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# Multislice Computed Tomography for Preoperative and Postoperative Assessment in Totally Endoscopic Coronary Artery Bypass Grafting

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## ABSTRACT

This article reviews the clinical value of noninvasive multislice computed tomography (MSCT) angiography before and after totally endoscopic coronary artery bypass surgery. The use of coronary and aorto-iliaco-femoral MSCT angiography in the preoperative assessment is addressed and the use of bypass MSCT angiography for postoperative control of bypass graft patency is discussed.

## INTRODUCTION

Totally endoscopic coronary artery bypass grafting (TECAB) techniques [Argenziano 2006; Bonatti 2006] are using robotic surgical systems such as the Da Vinci telemanipulator (Intuitive Surgical, Mountainview, CA, USA). Its robotic instruments are inserted left-lateral transthoracically via 3 small holes. Therefore, sternotomy can be avoided, but because panoramic view through endoscopes is limited, accurate information about thoracic anatomy would be desirable before endoscopic coronary artery bypass grafting (CABG).

Multislice computed tomography (MSCT) is an emerging noninvasive imaging modality that has created new applications in the field of cardiovascular imaging over the past few years. Since the introduction of 16-slice computed tomography scanners in 2002, MSCT coronary angiography has become feasible. Recent advances include 64-slice computed tomography technology and dual-source computed tomography scanners that provide improved spatial and temporal resolution (>83 ms) [Flohr 2004]. These modalities allow comprehensive electrocardiographic (ECG)-gated "thoracic imaging" (Figure 1), which means imaging of coronary and great vessel angiography and the complete cardiac and extracardiac anatomy.

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## VALUE OF MSCT BEFORE TECAB

Because of the development of 16-slice computed tomography, noninvasive coronary angiography has gained clinical interest. Several studies have shown promising results for the detection of coronary stenosis >50% [Kuettner 2004; Hoffman 2005], but technical limitations were observed such as image artefacts at high heart rates or in the presence of heart rate irregularities. The diagnostic performance and accuracy has been improved by using 64-slice computed tomography scanners [Mollet 2005a; Raff 2005], thus justifying routine clinical application. Another main advantage of MSCT coronary angiography over invasive angiography is its potential in imaging atherosclerosis. Noncalcifying plaque can be differentiated from calcifying plaques based on computed tomography densities (Hounsfield Units) [Leber 2005] (Figure 2), which is of particular importance regarding the selection of the anastomotic site. Severe coronary calcification may lead to difficulties in suturing the anastomosis. An elegant study by Mollet et al has reported on the prevalence and distribution of noncalcifying versus calcifying plaques among all coronary segments. They found a lower prevalence of plaques at distal coronary segments when compared with proximal segments; however, the prevalence was still 35% in distal left anterior descending (LAD) segments and 62% in the distal right coronary artery [Mollet 2005b].

MSCT allows a precise display of myocardial bridging of the LAD and a measurement of the myocardial tunnel length and depth (Figure 3). Knowledge of these facts is of great interest before TECAB [Herzog 2003] in order to select an appropriate site for placement of the left internal mammary artery (LIMA). The characteristic "milking phenomenon" can be difficult to see during invasive angiography, thus the numbers of myocardial bridges identified by invasive angiography is remarkably lower when compared with autopsy studies suggesting many missed cases.

Given the fact that invasive angiography frequently fails in displaying the distal coronary artery in the presence of 100% proximal artery occlusion, MSCT can help again. Because MSCT image acquisition is performed after a time delay of approximately 10 seconds, the distal coronary vessel is properly opacified and can be visualized in its entire

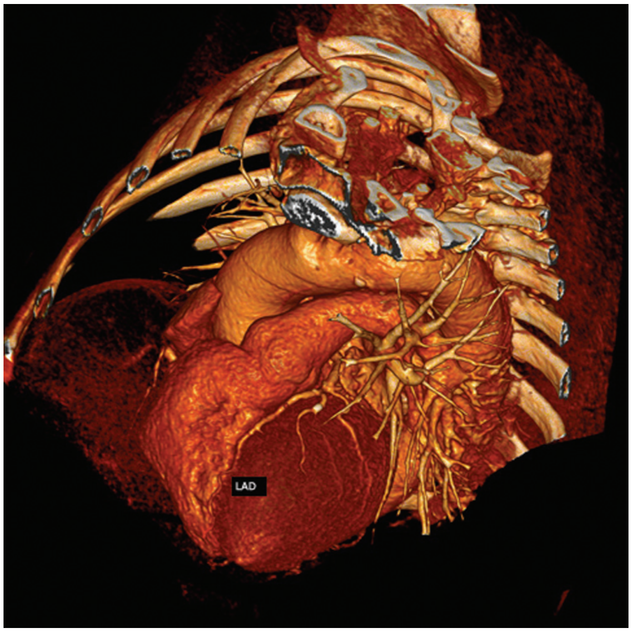


Figure 1. Preoperative multislice computed tomography (MSCT) angiography of the coronary arteries (see left anterior descending artery) allows comprehensive assessment of the aorta and extra-cardiac anatomy, which is helpful for planning totally endoscopic coronary artery bypass grafting. Three-dimensional MSCT image reconstructions are obtained with the volume-rendering technique.

course (Figure 4). MSCT also permits measurement of the occluded segment; in a head-to-head comparison of MSCT versus invasive angiography, MSCT succeeded in 100% of cases while invasive angiography was accurate in only 66% [Mollet 2005c].

MSCT also offers noninvasive angiography of the internal mammary arteries to prove its eligibility for take down. Severe atherosclerosis is very rare, with a prevalence <2% [Singh 1983], but it can be nicely shown with MSCT. The distance between the LIMA and LAD can be measured, which is mainly determined by the size of the precordial fatpad, thus representing a parameter to predict the anastomosis suturing time [Schachner 2005]. Three-dimensional measurement of the length of the internal mammary arteries and the curved length of their future course to the anastomosis after the take down can be performed by curved multiplanar reformations [Feuchtner 2006a], which is of particular interest before double-vessel TECAB (LIMA/circumflex artery and right internal mammary artery/LAD) to define their appropriateness as grafts. In one patient, the length of the LIMA was found to be too short intraoperatively, necessitating conversion to conventional venous CABG grafting.

TECABs may be performed either on the arrested heart or on the beating heart. In arrested-heart TECAB procedures, cardiopulmonary bypass is established with a femoral access perfusion device that carries a balloon for aortic endo-occlusion [Schachner 2004]. Even mild atherosclerosis of the ascending aorta may have an adverse influence on the balloon and has shown to be associated with intra-aortic balloon-related intraoperative difficulties such as balloon migration in the presence of noncalcifying atherosclerosis or balloon rupture because of small calcifying plaques [Feuchtner 2006b]. Mild atherosclerosis can be accurately imaged with ECG-gated MSCT. MSCT also offers precise measurement of the diameter of the ascending aorta, which is an important parameter for arrested-heart TECAB planning since an increased ascending aortic diameter (greater than 3.8 cm) precludes the use of a cardiopulmonary bypass perfusion system such as the Estech cannula (Danville, CA, USA) [Schachner 2004]. Additionally, whole-body aorto-iliac-superiorfemoral MSCT angiography (Figure 5a) provides valuable information regarding the severity of atherosclerosis and stenosis [Catalano 2004]. In patients with severe atherosclerosis and stenosis <0.7-cm vessel diameter, the use of the 21 F Estech cannula is contraindicated. Aorto-iliac-superior femoral MSCT angiography can be performed easily following the cardiac ECG-gated MSCT scan by using a dedicated customized biphasic iodine contrast agent injection protocol at a scan delay >40 seconds [Fleischmann 2004]. Massive kinking of the iliac vessels, which may also lead to problems related to the cardiopulmonary bypass perfusion system implementation, can be shown 3-dimensionally with MSCT (Figure 5b).

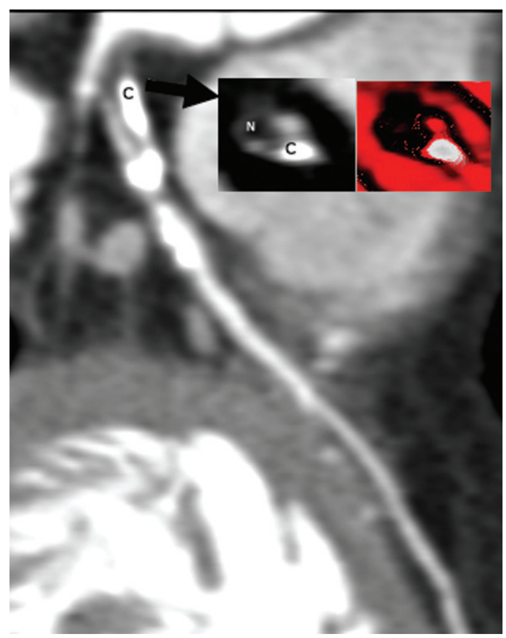


Figure 2. Severe calcifying plaque (C, white) proximally with a noncalcifying plaque component (N, black) shown with multislice computed tomography coronary angiography. Note that the distal left anterior descending artery (LAD) is spared from calcifying plaque and qualifies for suturing the anastomosis. The inlay images (black arrow) show a cross-sectional slice through the LAD proximally at the level of the black arrow.

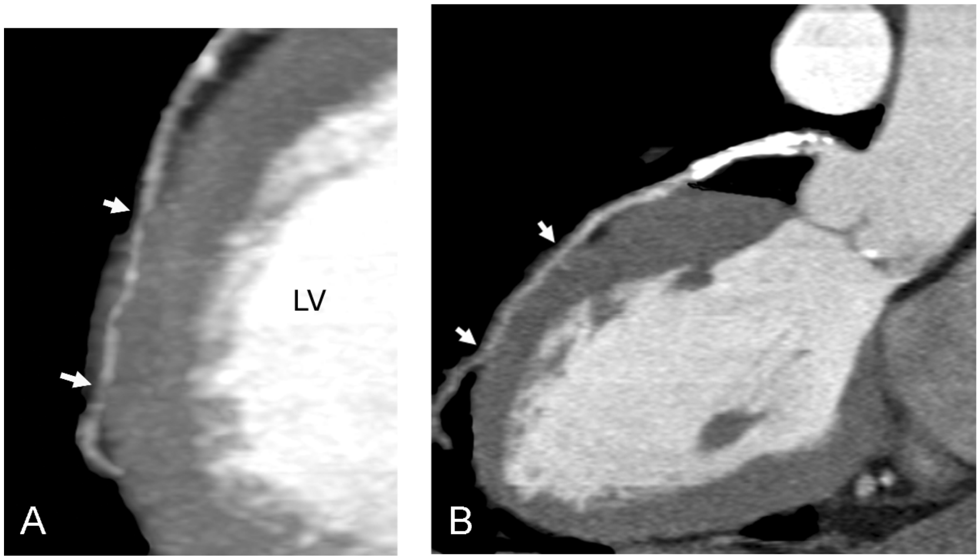


Figure 3. Myocardial bridging. A, myocardial bridging of the left anterior descending artery (LAD). White arrows denote the entrance and exit of the LAD from the myocardium. The length of the "tunnelling" can be measured with multislice computed tomography (MSCT). B, Myocardial "attachment" of the LAD. This LAD is attached to the myocardium but is not intramyocardial. Nonetheless, severe difficulties in suturing the anastomosis of the LAD had occurred intraoperatively in this 49-year-old man and, finally, the diagonal branch had to be taken for revascularization.

In summary, MSCT provides useful information for preoperative planning of TECAB procedures (Table), which is helpful for detailed planning of the operative strategy (eg, beating-heart versus arrested-heart TECAB).

## VALUE OF MSCT AFTER TECAB

Sixteen- and 64-slice computed tomography scanners offer a noninvasive assessment of bypass graft patency (Figure 6).


Figure 4. Complete occlusion (100%) of the right coronary artery. White arrows denote the occluded segment. The coronary artery distal of the occlusion can be displayed by multislice computed tomography coronary angiography with volume-rendering technique (A) and curved multiplanar reformations (B).

Several studies have reported high diagnostic accuracy for the detection of complete graft occlusion by using 16-slice computed tomography scanners [Martuscelli 2004; Schlosser 2004; Chiurlia 2005; Schachner 2007]. However, evaluation of the distal anastomosis has been technically limited; for example, artefacts from metallic surgical clips or residual cardiac motion in 16% to 23% of grafts have been reported [Martuscelli 2004; Schlosser 2004].

Sixty-four slice computed tomography technology offers higher temporal (83-165 ms) and higher spatial resolution ($0.4 \times 0.4 \times 0.4$ mm$^2$) [Flohr 2004] when compared with 16-slice computed tomography (105-250 ms and $0.5 \times 0.5 \times 0.6$ mm$^2$, respectively), which has improved the visualization of grafts and the distal anastomosis. Clinical studies suggest an improved diagnostic accuracy in detecting bypass graft stenosis <50% [Malagutti 2006; Pache 2006]. However, overestimation of distal graft stenosis was observed [Malagutti 2006], in particular in the presence of small distal coronary vessel or metallic surgical clips. As the prevalence of stenosis was relatively low with <20% in both studies, data from ongoing studies should be awaited.

In summary, both 16- and 64-slice computed tomography can be used in clinical practice as a reliable tool to determine postoperative graft patency. The major advantage of MSCT when compared with invasive angiography is its noninvasiveness with minor associated risks for the patient and the simultaneous assessment of extracardiac pathologies causing postoperative dyspnea and chest pain (eg, pneumothorax, atelektasis, pleural effusion, pulmonary embolism). In a "comprehensive" fashion, MSCT can also assess cardiac valves [Feuchtner 2006c, 2006d], the myocardium, and left ventricular function in one scan.


Figure 5. Aorto-iliaco-femoral artery multislice computed tomography angiography. A, Moderate atherosclerosis (black arrow), mild kinking, and absence of stenosis of the common iliac arteries. The external iliac arteries and the femoral arteries are spared from atherosclerosis. Arrested-heart totally endoscopic coronary bypass surgery was performed without complications. B, Severe kinking of the iliac arteries (180° angulation). Previous problems with the guidewire during invasive coronary angiography were reported and, therefore, arrested-heart totally endoscopic coronary bypass surgery was avoided.

### Useful Multislice Computed Tomography (MSCT) Findings for Preoperative Planning before Totally Endoscopic Coronary Artery Bypass Grafting (TECAB)*

| MSCT Finding | Usefulness for Preoperative Planning |
|---|---|
| 1. Heavy calcifying coronary plaque (Distal?) | Selection of the anastomotic site |
| 2. Myocardial bridging (Localization? Length? Depth?) | Selection of the anastomotic site |
| 3. Coronary artery occlusion (100%) (Course of the coronary artery distal of occluded segment?) | Selection of the anastomotic site |
| 4. IMA | |
| 4.1. Left IMA distance to left anterior descending artery (size of epicardial and precordial fatpad) | Predicts anastomosis suturing time |
| 4.2. IMA atherosclerosis? | Proof of IMA appropriateness |
| 4.3. IMA length versus future course to anastomosis | Proof of IMA appropriateness |
| 5. Ascending aorta | Atherosclerosis and >3.8-cm diameter preclude AHTECAB |
| 6. Great vessels (Aorta, iliac arteries, superior femoral artery) | Severe atherosclerosis, severe kinking, and stenosis preclude AHTECAB |
| 7. Extra-thoracic anatomy (Emphysema in lungs, etc?) | |

*IMA indicates internal mammary artery; AHTECAB, arrested-heart TECAB.

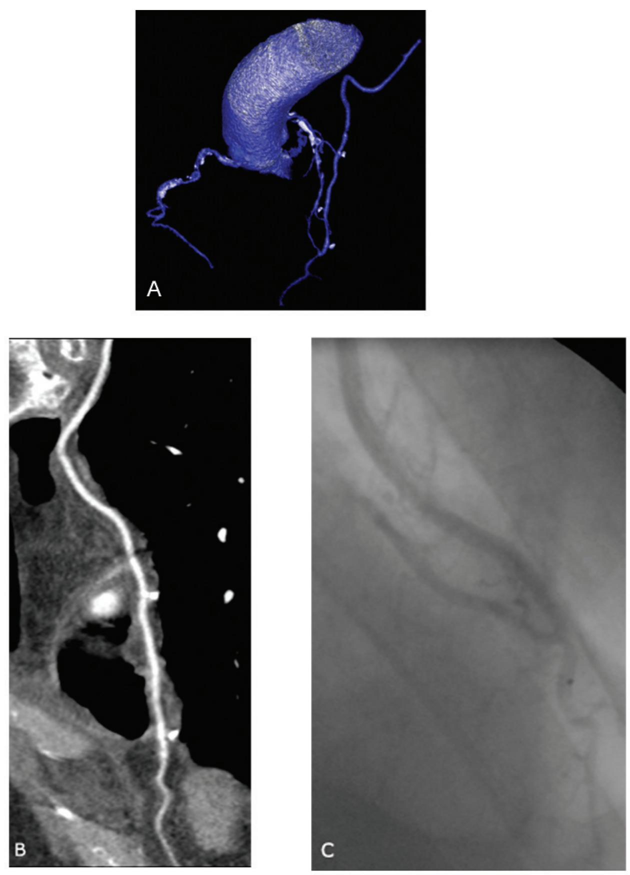


Figure 6. Postoperative bypass multislice computed tomography angiography allows an assessment of graft patency.

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