Detection of Coronary Stenoses by Multidetector Computed Tomography: It’s All About Resolution*

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Noninvasive imaging of the coronary arteries is fraught with great difficulties: Most obviously, coronary vessels have small dimensions, which requires high spatial resolution. Also, they are subjected to rapid motion because of cardiac contraction. Sufficient temporal resolution is thus necessary to avoid artifacts. Finally, in invasive angiography, the coronary artery lumen can be selectively filled with a high concentration of contrast agent, whereas this is not possible in noninvasive imaging. Any contrast agent given will therefore also enhance the lumen of the blood pool (e.g. the left ventricle). This makes any form of projectional imaging difficult and poses a severe obstacle for such attempts, for example, the otherwise-elegant principle of dichromatic angiography with synchrotron radiation (1–3). Thus, cross-sectional imaging techniques must be used to noninvasively visualize the coronary lumen. Magnetic resonance imaging is one possible approach. Although magnetic resonance techniques are evolving rapidly, the spatial resolution in particular still poses difficulties (4,5). Examination times typically are very long, easily reaching 60 min or more. Accuracy for stenosis detection in clinical trials has so far been unsatisfactory (6).

Computed tomography (CT) imaging represents an alternative approach to noninvasive coronary imaging. However, conventional CT has a low temporal resolution (because a heavy X-ray tube needs to rotate around the patient). The first approach to overcome this limitation was the development of electron beam tomography scanners, which operate completely without mechanical motion and provide a so-far-unsurpassed temporal resolution of 50 to 100 ms. Very promising initial results could be obtained with this technology (7–9), although somewhat-limited spatial resolution and image noise prevented adequate visualization of many coronary segments. Although technical developments to improve electron beam tomography scanners continue, an alternative approach has been to increase the gantry rotation speed of conventional CT scanners and implement software algorithms to reconstruct images using only parts (typically one half) of one rotation. The development of detectors that permit acquisition of several parallel, thin slices simultaneously provides for increased spatial resolution. Approximately three years ago, four-slice multidetector CT (MDCT) scanners with a gantry rotation time of 500 ms were introduced. Typically, a temporal resolution of approximately 250 ms can be achieved with these scanners, and initial results have demonstrated the feasibility of coronary artery visualization (10). Several reports—in somewhat selected patient groups—found sensitivities ranging from 72% to 91% and specificities between 71% and 98% for the detection of coronary artery stenoses (11–17). However, up to 32% of all coronary segments had to be excluded from analysis, and the most frequent reasons for this had to do with resolution: on one hand, temporal resolution was still not sufficient and motion artifacts, especially of the rapidly moving right coronary artery, were common. On the other hand, pronounced coronary calcification frequently rendered coronary segments un evaluable. This phenomenon is directly related to spatial resolution and the so-called “partial volume effect”: Image pixels that are only partly occupied by a structure of very high CT density (such as calcium) will appear very bright in the CT image. By looking at the image, it is not possible to tell whether calcium occupies all of the pixel or only part of it and, typically, structures of high CT density appear larger than they are in reality. Thus, calcified coronary plaques can seem to take up much more of the coronary cross-section than they actually do, making the residual contrast-enhanced lumen undetectable and consequently rendering affected coronary segments un evaluable. Increased spatial resolution could help overcome that effect because the image is then made up of smaller pixels.

In this issue of the Journal, Kueftner et al. (18) report their results of using four-slice MDCT to detect coronary artery stenoses in a group of 66 patients with previously known coronary artery disease. At first sight, the results seem extremely disappointing: only 39 of 105 coronary stenoses were correctly identified (yielding a sensitivity of 37% and specificity of 99%), indicating that MDCT imaging is essentially useless for any clinical purpose in this group of patients. The authors perform an analysis of the reasons that prevented detection of coronary stenoses, and resolution again is the answer: A high heart rate (temporal resolution) and the presence of coronary calcifications in particular (spatial resolution) were identified as the major contributors to false-negative findings and impaired image quality. It then becomes obvious why results are substantially worse than in previous studies, which frequently were conducted in patient groups with a low prevalence of coronary disease. First of all, coronary calcifications are more prevalent in patients with known coronary artery disease. Also, although the authors do not report on this, it is possible that the prevalence of diabetes was high. Diabetic

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patients frequently have a smaller coronary artery lumen, which aggravates the effects of limited spatial resolution. Finally, the authors deliberately chose not to give beta-blockers in preparation for the MDCT scan. Beta-blockade is suggested by many authors to reduce the heart rate, thus increasing the duration of diastole and attenuating the effects of insufficient temporal resolution by providing a longer interval of no or little coronary motion.

In this respect, the report by Kuettner et al. (18) is an extremely valuable one. Besides illustrating the limitations of CT coronary angiography using a four-slice MDCT system, it very clearly shows that the results that can be achieved depend very strongly on the group of patients that is studied. Two lessons can be learned from this report. First, before a new technology can be used clinically, it must be thoroughly evaluated in the very group of patients in which it shall be applied. Second, to improve clinical results, cardiac CT equipment needs to provide higher temporal and spatial resolution than the technology used by Kuettner et al. Meanwhile, such equipment has become available: Two initial reports of MDCT with 16-slice scanners that acquire thinner slices and rotate faster clearly showed higher accuracy and a lower fraction of unevaluable arteries as compared with the previous scanner generation (19,20).

Hopes that CT coronary angiography may eventually be a clinically valuable tool in selected patient groups seem justified.

Obviously, establishing a clinical role for CT coronary imaging takes yet another kind of resolution—the resolution of CT manufacturers to continuously improve their products as well as the resolution of clinical researchers to conduct well-planned trials and subject the new technologies to appropriate and thorough evaluation in various clinical situations.

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REFERENCES


