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EDITORIAL COMMENT

Quantification of Coronary Artery Stenoses by Computed Tomography*

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Coronary computed tomography (CT) angiography is being increasingly employed for the evaluation of coronary artery disease (CAD). Recent publications using 64-slice CT (1,2), and dual-source CT (3,4) have demonstrated high accuracy for the detection of coronary stenoses in comparison with invasive angiography. The high negative predictive value makes CT angiography an especially attractive tool to rule out CAD with a degree of certainty and confidence that is higher than any other noninvasive and more indirect tests, such as myocardial perfusion imaging (5). A recent expert consensus document has proposed *appropriate* indications for coronary CT angiography, which include chronic stable angina with intermediate likelihood of CAD and equivocal results of a stress test, as well as acute chest pain with an intermediate likelihood of CAD based on clinical assessment and noncontributory enzymes, or electrocardiogram changes (6).

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Since coronary CT angiography is an anatomy-based diagnostic test, its performance is validated against invasive coronary angiography. Similar to the invasive angiogram, CT allows assessment of coronary luminal narrowing, albeit not with the same degree of accuracy for quantification. Many reasons can explain the lower degree of accuracy. First, the physical properties of CT set limits to the accuracy with which the dimensions of the coronary lumen can be measured. Although spatial resolution of CT has increased substantially over the past years, it remains lower (~0.5 mm) than that of the invasive angiogram (~0.2 mm). Further, artifacts caused by the limited temporal resolution of CT, such as blurring of vessel contours or streaks emanating from calcified plaques, as well as image noise may compromise the accuracy of CT measurement of the coronary luminal diameter. This is the reason why most previous studies on coronary CT angiography have used binary cutoff values, such as >50% diameter stenosis or >70% diameter stenosis, to define a *clinically relevant* coronary artery stenosis by CT angiography. Few trials have tried to use quantitative approaches for determining percent stenosis and comparing these values to quantitative coronary angiography. In these studies, although the correlation (a poor measure of the agreement of 2 parameters) between the degree of stenosis detected by CT and invasive angiography was usually *significant*, the relationship showed substantial scatter and limits of agreement typically ranged from 20% to 40% (7–11). Since precise quantification of degree of stenosis is not possible by CT angiography, and a binary *disease present* or *disease absent* decision not truly acceptable, the use of categorical scores to grade stenosis in CT angiography makes eminent sense. Cheng et al. (12), in this issue of *iJACC (JACC: Cardiovascular Imaging)*, propose a 5-point scale (Table 1) to grade coronary artery stenosis by CT angiography and demonstrate a significant agreement with quantitative invasive coronary angiography. Interestingly, visual estimation was just as good as quantitative measurements of stenosis degree in CT angiography and a <50% lesion in CT angiography, according to their results, is virtually exclusive of a stenosis ≥70% in invasive angiography. Earlier authors have proposed different scoring systems (Table 1) (10,13) to grade severity of stenosis; each has its advantages and disadvantages. For instance, based on the wide

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Table 1. Proposed Grading Systems for Luminal Diameter Stenosis in Coronary Computed Tomography Angiography

Cheng et al. (12)		Cury et al. (10)		Goldstein et al. (13)	
Grade	Luminal Diameter Stenosis	Grade	Luminal Diameter Stenosis	Grade	Luminal Diameter Stenosis
1	<25%	Mild	0%–40%	1	1%–25%
2	25%–49%	Moderate	41%–70%	2	26%–50%
3	50%–69%	Severe	71%–100%	3	51%–70%
4	70%–89%			4	71%–99%
5	≥90%			5	100%

limits of agreement for stenosis quantification by CT, Cury et al. (10) used a wide category of *moderate* stenosis, ranging from 41% to 70%, which would necessitate further testing for ischemia for complete characterization of coronary disease. On the other hand, Goldstein et al. (13) included a separate category for total coronary occlusion, often an important distinction from high-grade stenosis. The grades proposed by Cheng et al. (12) have been validated thoroughly, and the agreement with clinically relevant categories of coronary stenosis verified by invasive coronary angiography is compelling. CT interpreters should give serious thought to adopting one or more of these systems.

Importantly, however, the authors of these reports make it very clear that their systems refer *only* to the assessment of luminal narrowing. It should be noted that CT imaging has the potential to reveal more than only luminal narrowing. A high-quality CT data set will also demonstrate the atherosclerotic plaque that causes the stenosis, and it is not uncommon to encounter large plaques that cause only mild or moderate luminal stenosis because compensatory remodeling substantially attenuates their encroachment on the lumen. As such, in comparison with the invasive angiogram, estimation of the degree of stenosis by CT angiography may be misleading when the observer does not take into account a substantial impact of *positive remodeling* of the lesions. Based on cross-sectional images, when comparing patent vessel lumen to the overall vessel cross section, the degree of stenosis could be interpreted as more severe than in the invasive angiographic assessment, which considers luminal stenosis only by comparison to the vessel lumen in proximal and distal reference segments (Fig. 1). The often pronounced remodeling and the small vessel lumen in comparison to the large overall vessel diameter do contribute to a tendency to visually overestimate stenosis degree in CT. Interpreters of cardiac CT need to be cautious when making their assessment of stenosis severity in order to avoid overdiagnosis of *significant* coronary artery stenoses, which may lead to unnecessary invasive coronary angiograms.

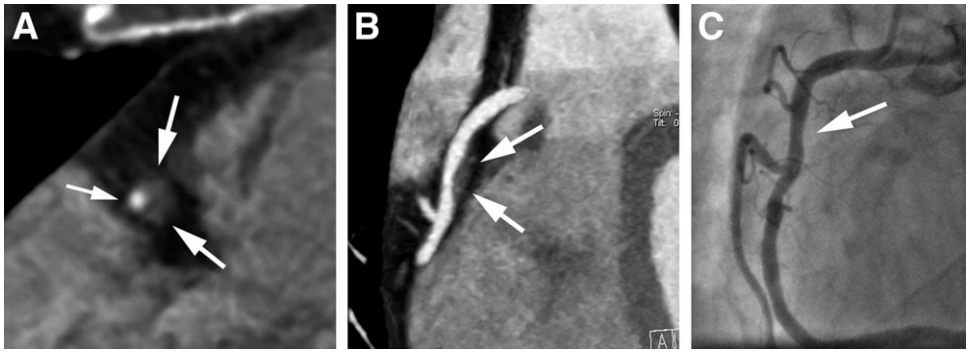

Figure 1. Assessing Degree of Stenosis by CT and Invasive Angiography

Coronary atherosclerotic lesion of the proximal right coronary artery in a 53-year-old woman. **(A)** A cross-sectional computed tomography (CT) image suggests a high-grade lesion with a large noncalcified plaque **(large arrows)** and a small remaining vessel lumen **(small arrow)**. **(B)** A longitudinal display of the lesion in CT angiography demonstrates extensive *positive remodeling* **(arrows)**. Consequently, the degree of *luminal* narrowing appears less than suggested by the cross-sectional display of the vessel in **panel A**. According to Cheng et al. (12), the lesion would probably visually be quantified as *grade 2* (25% to 49% stenosis). **(C)** Invasive angiogram of the right coronary artery confirms that the degree of stenosis **(arrow)** is mild and should have been classified as *grade 1* (<25% stenosis).

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Visualization of lumen *and* plaque by CT, therefore, is a 2-sided sword. As a downside, it sometimes leads to overestimation of stenosis degree. However, it allows a more comprehensive assessment of coronary lesions, including their associated plaque burden. Complete quantification of a coronary lesion by CT angiography could—and potentially will—also include plaque dimensions (14,15), the degree of remodeling (16), and plaque characteristics such as CT attenuation and calcification (15,17,18). Future studies will certainly help elucidate how accurately CT allows the description of such lesion characteristics and what their relevance is in respect to the clinical importance of a given coronary artery stenosis. The last word on lesion quantification by CT has certainly not yet been spoken.

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