Angio-CT: heart and coronary arteries

Andreas F. Kopp*
Tu¨bingen University Hospital, Tu¨bingen, Germany

Received 22 November 2002; received in revised form 25 November 2002; accepted 26 November 2002

Abstract

Despite a multitude of different medical and interventional strategies to treat coronary artery disease (CAD), the natural course of CAD is a relentless progression. The current gold-standard to assess the degree of stenosis is coronary angiography. In Germany alone, the total number of angiographic procedures rose by 45% from 1995 to 2000, while the fraction of interventional procedures remained almost constantly low at about 30% [Z. Kardiol. 90 (2001) 665]. Although coronary angiography has become a safe procedure with only a small risk associated, the inconvenience for the patient as well as the economic burden have fueled the quest to find an alternative, non-invasive method to visualize and assess coronary arteries. The following article will explore the application of computed tomography (CT) coronary angiography for detection of stenoses, and the issue of imaging of non-calcified and unstable plaques with MDCT.

Keywords: Coronary arteriosclerosis; CT angiography; Plaque morphology; Contrast media

1. CTA coronary angiography for detection of stenoses

The imaging protocol for MDCT angiography of the coronary arteries is relatively straightforward (Table 1) [1]. To establish the scan delay time a test bolus of 15 ml CM and 20 ml saline chaser bolus is used. The circulation time is determined by measurements of computed tomography (CT) density values in the ascending aorta. Imaging commences at the circulation time plus 3 s [2]. A bolus of 120 ml nonionic contrast (400 mg I per ml) is injected through an 18-gauge catheter into an antecubital vein. The concentration of 400 mg I per ml was selected for the imaging protocol, because it is important to achieve a high concentration rapidly (Table 2). Higher attenuation values are thus achieved in the arteries with the same amount of contrast medium as compared with the standard iodine concentration (300 mg I per ml). This permits depiction of smaller vessels, facilitates post-processing and reduces the overall volume of contrast medium required by approximately 30%. The angiographic series is a continuous spiral scan with the calculated pitch. The z-resolution is significantly improved compared with electron beam CTA, where only sequential ECG-triggered 3 mm slices can be obtained. With MDCT technology 1 mm slices and sub-millimeter image increment provide a 3D data set within a single breath-hold for high resolution CT volume imaging [3]. For optimal image quality the reconstruction window within the cardiac cycle should be selected individually for each of the three major coronary arteries [4–6].

Even with four-row technology non-invasive MDCTA showed a high diagnostic accuracy in the detection and quantification of coronary lesions [7,8]. The results of MDCT coronary angiography obtained so far from different centers are encouraging: CTA of the coronary arteries yielded a sensitivity of 75–90%, a specificity of 90–95%, a positive predictive value of 0.7–0.9, and a negative predictive value of 0.8–0.9 for detection of hemodynamically significant stenoses in the major segments of the coronary arteries [7,9–13]. Not only severe, but also intermediate lesions could be visualized [14]. Furthermore, MDCT angiography yielded promising results for assessment of bypass graft patency [10] (Figs. 1 and 2).

* Tel.: +49-7071-297-2087; fax: +49-7071-295-845.
E-mail address: kopp@radiology2000.org (A.F. Kopp).

0720-048X/03/$ - see front matter © 2002 Published by Elsevier Science Ireland Ltd.
doi:10.1016/S0720-048X(02)00360-1
2. Plaque imaging

It is widely accepted that only one third of myocardial infarctions directly arise from significant coronary stenosis. Non-stenotic (< 75%) plaques cause about 80% of deadly myocardial infarctions. Approximately 90% of all patients with acute myocardial infarction had no hemodynamically relevant lesion. Much more frequently, rupture of a vulnerable plaque with subsequent thrombus formation is the reason for occlusion of a coronary artery [15]. Most of the standard imaging techniques, however, identifies only luminal diameter and stenosis, none can characterize plaque composition. Preliminary data indicate that MDCTA might allow detection and assessment of non-calcified lipid-rich plaques [14,16]. Schröder et al. investigated non-invasive detection of coronary plaques and plaque composition by MDCT in comparison with intracoronary ultrasound (ICUS) as a gold-standard. MDCT and ICUS yielded identical results in regard of plaque composition and quantification of lesions. Becker et al. also investigated the criteria that allows for morphological characterization of atherosclerotic coronary lesions based on MDCT imaging in human cadaver heart specimens. They compared the MDCT findings with histopathology. Becker found a high sensitivity for detection of atherosclerotic lesions type IV, Va, Vb, and Vc according to the AHA-classification [17]. Based on mean CT-attenuation he could reliably differentiate predominantly lipid-rich plaques from predominantly fibrous-rich plaques. Thus, this new technology holds promise to allow for the non-invasive detection of rupture-prone soft coronary lesions and may have the option to lead to early onset of therapy [16,18].

3. Limitations

With four-row technology a number of factors are known to decrease image quality of MDCTA and make image interpretation difficult [19]. The two factors mostly held responsible are higher heart rates and severe calcifications. Becker was one of the first to describe the negative effect of higher heart rates on image quality. These data have been confirmed by others [20]: excellent diagnostic image quality can only be obtained at heart rates < 65 bpm. The reason for this heart rate limitation lies in the temporal resolution of the CT image acquisition and reconstruction system. To obtain heart rates...
below 65 bpm for optimal image quality either 80 mg Esmolol i.v. or 50–100 mg metoprololtartrate orally can be administered prior to the scan.

Assessment of luminal diameter in the presence of severe calcifications yields unsatisfactory results. Especially if non-high grade coronary lesions are known, it can be difficult to determine the progress of that specific lesion. However, there is only limited published data available that quantifies the amount of calcification critical for image interpretation. In a recent study we included a total of 66 patients with a history of coronary artery for MDCTA. Total calcium score as well as all coronary arteries including distal segments and side branches were assessed in respect of evaluability and the presence of coronary artery lesions or occlusions. Results were then compared with quantitative coronary angiography. Of all patients only 24 (36%) were diagnosed correctly. In the other 42 patients the clinical diagnosis was either not possible or incorrect. Artifacts due to elevated heart rates or severe coronary artery calcification were the main cause of degraded image quality inhibiting correct diagnosis. Analysis of the data suggested a threshold for maximum heart rate and maximum calcification (63 bpm and Agatston Score

Fig. 2. MDCT coronary angiography (collimation 4 × 1 mm; pitch 1.5; 120 ml Iomeron 400) and conventional coronary angiography: Volume rendered image (a) depicts high-grade stenosis (arrow) in the LAD. Sliding thin-slab maximum-intensity projection (slab thickness 8 mm); (b) in this location depicts eccentric non-calcified plaque. Invasive coronary angiography (c) confirms presence of stenosis (arrow; 90% diameter reduction).
Table 2

High Iodine concentration contrast media

<table>
<thead>
<tr>
<th>High Iodine Concentration Contrast Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>High concentration of iodine must be rapidly reached</td>
</tr>
<tr>
<td>Even more important for eight-, 16-, . . . row scanners</td>
</tr>
<tr>
<td>Facilitate postprocessing</td>
</tr>
<tr>
<td>Depiction of smaller vessels</td>
</tr>
<tr>
<td>Reduction of overall amount of contrast</td>
</tr>
</tbody>
</table>

300, respectively). A second analysis was made using these thresholds. Now 22 out of 24 (91%) patients were correctly diagnosed. This indicates that MDCTA can also be performed in-patients with manifest CAD when selected properly within certain thresholds. Reasonable thresholds might be heart rates > 63 bpm and severe calcifications with a total Agatston score > 300.

4. From four to 16 rows

True isotropic resolution has not yet been reached with four-slice CT systems. An increased number of simultaneously acquired slices and sub-millimeter collimation for cardiac applications will be the next step on the way towards true isotropic scanning with multislice CT. The recently introduced multislice 16-row CT scanner (Siemens SOMATOM Sensation 16) offering simultaneous acquisition of 16 slices with 0.75 or 1.5 mm collimated slice width each, is the first scanner of this new generation [21]. Similar to the four-slice CT scanner the 16-row scanner has an Adaptive Array Detector. It consists of 24 detector rows, the 16 central ones being 0.75 mm wide in the center of rotation, the four outer ones on both sides being 1.5 mm wide. The total z-coverage in the iso-center is 24 mm. For calcium scoring we use a collimation of 1.5 mm, for CTA of the coronary arteries a collimation of 0.75 mm (13.2 mm/s feed) with a gantry rotation time of 420 ms. Spiral scanning with 16 sub-millimeter slices provides true isotropic resolution. As a consequence, the distinction between longitudinal and in-plane resolution will gradually become a historical remnant, and the traditional axial slice will lose its clinical predominance. In our first experience the new 16-slice CT allowed accurate visualization of the entire coronary tree including the distal and side branches without respiratory and reconstruction artifacts (Table 2).

References