Noninvasive Coronary Angiography
Hype or New Paradigm?

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When Sones inadvertently performed the first coronary angiogram in 1958,1 he could not anticipate the profound future implications of that event. Four years later, when he reported his experience with more than 1000 procedures,2 the technique was still considered experimental and was dismissed by many leading authorities in cardiovascular medicine. Yet, the introduction of coronary angiography started a new era, leading to the rapid development of coronary artery bypass graft surgery and percutaneous revascularization for the routine management of ischemic heart disease. Four decades later, more than 2 million angiographic procedures are performed annually in the United States alone.3 Although invasive coronary angiography clearly has led to improved outcomes, it also has contributed to greater expenses in health care cost,3 limiting its potential to become more widely available. This has led to a growing interest in the scientific community in the development of less expensive, noninvasive alternative methods for evaluating coronary anatomy.

Multislice computed tomography (MSCT) has recently emerged above other competing technologies, such as electron-beam computed tomography and magnetic resonance imaging, as a practical alternative to invasive coronary angiography. Modern MSCT systems can provide electrocardiogram-gated acquisition with adequate temporal resolution (100-220 ms) and with the submillimeter spatial resolution needed to visualize with sufficient detail the lumen of the coronary arteries. Several studies have investigated the accuracy of MSCT in patients with known or suspected coronary artery disease (CAD).4-11 In these studies, analysis of MSCT has been mostly limited to coronary segments greater than or equal to 1.5 mm in diameter, and up to 5% to 20% of all analyzable segments have been deemed nonevaluable due to motion artifacts, severe calcified plaques, and other technical imaging problems. The sensitivity and specificity of MSCT for detecting a 50% or greater diameter reduction in coronary segments has ranged between 72% and 95% and between 85% and 100%, respectively. Many of the published series have enrolled nonconsecutive patients, and only a few have reported the performance characteristics of MSCT using each patient as the unit of analysis.5,8-10

In this issue of JAMA, Hoffmann and colleagues12 evaluated the diagnostic accuracy of MSCT for the detection of obstructive CAD. Their study includes a large series of nonselected patients in whom very few (6.4%) coronary segments larger than 1.5 mm in diameter were excluded from analysis due to limited image quality. The majority (68%) of these excluded segments were considered nonevaluable due to imaging artifacts related to cardiac motion, most often in patients with resting heart rates greater than 80/min. Motion artifacts still represent an important limitation of current MSCT technology, even though most investigators now routinely administer ß-blockers to reduce resting heart rate. Extensive vessel calcifications also limit the interpretation of luminal stenosis by MSCT, often leading to overestimation of severity. These accounted for many of the false-positive results observed by Hoffmann et al.12 Despite these limitations, their reported per-segment sensitivity (95%) and specificity (98%) are noteworthy, particularly when these performance characteristics are compared with those of other indirect methods used for the detection of obstructive CAD, such as nuclear scintigraphy or echocardiographic stress tests.

The authors also report diagnostic characteristics according to a per-patient-based analysis. This is critically important, since the implications of detecting or missing the presence or absence of any significant coronary obstruction are more clinically relevant from the perspective of the individual patient. Even after accounting for nonevaluable segments, the high positive (90%) and negative (95%) predictive values strongly support the conclusion that, in this patient population, MSCT is a robust test for establishing the diagnosis of obstructive CAD. In addition to the conventional binomial analysis, the authors performed a quantitative comparison of percentage luminal stenosis as determined by MSCT and invasive angiography. Receiver operating characteristic curves were constructed to estimate discriminative power for identifying patients who might be candidates for revascularization. The area under the curve was 0.97 (95% confidence interval, 0.91-1.00) for detecting greater than 50% left main artery disease, greater than

See also p 2471.
70% stenosis in any other epicardial vessel, or both, also confirming excellent diagnostic accuracy.

The study by Hoffmann et al provides evidence supporting the concept that among patients with suspected CAD who are referred for diagnostic coronary angiography, MSCT could alternatively provide similar diagnostic information. In their study population, the vast majority of patients (98%) had intermediate or high probability of disease. If MSCT would have been used as an initial diagnostic test, more than 40% of the patients in this group could have avoided unnecessary invasive angiography, and only 2 patients (2%) having significant disease would have been missed. Undoubtedly, if these results could be replicated in clinical practice, the clinical and economic implications could be substantial.

Despite these promising results, several important limitations of MSCT must be considered. First, MSCT requires ionizing radiation. In the study by Hoffmann et al, the average dose used was 8.1 mSv for a 75-kg patient. This dose is equivalent to 2 to 3 times the dose typically administered during a diagnostic invasive angiogram. Although the long-term risks associated with this level of radiation exposure are relatively low, it raises a concern about repetitive use or use in younger individuals and women of childbearing age. On the other hand, this level of radiation exposure is equivalent to that received during nuclear scintigraphic stress testing.

Second, the extent and severity of coronary calcifications in the population studied by Hoffmann et al is not known definitively. The mean age of the study group was 61 years. Since the prevalence and severity of calcifications increases with age, it is likely that the diagnostic accuracy of MSCT would decrease with advancing age. In clinical practice, performing a low-radiation noncontrast calcium scan prior to MSCT angiography may identify patients with extensive calcification, in whom the procedure may not be all that helpful.

Third, in-stent visualization with MSCT angiography is either not feasible or is inaccurate in most cases. Even though other segments can still be analyzed, the potential clinical usefulness of MSCT angiography is clearly limited if restenosis cannot be ruled out. In patients with previous coronary artery bypass graft surgery, MSCT has demonstrated good accuracy in detecting graft patency, but it is often difficult to evaluate the distal anastomosis and native vessels. Therefore, at the present time, there is limited evidence to suggest that MSCT angiography could be useful in these settings.

Fourth, since MSCT angiography requires electrocardiogram-gated acquisition and reconstruction from several cardiac cycles, it is presently limited to patients with stable, regular heart rates. The existing limitations in temporal resolution are determined by the rotational speed of the MSCT gantry (375-420 ms/revolution). It is likely that this will rapidly improve with technological advances. Meanwhile, as is supported by the findings of Hoffmann et al, MSCT should be avoided in patients for whom resting heart rate exceeds 80 beats per minute after judicious administration of negative chronotropic agents.

And fifth, image resolution may be compromised in morbidly obese patients due to x-ray attenuation. In the study by Hoffmann et al, the average body mass index was 26.5. It remains to be determined whether MSCT coronary angiography could be obtained with similar diagnostic quality in patients with higher body mass index, who unfortunately represent an increasingly prevalent segment of the US population.

Despite these existing limitations, there is an important segment of the population at risk for heart disease in whom MSCT angiography could provide coronary anatomic information with sufficient diagnostic quality. Indeed, MSCT may offer another advantage over conventional angiography, which is the potential ability to detect and quantify atherosclerotic plaques in the coronary vessel walls. Nevertheless, in the absence of outcome and cost analysis studies, it is not yet clear how MSCT coronary angiography should be integrated in the clinical practice. Should it be used as a first test for the evaluation of chest pain or as a complementary test in patients with equivocal stress test results? In either case, adequate patient selection will be critically important. The results of the study by Hoffmann et al cannot be extrapolated from their intermediate- to high-risk patients to a low-risk population, which will be tempting. It is well documented that diagnostic tests will not perform as well when extended to populations with low disease prevalence; inevitably, higher rates of false-positive results will occur. Moreover, the risks of ionizing radiation probably exceed the potential benefits in this group.

Should MSCT coronary angiography be used as a screening test in asymptomatic patients at risk? It is clearly established that the prognostic information derived from lipid analysis, electrocardiography, nuclear perfusion studies, or stress echocardiography is independent of angiographic results. Thus, MSCT probably will not entirely eliminate the need for these tests. Nevertheless, the potential value of atherosclerotic plaque assessment by MSCT could prove to be useful in guiding preventive and therapeutic strategies.

Future outcome studies will likely address these questions and help to define the role of MSCT coronary angiography in the clinical practice. Meanwhile, the growing enthusiasm for MSCT in the community must be matched with adequate training, proper credentialing and, above all, appropriate utilization.

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REFERENCES

International Adoption, Behavior, and Mental Health

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ADOPTION HAS BEEN A PART OF HUMAN CULTURE SINCE earliest recorded times: Moses is perhaps the most famous adopted person in history.1,2 Fascination with adoption pervades literature (from fairy tales and myths to modern novels), psychology, and medicine. Researchers have long studied adoption in attempts to isolate the effects of “nature” and “nurture” on behavioral outcomes and mental health.3 Genetic factors, separation from birth parents, environmental exposures (both prenatal and postnatal), and aspects of the adoptive home environment have all been cited as possible contributors to adverse behavioral and mental health outcomes among adoptees.4

Although numerous articles have been published under the search headings of “adoption and mental health” or “adoption and behavior,” the use of disparate patient populations, diverse research questions, and varied methods make the results bewilderingly difficult to synthesize. Positive adoption outcomes are undoubtedly underreported.5 Furthermore, reports of increased prevalence of mental health problems among adoptees may be due in part to their adoptive family characteristics.6-8 Adoptive families are usually economically advantaged, well-educated, and familiar with available social and mental health services and are therefore likely to be overrepresented among populations receiving such assistance.

Another limitation in many studies of mental health and behavioral outcomes of adopted children is a focus on a single time point. Results of such cross-sectional studies may be misleading: evidence suggests that adopted children improve their behavior as adolescence progresses, especially if they have received earlier supportive or therapeutic services.9 Indeed, adoptees are underrepresented in juvenile court and adult mental health populations.10

Other research investigations do not differentiate between various types of adoption (private vs social services, international vs domestic), the age of the child at adoptive placement, the reasons for placement, and adoptive family characteristics. Criteria used to match children and parents are rarely examined critically.11 For children placed after infancy, few investigations differentiate between problems noted at placement and those that manifest later. Studies of biological predictors of behavioral or mental health outcomes of adoptees are hampered by outdated or unreliable information about the birth parents. Moreover, few out-

See also p 2501.

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