Screening CT–Coronary Angiography: Ready for Prime Time?

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Computed tomographic coronary angiography (CTCA) can assist with the diagnosis of a variety of cardiovascular disorders. The rationale for performing screening CTCA is to define the presence, absence, and severity of coronary artery disease, particularly in those patients who are categorized to be at intermediate risk by conventional risk factor assessment for a cardiovascular event. In addition to coronary artery disease, the interventional cardiologist can also use CTCA to evaluate the presence of an anomalous origin of the coronary arteries, the size of the coronary arteries for potential stent placement, the extent of coronary calcium in the obstructive segment and bypass graft patency. With conventional coronary angiography, the combined radiogenic and nonradiogenic mortality is 0.13%, compared to 0.07% with CTCA. Radiation to the clinician is also greatly reduced.

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Key words: Computed tomographic coronary angiography • Coronary artery disease • Single photon emission computed tomography • Contrast exposure • Radiation exposure

The commercial availability of 64-slice computed tomography (CT) for cardiac imaging has allowed for its acceptance as a means of evaluating coronary artery anatomy. At Westside Medical Imaging (Beverly Hills, CA), our group has performed nearly 4000 64-slice cardiac CT studies, and we have discovered the utility of this method in the evaluation of a host of cardiovascular disorders (Table 1). An inherent strength of CT technology is its ability to generate images that allow for assessment of all of these conditions without any

Table 1
Uses of Computed Tomography in Cardiovascular Disorders

Identify non-calcified and calcified coronary plaque
Semiquantitatively estimate coronary artery stenosis severity
Define anomalous origins of coronary arteries
Evaluate pulmonary vein anatomy prior to and following atrial fibrillation ablation
Evaluate coronary sinus and anterolateral vein anatomy prior to placement of biventricular lead
Identify pericardial effusion and thickening
Identify myocardial infarct (transmural and subendocardial)
Visualize patency of saphenous vein grafts and arterial bypass conduits
Quantitative assessment of the aortic valve area
Define the anatomy of aortic valves (bicuspid vs tricuspid)
Assess global and regional left and right ventricular function
Identify interatrial communications (atrial septal defects and patent foramen ovale)
Identify left atrial thrombi
Identify cardiac tumors
Identify thoracic aneurysms and dissections
Identify pulmonary emboli

additional exposure to radiocontrast or ionizing radiation than is needed for the coronary study. In order to use CT coronary angiography (CTCA) to evaluate for cardiovascular disorders, the clinician must have skill sets and experience in 3-dimensional reconstruction in addition to those that are required to interpret conventional coronary angiography.

Coronary Artery Assessment

The 64-slice CTCA has become a reliable screening examination to define the presence or absence of coronary artery disease in the vast majority of patients with cardiac risk factors. It is also reliable as a diagnostic examination to assess the etiology of symptoms suggestive of coronary insufficiency. Patients in whom it continues to be a challenge to obtain diagnostic quality images include those with atrial fibrillation, frequent premature beats, and heavy coronary calcification.

The use of 64-slice CTCA for screening examinations is becoming more popular, but it has not yet gained universal acceptance in the cardiovascular community. Before this acceptance becomes a reality, we will need to define the population of patients in whom the benefits of this examination warrant the costs and risks. With the prevalence of coronary artery disease as high as it is in the United States, and with many patients initially presenting with sudden cardiac death and myocardial infarction, early identification of this disease is mandatory if we wish to reduce event rates from where they are today (Figure 1). Intravascular ultrasound (IVUS) evaluations of otherwise healthy hearts that were to be utilized as heart transplant donors found the prevalence of coronary atherosclerosis to be more than 60% in patients in their fourth decade of life and more than 70% in patents in their fifth decade of life.[1] Based on our experience, it is clear that the only technology available today that can provide safe and effective IVUS-like evaluations is 64-slice CTCA.

Once a patient has developed overt manifestations of coronary artery disease, the disease process is often well advanced and the patient has endured an event (acute coronary syndrome, acute myocardial infarction, sudden cardiac death) or undergone an expensive revascularization procedure (percutaneous coronary intervention, coronary artery bypass surgery). The rationale for performing screening CTCA is to define the presence or absence of coronary artery disease, particularly in those patients who are categorized

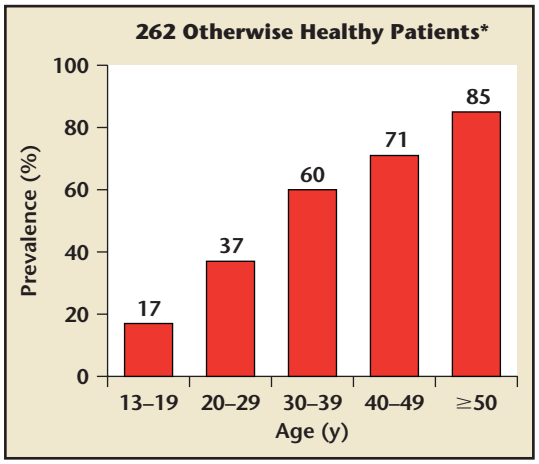

Figure 1. *Prevalence of IVUS-detected coronary artery atherosclerosis. *Intravascular ultrasound (IVUS) performed on donor heart transplant recipients. Adapted with permission from Tuzcu EM et al.*[1]
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Table 2
ATP 2004 Update: LDL-C Therapy by Risk Categories Based on Recent Clinical Trial Evidence

Risk Category	LDL-C Goal	Initiate Therapeutic Lifestyle Changes	Consider Drug Therapy
High risk: CHD or CHD risk equivalents (10-year risk > 20%)	< 100 mg/dL	≥ 100 mg/dL	≥ 100 mg/dL
Very high risk	Optional goal of < 70 mg/dL		
Moderately high risk: ≥ 2 risk factors (10-year risk 10%-20%)	< 130 mg/dL (optional goal < 100 mg/dL)	≥ 130 mg/dL	≥ 130 mg/dL (consider drug options if LDL-C 100-129 mg/dL)
Moderate risk: ≥ 2 risk factors (10-year risk < 10%)	< 130 mg/dL	≥ 130 mg/dL	> 160 mg/dL
Low risk: ≤ 1 risk factor	< 160 mg/dL	≥ 160 mg/dL	≥ 190 mg/dL (consider drug options if LDL-C 160-189 mg/dL)

ATP, Adult Treatment Panel; LDL-C, low-density lipoprotein cholesterol; CHD, chronic heart disease. Adapted with permission from Grundy SM et al.[16]

Table 3
Point System for Conventional Risk Factors

Risk Factor	Risk Points Men	Risk Points Women
Age, y		
< 34	−1	−9
35-39	0	−4
40-44	1	0
45-49	2	3
50-54	3	6
55-59	4	7
60-64	5	8
65-69	6	8
70-74	7	8
Total cholesterol, mg/dL		
< 160	−3	−2
169-199	0	0
200-239	1	1
240-279	2	2
≥ 280	3	3
HDL-C, mg/dL		
< 35	2	5
35-44	1	2
45-49	0	1
50-59	0	0
≥ 60	−2	−3
Systolic blood pressure, mm Hg		
< 120	0	−3
120-129	0	0
130-139	1	1
140-159	2	2
> 160	3	3
Diabetes		
No	0	0
Yes	2	4
Smoker		
No	0	0
Yes	2	2

HDL-C, high-density lipoprotein cholesterol. Reprinted with permission from Grundy SM et al.[18]

to be at intermediate risk for a cardiovascular event. The implications of identifying the presence or absence of coronary disease by an examination such as CTCA could help define whether a patient should be treated with lipid-lowering drug therapy and then to what low-density lipoprotein cholesterol level (Table 2) goal. Prior to the advent of noninvasive coronary imaging, risk in asymptomatic patients was determined either by identifying the number of conventional risk factors (Table 3) or by attributing numerical value to particular risk factors, and then applying the sum to a model that approximated relative risk (Table 4).

The focus of the Integrated Biomarker and Imaging Study (IBIS) was the identification and characterization of nonobstructive, subclinical coronary atherosclerotic disease rather than high-grade symptomatic luminal obstruction (Table 5).[2] One of the major aims of the study was to determine the potential of multislice CTCA in the detection of subclinical, nonflow-limiting coronary atherosclerosis. With IVUS as the gold standard, noninvasive multislice CTCA was able to identify atherosclerotic plaque in vessels that had only minimal angiographic disease, with high sensitivity and moderate specificity.[2]

The Framingham risk model, although useful for helping to identify relative risk of cardiac events, seems much less helpful in identifying the presence, absence, or severity of coronary artery disease. In a recently published analysis of patients in the Reversal of Atherosclerosis with Aggressive Lipid Lowering (REVERSAL) trial, there seemed to be a disconnect between some of the traditional cardiac risk factors and the coronary artery disease burden as determined by IVUS. Only male sex and diabetes were predictors of disease burden by multivariate analysis, with neither of these predictive of angiographically

determined stenosis severity. The investigators commented that these findings "highlight the complex relationship promoting the translation of emerging risk factors and the incidence of cardiovascular disease."[3]

In a recent analysis comparing noninvasive 16-slice CTCA with the Brilliance 16-slice (Philips Medical Systems, Cleveland, OH), 1384 segments (≥ 1.5 mm diameter) were identified by invasive coronary angiography.[4] Nondiagnostic image quality of multislice CT was identified for only 88 (6.4%) of these segments. Compared with invasive coronary angiography for detection of significant lesions (> 50% stenosis), segment-based sensitivity, specificity, and positive and negative predictive values of multislice CT were 95%, 98%, 87%, and 99%, respectively. Another analysis comparing 64-slice CTCA to conventional coronary angiography showed a high degree of accuracy.[5]

Protocols have now been developed allowing for CTCA in the vast majority of patients screened. High-resolution images can be generated using approximately 70 cc of radiocontrast and regulating heart rates, with the use of either oral or intravenous beta-blockers, to a heart rate range of 60 bpm to 75 bpm. We define the character of a coronary plaque as either noncalcified, calcified, or complex, or having calcified and non-calcified components (Figure 2). Lesion severity is noted to be either mild (< 30%), mild to moderate (30% to 50%), moderate (51% to 70%), moderately severe (71% to 90%), or severe (> 90%).

There does seem to be a significant incremental benefit of performing a CTCA over obtaining a coronary calcium score in order to define the presence and severity of disease. In our study of 984 lower risk patients undergoing screening CTCA, nearly 10% of patients with low-risk coronary

Table 4
Estimation of Risk

Men Age	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74		
(Low-risk level)*	(2%)	(3%)	(3%)	(4%)	(5%)	(7%)	(8%)	(10%)	(13%)	Absolute Risk	Absolute Risk†
Points‡										Total CHD†	Hard CHD§
0	1.0									2%	2%
1	1.5	1.0	1.0							3%	2%
2	2.0	1.3	1.3	1.0						4%	3%
3	2.5	1.7	1.7	1.3	1.0					5%	4%
4	3.5	2.3	2.3	1.8	1.4	1.0				7%	5%
5	4.0	2.6	2.6	2.0	1.6	1.1	1.0			8%	6%
6	5.0	3.3	3.3	2.5	2.0	1.4	1.3	1.0		10%	7%
7	6.5	4.3	4.3	3.3	2.6	1.9	1.6	1.3	1.0	13%	9%
8	8.0	5.3	5.3	4.0	3.2	2.3	2.0	1.6	1.2	16%	13%
9	10.0	6.7	6.7	5.0	4.0	2.9	2.5	2.0	1.5	20%	16%
10	12.5	8.3	8.3	6.3	5.0	3.6	3.1	2.5	1.9	25%	20%
11	15.5	10.3	10.3	7.8	6.1	4.4	3.9	3.1	2.3	31%	25%
12	18.5	12.3	12.3	9.3	7.4	5.2	4.6	3.7	2.8	37%	30%
13	22.5	15.0	15.0	11.3	9.0	6.4	5.6	4.5	3.5	45%	35%
> 14	26.5	> 17.7	> 17.7	> 13.3	> 10.6	> 7.6	> 6.6	> 5.3	> 4.1	> 53%	> 45%

Women Age	40-44	45-49	50-54	55-59	60-64	65-69	70-74		
(Low-risk level)*	(2%)	(3%)	(5%)	(7%)	(8%)	(8%)	(8%)	Absolute Risk	Absolute Risk
Points‡								Total CHD†	Hard CHD§
0	1.0							2%	1%
1	1.0							2%	1%
2	1.5	1.0						3%	2%
3	1.5	1.0						3%	2%
4	2.0	1.3						4%	2%
5	2.0	1.3						4%	2%
6	2.5	1.7	1.0					5%	2%
7	3.0	2.0	1.2					6%	3%
8	3.5	2.3	1.4	1.0				7%	3%
9	4.0	2.7	1.6	1.1	1.0	1.0	1.0	8%	3%
10	5.0	3.3	2.0	1.4	1.3	1.3	1.3	10%	4%
11	5.5	3.7	2.2	1.6	1.4	1.4	1.4	11%	7%
12	6.5	4.3	2.6	1.9	1.6	1.6	1.6	13%	8%
13	7.5	5.0	3.0	2.1	1.9	1.9	1.9	15%	11%
14	9.0	6.0	3.6	2.6	2.3	2.3	2.3	18%	13%
15	10.0	6.7	4.0	2.9	2.5	2.5	2.5	20%	15%
16	12.0	8.0	4.8	3.4	3.0	3.0	3.0	24%	18%
≥ 17	> 13.5	> 9.0	> 5.4	> 3.9	5.4	5.4	5.4	> 27%	> 20%

(*Continued*)

Table 4
(Continued)

Color Key for Relative Risk

Green	Violet	Yellow	Red
Below average risk	Average risk	Moderately above average risk	High risk

*Low absolute risk level = 10-year risk for total CHD endpoints for a person the same age, blood pressure < 120/< 80 mm Hg, total cholesterol 160-199 mg/dL, HDL-C ≥ 55 mg/dL, nonsmoker, no diabetes. Percentages show 10-year absolute risk for total CHD endpoints.
†10-year absolute risk for total CHD endpoints estimated from Framingham data corresponding to Framingham points (Table 3).
‡Points = number of points estimated from Table 3.
§10-year absolute risk for hard CHD endpoints approximated from Framingham data corresponding to Framingham points (Table 3).
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calcium scores had hemodynamically significant (≥ 50%) coronary arterial stenosis.[6] In a report from the Screening for Heart Attack Prevention and Education (SHAPE) Task Force, recommendations are made to screen all at-risk men ages 45 to 75 years and all at-risk women ages 55 to 75 years, unless they have none of the following: cholesterol level greater than 200 mg/dL, blood pressure greater than 120/80 mm Hg, diabetes, smoking, metabolic syndrome, or family history of coronary artery disease.[7]

Therefore, in patients with coronary risk factors, it would seem very reasonable to perform screening angiography because of the high incidence of cardiovascular disease in the asymptomatic population; the inability of risk factor assessment to define with a high degree of certainty the presence, absence, or severity of coronary artery disease; and the ability of coronary CTCA to define disease.

Contrast and Radiation Exposure

When one decides there is a need to consider performing a CTCA, the risk-benefit analysis must take into account the benefit gained by the information from the study versus the risk from contrast and radiation exposure. In addition, it is also important to compare this exposure to other examinations commonly used to diagnose coronary artery disease, including single photon emission computed tomography (SPECT) imaging and conventional coronary angiography (Figure 3). A recent analysis showed that 16-slice coronary angiography delivered a dose of 14 mSv compared to 6 mSv for conventional coronary angiography.[8] The equivalent dose received from 10 chest x-rays is 1 mSv. With conventional coronary angiography, mortality risks for radiogenic mortality (0.02%) and non-radiogenic mortality (0.11%) combined are 0.13%, which is almost 50% higher than the 0.07% combined mortality risk associated with CTCA.[9]

Per case exposure to the operating interventional cardiologist ranges from 0.04 mSv to 0.16 mSv. It has been estimated that approximately 40% to 50% of diagnostic conventional coronary angiograms show minimal disease. For an average annual volume of 200 diagnostic cases, if half are replaced by CTCA, the primary operator can avoid up to 16 mSv per year of exposure.[10-13]

To put the radiation exposure into proper context, the typical effective dose for a rest-stress myocardial SPECT scan using thallium-201 is 18 mSv, and for technetium-99m it is 8 mSv.[14] Coronary catheterization procedures are also associated with a vascular complication rate of 1.5% to 9.0%.[15]

Benefits

With CTCA, the interventional cardiologist can not only identify the presence, absence, and severity of coronary artery disease, but can also gather other useful information such as the presence of an anomalous origin of the coronary arteries, the size of the coronary arteries for potential stent placement, and the extent of coronary calcium in the obstructive

Table 5
IBIS: MSCTA Compared to the Gold Standard IVUS to Detect Plaque

Any Significant Plaque	
Sensitivity	86%
Specificity	69%
Positive predictive values	90%
Negative predictive values	61%
Sensitivity to Detect	
Small (< 1 mm)	60% (30 of 50)
Medium (1 to 2 mm)	76% (80 of 105)
Large (> 2 mm)	79% (26 of 33)

IBIS, Integrated Biomarker and Imaging Study; MSCTA, multislice computed tomography angiography; IVUS, intravascular ultrasound. Adapted with permission and data extracted from Van Mieghem CA et al.[2]

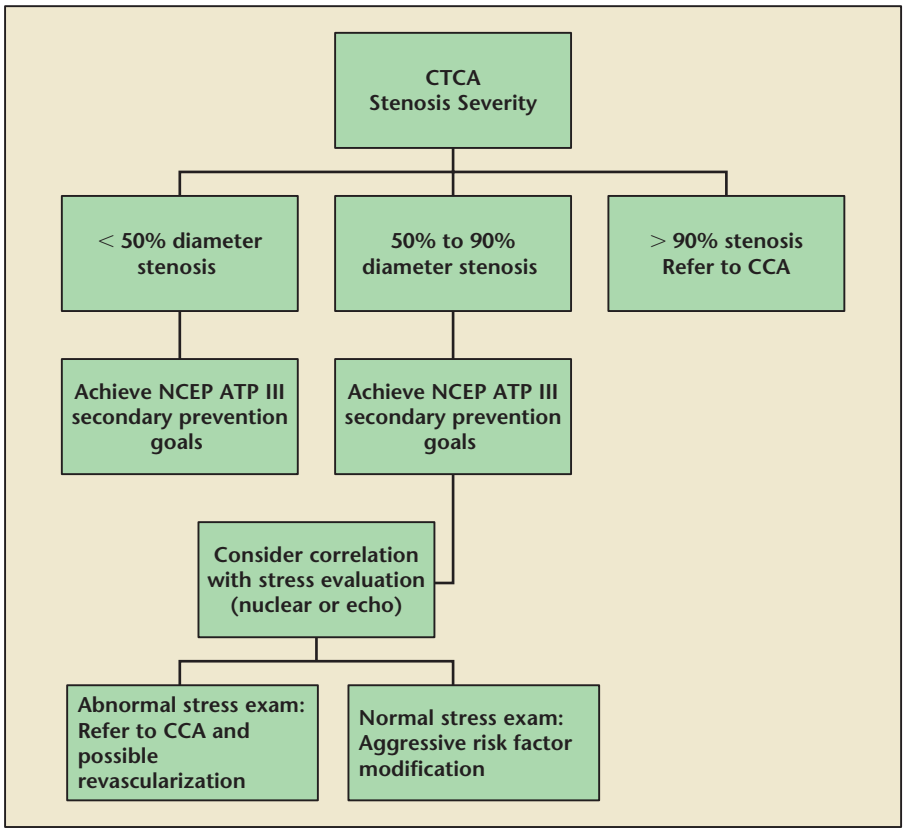
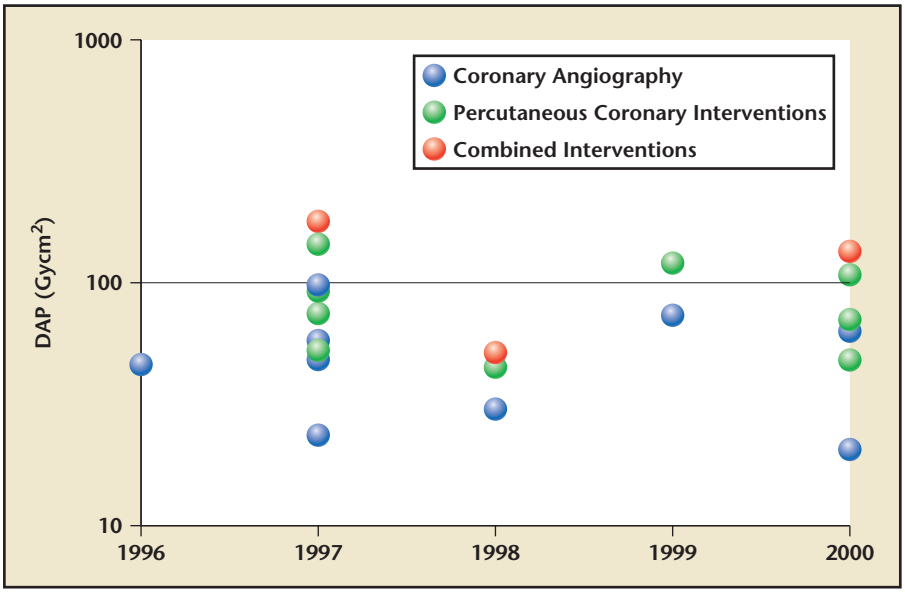


Figure 2. *Treatment according to stenosis severity. CTCA, computed tomography coronary angiography; CCA, conventional coronary angiography; NCEP, National Cholesterol Education Program; ATP, Adult Treatment Panel.* www.medreviews.com

Figure 3. *Mean radiation exposure to patient due to diagnostic and therapeutic cardiac catheterization. DAP, dose area product. Reprinted with permission from Kuon E and Kaye AD.*[17] www.medreviews.com



segment—which may lend itself to treatment with ancillary technologies such as rotational atherectomy. In addition, identification of both arterial and venous coronary artery bypass grafts is very helpful because it allows the coronary interventionalist to know in advance whether a graft is patent or occluded, thereby reducing the exposure to contrast and radiation during the CCA. Of course, the other benefits of CTCA include the ability to use the same amount of contrast and radiation exposure to evaluate the thoracic aorta for aneurysmal dilation and dissection, and the ability to assess the pulmonary vasculature, mediastinum, and lungs for any significant abnormalities.

Summary

With the availability of 64-slice CTCA, we now have at our disposal a tool that can provide a high degree of accuracy in determining the presence, absence, and severity of coronary artery disease. In asymptomatic patients with multiple coronary risk factors who are not deemed to be at high cardiac risk by conventional risk factor assessment, this technology will allow for improved triaging of those patients into those who have coronary disease and those who do not, and it should expedite treatment of those with the disease before they suffer a cardiovascular event. Two questions that remain to be answered prior to widespread utilization of CTCA for screening are: (1) Will screening CTCA affect long-term outcomes? and (2) What is the most effective and efficient screening modality (carotid IMT coronary calcium scores or CTCA)? ■

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Main Points

- The implications of identifying the presence or absence of coronary disease by an examination such as computed tomography coronary angiography (CTCA) could determine whether a patient should be treated with drug therapy and to what goal low-density lipoprotein cholesterol level.
- The strength of computed tomography technology is its ability to generate images that allow for assessment of many cardiovascular conditions without any additional exposure to radiocontrast or ionizing radiation than is needed for the coronary study.
- For an average annual volume of 200 diagnostic cases, if half are replaced by CTCA, the primary operator can avoid up to 16 mSv per year of exposure.
- Therefore, in patients with coronary risk factors, it would seem very reasonable to perform screening angiography because of the high incidence of cardiovascular disease in the asymptomatic population; the inability of risk factor assessment to define with a high degree of certainty the presence, absence, or severity of coronary artery disease; and the ability of coronary CTCA to define disease.