

CTA Case Studies

Clinical utility of cardiac CTA in patients with previous CABG.

BY JASON T. BRADLEY, MD; MITCHELL N. RASHID, MD; AND MATTHEW W. WATKINS, MD, FACC

Multidetector computerized tomography (MDCT) has been studied most in patients at low to moderate risk.^{1,2} CTA has been best validated for the evaluation of coronary arteries in patients without known coronary disease. In this patient group, MDCT has a high sensitivity (>95% in recent reports) and negative predictive value.² However, there are limited data on the accuracy and use of cardiac CTA for the evaluation of patients with known CAD and in particular, patients with previous coronary artery bypass graft (CABG).

For patients with previous CABG, there is no “normal” result, with most coronary segments and all patients having varying degrees of CAD. The coronary anatomy is more complex, and MDCT results must address bypass graft patency, bypass graft stenosis, and the severity of native coronary disease in nongrafted segments both proximal and distal to the anastomosis site. The case studies we present demonstrate the utility of MDCT in CABG patients, focusing on the information that MDCT adds to diagnosis and management. The subsequent literature review and discussion highlights recent results comparing accuracy of CTA to invasive angiography in bypass patients and our current approach to MDCT in the management of post-CABG patients.

EXAMPLES OF MDCT IN PATIENTS WITH PREVIOUS CABG

Case 1

A 74-year-old man presented with known CAD and a recent history of progressively worsening symptoms of chest pain and shortness of breath with exertion. These episodes are similar to previous anginal episodes. There were no symptoms at rest. The patient had CABG in 1991 with three distal anastomoses. A previous coronary angiogram in 2005 revealed no significant disease in the bypass grafts. The patient was seen in the clinic, and a 64-slice gated cardiac CTA was performed to evaluate for interim changes in bypass graft disease in the setting of increasing stable angina.

Retrospectively gated CTA images were acquired at .625-mm thickness, reconstructed at .8 mm, and reviewed at 10% increments of the cardiac cycle. The CTA showed a patent left internal mammary artery (LIMA) to the left anterior descending artery (LAD) with no significant disease below the LIMA touchdown. The saphenous vein graft (SVG) to an obtuse marginal branch had a focal plaque with 50% to 75% luminal narrowing in the mid-portion of the graft (Figure 1A, B). The SVG to the distal RCA contained a 50% to 75% stenosis in the proximal portion (Figure 1A, C). The native coronaries had proxi-

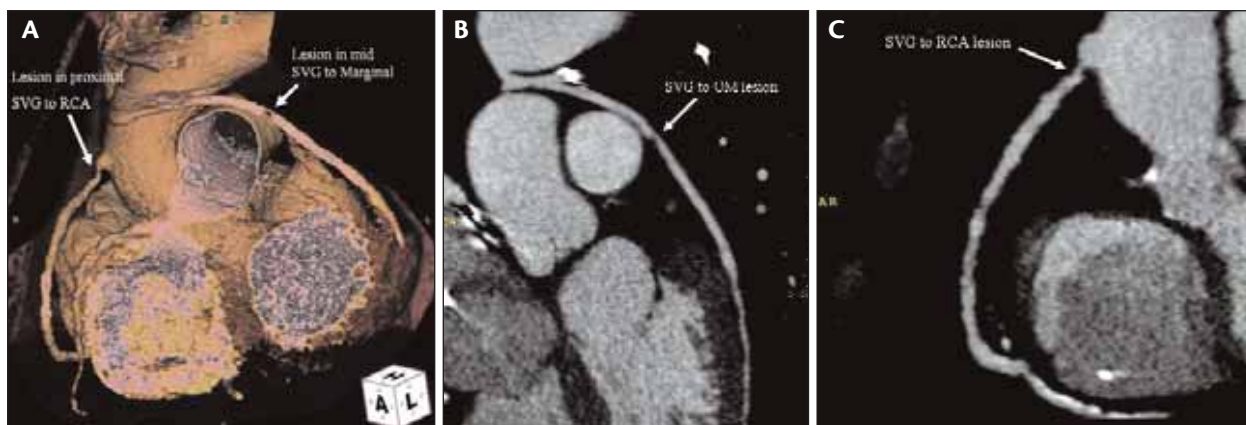


Figure 1. A 74-year-old patient with stable angina and a remote history of bypass surgery. Three-dimensional reconstruction of the SVG to the marginal artery and the SVG to the right coronary artery (RCA) demonstrating 50% to 75% lesions (A). Curved multiplanar reformatted image of a 50% to 75% lesion in the mid SVG to the obtuse marginal branch artery (B). Curved multiplanar reformatted image of a 50% to 75% lesion in the proximal SVG to the RCA (C).

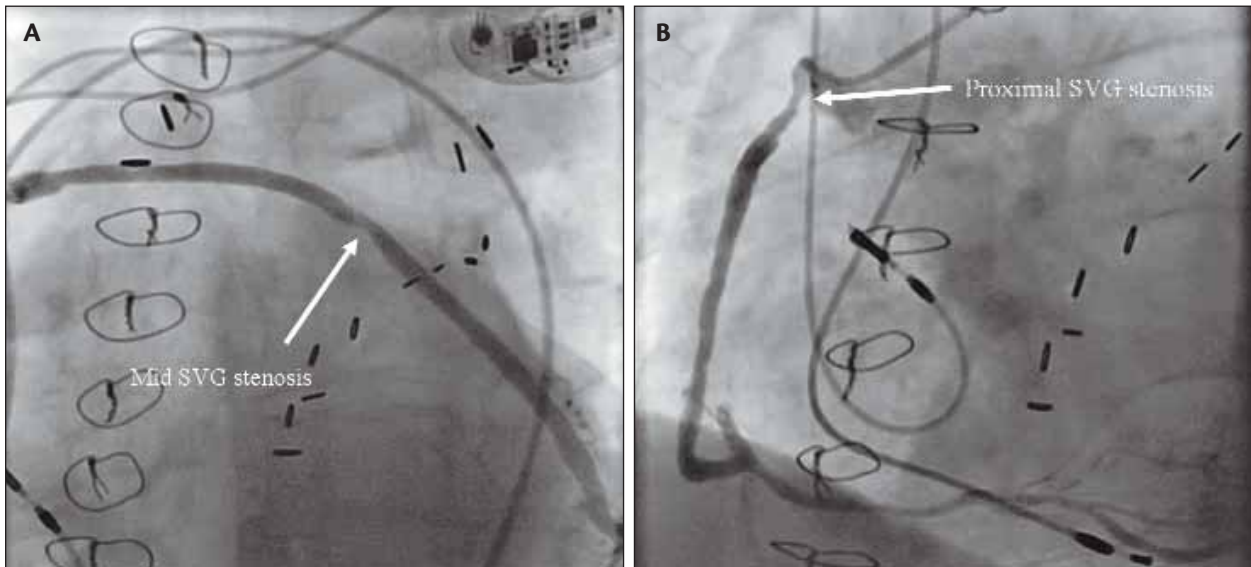


Figure 2. A 74-year-old patient with stable angina and a remote history of bypass surgery. Invasive angiography of the SVG to the obtuse marginal branch artery, with 80% stenosis in the midportion (A). Invasive angiography of the SVG to the RCA, with 70% stenosis in the proximal portion (B).

mal diffuse calcification and >50% to 75% stenosis in the LAD, circumflex, and RCA, but native runoff below the patent bypass grafts was patent with <50% stenosis.

A few days after the cardiac CTA, the patient was admitted to an outside hospital due to chest pain and shortness of breath. The patient was ruled out for a myocardial infarction and was transferred for cardiac catheterization based on the abnormal findings of his cardiac CTA. Invasive coronary angiography was performed to evaluate

the SVGs. The SVG to the obtuse marginal artery had a new 80% stenosis in the midportion that corresponds to the lesion on CTA (Figure 2A). The SVG to the distal RCA contained a new 70% proximal stenosis corresponding to the CTA (Figure 2B). Corresponding to CTA results, there was also <50% stenosis in the native vessel runoff below these grafts. The patient underwent percutaneous coronary intervention of the proximal portion of the SVG to the distal RCA with a single 4-mm bare-metal stent with

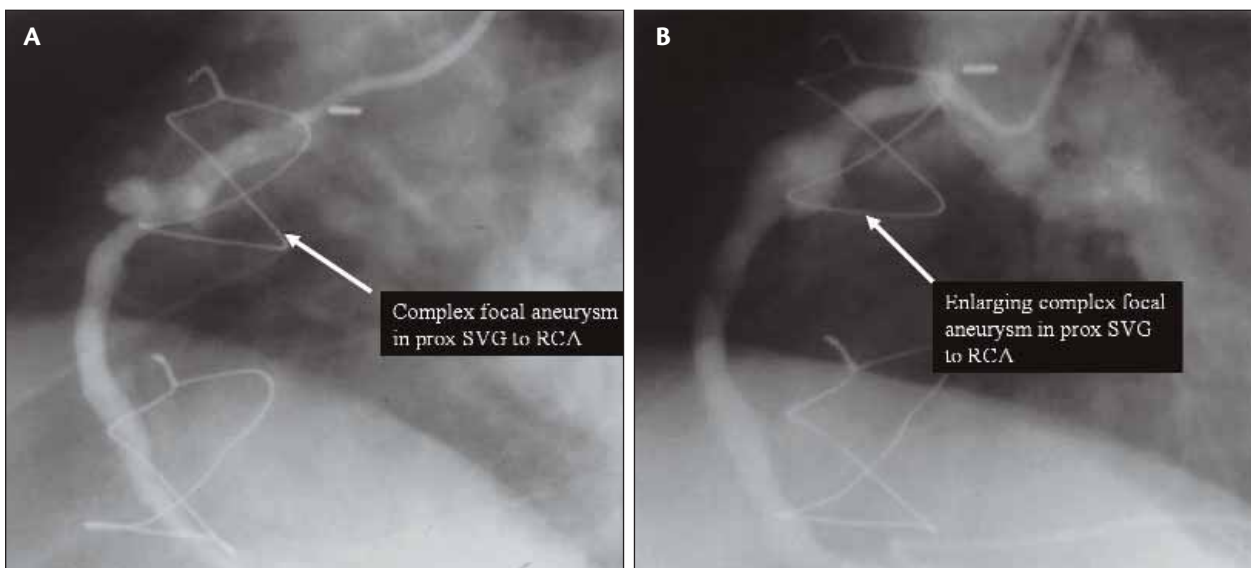


Figure 3. A 62-year-old patient with atypical chest pain and a history of aneurysmal SVG after bypass surgery. Invasive angiography showing a complex aneurysm in the SVG to the RCA in 2000 (A). Invasive angiography showing enlargement of a complex aneurysm in the SVG to the RCA in 2003 (B).

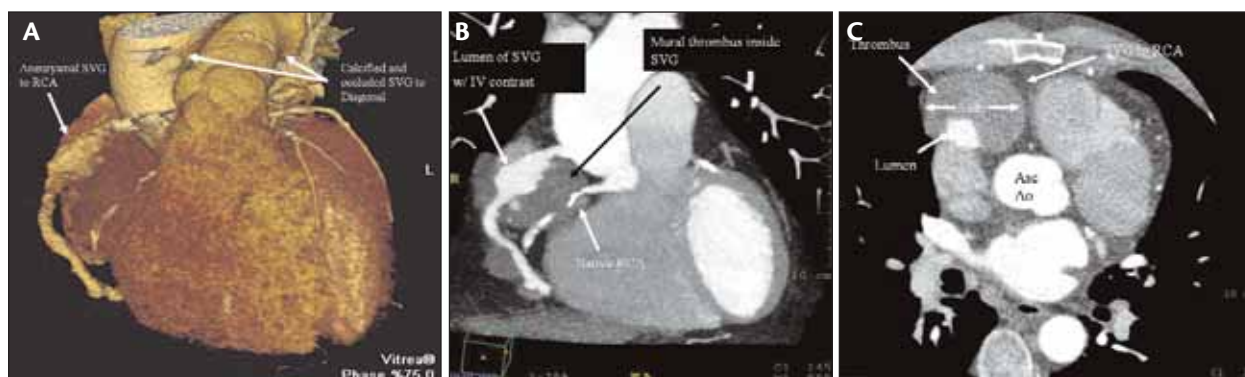


Figure 4. A 62-year-old patient with atypical chest pain and a history of aneurysmal SVG after bypass surgery. Three-dimensional reconstruction of aneurysmal SVG to the RCA and occluded SVG to the diagonal branch artery (A). Oblique maximum intensity image (MIP) of aneurysmal SVG to the RCA showing both the lumen and the surrounding mural thrombus (B). Axial MIP image of aneurysmal SVG to the RCA showing both the lumen and the surrounding thrombus (C).

good result. The lesions in the proximal and midportions of the SVG to the obtuse marginal were successfully treated with a total of three 4-mm bare-metal stents.

Case 2

A 62-year-old man presented with known CAD and remote CABG more than 15 years ago at an outside hospital. He had placement of SVGs to the RCA and diagonal arteries. Invasive angiography in 2000 demonstrated an occlusion of the SVG to the diagonal and a focal, complex aneurysm of the proximal SVG to the RCA (Figure 3A). Subsequent invasive angiography in 2003 revealed enlargement of the aneurysm in the proximal SVG to the RCA graft with a continued patent lumen (Figure 3B). The patient has had a recent increase in complaints of atypical chest pain with a pleuritic component leading to an outside chest CT that showed a mass abutting the right atrium. Given the history of SVG aneurysm, a 64-slice gated cardiac CTA was performed for further evaluation of SVG disease and characterization of the pericardiac mass.

Retrospectively gated CTA images were acquired at .625-mm thickness, reconstructed at .8 mm, and reviewed at 10% increments of the cardiac cycle. The SVG to the diagonal artery is clearly occluded proximally, and a cast of calcification is seen in the midsection of the remnant graft (Figure 4A). Analogous to previous invasive angiography, the lumen of the SVG to the RCA shows a large, irregular aneurysm (Figure 4A). However, CTA imaging also reveals a mass surrounding the lumen of the SVG, up to 6 cm X 4.5 cm in diameter, with a density of 35 to 40 Hounsfield units; this is consistent with chronic mural thrombus inside the SVG (Figure 4B, C). The complex relationship between the patent SVG lumen and the massive surrounding mural thrombus, as well as its location filling a space between the right atrium and the sternum, is shown clearly by CTA imaging and

not by previous invasive angiography. CTA also demonstrated >75% proximal stenosis in the nongrafted LAD and circumflex system. Based on the cardiac CTA findings, the patient is currently being evaluated for possible surgical ligation of the massive SVG aneurysm and repeat CABG.

DIAGNOSTIC CHALLENGE OF POST-CABG PATIENTS

The evaluation of patients with recurrent chest pain after bypass surgery remains a challenge for the cardiologist. Patients develop recurrent angina in a time-dependent manner following CABG, with at least 30% of patients developing anginal symptoms by 10 years after surgery.³ Patients are likely to acquire ischemic symptoms both due to progression of native coronary disease and secondary to progressive disease in bypass grafts. Multiple studies evaluating long-term patency of bypass grafts demonstrate vein graft patency at 10 years as low as 40% to 50%, and a more durable arterial graft patency of 51% to 98% at 15 years.⁴⁻⁶ Currently, the standard of care in managing coronary bypass patients includes a detailed history and physical, aggressive medical management, and continued cardiac risk factor reduction. For those individuals with new symptoms, either typical or atypical for angina, noninvasive testing is generally performed. Often, these patients have multiple comorbidities, and exercise treadmill testing is limited. Pharmacologic tests with SPECT imaging or stress echocardiography are among the most commonly used methods of evaluation. However, in this patient population, with underlying diffuse CAD, there is a high incidence of abnormal noninvasive studies, and many of these patients go on to invasive catheterization with coronary and graft angiography. For MDCT to meet this diagnostic challenge, it must be able to accurately assess graft patency, graft stenosis, and native vessel disease, while identifying severe stenosis in patients with diffuse background CAD.

MDCT APPLIED TO CABG PATIENTS

Cardiac CTA has progressed rapidly in the diagnosis and management of cardiac disease since the advent of multi-slice spiral or “helical” CT in 2000. Improved gantry rotation of <.5 seconds has led to a temporal resolution of <250 ms. This combined with the patient’s ECG allows retrospective image reconstruction at quiescent cardiac phases and evaluation of the coronary arterial anatomy largely free of cardiac motion artifact. Spatial resolution has improved with current-generation 40- and 64-slice scan resolution of <.8 mm.^{7,8} Patient selection and preparation remain critical to obtaining high-quality cardiac CTA results. These factors include a stable heart rhythm and rate <65 bpm (in our experience this requires prescan beta blockers in almost all cases) and patient coaching to improve breath holding and minimize motion. Several factors related to MDCT image quality are of particular importance in CABG patients. A larger region of interest is examined in graft cases, including the aortic arch, which translates to longer scan times and increased contrast administration. In our experience, this requires a patient breath hold of 20 seconds and a contrast volume of 120 mL administered at 5 mL/s with a saline bolus chase. Bypass graft motion is less than native vessels, but rigorous attention to heart rate control remains important to improve image quality in the native vessels, which typically have extensive CAD. Finally, CTA image quality in CABG patients may be significantly limited by the presence of sternal wires, surgical clips along grafts, and diffuse native vessel calcium (Figure 5). The beam hardening and blooming artifacts associated with these factors remains a significant limitation in some cases.⁹⁻¹⁴

ACCURACY OF MDCT COMPARED TO ANGIOGRAPHY

In general, studies evaluating the accuracy of MDCT in CABG patients have compared CTA results in patients subsequently undergoing elective cardiac catheterization. Of note, bypass grafts and coronary segments that are deemed noninterpretable, often >5% of the total segments/grafts, are typically omitted from the calculation of MDCT accuracy compared to invasive angiography.

Table 1 compares the sensitivity, specificity, negative predictive value, and positive predictive value for the evaluation of graft occlusion, graft stenosis, and native vessels in five recent studies utilizing either a 16- or 64-slice MDCT. In contrast to CTA in nonbypass patients in whom >95% sensitivity and >90% specificity has routinely been reported,^{2,7,8} CTA accuracy in bypass patients is both lower and, in our view, more dependent on the improved temporal and spatial resolution of 64-slice and greater scanners. As an example, the distal graft anastomosis site could be visualized in only 74% of cases in a representative 16-slice

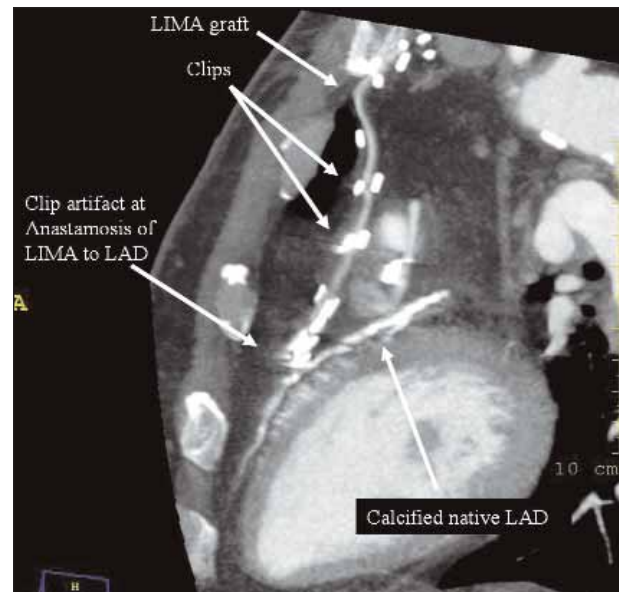


Figure 5. Examples of MDCT artifacts. MIP-modified sagittal image showing metal clip artifact along the LIMA graft to the LAD and “blooming” artifact from the severely calcified native LAD (Note: Clip artifact obscures the anastomosis site).

study.¹⁰ Overall, 16-slice MDCT has been reported to accurately detect bypass occlusion and significant graft stenosis, but is limited downstream in the evaluation of distal graft anastomotic sites and native disease in calcified, diseased runoff vessels and in minimizing artifacts due to motion or metal clips.⁹⁻¹²

Recent reports with 64-slice scanners have been more encouraging. Ropers et al, using 64-slice MDCT, were able to evaluate and correctly classify 138 SVGs as patent or occluded with 100% sensitivity and 94% specificity.¹³ Importantly, downstream imaging accuracy was improved, with 40% of all graft stenoses seen being detected at the distal anastomosis site and 91% of distal runoff vessels able to be evaluated. In the distal native vessels, sensitivity was 86% and specificity was 76% for detection of stenosis >50%. Meyer et al, using 64-slice MDCT, studied 138 consecutive patients (418 bypass grafts) with recurrent chest pain for the detection of >50% stenosis in grafts only.¹⁴ In contrast to Roper et al, native vessels were not evaluated. However, in this study, 30% of patients had arrhythmias during CTA, a common finding in this patient group, and were not excluded from the analysis. Bypass grafts were interpretable in 98% of cases (motion artifacts and metallic clips led to no interpretation in nine of 418 grafts). In all 84 cases, MDCT correctly identified total graft occlusions, and 29 of 32 graft stenoses were correctly identified by MDCT. Despite the imaging improvements reported previously, modern MDCT technology still faces important hur-

TABLE 1. ACCURACY OF MDCT COMPARED TO INVASIVE ANGIOGRAPHY IN PATIENTS WITH PREVIOUS CABG

Study	Sensitivity	Specificity	Negative Predictive Value	Positive Predictive Value
Ropers et al (64-slice)¹³				
Graft stenosis	100 (%)	94 (%)	100 (%)	92 (%)
Native arteries	86	76	96	44
Nongrafted and runoff	86	90	98	54
Meyer et al (64-slice)¹⁴				
Graft stenosis	97	97	99	93
Yamamoto et al (16-slice)¹¹				
Graft occlusion	100	93	100	33
Graft stenosis	100	99	100	67
Burgstahler et al (16-slice)¹²				
Graft occlusion and stenosis	100	93	100	89
Native arteries	83	59	67	78
Anders et al (16-slice)¹⁷				
Graft occlusion	100	98	100	97
Graft stenosis	80-82	85-88	94-95	57-64

dles in postbypass patients, which include metal artifacts and accurate evaluation of calcified and diffusely diseased native vessels.

An additional recent application of MDCT, which is pertinent to patients after CABG, has been to facilitate planning for PCI for chronic total coronary occlusion. These procedures have previously been guided by angiography alone. The course of the totally occluded segment cannot be ascertained by angiography. Pre-PCI MDCT has proven useful to define the course of the occluded segment.

SUMMARY

MDCT imaging in patients with previous CABG is inherently more challenging compared to patients without revascularization. These patients have more diffuse native CAD, frequent postsurgical metal artifacts, and fewer normal vascular segments. High-quality CTA scans are both more difficult to perform in this group and more challenging to interpret. However, recent improvements in MDCT technology have led to an impressively low incidence of noninterpretable bypass grafts at 0% to 2%. This is a lower rate of noninterpretable segments compared to the 5% to 9% rate reported for native vessels in patients without CABG.¹⁵ The 64-slice MDCT improves on previous-generation

scanners to allow visualization of coronary bypass grafts including the anastomotic site and native vessels.

MDCT is highly accurate for the diagnosis of overall bypass graft patency with a sensitivity and specificity approaching 98% and 94% in recent reports. MDCT diagnosis of significant graft stenosis is less accurate than graft occlusion. In contrast, MDCT is significantly less accurate in detecting native vessel lesions in CABG patients due to a high incidence of calcium and diffuse CAD. Definitive recommendations regarding appropriateness and indications for MDCT in CABG patients are evolving and await prospective trials. We agree with recent consensus statements that MDCT is not generally indicated either as a screening tool in asymptomatic CABG patients or in patients presenting with unstable coronary syndromes.^{16,17} An exception to the former is a clinical scenario in which documentation of chronic bypass graft patency will change patient care, such as establishing LIMA status in a CABG patient with an unexpected anterior perfusion defect. In conclusion, cardiac CTA is most likely to alter clinical management in selected symptomatic patients, in whom the presence of severe graft stenosis or native disease in nongrafted vessels would lead to invasive testing and possible interventional therapy. ■

Cardiac Interventions Today

Submission Guidelines

The authors would like to acknowledge Heidi Streeter, BS, RT(R)(M)(CT), and Frank Flynn, AS, RT(R)(CT), 3D/CT imaging technologists, for their assistance in the preparation of the images for this manuscript.

Jason T. Bradley, MD, is from the Department of Cardiology at Fletcher Allen Health Care/University of Vermont, Burlington, Vermont. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein. Dr. Bradley may be reached at (802) 847-3734; jason.bradley111@gmail.com.

Mitchell N. Rashid, MD, is from the Department of Cardiology at Fletcher Allen Health Care/University of Vermont, Burlington, Vermont. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein. Dr. Rashid may be reached at (802) 847-3734; rashid2@earthlink.net.

Matthew W. Watkins, MD, FACC, is from the Department of Cardiology at Fletcher Allen Health Care/University of Vermont, Burlington, Vermont. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein. Dr. Watkins may be reached at (802) 847-2700; matthew.watkins@vtmednet.org.

1. Reberg R. Computed tomographic angiography: more than a pretty picture? *J Am Coll Cardiol.* 2007;49:1827-1829.
2. Raff G, Goldstein J. Coronary angiography by computed tomography: coronary imaging evolves. *J Am Coll Cardiol.* 2007;49:1830-1833.
3. Kaehler J, Koester R, Wibke B, et al. 13-year follow-up of the German angioplasty bypass surgery investigation. *Eur Heart J.* 2005;26:2148-2153.
4. FitzGibbon G, Leach A, Kafka H, et al. Coronary bypass graft fate: long-term angiographic study. *J Am Coll Cardiol.* 1991;17:1075-1080.
5. FitzGibbon G, Kafka H, Leach A, et al. Coronary bypass graft fate and patient outcome: angiographic follow-up of 5,065 grafts related to survival and reoperation in 1,388 patients during 25 years. *J Am Coll Cardiol.* 1996;28:616-626.
6. Mack M, Osborne J, Shennib H. Arterial graft patency in coronary artery bypass grafting: what do we really know? *Ann Thorac Surg.* 1998;66:1055-1059.
7. Gaspar T, Halon D, Peled N. Advantages of multidetector computed tomography angiography in the evaluation of patients with chest pain. *Coron Artery Dis.* 2006;17:107-113.
8. Watkins M. Recent advances in cardiac computed tomography. *Coron Artery Dis.* 2006;17:97-98.
9. Ropers D, Ulzheimer S, Wenkel E, et al. Investigation of aortocoronary artery bypass grafts by multislice spiral computed tomography with electrocardiographic-gated image reconstruction. *Am J Cardiol.* 2001;88:792-795.
10. Schlosser T, Konorza T, Hunold P, et al. Noninvasive visualization of coronary artery bypass grafts using 16-detector row computed tomography. *J Am Coll Cardiol.* 2004;44:1224-1229.
11. Yamamoto M, Kimura F, Niinami H, et al. Noninvasive assessment of off-pump coronary artery bypass surgery by 16-channel multidetector row computed tomography. *Ann Thorac Surg.* 2006;81:820-827.
12. Burgstahler C, Beck T, Kuettner A, et al. Non-invasive evaluation of coronary artery bypass grafts using 16-row multi-slice computed tomography with 188 ms temporal resolution. *Inter J Cardiol.* 2006;106:244-249.
13. Ropers D, Pohle F, Kuettner A, et al. Diagnostic accuracy of noninvasive coronary angiography in patients after bypass surgery using 64-slice spiral computed tomography with 330-ms gantry rotation. *Circulation.* 2006;114:2334-2341.
14. Meyer T, Martinoff S, Hadamitzky M, et al. Improved noninvasive assessment of coronary artery bypass grafts with 64-slice computed tomographic angiography in an unselected patient population. *J Am Coll Cardiol.* 2006;49:945-950.
15. Watkins MW, Hesse B, Green CE, et al. Detection of coronary artery stenosis using 40-channel computed tomography with multisegment reconstruction. *Am J Cardiol.* 2007;99:175-181.
16. Hendel RC, Kramer CM, Patel MR, et al. ACCF/ACCR/SCCT/SCMR/ASNC/NASCI/SIR appropriateness criteria for cardiac computed tomography and cardiac resonance imaging. *J Am Coll Cardiol.* 2006;48:1475-1497.
17. Anders K, Baum U, Schmid M, et al. Coronary artery bypass graft (CABG) patency: assessment with high-resolution submillimeter 16-slice multidetector row computed tomography (MDCT) versus coronary angiography. *Eur J. Radiol.* 2006;57:336-344.

If you would like to submit an article for publication in *Cardiac Interventions Today*, first query in writing with an outline of your proposed article.

Editorial Policies. All articles published in *Cardiac Interventions Today* are reviewed by members of our Editorial Advisory Board and Editor-in-Chief, who have sole discretion to accept, reject, or edit any article submitted for consideration. All articles must be original and must not have been published elsewhere.

Format. We accept manuscripts in Microsoft Word format. Drafts should be e-mailed to the Editor-in-Chief.

Deadlines. All assigned work must be submitted by the first day of the month, 2 months prior to publication.

Length. Unless otherwise agreed to by our Editor-in-Chief, articles shall be at least 1,200 words in length.

Author Information. Please include (1) a complete article title, (2) the author (s) full name(s), academic degree(s), affiliation(s), financial connection to any products mentioned, and (3) full address for correspondence, including complete mailing address, fax number, telephone number, and e-mail address.

Artwork. A minimum of two figures (and related legends) should be supplied with each article. Digital files can be sent in JPG, TIF, or EPS format, and should be approximately 300 dpi at 4 inches wide. If sending via e-mail, JPEG images are preferred. Original slides and photos are also acceptable. Please be sure to indicate numbering and orientation of images.

References. References should be numbered in the order in which they appear in the text and listed at the end of the manuscript. Unpublished data (such as papers submitted but not yet accepted for publication and personal communications) should be cited parenthetically within the text.

Direct queries to Pete Christy, Editor-in-Chief, at pchristy@bmc-today.com or (484) 581-1825. Address correspondence to Cardiac Interventions Today, c/o Bryn Mawr Communications II LLC, 1008 Upper Gulph Road, Suite 200, Wayne, PA 19087.