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Ultrafast Computed Tomography for Quality Control of Automated Proximal Anastomoses

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ABSTRACT

Background: The Symmetry aortic connector uses a nitinol implant to create proximal anastomoses with saphenous vein grafts. Multiple detector-row cardiac computed tomography (MDCT) is used as a noninvasive method of quality control at our institution.

Methods: In 50 elective coronary artery bypass grafting patients who participated in a randomized trial comparing automated with conventionally hand-sewn proximal anastomoses, MDCT was performed on postoperative day 5. Fifty-three automated Symmetry anastomoses were created in 34 patients (group 1). Twenty-five conventionally hand-sewn anastomoses created in 16 patients served as controls (group 2). Graft patency and the presence or absence of high-grade stenosis at the proximal anastomotic site were evaluated.

Results: In group 1, 2 (3.8%) of the grafts were found occluded at MDCT or coronary angiography, and no further relevant stenosis was observed. In group 2, at postoperative MDCT all grafts were found patent without significant narrowing of the proximal anastomotic site.

Conclusions: The feasibility of proximal anastomoses using the Symmetry device has been reported. Patency control with invasive angiography has been performed by other groups. With MDCT, noninvasive evaluation of proximal anastomotic quality and graft patency is possible, even if nitinol is implanted.

INTRODUCTION

In coronary artery bypass grafting (CABG), proximal anastomoses are almost exclusively performed with running sutures. Devices for proximal anastomoses may reduce dependency on surgical skill as prognostic factor for long-term patency. Avoiding aortic side clamping also may be useful for avoiding particulate embolization [Guyton 1979, Calafiore 2001, Eckstein 2001]. Ultrafast cardiac computed tomography (CT) as a noninvasive method for assessment of graft patency after CABG was suggested by the groups of Bateman [1987] and Stanford [1988], who found a predictive accuracy of 96% and 92%, respectively. These investigators concluded that technically adequate studies could be performed effectively in the majority of CABG patients. Despite reasonably high temporal and spatial resolution of the scanner, limitations were seen in differentiation of obstructed and unobstructed grafts. Details of proximal and distal anastomoses and the distal vasculature were not obtained with recent CT scanners.

The limited effectiveness of CT for visualization of the distal anastomotic site and detection of possible graft stenosis was confirmed by Engelmann et al in 1997. These investigators compared CT with angiography and reported an accuracy of 96% in evaluation of venous graft patency. Three-dimensional reconstruction of the grafts had only limited diagnostic advantages [Engelmann 1997]. Three years later, the same group had improved the accuracy of CT to 100% in evaluation of graft patency in follow-up of CABG patients [Engelmann 2000]. In 2000, visualization of the proximal anastomosis for evaluation of anastomotic quality was successfully demonstrated with electrocardiographic (ECG) triggering of conventional CT scanners. Ten postoperative CABG patients underwent ECG-triggered CT with slices of 2 mm in the region of the proximal anastomosis at the ascending aorta. One of 18 proximal anastomoses was found occluded; the others were visualized as patent and nonstenotic [von Smekal 2000].

In proximal anastomoses with nitinol implants, such as the Symmetry aortic connector (St. Jude, St. Paul, MN, USA), patency control with spiral CT has not been reported. The aim of our study was to evaluate proximal anastomotic quality and graft patency in the presence of nitinol implants. Because coronary angiography is an invasive method and therefore often denied by patients after intervention, multiple detector-row cardiac CT (MDCT) was performed for quality control in 50 patients who participated in a randomized trial of automated versus conventionally performed proximal anastomoses.

MATERIAL AND METHODS

MDCT was performed on postoperative day 5 in 34 patients who underwent CABG performed with the Symmetry proximal

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Distal Anastomoses

	Group 1	Group 2
Right coronary artery (or branches of)	31	14
Right circumflex artery (or branches of)	34	13
Diagonal branch	10	4

connector (group 1, 53 anastomoses with nitinol implants). Sixteen patients receiving 25 conventionally hand-sewn proximal anastomoses served as controls (group 2). The study was approved by our institutional review board, and written informed consent was obtained from all patients. Mean age was 66 ± 7.4 years for group 1 and 68 ± 6.1 years for group 2 (not significant). All patients suffered from 2- or 3-vessel coronary disease and received an internal thoracic artery graft to the left anterior descending coronary artery. Target vessels for the vein grafts are summarized in the table. The number of distal vein graft anastomoses was 75 for group 1 and 31 for group 2. Jump-graft techniques were used in most patients. All the procedures were performed by the same surgeon.

CT was performed with a spiral MDCT scanner (Somatom Plus 4 Volume Zoom WIP-Version VA 20; Siemens, Forchheim, Germany). Patients with heart rates higher than 70 beats/min had previously received a short-acting β-blocker (esmolol [Brevibloc] 100 mg, 1 mL/10 kg body weight; Baxter, Chicago, IL, USA) to obtain heart rates of 60 beats/min or less. However, because drug treatment often was not effective, heart rates even higher than 80 beats/min had to be accepted in some patients. A standard scan protocol was used with 4 mm × 1 mm slice collimation, 1.5-mm table feed per rotation, and 500 milliseconds rotation time. Owing to 180-degree linear interpolation, exposure time was minimized to 250 milliseconds. Each scan was obtained at 120 kV and 300 mA. All patients received 140 to 160 mL of noniodine contrast medium (Ultravist; Schering, Berlin, Germany) through an 18-gauge intravenous antecubital catheter infused with a flow rate of 3.5 mL/s.

Image reconstruction was performed with 1.25-mm effective slice thickness, 0.5-mm increment, and kernel B30, a medium soft-tissue kernel. All reconstructions were performed with retrospective ECG gating. For this technique, an ECG file recorded simultaneously during the scanning procedure was retrospectively assigned to the data set, thus allowing reconstruction of the scanned volume during any phase of the cardiac cycle [Ohnesorg 2000]. Depending on the heart rate, 2 different reconstruction algorithms were applied: a single-segment reconstruction (SSR) (<65 beats/min) and an adaptive 2-segment reconstruction (ASR) (>65 beats/min). For reconstruction of each 1.25-mm slice, SSR required data from only 1 rotation and ASR required data from at least 2 rotations [Flohr 2001]. Because of scanner geometry, temporal resolution for ASR amounted to 125 milliseconds. Taking basic cardiac physiology into account, sufficient image reconstruction seemed to be feasible solely if performed between late systole (ie, ascending T wave) and late diastole (ie, beginning of P wave) [Luisada 1972]. Each data set was consequently reconstructed at multiple time points within this interval, differing from one another by 50 milliseconds. Reconstruction was performed antegrade in relation to the R peak and in absolute values; that is, the starting point of each reconstruction was given in milliseconds after the preceding R peak. For each patient and each proximal anastomosis separately, one specific reconstruction was determined that showed the least impairment by motion artifacts in the ascending aorta.

Evaluation of images was performed with transverse scans and secondary reformations; that is, it was multiplanar (MPR). Transverse and MPR scans were analyzed on a workstation (VZ Wizard; Siemens, Erlangen, Germany) on a 512 × 512 matrix. The criterion analyzed for evaluation of graft patency was opacification of the graft on at least 2 noncontiguous levels (Figure 1). Evaluation of the proximal anastomoses was performed with 2-dimensional reconstructions (Figure 2). More than 50% narrowing of the lumen at the anastomotic site was regarded as relevant.

RESULTS

One patient in group 1 showed clinical signs of perioperative myocardial infarction with relevant creatine kinase elevation on postoperative day 1 and was referred for early angiography. A vein graft to the circumflex artery was occluded, but distal vessels seemed to be filled by collaterals. Because contractile function was not impaired, we decided not to perform reintervention. The patient died 3 days later of left ventricular rupture.

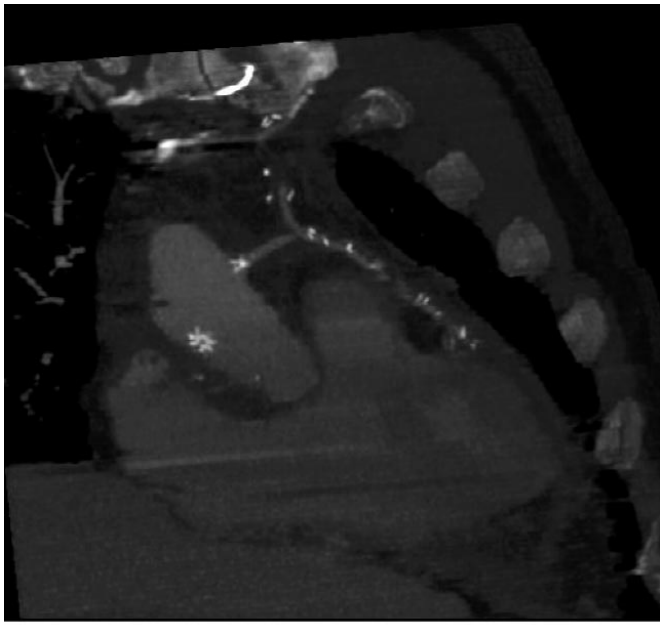

Figure 1. Patency control of grafts with multiple detector-row cardiac computed tomography, coronal reconstruction. The vein graft to the circumflex artery crosses the internal thoracic artery graft to the left anterior descending artery. Both grafts show the same opacification compared with the ascending aorta.

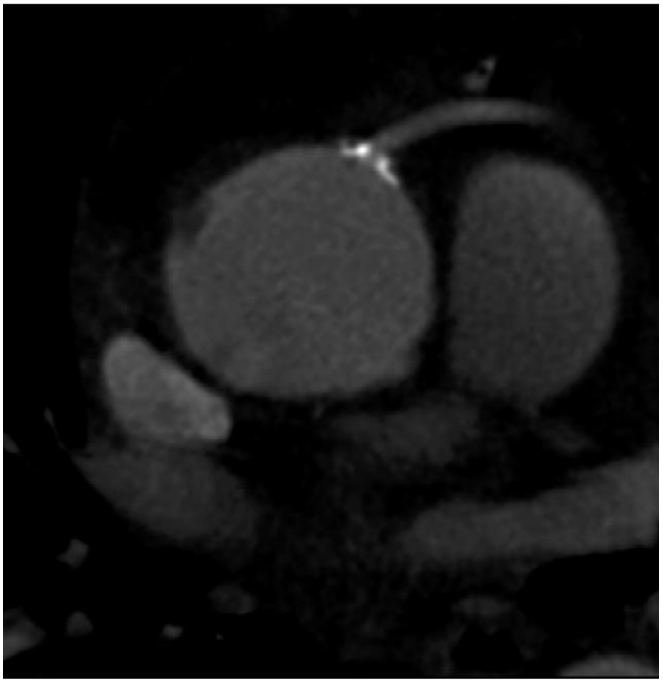

Figure 2. Two-dimensional reconstruction of automated proximal anastomosis with a nitinol implant.

The other patients underwent postoperative MDCT as scheduled. All grafts were visualized, and evaluation of the proximal anastomoses was possible in almost every patient (Figures 2 and 3), even those with nitinol implants. In 2 anastomoses in group 1 and 1 anastomosis in group 2, visualization was unsatisfactory because of artifacts. One graft occlusion was detected in group 1. The postoperative course of the patient had been uneventful. The vein graft to the circumflex artery did not show opacification at MDCT. Figure 4 shows the CT scan of the occluded graft. Our findings were confirmed by angiography 2 days later. All other grafts in group 1 and 2 were patent, and the proximal anastomoses were found without relevant stenosis in both groups. The 2 graft occlusions in group 1 resulted in an early occlusion rate of 3.8% with the aortic connector, compared with a 0% occlusion rate in controls (group 2).

DISCUSSION

Perioperative death occurred in 1 patient in our study group; graft occlusion had led to myocardial infarction. Early graft occlusion may be caused by proximal or distal anastomotic problems, twisting of the vein graft, or poor graft function. The causes of the 2 graft occlusions remain unclear. However, an early occlusion rate of 3.8% does not exceed occlusion rates reported in the literature on large series of vein grafts [Fitzgibbon 1996]. Mechanical devices for sutureless aorta–saphenous vein graft anastomoses were described in 1979 [Guyton 1979]. Feasibility and possible advantages such as minimizing aortic manipulation have been reported recently [Calafiore 2001, Eckstein 2001]. Patency control was performed with coronary angiography in most studies of new proximal or distal anastomotic devices. Regarding proximal anastomoses, alternative methods such as CT for patency control have been evaluated [von Smekal 2000], and accuracy has been proved for conventional

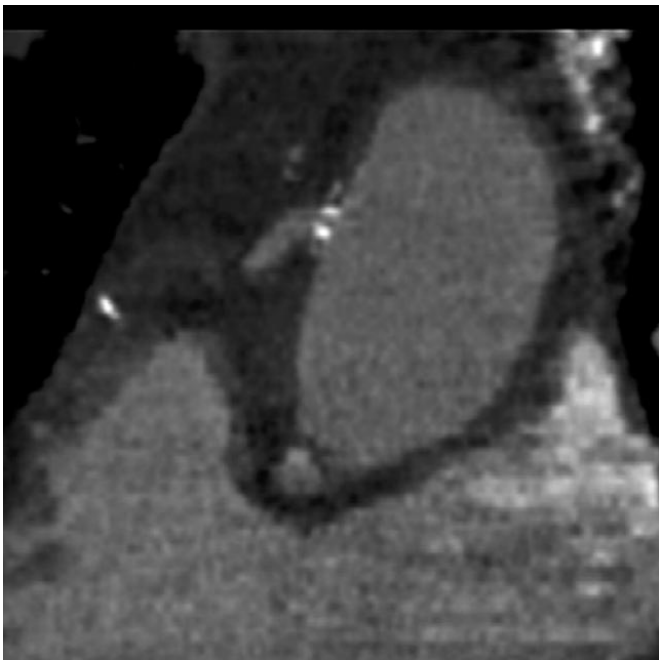

Figure 3. Sagittal reconstruction of an automated proximal anastomosis.

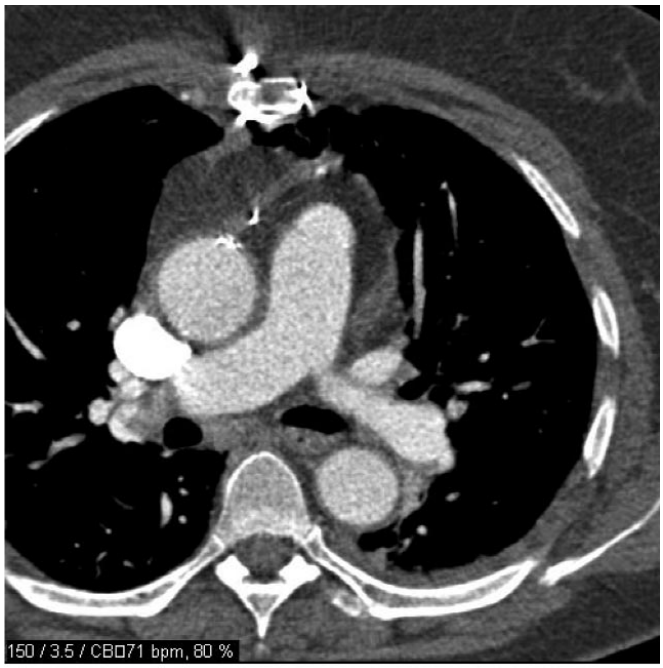

Figure 4. Occluded vein graft to the circumflex artery.

anastomoses. Patency control of proximal anastomoses using nitinol implants such as the Symmetry aortic connector with CT has not yet been described.

For postoperative evaluation of proximal anastomoses, MDCT is a less invasive and less expensive alternative to angiography. Acceptance of quality control by patients in a clinical trial is dependent on the invasiveness of the method proposed. Compared with visualization of distal coronary anastomoses, visualization of proximal anastomotic sites of vein grafts by MDCT is less impaired by motion artifacts. In addition to evaluation of graft patency, detection of proximal stenosis is possible with this method. However, evaluation of 3 proximal anastomoses was unsatisfactory because of artifacts. Regarding distal anastomotic quality, coronary angiography provides more information than the current generation of CT scanners and has the advantage that immediate intervention in a stenotic vessel is possible. For this reason, we performed coronary angiography in the patient who presented clinical signs of myocardial infarction. The other graft occlusion, initially diagnosed with MDCT, was confirmed by angiography, thus demonstrating the reliability of our method. We concluded that MDCT provides reliable data for screening of graft patency and proximal anastomotic quality after CABG, even in the presence of metal implants.

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