Coronary artery disease (CAD) and its consequences remain a leading cause of morbidity and mortality among most age groups in the USA and most Western countries. In 50–65% of all patients, myocardial infarction (MI) is the first clinical presentation of CAD in previously asymptomatic patients. Approximately 35% of these first MIs are lethal. In symptomatic patients with acute or chronic chest pain, establishing the presence of myocardial ischemia secondary to severe CAD as the cause can be challenging and expensive. Consequently, much clinical research has been devoted to establishing “new” techniques to predict MI and sudden cardiac death in intermediate- or high-risk populations (prognostication), and to diagnose high-grade CAD in asymptomatic patients (diagnosis). Ultimately, the clinical objective of employing these techniques is to facilitate patient management decisions that will improve patients’ longevity or quality of life (therapy). Many tools exist to address prognostication and diagnosis of CAD, which all have different strengths and weaknesses.

Coronary computed tomographic angiography: current role in the diagnosis and management of coronary artery disease

Andrew W. Bowman1, Birgit Kantor2, Thomas C. Gerber1,3

1 Department of Radiology, Mayo Clinic, Jacksonville, FL, United States
2 Division of Cardiovascular Diseases, Mayo Clinic, Rochester, MN, United States
3 Division of Cardiovascular Diseases, Mayo Clinic, Jacksonville, FL, United States

Correspondence to: Thomas C. Gerber, MD, PhD, Division of Cardiovascular Diseases, Mayo Clinic, 4500 San Pablo Road, Jacksonville, FL 32224, USA, e-mail: gerber.thomas@mayo.edu

Received: April 24, 2009.
Accepted: May 1, 2009.
Conflict of interest: this work was supported in part by National Institutes of Health (NIH) grant 1R01EB007986-02 ("Non-Invasive Localization of Vulnerable Plaques") awarded to Dr Birgit Kantor.

Copyright by Medycyna Praktyczna, Kraków 2009

ABSTRACT

Advances in computed tomography (CT) technology allow images to be obtained with high spatial and temporal resolution. These features now permit noninvasive coronary CT angiography (CCTA). Many studies addressing proof of concept, feasibility, and clinical robustness have been published since CCTA was first described. More recently, the scientific evaluation of CCTA has rightly focused less on technical aspects and more on multicenter trials of the diagnostic value of CCTA and on head-to-head comparisons with other noninvasive modalities for the detection of coronary artery disease (CAD), such as stress myocardial perfusion imaging (MPI) with radionuclides. Recent peer-reviewed publications that compare CCTA to invasive, selective coronary angiography (SCA) or MPI, or that address radiation protection issues related to CCTA, were reviewed and summarized. Overall, there is high agreement between CCTA and both SCA and MPI for the presence of CAD. However, CCTA can over- or underestimate the severity of CAD compared to SCA as a reference standard. Initial studies that compared CCTA to MPI found their accuracies for determining the presence of high-grade luminal obstructions comparable. Limitations of CCTA include inability to reliably assess the coronary artery lumen dimensions in patients with large amounts of coronary artery calcium, artifacts caused by coronary and respiratory motion, and the need for ionizing radiation and intravenous administration of iodinated contrast material. Various dose reduction methods for CCTA now exist that may substantially lower patient dose to levels less than those of SCA or MPI. Although current expert consensus does not call for CCTA to be a first-line test for CAD, particularly for screening in asymptomatic individuals, current data suggest a promising role in the evaluation of symptomatic patients for possible CAD.

KEY WORDS cardiology, computed tomography, coronary angiography, imaging, ionizing radiation
in population-based longitudinal studies such as the Framingham study. However, approximately ⅓ of cardiovascular events are not readily explained by these “traditional” cardiovascular (CV) risk factors. Therefore, a large body of literature has examined the predictive value of “novel” cardiac risk factors such as lipoprotein(a), homocysteine, highly sensitive C-reactive protein (CRP), or biomarkers of atherosclerosis and inflammation, such as CRP, interleukin 6, or matrix metalloproteinase. Another relatively new approach to cardiovascular risk stratification uses imaging of “subclinical” atherosclerosis. Examples include ultrasonic measurement of carotid intima-media thickness or scanning for coronary artery calcium by CT. The rationale for imaging to find non-obstructive, clinically silent plaque is to provide evidence for a genetic susceptibility for responding to the presence of CV risk factors with development of atherosclerosis. This approach could theoretically identify “vulnerable” patients at a time when aggressive risk factor modification can slow or halt the atherosclerotic process and reduce the risk of progression to the stage of symptomatic disease.

The noninvasive identification of ischemia in symptomatic patients relies on stress testing. Current guidelines by the American Heart Association (AHA) and American College of Cardiology suggest treadmill stress electrocardiography as the test of first choice. Stress testing combined with imaging in the form of echocardiography or myocardial perfusion imaging (MPI) with radioisotopes is indicated only if the electrocardiography cannot be reliably interpreted for ischemic changes (i.e. ST-segment abnormalities at baseline, left bundle branch block). Treadmill exercise is recommended as stress modality of first choice over pharmacologic stress agents such as dobutamine or adenosine as long as the patient is able to exercise effectively.

A great strength of stress testing lies in the functional information it can provide. Common to all stress tests is the ability to detect impaired coronary flow reserve, which can serve as a “roadmap” to plan percutaneous or surgical revascularization if more than one anatomically “significant” stenosis is found eventually on selective coronary angiography (SCA), and has prognostic value if not only the presence but also the extent and degree of ischemia is considered. Unique to exercise tests is the prognostic information conveyed by a patient’s exercise capacity.

What are the shortcomings of our current approaches? The traditional noninvasive tests for CAD rely on indirect evidence for high-grade coronary artery stenoses from the “ischemic cascade” in the form of myocardial perfusion defects (MPI), inducible regional myocardial dysfunction (stress echocardiography) or typical electrocardiographic abnormalities (treadmill exercise testing) for the diagnosis of significant CAD. Owing to this principle, imaging stress tests with...
Recent advances in computed tomography angiography (CTA) allow visualization of the coronary arteries, and many patients undergoing coronary angiography are candidates for CTA. Early studies of CTA reported large proportions of nondiagnostic studies, mostly due to the comparatively low temporal and spatial resolution. Initial meta-analyses indicated higher diagnostic accuracy and lower number of nondiagnostic studies with newer compared to older CT scanners. Most studies of CTA have reported diagnostic accuracy by coronary artery segment, coronary artery, and per patient. In newly symptomatic patients without prior history of CAD, the per-patient accuracy is the most meaningful parameter among these three for classifying individual patients as having or not having CAD. A recent meta-analysis of 23 single-center studies that compared CTA to SCA in a total of 2045 patients noted the following findings: for a significant coronary artery stenosis of ≥50% in patient-based analysis (the presence of coronary disease somewhere in the coronary tree of a given patient), vessel-based analysis (the presence of disease in a particular coronary artery) and segment-based analysis (the presence of disease in a particular segment of a particular coronary artery), CTA had sensitivities of 92% to 95%, specificities of 88% to ≥90%, variable positive predictive values (PPV) ranging from 69% to 93%, and negative predictive values (NPV) ranging from 96% to 100%. Given the dependence of PPV and NPV on the prevalence of disease, the comparatively high prevalence of significant CAD as determined by SCA in many of these selected study populations (61%) compared to the general population is a problem in appraising the value of CTA in clinical practice. Therefore, this meta-analysis also reported positive (+LR) and negative (–LR) likelihood ratios as prevalence-independent indicators of diagnostic accuracy. The +LR values

FIGURE 2 Abnormal coronary computed tomographic angiogram with confirmation from diagnostic catheterization shows tandem high-grade stenoses (arrows) in the left anterior descending artery.

A. Coronal computed tomographic angiogram reformatted in vertical long axis

B. Selective coronary angiogram in similar projection

Abbreviations: see FIGURE 1

echocardiography or MPI are somewhat limited in their sensitivity and specificity. For example, in prior meta-analysis the sensitivity of stress echocardiography was 79% (95% CI 78–81) and the specificity, 87% (95% CI 86–89). MPI was 88% sensitive (95% CI 87–90) and 73% specific (95% CI 69–77).

For many decades, invasive, catheter-based SCA was the only means to directly visualize the coronary artery lumen. To date, SCA remains the reference standard for the evaluation of CAD, but there is ongoing debate among clinicians as to the appropriate indications and timing for coronary catheterization.

The shortcomings of SCA are well recognized. First, the risk of “major” procedural complications such as MI, stroke, and need for emergent bypass surgery are low but appreciable at approximately 1 in 1,000 procedures. Second, SCA is a “battered gold standard” with low accuracy compared to pathology and a worrisome degree of interobserver variability in the determination of the degree of luminal obstruction. Third, the degree of luminal obstruction does not reliably predict the functional significance of a stenosis, i.e. ischemia. The fractional flow reserve in diseased coronary arteries depends on many morphologic parameters, and in studies and guidelines, “significant” coronary stenosis has variably been defined as 50% or 70% luminal narrowing compared to presumably normal reference segments. Uncertainty about the functional significance of intermediate (50–70%) stenoses is a well known limitation of “anatomic” imaging modalities such as angiography. Fourth and final, most plaque ruptures that cause acute coronary thromboses occur in segments with no more than moderate stenoses; hence, absence of high-grade stenoses does not guarantee freedom from cardiac events even in the near term.
In the study by Miller et al., patients with coronary artery disease (CAD) were enrolled. The area under the curve was 0.93 (95% CI, 0.90–0.96). The dotted line represents a calibration curve. A corresponding CCTA cutoff point can be determined by extending a vertical line from a point on the ROC curve to the calibration curve and then a horizontal line to the right ordinate, which describes the cutoff point.

Two recent prospective multicenter studies reported data on 64-slice multidetector CCTA in 360 and 291 subjects, respectively, who were referred for clinically indicated SCA. Using a coronary artery diameter reduction of ≥50% as significant, both studies found CCTA to be very sensitive for detecting overall significant CAD and at least moderately specific (Table 1). As stated above, per-patient analyses referred to the presence of at least one significant stenosis anywhere in the coronary system. This type of analysis did not necessarily imply that significant stenoses seen on CCTA were visible in the same coronary segment on SCA. When analysis of diagnostic accuracy was performed by vessel or segment, the results were markedly different (Figure 3), though comparable to the recent meta-analysis discussed above.

Receiver operator characteristics curves were generated in the study by Miller et al. demonstrating an area under the curve of 0.93 for the per-patient ability of CCTA to predict presence of at least one >50% stenosis diagnosed by SCA (Figure 3). The severity of disease expressed as a modified Duke score correlated well (r = 0.81) between CCTA and SCA.

These two recent multicenter studies discussed several methodological limitations of CCTA. In the study by Miller et al., patients with high coronary calcium scores (Agatston calcium score of >600) were automatically excluded from the analysis, under the argument that such levels of calcium would obscure too much of the vessel to accurately evaluate. In the study by Meijboom et al., no segments were automatically excluded because of high calcium scores, but the authors noted that such calcifications limited the accuracy of vessel and segment analysis. Accordingly, the typically high levels of coronary calcium in older patients (>75 years) or patients with known CAD limit the use of CCTA in these patient populations.

Also of importance was the high prevalence of CAD with ≥50% diameter reduction of 68% and 31% in these studies, respectively, both substantially higher than in the general population, which also limits the ability to extrapolate their findings to the general population.

Of concern in the study by Meijboom et al. was the high number of false positive findings on CCTA. For example, of 98 patients diagnosed to have three-vessel disease by CCTA, only 19 were confirmed by SCA, and 9 patients had no disease at all. The overall weighted k value for the agreement between CCTA and SCA in the determination of extent of disease was only moderate at 0.47. This finding, together with the low PPV of 47% in the per-segment analysis, exemplifies how limited CCTA was in precisely localizing significant coronary stenoses in a population with moderate prevalence of disease. Similarly, the study by Miller et al. also shows a high rate of misclassification of disease severity in CCTA compared to SCA. Indeed, Miller et al. themselves note that despite the overall excellent accuracy, sensitivity, and specificity of CCTA, “multidetector CT angiography cannot replace coronary angiography in this population of patients at present.” Conversely, both studies confirmed the previously noted very high NPV despite the high prevalence of disease. In both studies, if a patient’s CCTA was interpreted as being normal, significant CAD on SCA was virtually excluded.

**Coronary artery computed tomographic angiography vs. stress nuclear imaging** The limited PPV of CCTA compared to SCA invites combined “hybrid” imaging with MPI, or at least comparative studies between CCTA and MPI. An initial

### TABLE 1 Diagnostic performance of 64-slice computed tomography in detecting significant (≥50% stenosis) coronary artery disease in patient-based and vessel-based analysis

<table>
<thead>
<tr>
<th></th>
<th>Patient-based analysis (95% CI)</th>
<th>Vessel-based analysis (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensitivity (%)</td>
<td>99 (98–100)</td>
<td>85 (79–90)</td>
</tr>
<tr>
<td>specificity (%)</td>
<td>64 (55–73)</td>
<td>90 (83–94)</td>
</tr>
<tr>
<td>PPV (%)</td>
<td>86 (82–90)</td>
<td>91 (86–95)</td>
</tr>
<tr>
<td>NPV (%)</td>
<td>97 (94–100)</td>
<td>83 (75–89)</td>
</tr>
</tbody>
</table>

*Abbreviations: PPV – positive predictive value, NPV – negative predictive value*

---

**FIGURE 3** ROC curve (solid line) describing the diagnostic performance of CCTA to identify coronary stenosis of 50% or more in at least one vessel, as compared with invasive quantitative coronary angiography at the level of the patient. The area under the curve was 0.93 (95% CI, 0.90–0.96). The dotted line represents a calibration curve. A corresponding CCTA cutoff point can be determined by extending a vertical line from a point on the ROC curve to the calibration curve and then a horizontal line to the right ordinate, which describes the cutoff point.

**TABLE 2** Diagnostic performance of 64-slice computed tomography in detecting significant (≥50% stenosis) coronary artery disease in patient-based and vessel-based analysis

<table>
<thead>
<tr>
<th></th>
<th>Patient-based analysis (95% CI)</th>
<th>Vessel-based analysis (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensitivity (%)</td>
<td>99 (98–100)</td>
<td>85 (79–90)</td>
</tr>
<tr>
<td>specificity (%)</td>
<td>64 (55–73)</td>
<td>90 (83–94)</td>
</tr>
<tr>
<td>PPV (%)</td>
<td>86 (82–90)</td>
<td>91 (86–95)</td>
</tr>
<tr>
<td>NPV (%)</td>
<td>97 (94–100)</td>
<td>83 (75–89)</td>
</tr>
</tbody>
</table>

*Abbreviations: PPV – positive predictive value, NPV – negative predictive value*
TABLE 2  Diagnostic performance of multidetector computed tomography in detecting significant perfusion abnormalities in myocardial perfusion imaging\(^{25,26,29}\)

<table>
<thead>
<tr>
<th>Study</th>
<th>Gaemperli et al. (2007)(^a)</th>
<th>Sato et al.(^b)</th>
<th>Gaemperli et al. (2008)(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCA data included</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>sensitivity (%)</td>
<td>75</td>
<td>79</td>
<td>95</td>
</tr>
<tr>
<td>specificity (%)</td>
<td>90</td>
<td>92</td>
<td>53</td>
</tr>
<tr>
<td>PPV (%)</td>
<td>68</td>
<td>66</td>
<td>58</td>
</tr>
<tr>
<td>NPV (%)</td>
<td>93</td>
<td>96</td>
<td>94</td>
</tr>
</tbody>
</table>

CI were not reported.

\(a\) Data is for ≥75% stenosis correlating to any perfusion deficit.

\(b\) Data is for ≥70% stenosis correlating to a reversible perfusion deficit.

\(c\) Data is for ≥50% stenosis correlating to a reversible perfusion deficit.

Abbreviations: SCA – selective coronary angiography, others – see TABLE 1

...imaging can provide by offering diagnostic information and guidance for management. A recent report from the National Council for Radiation Protection and Measurements\(^1\) showed that, compared to 1986, the number of CT imaging studies increased by >10% per year, and that the collective dose received from diagnostic medical radiation including radiography and nuclear medicine studies has increased by >700% and the annual per-capita dose, by almost 600%. However, the report also showed that 80% of the 67 million CT studies in the USA in 2006 were performed in presumably very ill or at-risk patient populations, namely in the hospital setting and in the elderly.

TABLE 2  Diagnostic performance of multidetector computed tomography in detecting significant perfusion abnormalities in myocardial perfusion imaging\(^{25,26,29}\)

In order to understand the information on radiation exposure and dose that is often provided in passing in clinical studies of CCTA, it is important to have a basic working knowledge of radiation dosimetry and radiation biology.\(^{38}\) While the risk of malignancies at high radiation doses such as those received by the survivors of atomic bomb explosions or nuclear accidents is rarely disputed, the risk of cancer at the radiation dose levels in medical imaging is very controversial among medical physicists. Because no definite data on the dose-response relationship exist,
and possibly never will, the risks of medical radiation are usually discussed with the conservative assumption that there is no dose threshold below which ionizing radiation cannot cause malignancies, and that the risk varies proportionally and linearly with dose (the so-called "linear no-threshold hypothesis"). Based on the linear no-threshold hypothesis, a recent study modeled the lifetime attributable risk of cancer of a typical 64-slice CCTA: the risk varied between 0.7% (1 in 143) for 20-year-old women to 0.044% (1 in 2273) for 80-year-old men. However, the linear no-threshold hypothesis is not universally supported.

It is important to realize that there is a difference between dosimetry parameters that can be measured, such as the volume computed tomographic dose index or the dose length product, and parameters that are estimated based on modeling from complex assumptions, such as the effective dose (E) estimate. E, perhaps the dosimetry parameter most frequently quoted in CCTA studies, is an estimate of the biologic risk of a non-homogeneous irradiation of a part of the body (i.e. the chest) that is typical in medical imaging. E is a generic, not a patient-specific, estimate that is best used to compare the potential biologic risk between different CT imaging protocols, or between different types of radiological examinations, including comparisons between different types of radiation (i.e. X-ray-based CCTA vs. radionuclide-based MPI). It cannot be used to compare radiation doses between patients for the same imaging procedure. Given the various uncertainties related to the modeling process used to estimate E, E should be quoted as ranges, not numbers with several decimal places. Table 3 lists the representative values and ranges of E reported in the literature for selected radiological studies. For comparison, the average annual background exposure in the USA due to natural sources of radiation such as radon is approximately 3 mSv (range: 1–10 mSv).

The radiation output of CT scanners, and hence radiation dose estimates for CCTA, are related to several modifiable scanner settings. There is an inverse relationship between radiation dose and image noise. Radiation protection for the patient includes the challenge to keep patient dose as low as reasonably achievable while maintaining the image quality at a level that allows confident interpretation.

Traditionally, coronary multidetector CT angiography uses retrospective gating. In this mode, radiation is produced for the entire cardiac cycle over several cardiac cycles, until the patient table has moved through the gantry enough for the entire heart to be covered from its cranial to its caudal end. Planar, transaxial images are then reconstructed from the projection data at a retrospectively defined window during the cardiac cycle. This reconstruction window is chosen at a phase where cardiac motion is minimal, typically during mid-diastole just after passive ventricular filling is complete (diastasis, 60–70% of the R-to-R interval on the electrocardiogram). The remainder of the projection data, and the radiation invested to acquire it, is not used.

Several techniques exist to reduce patient dose from CCTA. Electrocardiographically controlled tube current modulation (ECTCM) reduces radiation output by approximately 80% during the portions of the cardiac cycle unlikely to be used for image reconstructions (i.e. typically during most of systole). In a recent international, multicenter survey of radiation dose in CCTA, ECTCM lowered E by 25% and was used in 73% of patients. Sequential scanning, sometimes also referred to as "prospective triggering," is a new CT scanning technique that entirely shuts off the X-ray tube during the portions of cardiac cycle unlikely to be used for image reconstruction. Sequential scanning lowered E by 78% and was used in 6% of patients. Reduction of tube voltage from 120 to 100 kVp reduced E by 46% and was used in 5% of patients. The low utilization of the techniques that reduced radiation dose the most, namely sequential scanning and tube voltage reduction, are likely related to the facts that sequential scanning was not widely available in 2007, when the survey was conducted, and to concerns among the cardiac

### TABLE 3

<table>
<thead>
<tr>
<th>Examination</th>
<th>Representative effective dose value (mSv)</th>
<th>Range of reported effective dose values (mSv)</th>
<th>Administered activity (MBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>chest X-ray PA and lateral</td>
<td>0.1</td>
<td>0.05–0.24</td>
<td>NA</td>
</tr>
<tr>
<td>coronary calcium CT</td>
<td>3</td>
<td>1–12</td>
<td>NA</td>
</tr>
<tr>
<td>64-slice CCTA without tube current modulation</td>
<td>15</td>
<td>12–18</td>
<td>NA</td>
</tr>
<tr>
<td>64-slice CCTA with tube current modulation</td>
<td>9</td>
<td>8–18</td>
<td>NA</td>
</tr>
<tr>
<td>prospectively triggered CCTA</td>
<td>3</td>
<td>2–4</td>
<td>NA</td>
</tr>
<tr>
<td>diagnostic invasive coronary angiogram</td>
<td>7</td>
<td>2–16</td>
<td>NA</td>
</tr>
<tr>
<td>percutaneous coronary intervention or radiofrequency ablation</td>
<td>15</td>
<td>7–57</td>
<td>NA</td>
</tr>
<tr>
<td>myocardial perfusion study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sestamibi (1-day) stress/rest SPECT</td>
<td>9</td>
<td>–</td>
<td>1100</td>
</tr>
<tr>
<td>thallium stress/rest SPECT</td>
<td>41</td>
<td>–</td>
<td>185</td>
</tr>
<tr>
<td>F-18 FDG PET</td>
<td>14</td>
<td>–</td>
<td>740</td>
</tr>
<tr>
<td>rubidium-82 PET</td>
<td>5</td>
<td>–</td>
<td>1480</td>
</tr>
</tbody>
</table>

a Data combine prospectively triggered and retrospectively gated protocols.
b 64-slice multidetector-row CT and dual-source CT studies published since 2005 only; data include a survey of the literature by Gerber et al.

Abbreviations: CT – computed tomography, CCTA – coronary CT angiography, FDG – fluorodeoxyglucose, NA – not applicable, PA – posteroanterior, PET – positron emission tomography, SPECT – single photon emitted computed tomography
The AHA scientific statement specifically discouraged use of CCTA for screening for subclinical CAD in asymptomatic patients, but encouraged research into the potential of CCTA to characterize and quantify coronary plaque burden as a means of risk stratification. Similarly, CCTA was not recommended for symptomatic patients with high probability of CAD because these patients were likely to need SCA given the fact that CCTA currently cannot be combined with percutaneous coronary revascularization.

The newer data discussed above do not warrant revision of these recommendations at the current time. However, given the consistently high NPV at many levels of disease prevalence, CCTA could perhaps in the future prove useful for “ruling out” significant coronary stenoses in patient groups where the predictive value of stress imaging is limited or where SCA is currently performed as a matter of course. Such scenarios include ruling out CAD in patients with unexplained left ventricular dysfunction, left bundle branch block, before non-coronary cardiac surgery, or after heart transplantation.

**Conclusions** Finding the place for CCTA in current clinical practice means weighing its known strengths against its potential risks. There are currently no generally accepted first-line indications for CCTA except for the evaluation of congenitally abnormal coronary arteries.

The value of atherosclerosis imaging in general (not limited to CCTA but also including coronary artery calcium scanning or carotid intima-media thickness by ultrasound) for prognostication and for improving patient outcomes as discussed above is controversial because no data from controlled randomized trials exist.

In particular, the rapidly increasing use of CCTA in patients with risk factors for CAD but no symptoms has drawn criticism in the USA for its high cost in the face of unproven value. The optimal management of non-obstructive, subclinical CAD is not established. On this background, we believe that the small hypothetical risk outweighs the unproven, potential benefit, and we advise against the use of CCTA for risk stratification in asymptomatic patients.

CCTA is clearly not useful in patients with enzymatic or electrocardiographic evidence for myocardial compromise where SCA should be used because it can readily be combined with percutaneous coronary revascularization if indicated. The limitations imposed by high levels of coronary calcium on confident image interpretation makes CCTA unsuitable for the assessment of patients with established CAD. Assessment of coronary artery bypass grafts is an interesting but currently unproven use of CCTA.

In symptomatic patients in whom the diagnosis of CAD remains unclear after conventional evaluation, the high sensitivity of CCTA in our opinion more than balances the potential risk of future malignancies, considering the possibly

**FIGURE 4** Coronary computed tomography angiogram demonstrating aberrant origin of the RCA from the left sinus of Valsalva, coursing between the PA and AO.

**A** Horizontal long axis at the level of the aortic root

**B** Vertical long axis.

The potential for compression of the anomalous RCA between the PA from anteriorly and the AO from posteriorly becomes apparent.

**Abbreviations:** RCA – right coronary artery, others – see Figure 1

Imaging community that use of these techniques might reduce image quality and diagnostic accuracy. Studies currently under way will hopefully alleviate these concerns and lead to wider acceptance of these highly effective means of radiation dose reduction.

**So what are the recommended indications for coronary computed tomographic angiography?** Given the limited evidence base to date, no guidelines by any professional associations of healthcare providers in the USA exist for the use of CCTA in clinical practice. A scientific statement by the AHA summarized clinical studies predating the information discussed above. This statement considered the evaluation of the proximal course of known coronary anomalies (FIGURE 4) a meaningful indication for CCTA, based on expert consensus among the Writing Group. Coronary magnetic resonance (MR) angiography, where available, was recommended over CT angiography for this indication in younger patients because of the potentially harmful consequences of exposure to ionizing radiation. There was also consensus that CCTA was indicated as a second-line test in symptomatic patients who remained at intermediate probability of having CAD after initial evaluation by history taking, physical examination, and conventional stress testing. For this indication, CCTA was considered better suited than MR angiography given the higher diagnostic accuracy of the former.
catastrophic consequences of missing high-grade coronary stenoses. This is particularly true for patients who present to the emergency department acutely. In addition, the typical chest pain patient with intermediate probability of CAD is at an age where they are likely to die of other causes before the 10–30 year latency period of radiation-induced malignancies has passed. Other potential indications that exploit the high NPV of CCTA await further study.

The substantial reduction of radiation dose to be expected from widespread implementation of current and future dose-sparing scanning protocols may well shift the risk-benefit balance for many patient groups, but concerns about cost-efficiency remain. Studies of the value of detecting and treating subclinical atherosclerosis in the form of noncalcified plaque for improving longevity are pivotal if the use of CCTA in asymptomatic patients with risk factors to be justified.

REFERENCES


Kantor B, Anavekar NS, Gerber TC. Good news on coronary computed tomographic angiography: answers that have questions! Eur Heart J. 2008. [Epub ahead of print].


Współczesna rola angiografii tętnic wieńcowych metodą tomografii komputerowej w diagnozowaniu i leczeniu choroby wieńcowej

Andrew W. Bowman¹, Birgit Kantor², Thomas C. Gerber¹,³

¹ Department of Radiology, Mayo Clinic, Jacksonville, FL, Stany Zjednoczone
² Division of Cardiovascular Diseases, Mayo Clinic, Rochester, MN, Stany Zjednoczone
³ Division of Cardiovascular Diseases, Mayo Clinic, Jacksonville, FL, Stany Zjednoczone

SŁOWA KLUCZOWE
angiografia wieńcowa, badania obrazowe, kardiologia, promieniowanie jonizujące, tomografia komputerowa

STRESZCZENIE
Postęp w technologii tomografii komputerowej (computed tomography – CT) pozwala na uzyskiwanie obrazów o wysokiej rozdzielczości przestrzennej i czasowej. Obecnie cechy te umożliwiają wykonywanie nieinwazyjnej angiografii tętnic wieńcowych metodą tomografii komputerowej (coronary CT angiography – CCTA). Od momentu opisania CCTA opublikowano wiele badań oceniających dowody słuszności koncepcji, wykonalność oraz solidność metody. W ostatnim czasie w ocenie techniki CCTA słusznie skoncentrowano się nie na jej technicznych aspektach, a bardziej na wielośródmieniowych badaniach analizujących wartość diagnostyczną metody i na bezpośrednim porównaniu z innymi nieinwazyjnymi technikami oceniającymi obecność choroby wieńcowej (coronary artery disease – CAD), takimi jak wysiłkowa scyntygrafia perfuzyjna serca (myocardial perfusion imaging – MPI) z użyciem radionuklidów. Dokonano przeglądu i podsumowania artykułów recenzowanych porównujących CCTA z inwazyjną, wybiórczą koronarografią (selective coronary angiography – SCA) lub MPI oraz badań dotyczących zagadnień ochrony radiologicznej związanej z CCTA. Istnieje wysoki stopień zgodności pomiędzy CCTA oraz SCA, jak i MPI w rozpoznaniu CAD. Jednakże CCTA może zbyt wysoko lub zbyt nisko oszacować stopień zaawansowania CAD, w porównaniu z SCA uznanym jako standard postępowania. We wstępnych badaniach porównujących CCTA z MPI stwierdzono podobną trafność obu technik w ocenie obecności istotnych zwężów w ścień naczynia. Ograniczeniami CCTA są niemożność wiarygodnej oceny wymiaru śródbłona naczynia wieńcowego u pacjentów z dużą liczbą związań tętnic wieńcowych, obecność artefaktów spowodowanych ruchem naczyń wieńcowych i oddychaniem oraz konieczność stosowania promieniowania jonizującego i jodowych środków kontrastowych. Obecnie istnieją różne sposoby zmniejszenia dawki promieniowania w metodzie CCTA, co może istotnie wpłynąć na zmniejszenie porcji promieniowania pacjenta nawet poniżej dawek stosowanych w SCA lub MPI. W oparciu o obecne stanowisko ekspertów nie zaleca się stosowania CCTA jako testu diagnostycznego z wyboru w CAD, głównie w badaniach przesiewowych u pacjentów bezobjawowych. Jednak aktualne dane wskazują, że CCTA może odegrać istotną rolę w ocenie obecności prawdopodobnej CAD u chorych objawowych.