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Evaluation of Atherosclerotic Plaque, Coronary Stent and Coronary By-Pass Grafts with 128-Slice CT and Technical Optimization: Our Single Center Experiences

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ABSTRACT

The purpose of this study was to evaluate the native coronary artery (CA), coronary atherosclerotic plaque, coronary by-pass grafts and coronary stents with 128-slice CT, comparison of findings with literature and technical optimization. In one hundred fifty patients who had undergone coronary computerized tomography angiography using 128-slice CT (CCTA), CAs were examined in terms of visibility, atherosclerotic plaque characteristics, by-pass graft and stent patency. In each case, CAs were divided into fifteen segments according to the American Heart Association (AHA) classification and then evaluated. Out of one hundred and fifty (150) cases, 2250 CA segments were examined according to AHA classification. A total of 1045 segments below 2 mm were examined for visibility. Fifty segments could not be visualized. Soft plaques were observed in 97 cases (4 cases with calcium load = 0). Atherosclerotic plaques were observed in 450 segments. By-pass grafts were observed in ten cases while 28 stents were observed in fifteen cases. In cases with by-pass graft, artifacts due to clips did not hinder the examination. In conjunction with technological advances, CAs can be non-invasively examined using new generation multi-dimensional computerized tomography. Clips artifacts in coronary stents and by-pass grafts do not hinder CA examination due to high spatial and temporal resolution of MDCT devices.

Key words: *Coronary by-pass graft, coronary stent, coronary vessels,128-slice computed tomography*

Aterosklerotik Plak, Koroner Stent ve Koroner By-Pass Greftlerin 128 Sıralı BT Ile Değerlendirilmesi ve Teknik Optimizasyon: Tek Merkezli Tecrübemiz

ÖZET

Bu çalışmanın amacı native koroner arter, koroner aterosklerotik plak, koroner by-pass greft ve koroner stentleri 128 sıralı BT ile değerlendirmek, sonuçları literatur verileri ile karşılaştırmak ve teknik optimizasyondur. 150 hastanın koroner arterleri tespit edilebilirlik, aterosklerotik plak karakterizasyonu, by-pass greft ve stent patensisi açısından 128 sıralı BT kullanılarak değerlendirildi. Her vakada koroner arterler AHA (American Heart Association) sınıflandırması temel alınarak 15 segmente ayrıldı ve değerlendirildi. AHA sınıflandırmasına gore 150 vakanın, 2250 koroner arter segmenti değerlendirildi. 2 mm nin altındaki 1045 segment tespit edilebilirlik için değerlendirildi. 50 segment visualize edilemedi. 97 vakada yumuşak plak gözlendi (4 vakada calsiyum skoru=0). 450 segmentte aterosklerotik plak gözlendi. 10 vakada by-pass grefti, 15 vakada 28 stent gözlendi. By-pass greftli vakalarda klipslere bağlı artefaktlar değerlendirmeyi etkilemedi. Teknolojik gelişmeler sayesinde koroner arterler çok dedektörlü bilgisayarlı tomografiler kullanılarak non-invaziv şekilde değerlendirilebilmektedir. Çok dedektörlü bilgisayarlı tomografilerle sağlanan yüksek uzaysal ve temporal rezolüsyon sayesinde koroner stentlerin ve by-pass greftlerin klips artefaktları görüntülerde artefakta neden olmamaktadır.

Key words: *Koroner by-passgreft, koroner stent, koroner damarlar, 128 sıralı bilgisayarlı tomografi*

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INTRODUCTION

Coronary catheter angiography (CCA) is the gold standard in the examination of CAs, by-pass grafts and stents (1). However, since CCA is an invasive method and it carries some risks, non-invasive and reliable imaging methods have started to emerge. Currently, anatomy, variation, anomaly, atherosclerotic stenosis, plaque characterization, by-pass graft, patency of CAs and main vasculature can be imaged in detail using new generation MDCT devices (64 slices and more), which can simultaneously acquire multiple images. Technologies enabling the examination of CA using MDCT include the following: increase in temporal and spatial resolution, fast gantry rotation, thin slice thickness and ability to create new reformatted images using raw images. The most important technical parameter is the increased temporal resolution that enables performance of CCTA by reducing cardiac and respiratory artifacts. There are many studies conducted with MDCT, which has MDCT with a varying number of detectors to examine CA pathologies. However, based on our knowledge, there is no study in the literature conducted with 128-slice CT, which simultaneously evaluates multiple parameters of CA, such as visibility, stenosis, atherosclerotic plaque characteristic, by-pass graft and stent patency (1-3). Here, we aimed to compare our findings, obtained by assessing CA pathologies with 128-slice CT, with the literature and to ensure technical optimization.

MATERIALS AND METHODS

In our study, a 128-slice CT device (Definition AS, Siemens Medical Solutions, Forchheim, Germany) was used. CCTA examinations were retrospectively evaluated. Ethics committee approval was obtained for the study.

Patient Selection

Patients referring for CCTA examination had complaints such as atypical angina, rapid exhaustion and a feeling of pressure on the chest. The study group was comprised of one hundred and fifty patients who had no by-pass graft or stent and who had coronary by-pass graft and stent. Age of patients ranged between 31 years and 80 years (mean age 53.7 +/-10.5) and 82 patients (69.9 %) were male, while 68 (30.1%) were female; mean heart rate ranged between 50 and 92 beats per minute (mean heart rate 67.73+/-8.99 beats/minute). Patients with following contraindications to CCTA were excluded from the study; known contrast allergy, renal dysfunction (serum creatinine > 1.5 mg/dl), pregnancy, difficulty in breathing, overall compromised health status, hyperthyroidism, epilepsy and conditions contraindicated for use of beta-blockers (left ventricular ejection fraction below 30 percent, history of bronchial asthma, Raynaud Syndrome, atrioventricular conduction block). All patients were informed before the procedure and consent was obtained.

Preparation of Patient

Before the imaging, all patients were reminded to fast for at least six hours in order to prevent vomiting and possible complications due to vomiting and to continue to receive regular, necessary medication. Each patient executed respiration exercises in order to ensure regular and rhythmic breathing (holding the breath for a mean 10 seconds), to relax patients and to increase adaptation to the procedure before the imaging was performed. Patients who failed to hold their breath and patients with arrhythmia were excluded from the study. Blood pressure and pulse rates of patients were recorded. Patients with a heart rate over 80 beats per minute were given oral ß-blocker (50 mg propranolol). Care was taken to ensure that patients already receiving ß-blocker received the prescribed dose before the imaging was performed. All patients had sinus rhythm, and pulse checks were performed at fifteen minute intervals. Venous line was opened using 20G cannula from the antecubital vein in the right upper extremity. After the heart rate of patients was reduced to below 80 beats per minute, they were made to lie in supine position on gantry. They were informed that depending on the bolus contrast agent to be administered, heat starting from the arm on the same side and diffusing to the whole body, and feeling the need to urinate might occur and that those signs are normal such that they should not have concerns about these signs and thus, efforts were made to avoid sudden anxiety with resultant increase in pulse and occurrence of arrhythmia. All patients were told that total immobility throughout the procedure and following the command of “hold your breath” would increase the quality and reliability of the examination. Moreover, all patients were administered vasodilator nitrate via sublingual route 2 minutes before the examination in order to dilate CA and thus obtain better visualization.

Table 1. *Origin of the by-pass graft patients, and graft patency.*

Patient	*LIMA/LAD*	*SAFEN-1/ RCA*	*SAFEN-2*	*RADIAL/OM1*
1	*LAD -Occlusion*	*RCA- Subocclusion*		
2	*LAD-Patent*	*RCA-Patent*	*OM1-Patent*	
3	*LAD-Patent*	*RCA- Occlusion*	*D2-Patent*	
4	*LAD-Patent*	*RCA- Subocclusion*	*OM1-occlusion*	
5	*LAD -Occlusion*	*RCA-Mid stenosis*	*LAD-Patent*	
6	*RCA-Mild stenosis*			
7	*LAD -Occlusion*	*OM2-Patent*		
8	*LAD-Patent*			*OM1-Patent*

LIMA: left internal mammarian artery; LAD: left anterior descending; RCA: right coronary artery, OM1: obtuse marginal artery; OM2: obtuse marginal artery

Calcium Scoring

Non-contrast imaging was performed in all patients in order to determine pre-CCTA calcium load of CAs (Calcium scoring= CACS). Imaging of calcium scoring was performed during inspirium by obtaining 3 mm thick helical images, of which 40 % were synchronized with R-R intervals recorded in (electrocardiography) ECG, starting from the post-scenogram carina, covering the carina and basal section of the heart to the basis of the heart. Calcium load was automatically estimated by the device using specifically produced programs by marking the calcified fields. According to Agatston scoring, lesions with CT density over 130 Hounsfield units (HU) in adjacent 2-3 pixels (an area larger than 1 mm^2) were regarded as calcification (2-3).

Imaging Protocol

Following calcium scoring, retrospective ECG-recorded helical images, covering the whole heart starting from the carina to the basal portion of the heart, were obtained during inspirium. Although the examination length may vary among patients, it was ended after a mean period of five heartbeats. Considering examinations performed for evaluation of by-pass, cranio-caudal sections from the entrance of the thorax to the level of the diaphragm were obtained depending on the operation and clinical features. A high iodine concentration (≥350 mg/mL) containing mean 64 ml contrast agent was administered using an automatic injector at rate of 5 ml/s. Following intravenous administration of the contrast agent, 40 ml saline was administered as bolus at a rate of 5 ml/s in order to reduce possible artifacts arising from the contrast agent in the right chamber of the heart and to include contrast agent in unused dead spaces (line, antecubital vein and right heart). For administration of contrast agent and saline, a two-way automatic injector (Stellant, Medrad, Indianola, USA) was used. Technical parameters of the device were as follows: during the examination, ECG-controlled tube flow modulation was used; gantry rotation time was 300 ms; collimation 0.6 mm, kV 120; mAs automatically estimated by the device was 180–200; and field of view (FOV) ranged between mean 19 and 22 cm. In the device used, the detector had 64 sequential 0.6 mm elements and an independent 128 data collection channel and could also generate 128 x 0.33 mm isotropic resolution. In addition to this, the pitch value was automatically adjusted by the device with reference to heart rate. For the imaging, the 'bolus tracking' method was used. For the bolus tracking method, although it may vary among patients, any value ranging between 120 and 150 HU was determined as ROI (Region of Interest), which was inserted into the center of the ascending aorta, with reference to the heart rate monitored in ECG, and this triggering value (Imaging procedure starting value) was used. In conjunction with contrast agent and saline infusion, sections were obtained at this level at one-second intervals. When the triggering value was reached, imaging was performed with a latency period of 5-7 seconds.

Assessing and Interpreting Images

Throughout the imaging period, heart rate and ECG trace recording was retrospectively performed. Resultant images were transferred to the Workstation (Leonardo, Siemens Medical Solutions, Forchheim, Germany) and analyzed. Reconstruction images with least movement in percentage were created in order to evaluate CAs.

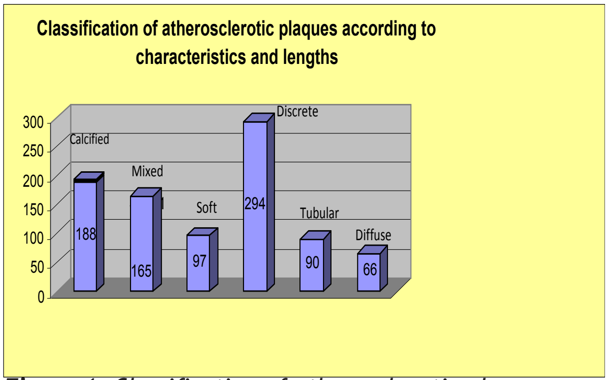

Figure 1*. Classification of atherosclerotic plaques according to characteristics and lengths.*

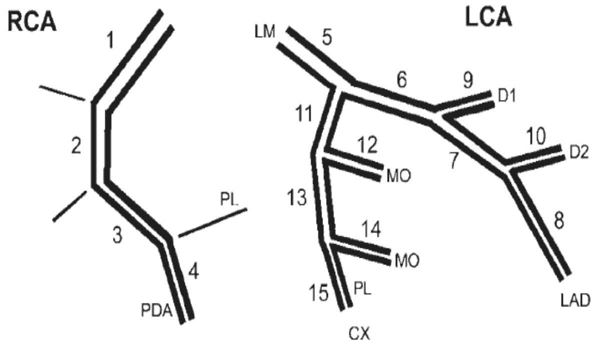

Figure 2*. According to the AHA classification of coronary arteries divided into 15 segments.*

Later, images in the format of two-dimensional maximum intensity projection (MIP), multiplanar reconstruction (MPR) and three-dimensional volume rendering format were generated using thin axial slices. In MPR and MIP images, vascular lumen, vessel wall, heart chambers and stenoses were evaluated in three dimensions.

In our study, reconstruction percents largely corresponding to 35-40 % for right coronary artery (RCA) and to 70 % for left main coronary artery (LAD) and circumflex artery (CAx) were used. All images were evaluated by two radiologists experienced in the field of cardiovascular radiology. CAs were examined over a total of 15 segments according to AHA classification (4). According to American Heart Association (AHA) classification: RCA is comprised of segments 1-4, the left main coronary artery and LAD are comprised of segments 5-10 and Cx is comprised of segments 11-15 (Figure 2). In our study, segmental anatomic and pathological names of CAs were determined according to AHA classification. CAs over two millimeters can be demonstrated with an accuracy of 70-90% in examinations performed using 4-MDCT and 16-MDCT (5). In our study, CAs below 2 mm were, therefore, assessed in terms of visibility. Obstructions over 50 % in lumen diameter of stenotic segment were interpreted as obstructive CAD with reference to stenotic lumen diameter proximal to the stenotic arterial segment. The resultant CA stenoses were divided into 4 groups; normal, non-obstructive (1–49%), significant stenosis (50–74%), high grade stenosis (75–99%) and occlusion (100%). Plaques were referred to as the following: calcified, soft and mixed according to the morphology; discrete plaque (<10 mm), tubular plaque (10-20 m), diffuse plaque (>20 mm) according to length; soft (no calcification, 0-130 HU), mixed (calcification present [<130] and also contains soft component) and calcified plaque (>130 HU) according to the presence of calcification (6-7).

Statistical analysis

Statistical analysis of the study was performed using SPSS version 15.0 software package. Continuous variables were expressed as arithmetical mean ± standard deviation, while categorical variables were expressed as percentages (%).

RESULTS

Visibility of CAs

According to AHA classification, a total of 2250 (150 x 15) segments were evaluated, including 15 coronary arterial segments for each patient. A total of 1205 (53.6%) segments were below 2 mm with reference to visibility, 1045 segments (46.4 %) below 2 mm were assessed; 940 segments (90%) were well visible, 55 segments (5.2%) were poorly visible and 50 segments (4.8%) could not be visualized. Distribution of non-visible segments was as follows; 16 were in segment 2, 18 were in segment 3, 10 were in segment 13 and 6 were in segment 11.

Findings of calcium scoring

CACS were observed to be 0 in 52 cases, between 1 and 10 in 45 cases, between 11 and 100 in 35 cases, and between 101 and 400 in 18 cases.

Character, length, stenosis and segmental distribution of coronary atherosclerotic plaques

In ninety-two out of one hundred cases (61.3%), atherosclerotic plaque was observed in 450 segments. Atherosclerotic plaques were classified according to character, length and the resultant stenosis. The following plaques were observed: 188 (41.8%) calcified, 165 (36.7%) mixed and 97 (21.5%) soft plaques according to the characteristics of the atherosclerotic plaques; 294 (65.3%) discrete, 90 (20%) tubular and 66 (14.7%) diffuse plaques, according to length were observed (Figure 1). Of ninety-two cases with atherosclerotic plaque, mild stenosis was observed in 18 cases (19.6%), mild-moderate in 26 cases (28.3%), advanced in 19 cases (20.7%) and occlusion was observed in two cases (2.2%). In two cases with occlusion, there was a history of previous by-pass operation; the procedure was performed in proximal segment of RCA in the first case, and in first diagonal (D1) branch in the second case. Distribution of atherosclerotic plaques by segments was as follows: 78 (17.3%) in segment 6, 52 (11.6%) in segment 1, 51 (11.3%) in segment 7, 48 (10.7%) in segment 2, 35 (7.8%) in segment 5, 32 (7.1%) in segment 11, 38 (8.4%) in segment 8, 24 (5.3%) in segment 9, 20 (4.4%) in segment 3, 25 (5.5%) in segment 13, 13 (2.9%) in segment 12, 12 (2.7%) in segment 10, 7 (1.6%) in segment 4, 8 (1.8%) in segment 14 and 7 (1.6%) in ramus intermedius (Figure 2).

Evaluation of By-Pass Grafts

By-pass grafts were observed in a total of eight cases (6.7 %), including 3 grafts in each of three cases, two grafts in each of 4 cases and one graft in each of three cases. By-pass grafts were comprised of two groups, including one with arterial origin and one with venous origin. There were 8 arterial by-pass grafts and 12 venous by-pass grafts. Considering arterial by-pass, left internal mammarian artery (LIMA) was used in 7 cases and radial artery in 1 case. In arterial by-pass grafts, LIMA was anastomosed to LAD (LIMA-LAD) in 7 cases and the radial artery was anastomosed to obtuse marginal artery (OM1) (Radial-OM1) in one case (Table 1). Saphenous vein was used as venous by-pass graft. Saphenous vein was anastomosed to LAD (saphenous-LAD) in three cases, to second diagonal artery (D2) (saphenous-D2;) in 1 case, to OM1 (saphenous-OM1) in 2 cases, to OM2 (saphenous-OM2) in 2 cases and to RCA (saphenous-RCA) in 4 cases. Of the arterial by-pass grafts, 3 were occluded and 5 were patent, and of venous by-pass grafts, 2 were occluded, 2 were sub-occluded, 6 were patent and 2 were mildly and moderately stenotic at anastomosis level. Grafts used in eight cases with by-pass graft.

Evaluation of Stents

Among one hundred and fifty patients, 15 had 28 stents. Of the nine patients each had stents, while 4 patients each had two and two patients each had one stent. Seven stents were patent, 9 had neointimal hyperplasia and 4 had in-stent restenosis.

DISCUSSION

CAD is one of most common reasons for death in developed countries and early diagnosis is important in terms of prognosis. In the evaluation of CAs, although CCA is the gold standard due to advantages such as obtaining details about lumen and ability to perform percutaneous balloon angioplasty and stent insertion in the same sequence. However it is invasive and the association with morbidity and mortality (even though incidences are low). The inability to provide details about extraluminal parameters and poor ability to demonstrate early changes in the vessel wall are disadvantages. In additionally, it was reported that in more than 40 % of CCA examinations, CAD was determined, but no invasive or surgical procedure was performed (8). In a study conducted by Papaconstantin et al (9) authors reported that CAD was not found in 25 % of patients who had undergone CCA and only coronary atherosclerotic disease was found in 66 percent. In our study, 27 subjects who had undergone CCTA examination were normal, and mild stenosis was found in 18 cases. Thus, an unnecessary invasive angiography procedure was avoided in a total of 45 cases. Our cases with mild and moderate stenosis were followed up under medical treatment.

Contrary to helical (spiral) CT systems which can retrieve only one slice in each rotation of the tube around the patient, MDCT systems are comprised of multiple sequential detectors aligned along z axis (direction of patient table) and thus, they may acquire 4 or more (8, 16, 32, 40, 64, 256, 320) slices during each rotation (10-11). In conjunction with the advances in MDCT technologies, respiratory artifacts can be reduced since long distances can be imaged in a short time and at high resolution. The examination of CAs can be performed in a shorter time, for example 5 seconds, with 64 or more detectors. In our study, effective visualization of CAs in a moving organ, namely the heart, with MDCT was ensured with a device which has 64 detector sequential 0.6 mm elements with ECG triggering integration, an independent 128 0.3 mm data collection channel and that can generate 128 x 0.33 mm isotropic resolution. The examination was performed in a mean period of five heartbeats.

Image quality in cardiac imaging is dependent on movement artifact due to the shifting of CAs during systole and diastole and resultant blurred image of vessel. Since the ability to detect non-calcified plaques and stenosis is dependent on imaging CAs without artifacts, image quality of CAs is important (12). In our study, a simultaneous ECG trace recording was performed in order to reduce cardiac movement effect. Reconstruction percentages corresponding to 35-40 % in ECG trace for RCA and 70% for LCX were used. Increased scanning rate is associated with use of contrast agent at lower doses particularly in CT angiography procedures. With 4-detector CT, 160 cc of opaque material is used, while the volume is reduced to 80 cc with 64-detector CT (13). In our study, mean amount of contrast agent used with 128-slice CT was estimated at 64 cc.

In a study conducted with 64-MDCT on 50 patients for examining visibility of CAs, Pannu et al (13) examined a total of 714 segments and they found CAs with diameter over 2 mm in 374 segments. In 340 segments with diameter below 2 mm, CAs were classified as good visibility, poor or not visualized in terms of visibility characteristic. They reported mean visibility values as 320 (85.4%), 19 (4.9%) and 31 (9.3%), respectively. In our study, a total of 2250 segments were evaluated in 150 patients. One thousand two hundred and five segments were over 2 mm. Moreover, 1405 segments below 2 mm were assessed with respect to visibility. Visibility values were determined as follows: good in 940 (90%) cases, poor in 55 (5.2%) cases and not visualized in 50 (4.8%) cases. When results were compared with that of Pannu et al. (12), the visibility rate of CAs was found to be higher in our study. Distribution of fifty non-visible segments was as follows: 16 in segment 2, 18 in segment 3, 10 in segment 13 and 6 in segment 11.

The principal factor influencing visibility in segments 13, 14 and 15 of patients was considered to be that those segments had significantly thin calibrations. The principal factor restricting visibility in segments 2 and 3 was artifact images visualized as staggering due to heart rate or blurring. Visibility of LAD was, in general, better than that of Cx and RCA. Different reconstruction ranges were used in order to evaluate visibility of LAD, Cx and RCA and suitable systolic – diastolic reconstruction ranges were selected. For LAD -and LCx, largely diastole-weighted (mean 70+/- 6.9%) and largely systole-weighted (mean 35+/-4.6%) reconstruction ranges were used. There is a significant relationship between presence of CA calcium, quantity, atherosclerotic plaque and severity of CAD (14). In our study, in four cases with symptoms and CACS 0, soft plaque formation was found. Therefore, symptomatic cases should be carefully examined with regards to CAD, even if CACS is 0. In the conclusion notification published by AHA, symptomatic cases with CACS equal to 0 are recommended to first undergo invasive coronary angiography, suggesting support of our results.

In the diagnosis of CAD, exercise ECG test is a non-invasive method which has common clinical use. High incidence of CAD influences the sensitivity of this test. Sensitivity of exercise ECG test is reported below 50 % in single vessel pathology and around 85% in three-vessel pathology (15). Therefore, alternative diagnosis and therapy methods are used, including CCA, intravascular ultrasonography (IVUS), MRA (Magnetic Resonance Angiography) and MDCT. Although non-use of ionizing radiation and contrast agent in MRA may seem like an advantage, images can be obtained in all cardiac cycles in MRA. However, cardiac and respiratory movements, small vessel diameter and tortuous trace of CAs cause technical problems for this imaging technique (16). Moreover, a prolonged examination period and inadequate spatial resolution also lead to important disadvantages against this examination mode.

Atherosclerotic plaque formation on the vessel wall predominantly precedes the intra-luminal stenosis and most myocardial infarctions occur due to disintegration of those plaques with resultant occlusion of lumen (17,18). CCA can only provide details of the inside of the lumen, while it provides no information on plaque formation, plaque composition, wall thickness and the wall itself. Due to its ability to visualize the vessel wall in addition to the vascular lumen, CCTA may indicate early atherosclerotic changes which do not cause significant intraluminal stenosis 19. Similar findings can be found with IVUS at high accuracy rates, but the method is invasive, expensive and non-practical (1,19). Concerning evaluation of CAs, MDCT is a rapid and non-invasive imaging method, which has high resolution capacity. Using MDCT, calcified and non-calcified plaques can be detected and several studies were conducted on this issue (1,20).

Coronary plaques missed by catheter angiography can be detected with MDCT and their composition can be characterized. Non-calcified plaques have a higher rupture tendency than calcified plaques (21). In a study, Motoyama et al (22) classified coronary plaques as follows: soft, fibrous and calcified plaque, and CT densities of plaques were determined as soft about 11 HU, fibrous about 78 HU, and calcified about 516 HU. Leber et al. (23) classified coronary plaques as calcified (calcium load <50 %), mixed (calcium load >50 %) and non-calcified (no calcium). In our study, similar to the classification made by Leber et al. (23), plaques were classified as follows: calcified, mixed and non-calcified. In a study of Nazeri et al (24) found atherosclerotic plaques in proximal and mid-section of LAD, Cx and RCA in decreasing frequency. Also, in our study, they were most frequently found in proximal and the mid-section of LAD followed by Cx and finally RCA, a result compatible with the literature. In our study, 27 cases were normal and mild stenosis was found in 18 cases in the CCTA examination, and thus, a total of 45 cases could avoid unnecessary invasive angiography procedure. Cases with mild and moderate stenosis were followed up under medical treatment. MDCT devices with 64 or more slices have high sensitivity in assessment of graft patency (25-26).

According to the recent evaluation of AHA, it is reported that specifity and sensitivity of MDCT in the assessment of stenosis and occlusion in coronary by-pass grafts is 96% and 93%, respectively. Although CCA is the gold standard in the assessment of by-pass grafts, previously mentioned disadvantages of CCA, the need for a higher number of personnel, high costs as well as the need to repeat the procedure in the following periods hinder use of the procedure and satisfactory results can be obtained with MDCT, a non-invasive method (27). Mannacio et al. (28) could not visualize by-pass graft in two cases due to artifact and in one case due to occlusion in a by-pass graft evaluation performed with 64-MDCT. Stenosis was observed in none of cases. In our study, there was no by-pass graft which could not be assessed due to artifact. Occlusion was found in five cases and stenosis in by-pass graft was determined in four cases. Artifacts due to hemoclips inserted adjacent to by-pass grafts hinder CT angiography examinations (29). However, in recent studies conducted with MDCT with 64 or more slices (26,30), occurrence of artifacts on images due to hemoclips is very low and they cause no insufficiency in imaging the CAs. In our study, artifacts due to clips did not cause any hindrance to the evaluation.

Concerning the evaluation of coronary stents, when minimum 64-slice MDCT devices are compared with 16-slice MDCT, they have spatial and temporal resolution enough to eliminate the artifact caused by stent (31). In a study examining in-stent restenosis (32), stenosis at a minimum rate of 50% were considered as restenosis. In our study, in-stent stenosis ≥50 % was also considered as in-stent restenosis. In our study, there were 8 stents with in-stent restenosis. In a study conducted for assessing stents with 64-slice CT, Rixe et al. (33) accepted a mean diameter of 3 mm for assessing 102 stent and authors concluded that a mean diameter below 3 mm was inadequate. In our study, there were 28 stents, all stent diameters were over 3 mm and all examinations were performed with CCTA. Intra-luminal patency was over 50% in 9 stents with neointimal hyperplasia and this finding was considered as stenosis.

In conclusion, 128-slice CT, a non-invasive method, can be routinely used in clinical practices to examine native CAs, by-pass grafts, stents and atherosclerotic plaques at a low cost, and with high image quality and adequate anatomic and pathological details.

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