed very high diagnostic accuracy (100% for both sensitivity and NPV).

In conclusion, 64-slice CT is highly sensitive for patient-based analysis and has a high NPV for segment-based detection of coronary artery disease. Ability to rule out significant coronary artery disease means that MSCT may have a role in the assessment of chest pain, particularly when the diagnosis remains uncertain despite clinical evaluation and simple non-invasive testing.

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