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Research Article

Coronary computed tomographic angiography findings in diabetic patients: A tertiary clinic findings

Diyabetli hastalarda koroner bilgisayarlı tomografi anjiyografi bulguları: Üçüncü basamak klinik bulguları

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Abstract

Aim: The aim of this study is to identify different types of plaques in diabetic patients suspected of coronary atherosclerosis using coronary computed tomography angiography (CCTA) and assess the extent of coronary artery disease (CAD).

Material and Methods: Data from 252 diabetic patients who underwent CCTA were reviewed retrospectively. The mean age of the patients was 60 ± 10 years, and all underwent MSCT angiography. Plaque types were categorized into three groups: calcified, soft, and mixed. Statistical analyses were performed using SPSS v. 15.0 software.

Results: Of the 252 diabetic patients, 137 (54.4%) were male and 115 (45.6%) were female. CCTA detected stenosis ≥30% in 40 patients (15%). Calcified plaques (38%) and soft plaques (40%) were observed most frequently in the proximal LAD. CCTA results showed high sensitivity and specificity when compared to invasive angiography.

Conclusion: While invasive coronary angiography is considered the gold standard, coronary CTA is a reliable and non-invasive method for evaluating atherosclerosis in diabetic patients. Its high negative predictive value may be effective in ruling out bypass graft stenosis and can reduce the need for invasive procedures, minimizing patient risk.

Keywords: Diabet, plaque, angiography

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Öz

Amaç: Bu çalışmanın amacı, koroner ateroskleroz şüphesiyle değerlendirilen diyabetik hastalarda, koroner bilgisayarlı tomografi anjiyografi (CCTA) kullanarak farklı plak tiplerini tanımlamak ve koroner arter hastalığının (KAH) kapsamını değerlendirmektir.

Gereç ve Yöntemler: CCTA uygulanan 252 diyabetik hastanın verileri retrospektif olarak incelendi. Hastalara CT anjiyografi uygulandı. Plak tipleri, kalsifiye, yumuşak ve miks olmak üzere üç gruba ayrıldı. İstatistiksel analizler SPSS v. 15.0 yazılımı ile yapıldı.

Bulgular: Toplamda 252 diyabetik hastanın 137'si (%54,4) erkek, 115'i (%45,6) kadındır. CCTA, %30 ve üzeri darlık bulunan 40 hastada %15 oranında stenoz bulguları tespit etti. En çok kalsifiye (%38) ve yumuşak plaklar (%40) proximal LAD'de gözlemlendi. Koroner anjiyografi sonuçları ile CCTA'nın bulguları karşılaştırıldığında, CCTA'nın tespit ettiği progresyonlar arasında yüksek bir duyarlılık ve özgüllük olduğu görüldü.

Sonuçlar: İnvaziv koroner anjiyografi altın standart olarak kabul edilse de , koroner CCTA, diyabetik hastalarda aterosklerozun değerlendirilmesi için güvenilir ve non-invaziv bir yöntemdir. CCTA'nın yüksek negatif prediktif değeri, bypass greft stenozunu dışlamakta etkili olabilir ve invazif prosedür gereksinimini azaltarak hasta riskini minimize edebilir.

Anahtar kelimeler: Diyabet, plak, anjiografi

Introduction

Coronary atherosclerosis is recognized as a leading cause of morbidity and mortality in industrialized countries. Diabetes is one of the well-known risk factors for the development of coronary artery disease (CAD) (1). Myocardial infarction occurs at an earlier age and is more recurrent in diabetic patients (2). Between 65-75% of patients with type 2 diabetes succumb to cardiovascular disease (3). The mortality rate of a diabetic patient who experiences an acute coronary event is >50% compared to a non-diabetic patient (4).

Silent ischemia is commonly observed in diabetic patients; the lack of symptoms leads to delayed diagnosis and makes it difficult to detect ischemia (5). Additionally, coronary disease in diabetic patients is more diffuse and has more distal localization, complicating revascularization (6).

Furthermore, diabetes worsens the prognosis in both the early and late stages of acute coronary syndrome. The presence of diabetes increases the risk of myocardial infarction, complications, and mortality during hospitalization (7). Compared to non-diabetic patients, the success rate of coronary interventions is lower in diabetic patients (8). Understanding the plaque characteristics seen in diabetic and non-diabetic patients and guiding risk factor modification is crucial in the approach to coronary artery disease (9).

Coronary computed tomography angiography (CCTA) is a valid imaging method for evaluating known or hidden coronary artery disease (10). Thus, CCTA can be useful in investigating the risks of asymptomatic diabetic individuals.

Our study aimed to identify the different types of plaques in diabetic patients who are either suspected of having coronary atherosclerosis, have undergone bypass surgery, or have received stents. Additionally, we sought to assess the extent of coronary artery disease in these patients using CCTA.

Material and Methods

The data of 252 diabetic patients who underwent coronary computed tomography angiography (CCTA) at Hacettepe University Faculty of Medicine, Department of Radiology, between April 2007 and January 2008, due to suspected coronary artery disease (CAD) or suspicion of progression of previously diagnosed CAD, were retrospectively reviewed. The study protocol was approved by the local ethics committee of Hacettepe University Faculty of Medicine (Ethics Committee No: 2010-10/38). All patients underwent coronary MSCT angiography. The angiography reports of 64 patients who had also undergone invasive coronary angiography were retrospectively reviewed and compared with the CCTA results. Inclusion criteria were adult individuals (age ≥ 18 years) diagnosed with diabetes mellitus, those who underwent CCTA for the evaluation of suspected CAD or for follow-up of previously diagnosed CAD, individuals with a history of coronary artery bypass graft surgery or stent placement. Exclusion criteria included patients with a documented severe allergy to iodinated contrast agents, those with renal insufficiency (glomerular filtration rate < 60 mL/min/1.73 m^2) that precluded the use of contrast media, pregnant women due to potential radiation risks, patients with non-diabetic etiology of atherosclerosis" method bölümüne eklendi (satır numarası 191).

All cardiac CT examinations were performed using a dual-source 64-slice CT scanner (SOMATOM Definition, Siemens

Medical Solutions, Forchheim, Germany). The gantry rotation time was 330 ms, the slice and detector thickness were 0.6 mm, the reconstruction interval was 0.6 mm, and the detector configuration was 2x32x0.6 mm. The pitch was automatically adjusted by the device according to the heart rate. An 18-20 gauge intravenous line was inserted into the patients before the examination, and their heart rates and rhythms were monitored using an ECG. Following the acquisition of a scanogram, a section passing through the level of the aortic root was obtained, and the bolus tracking method (CARE Bolus, Siemens Medical Solutions, Forchheim, Germany) was used by placing the region of interest (ROI) in the aortic root. Through an intravenous route, 100 ml of non-ionic contrast agent was administered at a rate of 5-6 ml/sec using an automatic injector (Ulrich, Germany). Data acquisition commenced when the ROI reached a density of 100 HU. Routine coronary CT angiography involved scanning from the level of the carina to the diaphragm in coronary CT angiography patients, and from the thoracic inlet to the diaphragm in examinations conducted for bypass assessment. Retrospective ECG-gated algorithms optimized for MSCT were used for raw data reconstruction. All coronary CT angiography examinations were completed without complications.

Coronary and bypass CT angiography examinations were conducted using 3-D software on a LEONARDO (Siemens) workstation. Each lesion was identified using multi-planar reconstruction (MPR) techniques and maximum intensity projection (MIP) in the transverse and axial planes.

Plaques were defined as structures larger than 1 mm in or adjacent to the vessel lumen, easily distinguishable from the lumen and surrounding pericardial structures. Atherosclerotic plaques were categorized into three groups: calcified, soft, and mixed.

The degree of coronary artery stenosis was classified as normal (0-29%), mild (30-49%), moderate (50% and above), and severe. A reduction in vessel diameter of more than 50% was considered significant stenosis. Vessel occlusion was defined as the complete interruption of luminal passage visible by contrast enhancement.

Statistical Analysis

In our study, qualitative data were described using numbers and percentages. For continuous numerical data, mean and standard deviation (mean ± SD) were used to describe normally distributed continuous variables, while median and interquartile range (IQR 25 and 75) were used for variables that did not follow a normal distribution. Normality was assessed using the Kolmogorov-Smirnov test. For values given as mean and standard deviation, either the independent samples t-test or one-way analysis of variance (ANOVA) was used, depending on the number of groups being compared. For values given as medians, the Mann-Whitney U test or Kruskal-Wallis test was used. For the analysis of categorical data, the chi-square test was employed, and Fisher's exact chi-square test was used when necessary, depending on sample size. Linear relationships among all variables measured continuously were examined. Pearson correlation coefficients were used for normally distributed variables, and Spearman correlation coefficients were used for non-normally distributed variables. The correlation coefficient was denoted by 'r,' and the significance value was denoted by 'p.' The data were analyzed using the SPSS v. 15.0 software package.

Results

Of the 252 diabetic patients included in our study, 137 (54.4%) were male and 115 (45.6%) were female. The patients' ages ranged from 28 to 86 years, with a mean age of 60 ± 10 years. There were 67 patients (26.6%) with bypass surgery, 26 patients (10.3%) with stents, and 8 patients (3.2%) with both stents and bypass surgery. A total of 151 patients had neither bypass nor stents. All patients underwent CTA. Among these, 30 of the patients without bypass or stents, 19 with bypass, and 12 with stents underwent invasive angiography (Figure 1 and 2). In 40 (15%) of the 252 diabetic patients, at least 30% stenosis was detected in 1 coronary artery; in 32 (12.7%) patients, stenosis was detected in 2 arteries; in 34 (13.5%) patients, in 3 arteries; in 12 (4.8%) patients, in 4 arteries; and in 1 (4%) patient, in 5 coronary arteries. In 133 (52.8%) patients, stenosis was found to be less than 30% (Table 1).

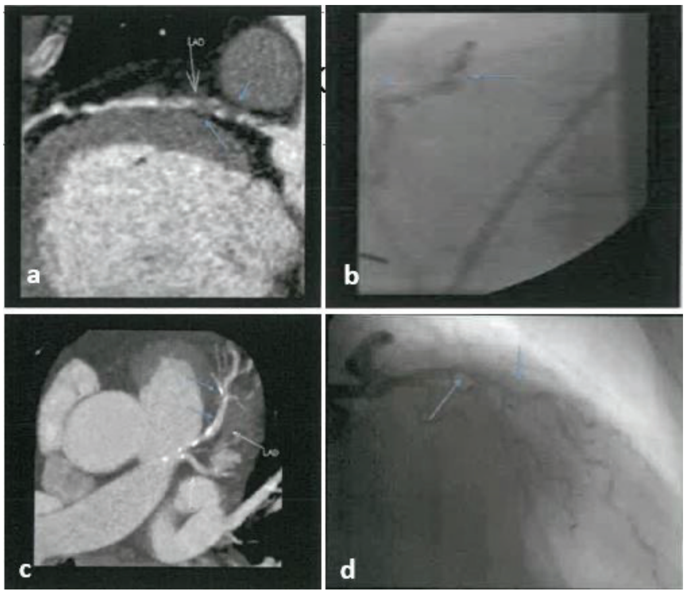

Figure 1. (a). The appearance of soft plaques observed in the proximal LAD on CT coronal images is shown. **(b)** The angiographic appearance of the stenosis caused by soft plaques in the LAD of the same patient is demonstrated. **(c)** Mixed type plaques are observed in MIP images in the LAD. **(d)** The appearance of stenosis caused by mixed-type plaques in the same patient on invasive angiography is demonstrated.

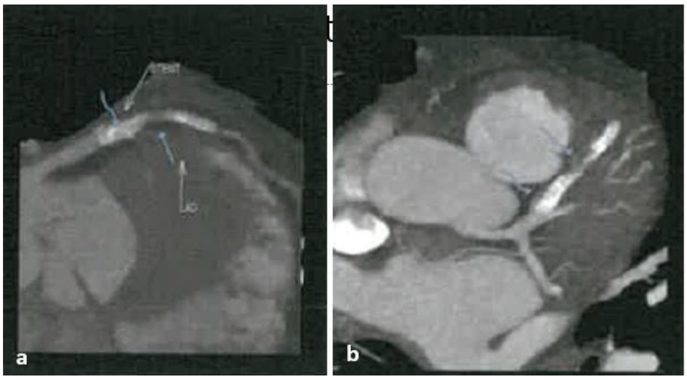

Figure 2. (a). There is soft plaque and intimal hyperplasia in the proximal stent (curved arrow). Dense atheroma plaques and critical stenosis are observed between the two stents.**(b)** The MIP reformat image of the same patient is shown. In MIP images, two stents placed in the LAD are observed. There is soft plaque and intimal hyperplasia in the proximal stent (curved arrow). On the appearance of dense atheroma plaques and critical stenosis between two stents (solid arrow)

Table 1. Important demographic characteristics of patients	
Female	115 (%‹45.6)
Male	137 (%54.4)
Age (year)	60+10
HDL (mg/dl)	49+13
LDL (mg/d1)	109+40
TG (mg/d1)	182+42
VKI (kg/m2)	28+4.9
BMI: Body mean index,HDL: High density lipoprotein, LDL: Low density lipoprotein, TG: Trigliserit	

Among the 151 patients without bypass or stents who were suspected of having coronary artery disease, coronary CTA revealed atherosclerosis in 91 patients, while 60 patients were evaluated as normal. Invasive angiography was performed in 30 of these 91 patients to determine treatment protocols. Of these patients, 6 had mild stenosis on CTA, and mild stenosis was confirmed in 4 patients on invasive angiography. Among the 6 patients with moderate stenosis on CTA, 5 were found to have moderate stenosis on invasive angiography. Advanced stenosis was confirmed in 12 of the 16 patients with more than 50% stenosis on CTA. Nine patients were evaluated as normal on invasive angiography.

Invasive angiography confirmed normal coronary arteries in 3 of the 60 patients with normal CTA results. The distribution of plaque types in different regions for the 91 diabetic patients with atherosclerosis, out of the 151 patients without bypass or stents (Table 2). In these 91 patients, the number of calcified plaques was 115 (38%), soft plaques were 124 (40%), and mixed plaques were 68 (22%). Calcified and soft plaques were most frequently observed in the proximal LAD, while mixed plaques were most frequently observed in the mid-LAD.

Invasive angiography was performed on 19 patients with bypass surgery. In 11 patients whose bypass vessels were open on coronary CTA, the invasive angiography results were also normal. In 6 patients with occlusion in one bypass vessel on CTA, invasive angiography confirmed the occlusion in 5 patients, while the stenosed graft could not be demonstrated in one patient. In 2 patients with occlusion in two bypass vessels on CTA, invasive angiography confirmed the occlusion in both bypass vessels.

Of the 26 patients with stents, the stents were optimally evaluated on coronary CTA in 24 patients. Among these, 20 patients (77%) had normal findings on CTA, 2 patients (7%) had intimal hyperplasia, 1 patient (4%) had mild stenosis, and 1 patient (4%) had moderate stenosis. Invasive coronary angiography was performed on 12 of the 26 patients with stents following coronary CTA. The sensitivity and specificity of coronary CTA in detecting stenosis were found to be 80% and 100%, respectively (Table 3).

Discussion

Conventional coronary angiography remains the gold standard for evaluating coronary artery disease (CAD). However, increasing evidence suggests that coronary angiography has inherent limitations as it only visualizes the lumen (10). These limitations are primarily due to coronary artery remodeling and diffuse coronary atherosclerosis (11).

Coronary CTA, on the other hand, can visualize both the lumen and the vessel wall, allowing for the diagnosis of early atherosclerotic disease before stenosis occurs. Due to anatomical changes, the difficulty in catheterizing grafts reduces the success of invasive angiography in evaluating bypass grafts. Coronary CTA, unaffected by these anatomical changes, provides a high sensitivity and specificity in evaluation (12-15).

In the study by Weustink et al., 52 patients with symptoms post-bypass surgery underwent CTA followed by invasive coronary angiography, with CTA showing a 100% accuracy in detecting or ruling out significant stenosis in arterial and venous grafts (16). Nieman et al. evaluated 24 patients with bypass surgery using MDCT and demonstrated high sensitivity and specificity for detecting graft stenosis. Sensitivity and specificity were 100% and 96% for venous graft occlusion, 100% and 85.7% for venous graft stenosis, and 100% and 100% for arterial graft stenosis, respectively (17).

Table 2. Distribution of plaque types by region in 91 diabetic patients with suspected coronary artery disease and atherosclerosis

	Calsific		Soft		Mix		Total	
	number	%	number	%	number	%	number	%
LM	15	9.7	4	2.6	5	3.2	24	15,5
LAD proximal	22	14.2	24	15.5	12	7.7	58	35.4
LAD middle	14	9	23	14.8	14	9	51	37.4
LAD distal	9	5.8	5	3.2	6	3.9	20	12.9
Diagonal	9	5.8	7	4.5	4	2.6	20	12.9
RCA proximal	11	7.1	8	5.2	6	3.9	25	16.2
RCA middle	10	6.5	12	7.7	8	5.2	30	19,4
RCA distal	7	4.5	8	5.2	4	2.6	19	12.3
circumflex proximal	9	5.8	13	8.4	2	1.3	24	15.5
circumflex middle	8	5.2	14	9	4	2.6	26	16.8
circumflex distal	1	0.6	6	3.9	3	1.9	10	6.4
Total	115	74.2	124	80	68	43.9	307	

LAD: Left anterior descending artery, RCA: Right coronary artery

Table 3. Distribution of plaques according to regions and degrees of stenosis in 26 patients with stents

	Mild		Moderate		Severe		Normal	
	number	%	number	%	number	°Z»	number	°Z»
LM	4	14.3	0	0	0	0	24	85.7
LAD proximal	7	25	2	7.1	3	10.7	16	57.1
LAD middle	4	14.3	3	10.7	6	21.4	15	53.6
LAD distal	4	14.3	1	3.6	4	14.3	19	67.9
Diagonal	4	14.3	1	3.6	1	3.6	22	78.6
RCA proximal	I	3.6	3	10.7	4	14.3	20	71.4
RCA middle	1	3.6	3	10.7	3	10.7	21	75
RCA distal	1	3.6	3	10.7	0	0	24	85.7
circumflex proximal	7	25	2	7.1	3	10.7	16	57.1
circumflex middle	2	7.1	0	0	4	14.3	22	78.6
circumflex distal	I	3.6	0	0	1	3.6	26	92.9

LAD: Left anterior descending artery, RCA: Right coronary artery

In a study by Ropers et al. evaluating a total of 182 grafts in 65 patients, similar to Nieman et al.'s results, graft occlusion was detected with 97% sensitivity and 98% specificity (18). In our study, all patients with bypass surgery who had normal findings on coronary CTA were confirmed to have normal findings on invasive angiography.

In a study by Mollet et al. involving diabetic patients with stable coronary artery disease, 24% of the patients had soft plaques, and 65% had calcified plaques on MDCT. Soft plaques, mostly non-obstructive, were observed in asymptomatic individuals, whereas calcified plaques were more common in symptomatic patients (19). Raggi et al. found that soft plaques were associated with the rate of cardiac events in a study involving 903 asymptomatic diabetic patients (20). In our study, the rates of calcified, soft, and mixed plaques were found to be 38%, 40%, and 22%, respectively.

In the study by Das et al., coronary CTA was performed after invasive coronary angiography on 53 patients with stents, correctly identifying restenosis in 91% of 107 stents (21). In a study by Libague et al. involving 47 patients with a total of 72 coronary lesions, coronary CTA and invasive angiography findings were compared post-stent placement. They concluded that MDCT more easily demonstrated stent lumens and stent kinks compared to invasive angiography (22). In our study, the stents in 24 of the 26 patients with stents were optimally evaluated by coronary CTA. Of these patients, 20 (77%) had normal findings on CTA, while 2 patients (7%) had intimal hyperplasia, 1 patient (4%) had mild stenosis, and 1 patient (4%) had moderate stenosis. Invasive coronary angiography was performed on 12 of the 26 patients with stents following coronary CTA. The sensitivity and specificity of coronary CTA in detecting stenosis were found to be 80% and 100%, respectively.

The 2016 guidelines from the Society of Cardiovascular Computed Tomography (SCCT) and the North American Society for Cardiovascular Imaging (NASCI) affirm that coronary CTA is a reliable, non-invasive diagnostic tool for assessing coronary artery disease. It provides high diagnostic accuracy for evaluating both acute and stable chest pain syndromes (23).

In our study, we offer a detailed characterization of plaque types (calcified, soft, and mixed) in diabetic patients, highlighting the importance of early detection of non-calcified and mixed plaques which can precede acute coronary syndromes . Unlike existing literature that predominantly emphasizes calcified plaques, our findings bring attention to the considerable presence of soft and mixed plaques, thereby providing a novel viewpoint in this area. Secondly, we demonstrate that CTA is a reliable method with a high negative predictive value, making it a safer alternative to invasive coronary angiography, especially beneficial for diabetic patients who are at high risk. Moreover, The comparison of CTA with invasive angiography in our study underscores the high sensitivity and specificity of CTA in detecting stenotic lesions, supporting its use in clinical practice to reduce the necessity for invasive procedures and thus minimizing patient risk (24).

This study's retrospective design may introduce selection bias, limiting the applicability of the findings to the broader diabetic population. Conducted at a single center, it may lack sufficient diversity, and the reliance on contrast-enhanced imaging poses risks for patients with renal impairment. Additionally, the study did not evaluate the long-term outcomes of plaque types identified by CCTA, indicating a need for future multicenter, prospective studies to address these limitations.

Although invasive coronary angiography is still considered the gold standard for evaluating graft patency and stenosis, it is an invasive procedure with potential complications such as arrhythmia, graft dissection, myocardial infarction, and embolism. Studies comparing 64-slice CT and invasive coronary angiography for evaluating coronary graft patency and stenosis have shown that 64-slice CT is a reliable and less invasive method than coronary angiography (25-27).

Conclusion

While invasive coronary angiography remains the gold standard for evaluating coronary artery disease, it is an invasive method. Coronary CTA is a reliable method for evaluating stent lumens. Coronary CTA is a non-invasive, reliable method that can be used to evaluate diabetic patients with suspected atherosclerosis, stents, and bypass grafts. It has a high negative predictive value for assessing stent patency. We believe that CTA is also useful in ruling out bypass graft stenosis in patients.

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Conflict of interest

The authors declare that they have no conflict of interest.

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval obtained from a local commitee.The ethics committee waived the need for consent because it was a retrospective study

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