

The Role of Coronary Computed Tomography Angiography in Detecting Coronary Artery Stenosis

Koroner Arter Darlıklarının Saptanmasında Koroner Bilgisayarlı Tomografi Anjiyografinin Rolü

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Öz

Bu çalışmanın amacı koroner arter darlıklarının saptanmasında minimal invaziv bir görüntüleme yöntemi olan Koroner Bilgisayarlı Tomografi Anjiyografi'nin rolünü değerlendirmektir. Çalışma Mayıs 2005 ve Kasım 2007 tarihleri arasında Ondokuz Mayıs Üniversitesi Hastanesinde Anjina pectoris, stent kontrolü, koroner arter hastalığı şüphesi olan hem Konvansiyonel Koroner Anjiyografi hem de Koroner Bilgisayarlı Tomografi Anjiyografi yapılmış 66 hastanın koroner arter segmentleri darlık yönünden retrospektif değerlendirmeye alındı. Koroner Bilgisayarlı Tomografi Anjiyografi ile koroner arter segmentleri American Heart Association sınıflaması kullanılarak proksimal, orta ve distal gruplara ayrıldı. Darlık düzeyleri hafif (%1-49), anlamlı (%50-74), ileri (%75-99) ve oklüzyon (%100) sınıflaması ile değerlendirildi. Elde edilen veriler Konvansiyonel Koroner Anjiyografi sonuçları ile retrospektif olarak karşılaştırıldı. Bu verilere göre tüm gruplarda Koroner Bilgisayarlı Tomografi Anjiyografi'nin duyarlılığı %87, özgüllüğü %97 olarak hesaplanmıştır. Proksimal segmentlerdeki aterosklerotik değişiklikler özgüllüğün azalması, distal segmentlerin değerlendirilmesindeki güçlük ise duyarlılığın azalması olarak yansımıştır. Bu bulgularla; koroner arter darlıklarının saptanmasında, yapılan çalışmalarda desteklemekte ki Koroner Bilgisayarlı Tomografi Anjiyografi, gelişen teknoloji ile birlikte, endüstriyel toplumlarda yaygınlığı hızla artan koroner arter hastalıkları tanısında ve risk altındaki asemptomatik hastaların taranmasında alternatif bir yöntem olmaya adaydır.

Anahtar Kelimeler: Darlık, Konvansiyonel Koroner Anjiyografi, Koroner Bilgisayarlı Tomografi Anjiyografi

Abstract

The aim of this study is to evaluate the role of Coronary Computed Tomography Angiography, a minimally invasive imaging method, in detecting coronary artery stenosis. This study retrospectively analyzed the coronary artery segments of 66 patients who underwent both Conventional Coronary Angiography and Coronary Computed Tomography Angiography at Ondokuz Mayıs University Hospital between May 2005 and November 2007. These patients were referred with indications such as angina pectoris, stent evaluation, or suspected coronary artery disease. Coronary artery segments were categorized into proximal, mid, and distal groups using the classification system defined by the American Heart Association. The degree of stenosis was evaluated based on the following classification: mild (1–49%), significant (50–74%), advanced (75–99%), and total occlusion (100%). The data obtained from Coronary Computed Tomography Angiography were retrospectively compared with the findings from Conventional Coronary Angiography. According to these findings, the sensitivity and specificity of Coronary Computed Tomography Angiography across all groups were calculated as 87% and 97%, respectively. Atherosclerotic changes in proximal segments led to a decrease in specificity, while difficulties in assessing distal segments resulted in reduced sensitivity. These results demonstrate that Coronary Computed Tomography Angiography, as supported by the literature, is a promising alternative method for detecting coronary artery stenosis. With advancements in technology, it is poised to become an effective tool for diagnosing coronary artery disease, which is rapidly increasing in prevalence in industrialized societies, and for screening asymptomatic patients who are at risk.

Keywords: Stenosis, Conventional Coronary Angiography, Coronary Computed Tomography Angiography

Introduction

Coronary artery disease (CAD) is primarily caused by the narrowing of coronary arteries due to atherosclerotic changes (1,2). Atherosclerotic diseases and their thrombotic complications are currently among the leading causes of morbidity and mortality worldwide (3). The most reliable method for anatomically detecting atherosclerotic disease in coronary arteries, as well as for planning and implementing treatment strategies, is conventional

coronary angiography (CCA), which remains the gold standard (4). However, despite advancements in catheter techniques, CCA is associated with certain risks and complications. Moreover, it has been reported that coronary artery pathology is not detected in 25% of patients undergoing CCA and that 66% of angiographic examinations are performed solely to determine the degree of coronary atherosclerotic disease (5,6).

In recent years, there has been an increasing focus on alternative diagnostic methods for CAD that are less invasive, more cost-effective, and lower risk. These methods include magnetic resonance imaging (MRI), intravascular ultrasound, electron beam tomography (EBT), and multislice computed tomography (MSCT), with ongoing research in these fields (7). Advances in computed tomography technology have enabled imaging of very small vessels, facilitating the evaluation of coronary vascular structures (7-10). Technological advancements in scanners have demonstrated that

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coronary computed tomography angiography (CCTA), when performed under optimal conditions in patients with low heart rates, can detect coronary artery pathologies with high sensitivity (9). Recent studies have indicated that CCTA is more sensitive in detecting stenosis in proximal segments than in distal segments (9,11,12), with reported sensitivity and specificity of 83% and 97%, respectively, for stenoses exceeding 50% (13). As a cross-sectional imaging method, CCTA allows evaluation of both the vessel lumen and wall. It provides valuable information on the normal anatomical course of coronary arteries through axial and 3D imaging techniques (14).

The aim of this study is to investigate the diagnostic accuracy of CCTA in detecting coronary artery stenosis.

Material and Method

Since May 2005, the Department of Radiology at 19 Mayıs University Faculty of Medicine has been conducting coronary CT angiography using internationally recognized technical standards. Within a period of 2.5 years, all patients meeting the established inclusion criteria have been incorporated into the study. Between May 2005 and November 2007, 66 patients (48 males, 18 females, mean age: 58 years) who underwent both CCA and CCTA at Ondokuz Mayıs University Faculty of Medicine Hospital for various reasons (e.g., angina pectoris, stent evaluation, suspected coronary artery disease) were retrospectively included in the study. Exclusion criteria were renal failure (creatinine >1.5 mg/dL), unstable angina pectoris, acute myocardial infarction, pregnancy, hyperthyroidism, epilepsy, advanced heart failure, and a history of contrast agent allergy. Patients unable to hold their breath for approximately 15 seconds, those with arrhythmia, or those with heart rates above 70 beats per minute despite pre-procedure β -blocker administration were also excluded.

A total of 64 stented coronary artery segments from 34 patients who had undergone percutaneous transluminal coronary angioplasty (PTCA) were excluded from the evaluation. Written informed consent was obtained from all patients after providing detailed information about the procedure. Patients without contraindications were administered oral β -blockers (50 mg metoprolol tartrate) 60 minutes before the procedure or intravenous β -blockers (5–10 mg metoprolol tartrate) diluted to half-strength at 5-minute intervals up to a maximum dose of 20 mg under the supervision of a cardiologist to achieve an optimal heart rate. Patients already on β -blocker therapy were advised to continue their medication before the scan.

Before the scan, patients were instructed on how to cooperate during the procedure to enhance

compliance and reduce scan time, including relaxation techniques and breath-holding exercises. Patients were positioned supine in the gantry, and electrocardiography (ECG) electrodes were attached to record baseline readings. An 18–20 gauge cannula was placed in the antecubital vein. A scout scan (120 kV, 50 mAs) was obtained to define the scan boundaries. The patency of the intravenous line was confirmed by injecting 30 mL of saline prior to the scan.

The scan was performed during a single breath-hold, from the carina to the cardiac base, using a 16-detector CT scanner (Aquilion; Toshiba Medical Systems, Tokyo, Japan). A total of 100 mL of nonionic contrast agent (iopromide, iohexol, or iomeprol) was injected as a bolus at a rate of 4–5 mL/sec, followed by 40 mL of saline at the same rate using an automatic injector. A fixed delay technique was used to determine the scan start time, with acquisitions beginning 18–20 seconds after contrast administration.

The imaging parameters were as follows: tube voltage, 120–135 kV; tube current, 350 mAs; collimation, 16×0.5 mm or 16×1 mm; rotation time, 500 ms; table speed, 4 mm/rotation; pitch, 0.25–0.5; field of view (FOV), 32 cm; and reconstruction interval, 1 mm. Retrospective ECG gating was used for image reconstruction.

From the acquired data, preliminary reconstructions of the proximal coronary arteries were performed using a 5% increment between 35–85% of the cardiac cycle to identify the least motion-affected phase. The best-quality images were then used for complete reconstruction and transferred to a secondary workstation (Vitrea; Toshiba Medical Systems, Tokyo, Japan). Evaluations were performed using axial views, maximum intensity projection (MIP), multiplanar reformations (MPR), and volume rendering technique (VRT).

The coronary arteries were evaluated in three groups—proximal, mid, and distal—based on the American Heart Association (AHA) classification. The analysis included 15 segments: the proximal group consisted of the proximal right coronary artery (RCA), left main coronary artery (LMCA), proximal left anterior descending artery (LAD), and proximal left circumflex artery (LCx); the mid group included the mid RCA, mid LAD, mid LCx, diagonal branches 1–2, and obtuse marginal branches 1–2; and the distal group included the distal RCA, distal LAD, distal LCx, and posterior descending artery.

The CCTA images of 66 successfully scanned patients were evaluated for coronary artery stenosis by two radiologists experienced in CCTA, blinded to the CCA findings. The CCTA results were retrospectively compared with CCA findings to determine sensitivity, specificity, positive predictive value, and negative predictive value.

Results

No complications were observed in any of the patients included in the study who underwent CCTA. Eleven patients with heart rates below 70 bpm were not administered β -blockers, while eight patients, already on oral β -blockers prescribed by their cardiologists, adjusted their medication timing before the procedure. Intravenous β -blockers were administered under cardiologist supervision to 32 patients during the examination. Five patients experienced transient side effects, such as weakness and dizziness, related to β -blockers, but no further complications were noted during follow-up. Fifteen patients with heart rates exceeding 70 bpm were successfully managed with oral β -blockers before the procedure.

The average duration of the coronary CCTA examination was approximately 15 minutes (minimum 10 minutes, maximum 20 minutes). Retrospective ECG gating was completed in 10 minutes at the first workstation, while reconstruction and reformations were performed at the second workstation within an average of 30 minutes.

In the study group of 66 patients, the stenosis rates in proximal, mid, and distal coronary artery

segments were compared with those detected by CCA. Coronary artery segments were classified as follows: normal; mild stenosis (1–49%); significant stenosis (50–74%); advanced stenosis (75–99%); and total occlusion (100%). A total of 793 coronary artery segments were analyzed, with 111 segments exhibiting stenosis of varying degrees and levels identified by CCA. Of these, 87% (n=97, true positive results) were consistent with findings from CCTA.

In total, 119 segments with stenosis were reported by CCTA. Both CCA and CCTA identified no stenosis in 660 segments (true negative results). In 22 segments, stenosis was reported by CCTA but not confirmed by CCA (false positive results), with 15 of these segments belonging to the proximal group. Conversely, stenosis was reported in 14 patients by CCA but was not detected by CCTA (false negative results).

The true positive, true negative, false positive, and false negative results for each group and all segments, along with the sensitivity, specificity, positive predictive value, and negative predictive value of CCTA, are summarized in Table 1 and Table 2.

Table 1. Diagnostic Performance of Coronary Computed Tomography Angiography

Group	TP	TN	FP	FN	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
All Groups	97	660	22	14	87	97	82	98
Proximal	49	169	15	2	96	92	77	99
Mid	43	246	5	3	93	98	90	99
Distal	5	245	2	9	36	99	71	96
All Groups (Stenosis $\geq$ 50%)	59	721	3	10	86	99	95	99

TP: True Positive, TN: True Negative, FP: False Positive, FN: False Negative, PPV: Positive Predictive Value, NPV: Negative Predictive Value.

Table 2. Diagnostic Performance of Coronary Computed Tomography Angiography for All Groups

All Groups		Conventional Angiography		Total
		Stenosis (+)	Stenosis (-)	
Coronary CT Angiography	Stenosis (+)	97	22	119
	Stenosis (-)	14	660	674
	Total	111	682	793

In the proximal group, a total of 235 segments were evaluated (Table 3). The statistical analysis showed 49 true positive results, 169 true negative results, 2 false negative results, and 15 false positive results. Among the two stenoses undetected by CCTA in the proximal group, they were described as atherosclerotic changes. Of the 15 stenoses identified by CCTA but not detected by CCA, two were located at the orifice level, likely due to over-advancement of the catheter during CCA. The remaining 13 stenoses were classified as mild due to the presence of small atherosclerotic plaques, which

were more frequently reported during the early stages of our experience.

Table 3. Diagnostic Performance of Coronary Computed Tomography Angiography for Proximal Group

Proximal		Conventional Angiography		Total
		Stenosis (+)	Stenosis (-)	
Coronary CT Angiography	Stenosis (+)	49	15	64
	Stenosis (-)	2	169	171
	Total	51	184	235

In the mid and distal groups, a total of 598 segments were evaluated, with 48 true positive results, 491 true negative results, 12 false negative results, and 7 false positive results recorded (Table 4).

Table 4. Diagnostic Performance of Coronary Computed Tomography Angiography for Mid-Distal Group

Coronary CT Angiography	Mid	Conventional Angiography		Total
		Stenosis (+)	Stenosis (-)	
	Stenosis (+)	43	5	48
	Stenosis (-)	3	246	249
	Total	46	251	297
	Distal			
	Stenosis (+)	5	2	7
	Stenosis (-)	9	245	254
	Total	14	247	261

In the mid and distal groups, a total of 598 segments were evaluated, with 48 true positive results, 491 true negative results, 12 false negative results, and 7 false positive results recorded (Table 4). Of the 12 stenoses undetected by CCTA, 9 belonged to the distal group. As noted in the literature, this limitation of CCTA in distal segments is primarily due to motion artifacts and insufficient contrast enhancement.

Statistical data for detecting stenoses of 50% or greater severity across all groups were also calculated (Table 5). For stenoses of 50% or greater, CCTA yielded 59 true positive results, 728 true negative results, 10 false negative results, and 3 false positive results. Of the 10 undetected stenoses, 2 were in the mid group and 8 in the distal group.

Table 5. Diagnostic Performance of Coronary Computed Tomography Angiography for Mid-Distal Group

Distal Group		Conventional Angiography		Total
All Groups (Stenosis $\geq$ 50%)		Stenosis (+)	Stenosis (-)	
Coronary CT Angiography	Stenosis (+)	59	3	62
	Stenosis (-)	10	724	731
	Total	69	724	793

Additionally, during the study, myocardial bridging in the mid segment of the left anterior descending (LAD) artery was identified in three patients via CCTA, two of which had been previously reported in CCA findings.

Discussion

According to the 1999 World Health Organization data, cardiovascular diseases (CVDs) accounted for only 10% of global deaths at the beginning of the 20th century. However, by 2020, CVDs were projected to become the leading cause of morbidity and mortality worldwide (3,15). The annual mortality rate from CAD is 5.1% in men and 3.3% in women (16). Although CCA remains the gold standard for visualizing coronary arteries, it is

an invasive procedure requiring hospitalization and may cause minor damage to the vascular wall. Nevertheless, it provides high spatial resolution for coronary artery imaging and plays a crucial role in treatment through additional interventional procedures. However, its invasiveness, inability to provide information about the morphological structure of stenotic plaques, high cost, and rare but potentially fatal complications drive the search for non-invasive and more cost-effective imaging methods (17).

Recent advancements in MSCT technology have led to significant progress in CT angiography. Reducing gantry rotation time and enabling thinner slices (less than 1 mm) allow the creation of high-resolution angiographic images of larger anatomical areas along the Z-axis. The ability to select submillimeter reconstruction intervals increases spatial resolution and provides higher-quality images (18,19).

In studies using 4-detector MSCT for detecting coronary artery stenosis, only coronary segments larger than 2 mm were evaluated, and the diagnostic accuracy was found to be moderate (8,10,20). Due to insufficient image quality, only 68% of coronary arteries could be evaluated with 4-detector MSCT (21,22). Subsequently, 16-detector MSCT systems with improved image quality were introduced. Nieman et al. (9), in a study of patients with suspected CAD, reported a sensitivity of 95% and specificity of 86% for detecting stenosis greater than 50% in coronary segments larger than 2 mm using 16-detector MSCT. Similarly, Ropers et al. (23) found sensitivity and specificity of 93% and 86%, respectively, for stenosis greater than 50% in coronary segments larger than 1.5 mm. In a more recent study, evaluating all segments with a diameter greater than 1.5 mm and stenosis greater than 50%, sensitivity was 86% and specificity was 98% (24).

In studies evaluating all coronary segments regardless of diameter, MSCT showed a sensitivity of 37% and specificity of 99% for detecting stenosis greater than 70%. When segments with technical limitations such as severe calcification, high heart rate, or respiratory artifacts were excluded, sensitivity increased to 66% and specificity to 98% (25). Another study reported sensitivity of 59% and specificity of 87% for detecting stenosis greater than 50% without diameter restrictions (26).

In our study, without diameter restrictions, the sensitivity for detecting stenosis was 96% in proximal segments, 93% in mid segments, and 36% in distal segments, while specificity was 92%, 98%, and 99%, respectively. Positive predictive values were 77%, 90%, and 71%, and negative predictive values were 99%, 99%, and 96%, respectively. Additionally, the sensitivity and specificity of coronary CTA for detecting stenosis greater than 50% across all coronary artery segments were found to be 86% and 99%, respectively.

The lower specificity in the proximal and mid groups compared to the distal group was attributed to an increased rate of false positives caused by atherosclerotic changes at the proximal level. Conversely, the lower sensitivity in the distal group was due to the difficulty in evaluating distal segments, resulting in a higher rate of false negatives, while the low rate of false positives contributed to the higher specificity.

The success of coronary CTA in detecting coronary artery stenosis varies depending on the location of the stenosis. Larger, proximal arteries with less motion artifact are easier to evaluate for stenosis or normal lumen and wall structures (20,22). In our study, distal coronary artery segments had lower sensitivity (36%) and high specificity (99%) for stenosis detection. Of the 12 stenoses undetected by coronary CTA, 9 belonged to the distal group, reflecting limitations of coronary CTA in distal segments due to motion artifacts and inadequate contrast filling, as noted in the literature. Further advancements in detector technology and clinical studies are needed to improve imaging quality in distal coronary artery segments.

The sensitivity of coronary CTA for significant stenosis depends on vessel diameter, ranging between 65% and 95%. Proximal stenoses are easier to detect compared to those in distal or smaller arteries. Coronary CTA is a non-invasive imaging method that can be used to rule out CAD in asymptomatic or high-risk patients (11).

One of the major limitations of CCTA performed with 16-slice MSCT is that the temporal resolution can only be reduced to 105–210 milliseconds. Consequently, it is challenging to obtain high-quality images in patients with heart rates exceeding 75 beats per minute. In our study, we advised patients to avoid factors that could increase their heart rates before the procedure, and β -blockers were administered to those with no contraindications when their heart rates exceeded 75 bpm. Another limitation of CCTA is that coronary arteries cannot always be successfully visualized in all patients undergoing the procedure. Factors such as poor patient compliance, cardiac and respiratory motion, severe coronary calcifications, ECG irregularities, and early or delayed contrast timing may result in suboptimal image quality. In our study, while image quality was sufficient for non-distal segments, the limitations in distal segments were reflected in our sensitivity and specificity results, representing a constraint of the study. Additionally, the limitation caused by severe calcifications increased the number of false-positive results in proximal segments.

The dataset in our study was obtained using a 16-slice MSCT during the late 2000s. The concluding statement of our thesis, which predicted that "with the increase in the number of detectors (32, 64, 128), successful imaging will be possible even in non-cooperative patients and those with heart rates

exceeding 70 bpm, and the increased Z-axis resolution will enable better evaluation of distal segments," has since been validated by time. Since the late 2000s, significant advancements in technology have resulted in the development of faster and more efficient CT scanners, such as 640-slice dynamic volume CT scanners, third-generation dual-source CT (DSCT) scanners, and spectral CT. These innovations have significantly reduced radiation exposure, contrast requirements, and patient wait times for CCTA while improving image quality and diagnostic accuracy.

As technology continues to evolve, further improvements in CT scanner capabilities are anticipated. In the near future, CCTA is expected to become a comprehensive, non-invasive tool for both anatomical and functional evaluation of CAD. This evolution will strengthen its role as the preferred diagnostic and prognostic tool for CAD, reducing the need for additional stress testing or invasive procedures. Furthermore, the integration of anatomical, functional, and perfusion data with artificial intelligence-based computer-aided diagnostic systems is expected to surpass the current practice of assessing only coronary artery anatomy. Significant strides have already been made in reducing radiation exposure and enhancing the cost-effectiveness of CCTA. These developments indicate that CCTA will continue to solidify its role as a more effective diagnostic modality for CAD in the future (27,28).

Conclusion

In this study, the role of CCTA as a minimally invasive method for detecting coronary artery stenosis was retrospectively compared with CCA findings, and the following conclusions were drawn:

CCTA is a fast, easily applicable, and minimally invasive imaging method. Using reconstructions and reformations obtained without the need for additional contrast agents or radiation, the heart and coronary vessels can be examined from various angles and planes.

According to the AHA classification, CCTA demonstrates high sensitivity and specificity in detecting stenoses in proximal and mid-coronary artery segments.

Motion artifacts and insufficient contrast filling are the primary limitations of CCTA, particularly in distal coronary artery segments.

The acquisition and interpretation of CCTA images are operator-dependent, with diagnostic accuracy improving alongside increasing operator experience.

In conclusion, the diagnostic accuracy of CCTA primarily depends on the number of detectors in the CT scanner, proper post-processing data, and patient compliance (cooperation and heart rate). As supported by previous studies, CCTA, with

advancing technology, is emerging as a promising alternative for diagnosing CAD, which is rapidly increasing in prevalence in industrialized societies, and for screening asymptomatic patients at risk.

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None

Conflict of interest statement

The authors declare that they have no conflicts of interest regarding this study.

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