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Coronary artery bypass graft (CABG) patency: Assessment with high-resolution submillimeter 16-slice multidetector-row computed tomography (MDCT) versus coronary angiography

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Abstract

Purpose: To investigate the ability of 16-slice multidetector-row computed tomography (MDCT) to visualize coronary artery bypass graft (CABG) patency and to detect bypass stenoses.
Materials and methods: Thirty-two patients with 94 grafts (20 mammary artery grafts, 74 venous grafts) were investigated by 16-slice MDCT using a scan protocol with 12×0.75 mm slice collimation (pitch 0.3), 420 ms rotation time and simultaneous electrocardiogram (ECG)-registration. One hundred milliliters iodinated contrast agent were injected with a delay according to the individually determined contrast agent transit time. Patients with heart rates above 60 bpm received oral beta-blockade.

Cross-sectional images with a slice width of 1.0 mm (0.5 mm increment) were reconstructed using an ECG-gated half-scan reconstruction or a multisegment reconstruction algorithm depending on the heart rate. Bypass grafts were evaluated concerning patency and presence of stenoses $\geq$50% diameter reduction on cross-sectional images, multiplanar reformations and maximum intensity projections by two independent observers. Results were compared to coronary bypass angiography.
Results: Sixteen-slice MDCT results were compared to those of invasive coronary angiography concerning absence or presence of bypass graft occlusion or relevant stenosis $\geq$50% lumen reduction.

Coronary CT angiography (CTA) permitted detection of bypass occlusion with 100% sensitivity (28/28) and 98% specificity (64/65). Seventy-eight percent (observer 1) and 84% (observer 2) of all patent grafts were found to be evaluable concerning presence or absence of stenosis. In 34 of 40 (observer 1) and 38 of 43 (observer 2) bypass grafts, high-grade stenoses were correctly ruled out (specificity 85% versus 88%, sensitivity 80% and 82%). Yet, if all patients with either unevaluable grafts/graft anastomosis or relevant graft stenosis were excluded, only 8/32 patients (25%) had fully diagnostic “negative” graft-CTA.

According to Kappa statistics, agreement between the observers was 1.0 and 0.93 concerning occlusion and relevant stenosis, respectively.
Conclusion: Sixteen-slice coronary CTA with sub-millimeter spatial resolution and premedication with oral beta-blockade permits non-invasive assessment of coronary artery bypass grafts with decreasing numbers of unevaluable graft segments. However, patient-based analysis reveals that only a relatively small number of patients (“negative” and completely evaluable graft-CTA) truly profits from noninvasive work-up and could be spared invasive angiography.

Keywords: Computed tomography; Helical; Coronary vessels; Bypass graft; Graft restenosis; Vascular

1. Introduction

During the last century, coronary artery disease has become the most common cause of hospitalization and mortality within the industrialized countries. Surgical placement

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of coronary artery bypass grafts (CABG) emerged as an effective and routine treatment for patients with multivessel disease and is associated with a long-term improvement in quality of life [1–3]. Nevertheless, venous or arterial bypass grafts are subject to arteriosclerotic changes and may thus occlude or develop stenosis [4–6].

Invasive coronary angiography is the gold standard for direct assessment of bypass graft patency. However, as an invasive examination method, cardiac catheterization is associated with certain risks and complications. Therefore, since the early 1980s, several trials have investigated the potential of computed tomography (CT) and magnetic resonance imaging as noninvasive alternatives to visualize CABG. While both methods were judged to be appropriate to determine graft patency versus occlusion, the exclusion of graft stenosis and the evaluation of distal graft anastomosis remained limited due to the sensitivity for motion artifacts in single-slice CT as well as magnetic resonance imaging [7–10]. Electron-beam tomography (EBT) on the other hand offers excellent temporal resolution, but is not widely available and-with a slice thickness of 1.5–3 mm also is afflicted with limited three-dimensional resolution. A further reduction of slice thickness in EBT results in increasing image noise due to significantly lower maximum effective tube current time product (effective mAs) compared to spiral CT and thus yields data of limited diagnostic value.

With the newest generation of CT-scanners, both temporal as well as spatial resolution could be substantially increased. Additional advances in terms of reconstruction algorithms (halfscan or multisegment algorithms) with electrocardiogram (ECG)-gated image reconstruction shortening image reconstruction windows could even further decrease the influence of cardiac motion on image quality [11–13]. Thus, nowadays, in carefully selected patients (absence of arrhythmia; heart rates below 60 bpm), 4- and 16-slice MDCT of the heart could be established as a reliable tool to visualize the coronary arteries [14,15].

Considering the recent technical advances, it should also be possible to more accurately determine absence or presence of stenotic lesions in CABG and to rule out atherosclerotic changes at coronary bypass anastomoses. In order to evaluate the potential of 16-slice MDCT in CABG follow-up, we compared 16-slice CTA (CT angiography) and invasive coronary angiography in 32 patients with a total of 94 bypass grafts.

2. Material and methods

2.1. Patients

Thirty-two consecutive, symptomatic patients with recurrent angina or newly developed ECG-changes after prior bypass surgery, who had been referred for invasive coronary angiography, were investigated by 16-slice MDCT coronary angiography and cardiac catheterization. Patients with chest pain at rest, contraindications to the administration of contrast agent, with cardiac arrhythmias or in unstable hemodynamic situation were not enrolled in the study. All patients gave written informed consent, and the study protocol was approved by the institutional review board.

2.2. Computed tomography

2.2.1. CT scan protocol

The cardiac CT scans were performed using a 16-slice MDCT scanner (SOMATOM Sensation 16, Siemens Medical Solutions, Forchheim, Germany). A volume data set was acquired in inspiratory breath hold (12 × 0.75 mm collimation, gantry rotation time 420 ms, table feed 2.8 mm per rotation, tube voltage of 120 kV), covering the distance from the aortic arch to the diaphragmal face of the heart. Tube current was modulated in accordance with the simultaneously registered ECG with a maximum of 500 effective mAs during a time period of 330 ms centered around the middle (55% of R-peak-to-R-peak interval) of each cardiac cycle and tube current reduction by 80% during the remaining time. Thereby depending on the patient's heart rate–radiation exposure can be reduced by 30–50% compared to protocols without tube current modulation, the resulting estimated effective radiation dose ranges from 3.4–4.8 mSv in male and 5.1–7.1 mSv in female patients [16,17].

2.2.2. Premedication

Patients with a heart rate above 60 bpm received 50 mg atenolol (Tenormin, AstraZeneca, Wedel, Germany) orally 1 h prior to the scan (no patients with severe obstructive pulmonary disease were enrolled). 0.8 mg of glycerol trinitrate were given sublingually immediately prior to the 16-slice MDCT scan in all subjects.

2.2.3. Contrast medium protocol

For all examinations, 100 ml of a non-ionic iodinated contrast medium (Ultravist 370, Schering AG, Berlin, Germany) were administered intravenously at a flow rate of 4.0 ml/s. Prior to the scan, each patient's individual contrast agent transit time from the cubital vein to the aortic root was determined by a test bolus injection (20 ml contrast, 50 ml saline flush, 4.0 ml/s) and subsequent low-dose single slice scans measuring bolus arrival time (peak enhancement in HU) in the ascending aorta. The calculated contrast peak arrival time was used as scan delay for the subsequent CTA acquisition.

2.2.4. Image reconstruction and evaluation

Cross-sectional images were reconstructed with a slice width of 1.0 mm and 0.5 mm increment using an ECG-gated half-scan reconstruction algorithm to obtain an image acquisition window of 210 ms in lower heart rates or a bisegmental reconstruction algorithm (reconstruction window 130–180 ms) for heart rates above 72 bpm. Initially, one data set was reconstructed with the reconstruction window starting at 55% of the cardiac cycle. If motion artifacts were present in any of the bypass grafts or the coronary