Cine Computed Tomographic Evaluation of Aortocoronary Bypass Graft Patency

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Evaluation of the patency of coronary bypass grafts has previously required hospitalization for invasive angiography. This report of three cases documents the unique capability of cardiac cine computed tomography to easily and accurately define coronary bypass graft patency. In each case, the findings altered therapeutic decisions. This early experience justifies wider application of this technique and suggests that it may eliminate the need for diagnostically motivated graft angiography. Large scale studies to establish the sensitivity and specificity of cardiac cine computed tomography for determining graft patency are indicated.

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One of the most difficult problems in the long-term management of patients with coronary artery bypass grafts is distinguishing progression of native coronary artery disease from graft closure as the cause of an acute ischemic event. Because the decision to reoperate is often based on this distinction, correct diagnosis is critically important. Although a variety of noninvasive imaging techniques have been proposed as suitable for determining bypass graft patency (1–6), only contrast-enhanced computed X-ray tomography has achieved acceptable levels of accuracy (5,6). This technique is seriously limited, however, by the need for repeated injections of contrast solution to image grafts at multiple levels. This limitation is so significant that hospitalization for bypass graft angiography is the accepted practice. In this report we describe, for the first time, a new technique that could be performed serially in outpatients, eliminate the need for diagnostically motivated graft angiography and in some cases avoid repeat bypass surgery.

Case Reports

Case 1
A 55 year old physician presented with an acute episode of prolonged chest pain accompanied by pulmonary edema and hypotension. Eight years earlier he had sustained an inferoposterior myocardial infarction complicated by congestive heart failure and postinfarction angina. He subsequently had two saphenous vein bypass grafts, one beyond two 90% proximal stenotic lesions of the left anterior descending coronary artery and one to a totally occluded left circumflex coronary artery. Postoperatively, the left ventricular ejection fraction was 29%, but the patient was asymptomatic until the time of rehospitalization.

Coronary angiography. During the current hospitalization, severe heart failure with a non-Q wave lateral wall myocardial infarction necessitated intensive treatment with an intraaortic balloon pump. Coronary angiography now revealed a normal right coronary artery, total occlusion of both the left anterior descending and circumflex vessels and a new 99% stenosis of a small diagonal vessel proximal to the left anterior descending bypass graft insertion. The saphenous vein bypass graft to the left anterior descending vessel was patent and normal (Fig. 1A). After repeated unsuccessful attempts to catheterize the graft to the left circumflex coronary artery, the angiographer considered this graft to be occluded. An aortic root injection was not performed because of the patient’s unstable hemodynamic state, which stabilized during the ensuing 2 weeks. On the basis of catheterization data, repeat bypass surgery was scheduled, because restoration of patency of the left circumflex graft could be critical for sustaining myocardial performance in the event of the threatened diagonal branch occlusion.

Cine computed X-ray tomography. This procedure was performed 2 weeks after the infarction. The patient was positioned supine within the scanner, perpendicular to its...
Figure 1. Case 1. A, Left anterior descending saphenous vein bypass graft as visualized on invasive selective graft angiography. B, Appearance of proximal portion of the same graft (white arrow) by cine computed tomography.

gantry. Renografin-76, 35 ml, was injected into a peripheral vein through a 1.5 inch (3.81 cm) 18 gauge intravenous catheter at a rate of 7 ml/s (Medrad). Beginning 10 seconds after injection, eight image acquisition sets were obtained covering approximately 8 cm from the aortic arch to the aortic valve. Acquisitions, gated to the R wave of a surface electrocardiogram, were triggered by each of 10 consecutive heartbeats. Total acquisition time of all 80 images was approximately 15 seconds.

The cine tomographic images acquired when contrast solution was maximal in the aortic root are shown in Figure 2. In contrast to the selective graft study, from this study it is apparent that there are two patent saphenous vein bypass

Figure 2. Case 1. Cine tomographic images of the aortic root, demonstrating contrast enhancement of two saphenous vein grafts. The order of the images is from the most cephalad slice (upper left) to the most caudal slice (lower right). Closed arrows = left anterior descending graft; open arrows = left circumflex graft.
grafts. The first is seen in a longitudinal projection over a distance of 5 cm as it arises from the aortic root and courses laterally toward the left anterior descending artery. This graft is then seen in cross section in more caudal slices. In the most caudal slice (eighth image) it is visible at its anastomosis to the left anterior descending vessel. The appearance of the proximal portion of this graft on cine computed tomography (Fig. 1B) is directly comparable with its appearance on invasive angiography (Fig. 1A).

In the fourth tomographic slice, a second saphenous vein bypass graft is identified at its origin from the aortic root. This graft is seen over a distance of approximately 6 cm as it travels sharply posteriorly. As with the anterior descending artery graft, it is seen in cross section in sequential caudal slices, as it approaches its anastomosis to the left circumflex vessel (sixth image). On the basis of this documentation of circumflex graft patency, the patient was spared repeat bypass surgery. He has remained asymptomatic after hospital discharge.

Case 2

Coronary arteriography. A 55 year old man had coronary and graft angiography for recurrent angina and lateral wall ischemia by thallium-201 scintigraphy. He had undergone saphenous vein bypass graft surgery to the left anterior descending coronary artery 7 years previously. Coronary angiography revealed a totally occluded left anterior descending artery and a 99% proximal left circumflex artery narrowing. The right coronary artery was normal. The left anterior descending artery graft was not visualized, and was presumed to be occluded. Because of this presumed graft occlusion associated with stress-induced ischemia in the distribution of the same vessel, he was scheduled for repeat bypass grafting to the left anterior descending vessel and a new bypass graft to the circumflex coronary artery.

Cine computed tomography. This procedure was performed after peripheral intravenous injection of 35 ml of Renografin-76. In contrast to the invasive catheterization, it proved that the left anterior descending graft was, in fact, patent (Fig. 3). Because the anterior descending artery graft did not need to be replaced, the therapeutic plan was changed. Percutaneous transluminal coronary angioplasty of the left circumflex vessel was performed rather than repeat surgery. On the basis of the cine computed tomographic study, the angiographer persevered at the repeat catheterization, and was able to locate the left anterior descending graft origin.
and to confirm that the graft was patent. Percutaneous transluminal coronary angioplasty was successful.

**Case 3**

A 63 year old woman was hospitalized with sudden and protracted atypical chest pain. Thirteen years previously she had had saphenous vein bypass graft surgery to the left anterior descending and right coronary arteries. She was asymptomatic until recently. Her cardiologist recommended angiography to determine the patency of the grafts and native vessels, but she consented to cine computed tomography.

**Tomography.** Renografin-76, 35 ml, was injected into a peripheral arm vein at the rate of 7 ml/s. A 20 second cine computed tomographic acquisition established that both bypass grafts were patent (Fig. 4). The left anterior descending graft was visualized in longitudinal section at the most cephalad surgical clip, where the graft arose from the aorta. It was then seen in cross section in four progressively caudal tomographic slices, the most caudal being at the distal anastomosis with the well visualized native anterior descending vessel. The right coronary graft was also seen at the site of proximal anastomosis, and was established to be patent over a distance of 6 cm. The most caudal slice was just above the graft-right coronary artery anastomosis. This information was critical in sparing this patient an invasive procedure. The cardiologist ordered an exercise test instead. Further laboratory studies established a noncardiac basis for the patient’s chest pain.

**Figure 4.** Case 3. Patent left anterior descending (closed arrows) and right coronary (open arrows) saphenous vein bypass grafts.

**Figure 5.** Standard placement of proximal anastomoses of saphenous vein grafts in the ascending aorta (cephalad to caudal: left circumflex, left anterior descending, right coronary artery grafts) and relation of imaging planes of cine tomographic (Imatron C-100) scanner.
Discussion

Cine computed X-ray tomography is a new cardiac imaging method that holds promise for the study of cardiac structure and function, intracardiac masses, the pericardium and possibly myocardial perfusion (7–10). This is the first report on its potential for assessing the patency of bypass grafts. This early experience suggests that it is a safe and relatively noninvasive method uniquely suited for this purpose.

Technical details. Interpretation of cine computed tomographic images of bypass grafts is aided by understanding the usual sequence of insertion of grafts in the aorta (Fig. 5) and their course after insertion (5). The most cephalad of the left-sided proximal anastomoses is the posterior circumflex artery graft. The intermediate, diagonal and left anterior descending artery grafts are then placed in descending order. The right coronary artery graft is placed most caudal and exits rightward. The cine computed tomographic scanning planes will allow observation of all grafts in longitudinal section as they exit from the aortic root, and then in cross section at the subsequent caudal levels when the orientation of the body to the scanning plane is optimal (Fig. 5).

The technique utilizes an electromagnetically focused high energy electron beam to generate high resolution rapid sequence (up to every 50 ms) X-rays that contain three-dimensional information at multiple scan levels (7). Tomographic images can be acquired nearly simultaneously over an 8 cm distance, so that saphenous vein grafts can be imaged at numerous levels from proximal to (or near to) distal anastomoses. When gated to the electrocardiogram, image acquisition can be timed to commence before a contrast bolus reaches the aortic root, while it traverses the aortic root and bypass graft and during the washout phase. The movement of the bolus can then be viewed in a closed-loop movie format to assess the status of the graft.

The scanning planes of the only commercially available cine computed tomographic device at present (Imatron C-100) are shown in Figure 5. Two contiguous 8 mm thick images are obtained from each of four X-ray target rings, separated by three 4 mm thick nonimaged gaps.

Imaging protocol. Proper scanning orientation is achieved by performing an eight level localization scan (232 ms; 250 mrad; no contrast). The computer immediately reconstructs these images (in less than 2 minutes), and the patient is then repositioned so that the most cephalad acquisition is at the level of the top surgical clip, which most commonly identifies the left circumflex artery graft origin. When no clips are placed, then the top level is placed at the aortic arch. The high frequency of late graft closure (11) and the emergence of this technology for graft imaging suggests that clip placement should be routine.

After repositioning, contrast material (Renografin-76) is injected through a peripheral vein at a volume of 0.5 ml/kg body weight at a rate of 6 to 9 ml/s. Total time for localization, image acquisition and reconstruction is less than 25 minutes.

Initial experience. The cases presented illustrate the clinical impact of visualizing patent grafts with this simple, relatively noninvasive test. Optimal value will be possible only if the test is both sensitive and specific for determining graft patency. We have evaluated 39 saphenous vein grafts in 13 patients in whom both cine computed tomography and invasive angiography have been performed within 2 weeks. Angiography identified 25 open and 14 occluded grafts. Cine computed tomography was concordant for the status of 37 of these 39 grafts, but proved that in fact only 12 rather than 14 grafts were occluded. Because aortic root injections were not done in many of these cases, these data do not establish true accuracy of cine computed tomography for evaluating bypass graft patency, but suggest that sensitivity and specificity will both be high.

Conclusions. These cases demonstrate that cine computed tomography has the potential to provide information critical to management of patients after coronary bypass graft surgery that previously could only be obtained by invasive angiography. Although the sensitivity and specificity of the technique remain to be defined, the clarity of the images, obtained at multiple levels, suggests that this could become the procedure of choice for defining coronary bypass graft patency. As illustrated in these cases, the ability to easily and accurately define coronary bypass graft patency represents a critical milestone in the management of coronary artery disease.

References


