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Evaluation of coronary artery bypass grafts with 64 slice CT, our initial experience

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Abstract

Aim

Purpose of our study is to assess the effectiveness of 64-slice cardiac computed tomography (CT) angiography, in detecting stenosis or occlusion of coronary bypass grafts in our patient population.

Material and methods

33 patients who have coronary bypass grafts and have applied to our radiology department for CT coronary angiography investigation between December 2008 and March 2010 were included in our study. All patients had cardiac CT investigation. 18 patients had both catheter coronary angiography (CCA) and cardiac CT. Cardiac CT angiography reports and images, CCA investigations, clinical follow-up and other results of the patients were evaluated retrospectively.

Results

94 grafts of 33 patients were included in our study. There were 32 left internal mammary arteries (LIMA), 1 radial artery, and 61 saphenous vein grafts. There were 50 grafts of 18 patients who also underwent CCA. 2 of these 50 grafts were not included in statistical analysis, because they could not been visualized in CCA due to lack of the catheterization. Totally, 48 grafts were included in statistical analysis. In comparison with CCA, the sensitivity of cardiac CT angiography in the detection of 50% or higher bypass graft stenosis or occlusion was 95.4%; specificity, 92.3%; accuracy, 93.7%; positive predictive value, 91.3%, and negative predictive value, 96%.

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Conclusion

64 slice cardiac CT investigation is a non-invasive imaging technique with high negative predictive value for evaluation of coronary bypass grafts.

Key words

Coronary artery bypass, coronary angiography, multidetector computed tomography, coronary disease, imaging

Introduction

As a result of the high prevalence of coronary artery disease in the Western World, coronary artery revascularization has become one of the most frequent medical procedures [1]. With the increasing success of these procedures, long term follow-up of these patients become a need [1].

Invasive CCA is accepted as diagnostic standard for this purpose [2]. But invasive procedure has some risks (death, myocardial infarction, cerebrovascular accident, arrhythmia, dissection etc.) and higher hospitalization costs [2].

Multidetector CT coronary angiography is a non-invasive imaging technique that can perform as outpatient procedure [2].

With the use of 64 slice CT in 2005, imaging with higher temporal and special resolution became possible [2]. While a temporal resolution is 105–250 milliseconds (ms) with 16 slice CT, it is 83–165 ms with 64 slice CT, and a special resolution increases from 0.5 x 0.5 x 0.6 millimetres (mm) to 0.4 x 0.4 × 0.4 mm [2].

In 2006 double source 64 slice CT, in 2007–256 slice CT, and in 2008–320 slice CT came into clinical use [3]. With this progress, it became possible to imagine the heart in one or two heart beats.

Purpose of our study is to assess the effectiveness of 64 slice cardiac CT angiography, in detection of stenosis or occlusion at coronary bypass grafts in our patient population.

Material and methods

33 patients who had coronary bypass grafts and evaluated with cardiac CT investigation between December 2008 and March 2010 in our radiology department were included in our study. 18 of 33 patients had both CCA and cardiac CT. Others had follow-up results after cardiac CT. Cardiac CT angiography reports and images, CCA investigations, clinical follow-up and other results of the patients were evaluated retrospectively. Patient informed consent, institutional academic board approval and ethical committee approval were obtained.

All patients were asked to come to the examination with 6 hours of hunger for solid diet and 12 hours of caffeine free diet. Scan area were chosen craniocaudally from thoracic inlet to basis of the heart. Region of interest was placed at the beginning of descending aorta for the bolus-tracking technique. When heart rate was higher than 75 beats per minute (bpm) and there was no contraindication for beta-blockers, patients were given 5 mg/ml of Beloc (Metoprolol tartrate, Astra Zeneca-Eczacıbașı Health Products Co., Istanbul, Turkey) intravenously. Metoprolol was diluted with saline solution (0.9% NaCl) to 10 cc and infused slowly. Most patients were under medication after their bypass surgery. It was not necessary to administer a beta-blocker for 50% patients. None of the patients needed more than 15 mg metoprolol (three times injection).

All cardiac CT angiography investigations were performed with 64 slice CT device (Philips Brilliance 64; Philips Medical Systems, Holland). Transaxial slices were reconstructed at increments of 0.45 mm, an effective slice thickness of 0.9 mm, an image matrix of 512 × 512 pixels and a field of view of 220 mm. Collimation was 64 × 0.625 mm and gantry rotation time was 0.4 seconds. Scan filter (kernel) was Xres Standard (XCB) and pitch was 0.2. When patient had stent in bypass grafts or native coronaries, the filter was changed to Xres Detailed Stent (XCD). Tube output was 120 kilovolts (kV) at 800 milliampere-seconds (mAs). These values were increased to 900–1000 mAs and 140 kV if patient was obese. 90 to 120 ml of non-ionic iodinated contrast media and following 40 ml saline solution were injected to patients. Saline solution was containing 20 per cent of non-ionic contrast media. Ultravist-370 (Iopromide, Bayer Schering Pharma AG., Leverkusen, Germany) or Iomeron 400 (Iomeprol, Bracco S.p.A. —Gürel İlaç Tic. A.S., Istanbul, Turkey) were used as contrast media. The contrast media injection speed was 6 ml per second. Radiation dose of the CT investigation was the same as in the available literature for 64 slice CT devices.

All scans were reconstructed by using retrospective gating. Different reformat images (80%, 75%, 45%, 35%, etc.) were prepared and evaluated. All standard and reformat images were evaluated in Philips Extended Brilliance TM work station (V3.5.0.2254, Philips Electronics N.V.2004) by two independent radiologists who are experienced in cardiac CT. Arterial and venous grafts were evaluated for occlusion, stenosis or patency, and a report was prepared. When there was no contrast passage, graft was evaluated as occluded. When the narrowing in graft diameter (according to normal diameter of graft before or straight after the narrowing) was 50% or more, graft was evaluated as stenotic. If lumen was normal or the narrowing was less than 50%, graft was evaluated as patent. If there was discordance between reports of two radiologists, the graft was evaluated again by both radiologists, and decision was made by consensus. In statistical analysis, occlusions and stenoses (50% and more) were evaluated together in one group.

94 grafts of 33 patients were included in our study. There were 50 grafts from 18 patients who also underwent CCA. 2 of those 50 grafts were not included in statistical analysis, because they could not been visualized in CCA due to lack of catheterization. Totally, 48 grafts were included in statistical analysis. Cardiac CT results were compared with CCA results. Cardiac CT findings of 44 grafts from 15 patients who did not have CCA correlation were discussed and mentioned separately in the text. According to the clinical evaluation, laboratory and follow-up results, CCA was not needed for this patient group according to cardiologist in charge.

Statistical analysis was performed by SPSS version 15.0 (SPSS Inc. Chicago, Illinois, USA) software for Windows. Sensitivity, specificity, accuracy, positive predictive value and negative predictive value were calculated for cardiac CT angiography. Also McNemar, Kappa and Spearman rank correlation coefficient tests were performed. P value <0.05 was considered statistically significant. The correlation coefficient values were interpreted as follows: 0.00-0.20, poor agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, good agreement; and 0.81–1.00, excellent agreement.

Results

There were no serious complications in any patients during cardiac CT angiography.

Demographic characteristics of patients were summarized in Table 1.

Table 1. **Demographic characteristics of patients in our study**

Patient Characteristics	Value
Age (year)	
Mean	62
Range	(42–76)
Gender	
Female	6
Male	27
Period between CCA — cardiac CT	
Maximum	10 months
Minimum	1 day
Mean*	44 days
Period between bypass surgery and cardiac CT	
Longest period	21 years
Shortest period	10 months
Mean	6 years**

* If 2 patients who had waiting period longer than one month between CCA and cardiac CT investigation were ignored, a mean period between two investigations decreased to 14 days.
** Mean time period between surgery and cardiac CT was 5.96 years and it was shown as 6 years.

There were 33 arterial (32 LIMA, 1 radial artery) grafts and 61 venous (all saphenous vein) grafts. Distribution of grafts according to graft type and distal anastomosis side were summarized in Table 2.

Table 2. **Distribution of grafts according to graft type and distal anastomosis side**

Vessel that distal anastomosis was performed	Saphenous vein graft	Arterial graft (LIMA, RA)
LAD	1	31
Diagonal artery	14	1
LCX	5	— -
Obtuse Marginal artery	20	1*
RCA*	20	— -
Acute marginal artery	1	— -
TOTAL	61	33

* Radial artery (RA) graft was shown.
** One of the grafts that distal anastomosis was made on RCA was connected to innominate artery at proximal anastomosis due to diffuse and severe atherosclerotic chances on ascendant aorta.

Occlusion of 8 LIMA grafts (25%), severe stenosis (50% and more narrowing) of 2 LIMA grafts, and patency of 22 LIMA grafts (69%) were detected at cardiac CT investigation. One LIMA graft which had 50% stenosis in cardiac CT was described as patent in CCA. One LIMA graft which was patent in cardiac CT was not added to statistical analysis due to lack of catheterization and visualization in CCA. Occlusion of 16 saphaneus vein grafts, severe stenosis (50% and more narrowing) of 6 venous grafts and patency of 39 venous grafts were detected at cardiac CT investigation. One venous graft which was stenotic in cardiac CT was evaluated as patent in CCA. 70% stenosis was described in CCA on another venous graft which had

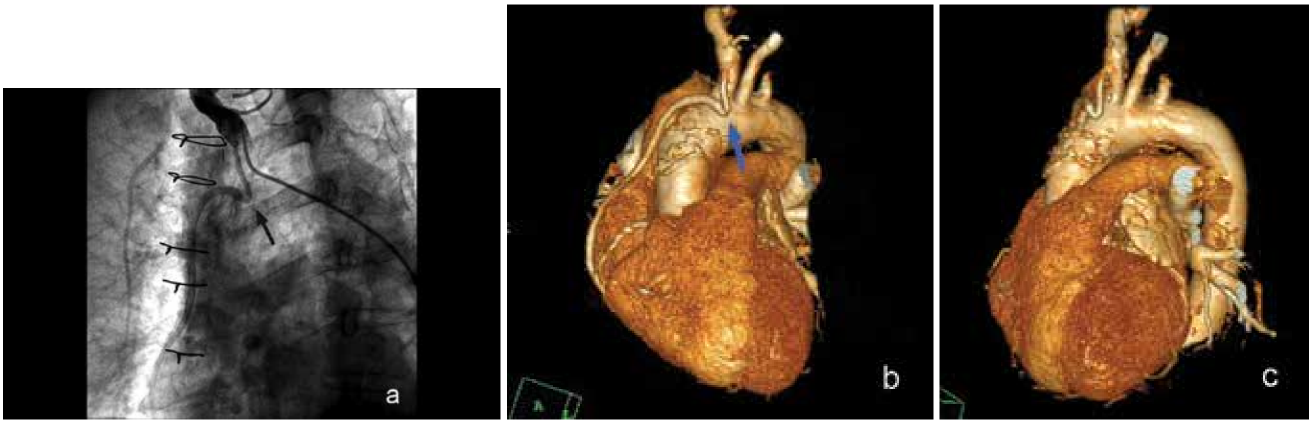

Figure 1. a, b, c. CCA image (a) and first volume rendering (VR) image (b) show stenosis more than 50% on brachiocephalic artery-RCA saphaneus venous graft (SVG). But in another angle on second VR image (c) the stenosis does not seem to be more than 50%

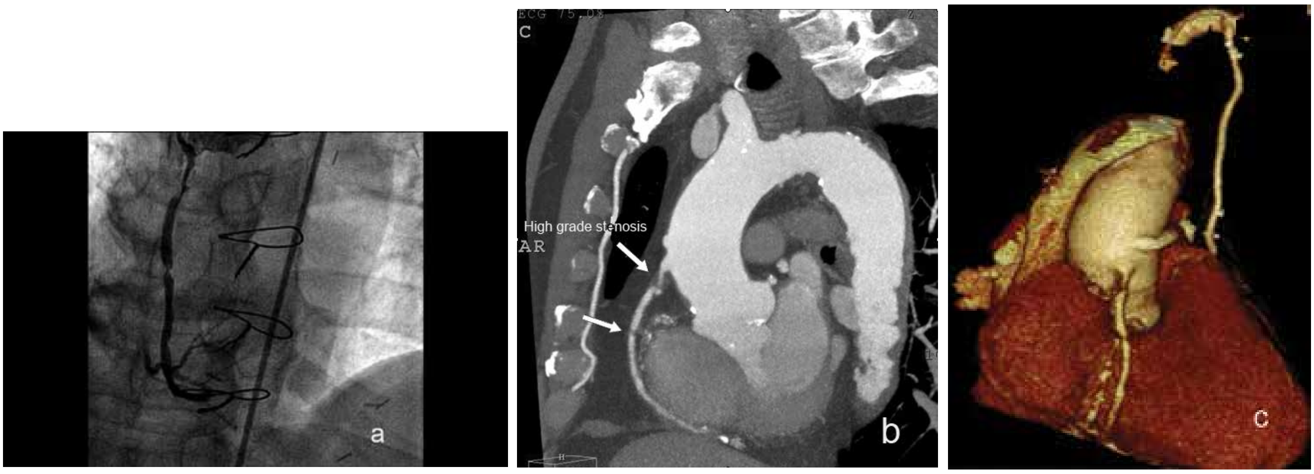

Figure 2. a, b, c. CCA (a), maximum intensity projection (MIP) (b) and VR (c) images show high grade stenosis on aorta-RCA-SVG

less than 50% stenosis and assumed as patent in cardiac CT (Figure 1). One radial artery graft was patent in both investigations.

In CCA correlation group (48 grafts of 18 patients), 21 of 22 grafts (95.4%) which were occluded or stenotic in CCA were found occluded or stenotic in cardiac CT too (Figure 2) (Table 3). 24 of 26 grafts (92.3%) which were patent in CCA were also found patent in cardiac CT. 2 grafts which were stenotic in cardiac CT were evaluated as patent in CCA.

Table 3. **Comparison of cardiac CT and CCA**

			CCA		Total
			occluded	patent	occluded
CT	occluded	count	21	2	23
		% within CT	91.3%	8.7%	100.0%
	patent	count	1	24	25
		% within CT	4.0%	96.0%	100.0%
Total		count	22	26	48
		% within CT	45.8%	54.2%	100.0%

2 grafts (1 LIMA, 1 saphenous) which were patent in Cardiac CT were not included in statistical analysis due to lack of catheterization in CCA.

In whole patient group, totally 32 of 92 grafts were occluded and 60 were patent in cardiac CT. There were 44 grafts of 15 patients in clinical follow-up group. 35 of these 44 grafts were patent in cardiac CT. Occlusion or severe stenosis were detected with cardiac CT on 9 grafts of 15 patients in clinical follow-up group. Patients were evaluated in follow-up period according to LIMA graft patency, at least one patent graft existence, chest pain presence, response to maximum medical treatment, ECG changes, and myocardial scintigraphy results. In spite of occlusion found in some grafts with cardiac CT, clinical follow-up decision for these grafts was made by a cardiologist according to the *American Heart Association* (AHA) and *American College of Cardiology* (ACC) guidelines and results of data mentioned above. The longest follow-up period was 10 months and the shortest — 2 months.

Statistical results

48 grafts of 18 patients who had CCA were evaluated statistically. In comparison with CCA, the sensitivity of cardiac CT angiography in the detection of 50% or higher bypass graft stenosis or occlusion was 95.4%;

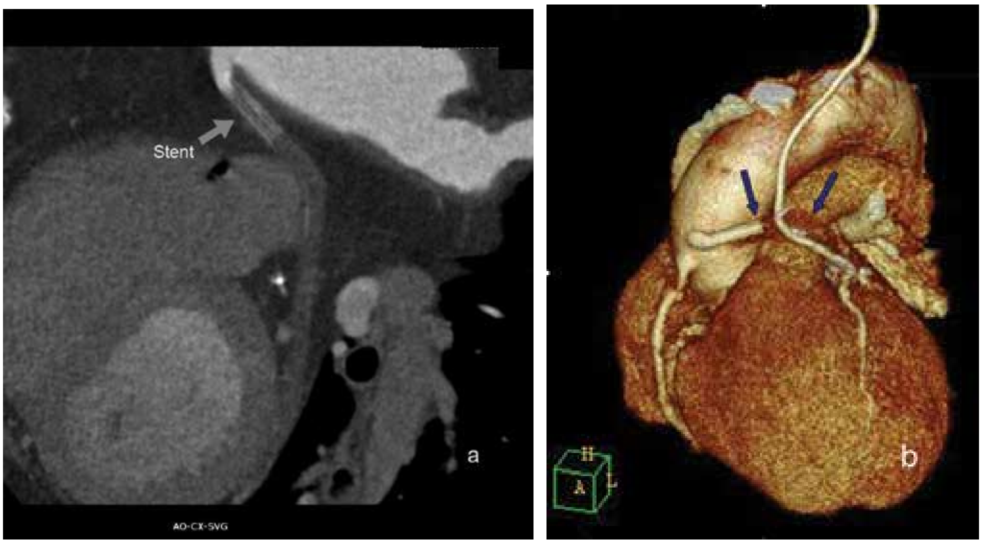

Figure 3. a, b. Occluded SVG is shown on MIP (a) and VR (b) images. Also there is occluded stent on proximal side of the graft

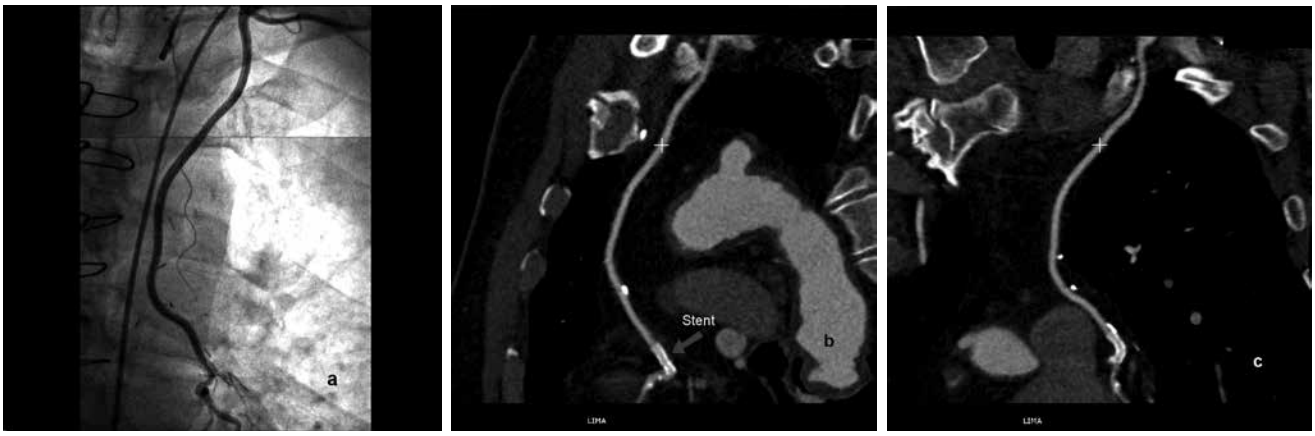

Figure 4. a, b, c. Patent LIMA graft is shown on CCA image (a). MIP images (b and c) show patent LIMA graft and also stent at distal anastomosis

the specificity, 92.3%; the accuracy, 93.7%; the positive predictive value, 91.3%, and the negative predictive value, 96%. There was no difference between two investigation methods statistically ($P>0.05$). Kappa (κ) value was 0.87 and r value was 0.0875 for these two investigation methods which was evaluated as excellent agreement and perfect match.

Discussion

Selective CCA is a gold standard for coronary bypass graft evaluation. But it is an invasive method and has a risk for serious major complications [2]. On the other hand, recent progress on multidetector CT technology showed that cardiac CT is a minimal invasive alternative method for evaluating coronary bypass grafts compare to CCA. In 2006 Ropers *et al.* [4] and in 2007 Feuchtner *et al.* [2] reported that none of the grafts were excluded from their study due to bad image quality. They used 64 slice CT in their studies. Like these two studies, no patients were excluded from our study due to bad image quality.

In a study, conducted by Feuchtner *et al.*, 70 grafts of 41 patients were evaluated, the sensitivity of 64 slice CT in the detection of 50% or higher bypass graft stenosis or occlusion was found 85%, and specificity was 95% [2]. Like this study, we evaluated 50% or higher bypass graft stenosis and occlusions together in the same group. The number of our patients (33 patients) was less than the one in the Feuchtner *et al.* study but the number of grafts evaluated (92 grafts) was higher. Feuchtner *et al.* had CCA correlation for all grafts in his study. Sensitivity was 95.4% and specificity was 92.3% in our study. Our sensitivity was higher than the one in the Feuchtner *et al.* study. On the other hand, Ropers *et al.* evaluated 138 grafts in his study and found that sensitivity of 64 slice CT in the detection of 50% or higher bypass graft stenosis or occlusion was 100%, and specificity was 94%. Sensitivity and specificity of our study were between the values of these two studies. Patients with stents in grafts or native coronaries were excluded from the Ropers *et al.* study. In addition to this, in this study much more aggressive beta-blocker treatment (oral and intravenous) compare to our study was given to the patients before the cardiac CT investigation to keep heart rate under 60 bpm. We did not exclude patients with stents in their grafts from our study (Figures 3 and 4). In our study, when the heart rate was 70 bpm or below, we performed cardiac CT investigation without beta- blocker administration. We think, low sensitivity and specificity values of our study compared to Ropers's study can be explained by these differences.

In the Feuctner *et al.* study, there were maximum two weeks between cardiac CT and CCA investigations. In our study, a mean interval between two investigations was 44 days. There were two patients who had long period (300 days and 252 days) between two investigations. First patient (300 days interval) had one graft, and the graft was occluded in both investigations. Other patient had two grafts which were defined as patent in both investigations. Because of these reasons, we thought there was no bias despite the long interval between investigations. If we ignore these two patients, the mean interval decreases to 14 days.

In 2006, Pache *et al.* [5] reported that 2 venous grafts and one arterial graft were missed at CCA investigation. Similarly, 1 saphaneus, and 1 LIMA graft could not be visualized and 1 patent right coronary artery (RCA) saphaneus graft was misdiagnosed as root of occluded RCA — saphenous graft with CCA in our study.

Indications for reoperation of patients with coronary bypass grafts were explained in *ACC/AHA* guidelines [6]. Presence of a functioning LIMA graft, anastomosed to left anterior descending coronary artery (LAD), with recurrent ischemia on other areas of the heart, potential loss of this graft may results in reoperation [6]. In our study, 44 grafts of 15 patients who did not have CCA investigation, were evaluated with only cardiac CT results. 2 of 14 LIMA grafts without CCA correlation were occluded and one was stenotic in cardiac CT. All of these three patients had additional patent grafts. At least one patent graft was present in each patient in clinic follow-up group. Because of these reasons, we thought that the follow-up decision was made by a cardiologist according to *ACC/AHA* criteria.

In 2009, Mannacio *et al.* [7] used 64 slice CT in their study to evaluate 73 grafts in 25 patients. CCA investigation was not performed for correlation of cardiac CT results in this study. They used clinical progress, cardiac specific biomarkers, homodynamic finding for evaluating early graft dysfunction. In 2009, Bassri *et al.* [8] used 16 slice CT in their study to evaluate 366 grafts and did not performed CCA correlation. Like these two studies, we did not have CCA correlation for the follow-up group.

Major limitation of our study was evaluation of 15 patients (44 grafts) only with cardiac CT results and lack of CCA correlation. But, as we mentioned above, some recent studies which were done with 64 slice CT did not have CCA correlation due to high sensitivity and specificity of 64 slice CT.

Another limitation of our study was to be a retrospective study. Because of this, standard examination quality could not be obtained.

In our study, the total number of grafts, especially with CCA correlation, was low. In literature, there are wide series like Meyer *et al.* [9] in which 406 grafts of 138 patients were evaluated.

CT technology has progressed really fast recently. In 2006 dual source 64 slice CT, in 2007–256 slice CT, and in 2008–320 slice CT were available in clinical use [3].

Dewey *et al.* used 320 slice CT in their study [10] and evaluated 30 patients. Their sensitivity was 100%, and specificity was 94%. In this study, a mean effective radiation dose of cardiac CT with 320 slice CT was 4.2 millisievert (mSv). On the other hand, it was 8.5 mSv for CCA. It was reported in the study that 87% of the patients would choose CT over CCA if investigation of their coronaries was needed again in the future.

Considering the recent progress on CT technology that mentioned above, we think that it would not be wrong to say, cardiac CT will be performed for all diagnostic investigations in the future, instead of CCA.

Conclusion

Cardiac CT investigation with 64 slice CT is a non-invasive method with high negative predictive value for imaging of grafts after coronary bypass operation. In our study, it has been established that in patient group in our university hospital, 64 slice cardiac CT has high specificity and sensitivity in detecting bypass graft patency, which is similar to the available literature.

As a result, we think this method is a powerful alternative to catheter angiography which is still accepted as gold standard for evaluation of bypass grafts.

Conflict of interest: None declared

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