EDITORIAL COMMENT

Computed Tomography of the Coronary Arteries

More Than Meets the (Angiographic) Eye*

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Coronary arteries are small and they move rapidly. Thus, imaging of the coronary arteries requires high spatial and high temporal resolution. Invasive, catheter-based coronary angiography has a temporal resolution ("shutter speed") of approximately 6 ms and a spatial resolution of approximately 0.25 mm. Noninvasive imaging modalities currently do not rival these parameters. All the same, computed tomography (CT) imaging particularly has gone through a tremendous technical development since the first generation of multi-slice CT scanners were introduced in the year 2000. Gantry rotation speed has increased rapidly, resulting in improved temporal resolution. Also, scanners now can acquire as many as 64 slices in one rotation. It is not so much the mere number of cross sections that can be acquired at the same time that constitutes the improvement but the fact that this speed allows the acquisition of thinner slices while still covering the complete volume of the heart in one short breath hold, with thinner slices translating into higher spatial

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resolution. In this issue of the *Journal*, Leber et al. (1) present a first evaluation of the latest generation of 64-slice CT for the detection of coronary artery stenoses and assessment of coronary atherosclerotic plaque. Their scanner acquired 64 slices of 0.6-mm collimation simultaneously with a gantry rotation time of 330 ms. For the scan protocol that was used, they cite a spatial resolution of 0.4 mm and temporal resolution of 83 to 165 ms—still substantially less than invasive coronary angiography but a continuous improvement over previous scanner generations.

In their thorough analysis, the authors considered the entire coronary artery tree evaluable concerning the presence of coronary stenoses in 55 of 59 patients. Sensitivity for detecting coronary stenoses of more than

50% by CT was 73% if all coronary segments were considered, which at first sight may seem disappointing. However, many of these lesions were localized in distal coronary segments, and of all those 27 stenoses that were subsequently considered to require revascularization, 24 were correctly detected by CT (sensitivity of 89%). More important still is the patient-based analysis, which showed that 17 of 18 patients who required revascularization were correctly detected by CT (sensitivity of 94%). It can thus be expected that the use of CT imaging permits one to reliably identify patients who do not need revascularization despite symptoms. In our opinion, this will be the major application of noninvasive coronary imaging by CT. It is very likely that appropriately designed studies will clearly demonstrate the ability of CT coronary angiography to rule out hemodynamically relevant stenoses and replace invasive, catheter-based coronary angiography with an associated medical and economic benefit in certain clinical settings in the near future.

A technical note: despite several previous studies that have shown that low heart rates improve image quality (2–5), Leber et al. (1) were quite "liberal" concerning heart rate during the CT scan and beta-blockade was used only in 21 of 59 patients. Although in their analysis of image quality they describe "diagnostic image quality" in 6 of 9 patients with a heart rate >70 beats/min, the mean heart rate of patients that were not fully evaluable was 77 beats/min (and, therefore, substantially higher than the average heart rate of the remaining patients, 62 beats/min). Also, they fail to provide an analysis of the reasons for missed detection of stenoses by CT. On the basis of previous experience (6–8), it is possible that motion artifacts may have contributed to false-negative findings. Most experts would still recommend strict lowering of the heart rate for CT coronary imaging, especially because lower heart rates not only improve image quality but also lead to lower radiation exposure in conjunction with electrocardiography-gated tube current modulation (9).

Importantly, Leber et al. (1) go one step beyond the assessment of mere angiographic stenosis in their study. Because CT is a cross-sectional imaging technique, coronary CT imaging not only shows the contrast-enhanced vessel lumen but also has the potential to visualize the vessel wall and coronary atherosclerotic plaque (Fig. 1). The visualization and quantification of coronary atherosclerotic plaque is even more difficult than the assessment of the coronary artery lumen: plaque dimensions are very small, and the contrast between plaque material and the surrounding tissue is low (with the exception of calcium, which, therefore, has been used as a surrogate marker for plaque burden for considerable time). All the same, Leber et al. (1) demonstrate the impressive ability of 64-slice CT to detect and quantify non-stenotic coronary atherosclerotic plaque, with a sen-

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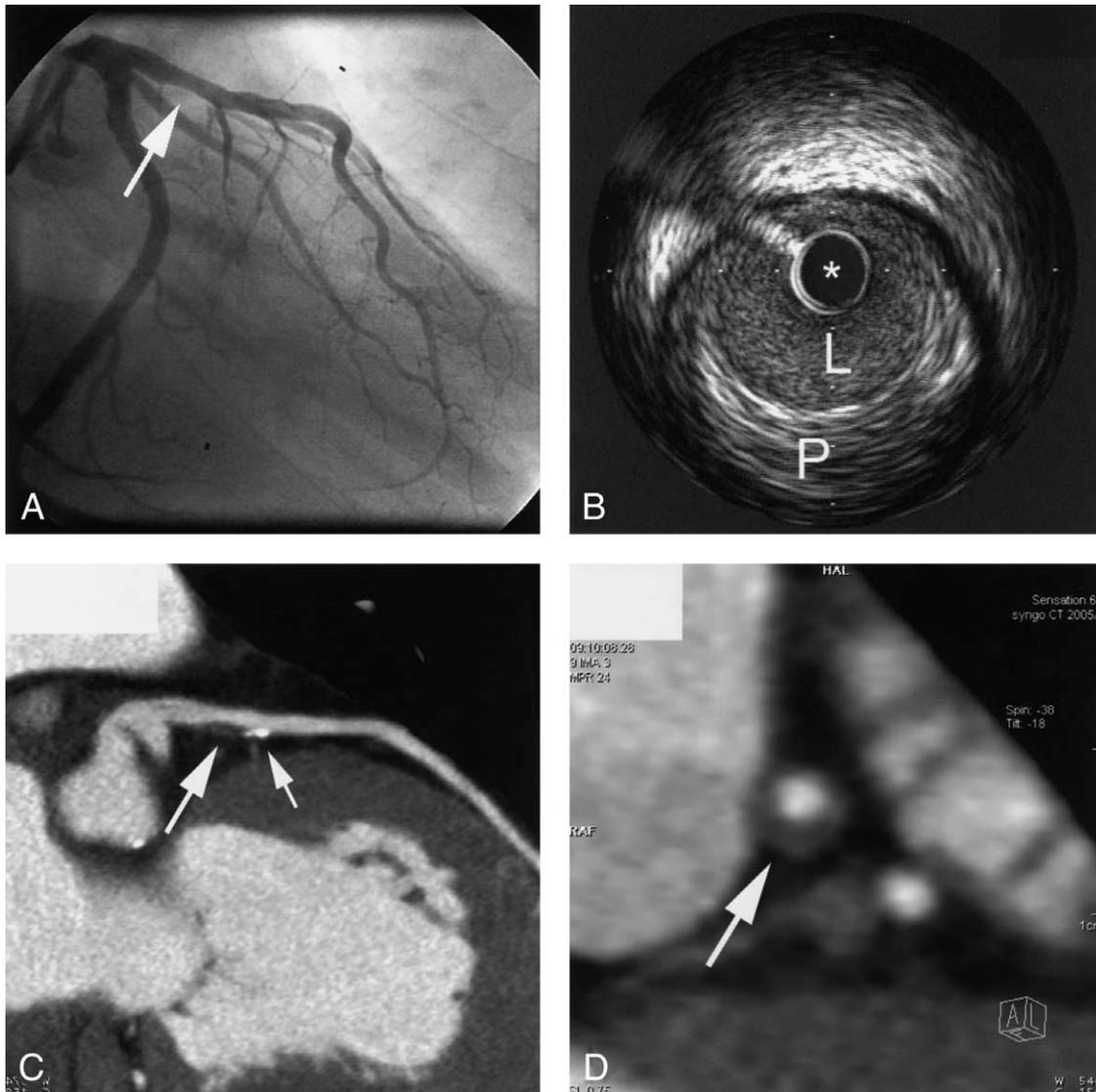
Fig. 1. Visualization of coronary atherosclerotic plaque by 64-slice computed tomography (CT). **(A)** Coronary angiography shows mild eccentric lumen reduction in the proximal left anterior descending artery **(arrow)**. **(B)** Intravascular ultrasound demonstrates the presence of excentric non-calcified coronary atherosclerotic plaque. L = lumen; P = plaque. *Intravascular ultrasound catheter. **(C)** Contrast-enhanced 64-slice CT shows the proximal left anterior descending artery in a multiplanar reconstruction. At the site of lumen reduction, a coronary atherosclerotic plaque with positive remodeling can be seen **(large arrow)**. A small calcification is present toward the distal border of the plaque **(small arrow)**. **(D)** Cross-sectional view of the lesion at the site of maximum plaque area by CT, demonstrating the bright, contrast-enhanced lumen and the eccentric plaque **(arrow)**.

sitivity of 84% and specificity of 91% for plaque detection and a correlation of r = 0.71 for plaque area (again, higher than previously reported) (10). Undoubtedly, the ability to detect and quantify plaque, as well as the accuracy for stenosis detection, will continue to increase with improvements in scan protocols and scanner technology.

The limitation to mere "lumenography" often has been held against invasive coronary angiography. Will the ability of contrast-enhanced CT to overcome that limitation and visualize both the coronary lumen and also coronary atherosclerotic plaque translate into clinical applications and benefit for individual patients? At the moment, we do not think that is the case. Although the predictive power of coronary calcium clearly has been

shown in many studies, there are no data that link the presence of atherosclerotic plaque observed in contrast-enhanced CT to the occurrence of future cardiovascular events, even though intuitively it may seem very likely to assume such a relationship. The substantial exposure to radiation and contrast agent necessary to detect noncalcified coronary plaque by CT has to be weighed against potential advantages over traditional risk assessment or imaging for quantification of calcium. Also, no proof exists that interventional treatment at the site of nonstenotic lesions has a prognostic benefit (11). Thus, little justification exists to draw any clinical conclusions or recommendations based on the finding of noncalcified plaque in contrast-enhanced CT of the coronary arteries at this moment in time. All the same, the potential of CT

to overcome the limitation of invasive angiography and to actually show the atherosclerotic plaque itself is intriguing and definitely worthy of further investigation.

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