

Role of Multi-detector Row CT Coronary Angiography in the Assessment of Coronary Artery Bypass Grafts

Thesis

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Abstract

Coronary artery bypass surgery with use of either venous or internal mammary artery (IMA) coronary artery bypass grafts has become an established treatment for symptomatic multi-vessel coronary artery disease. One of the most important variables that determine the successful clinical outcome of coronary artery bypass graft placement is the short- and long-term patency rate of the grafts.

So far, conventional coronary angiography has been considered the standard of reference for evaluation of the patency and luminal stenosis of coronary artery bypass grafts. However, the main drawbacks of conventional coronary angiography for this purpose include invasiveness, patient discomfort, and risk of complications. A less invasive imaging modality is desirable for evaluation of patients suspected of having graft stenosis or occlusion.

The use of multi-detector row CT is gaining increasing acceptance for noninvasive cardiac imaging. Recent years with the new emerging machines have demonstrated successful application of multi-detector row CT angiography for the less invasive assessment of coronary artery disease and the evaluation of coronary grafts.

The aim of this study is to evaluate multi-detector row CT angiography as a less invasive technique in the assessment of the coronary arteries bypass graft (CABG). Those are high risk patients and they may not need to undergo much more invasive techniques (e.g. conventional angiography) to assess the patency of their grafts.

This study included 62 patients with prior CABG surgery, 24 of them underwent conventional angiography as a gold standard for evaluation of the coronary artery bypass grafts. The indications of angiography were unstable angina in 41 cases (66%). The mean age of the included patients was 58 with an age range between 39 and 73 years. Male patients were 55 (88.7%) while females were 7 (11.3%).

A total of 169 coronary artery bypass grafts were included in this study; of these 5 were non-evaluable (3%) due to calcification or nearby surgical clips and were excluded from the study. Within the evaluable grafts 72 (43.9%) were arterial and 92 (56.1%) were venous. Out of the arterial grafts, 57 (79%) were found patent, 7 (9.7%) were significantly narrowed and 8 (10.3%) were completely occluded. As for the venous grafts they were 92 grafts, 43 (46.7%) of them were patent, 14 (15.3%) were significantly narrowed and 35 (38%) were completely occluded.

Twenty one patients underwent both conventional and MSCT coronary angiography. The patients who did not perform the conventional angiography were mostly due to the decision made by the referring physicians as there is increased confidence in the results of MSCT angiography, so those patients were referred for either conservative medical treatment or for a re-do. 47 grafts were evaluated by conventional angiography, 15 of them were LIMA in situ arterial grafts, 4 free radial artery grafts and 28 venous grafts. Conventional angiography was considered the gold standard technique and using it 12 of the LIMA grafts were seen patent, 1 narrowed and one occluded. One of the LIMA grafts was considered non-evaluable by MSCT angiography because of extensive beam hardening artifacts caused by the adjacent metallic clips. CT angiography compared to the conventional angiography as a gold standard technique gave us a sensitivity of 100%, a specificity of about 96% and an accuracy of about 93.6% in the assessment of any type of coronary artery grafts.

The latest multi-slice CT scanners show a potential to become a first-line tool for the noninvasive evaluation of patients with suspected graft dysfunction. Conventional angiography may be spared for patients who needs an intervention e.g. angioplasty or stent placement within a graft or within a native coronary artery.

Key Words:

Multi-detector row CT, Multi-slice CT, CT angiography, coronary artery grafts, CABG, Non-invasive vascular imaging.

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List of Abbreviations

CPR	Curved planer reformation
CTA	CT angiography
Cx	Left circumflex artery
Diag	Diagonal branch
IMA	Internal mammary artery
LAD	Left anterior descending artery
LIMA	Left internal mammary artery
LM	Left main coronary artery
MDCT	Multi-detector row CT
MIP	Maximum intensity projection
MPR	Multi-planer reformation
OM	Obtuse marginal branch
PDA	Posterior descending artery
PL	Postro lateral branch
RC	Right coronay artery
RIMA	Right internal mammary artery
SVG	Saphenous vein graft
VR	Volume rendering

Introduction

Conventional coronary angiography is considered the reference standard for evaluation of coronary artery stenosis, in-stent stenosis, and the patency of coronary artery bypass grafts. However, the risk of potentially serious adverse effects and the costs associated with such effects have led to a search for noninvasive alternatives. Good diagnostic accuracy has been reported with the use of alternative coronary imaging modalities such as CT and MRI. *(Kim et al, 2001)*

In the past several years, multi-detector CT has been investigated for various applications and increasingly has been used for coronary arterial imaging. The advantage of multi-detector CT over previous CT techniques results from the multiplicity of detectors, faster speed of gantry rotation, and sophisticated algorithms for reconstructing partial scan data or recombining data from various phases. ECG gated multi-detector CT coronary angiography achieve short effective exposure times, thereby freezing cardiac motion. *(Choi et al, 2004)*

Cardiac imaging is becoming a practical application of CT with the availability of multi-detector scanners. The role of cardiac CT imaging is progressing from simple determination of the presence of arterial calcifications on non-enhanced scans to demonstration of vascular stenosis on coronary CT angiograms. Optimization of the imaging technique and knowledge of coronary artery anatomy are both important for the development of CT of the heart. Technical factors such as a slow heart rate, a short scanning time, sub millimetric spatial resolution, high temporal resolution, and reconstruction of multiple image data sets at various intervals in the cardiac cycle result in optimal visualization of the coronary arteries. Image quality depends on the choice of a suited reconstruction interval. In patients with high heart rates, the best image

quality can be obtained with end-systolic and early-diastolic intervals; in patients with low heart rates, the best results are achieved with mid-diastolic intervals. (*Herzog et al, 2006*)

Coronary artery bypass graft (CABG) surgery is the standard of care in the treatment of advanced coronary artery disease. It is well known that the long-term clinical outcome after myocardial revascularization depends on the patency of the bypass grafts. In the past, invasive coronary angiography was used to assess the status of the grafts and check for graft occlusion. Recently, multi-detector CT with electrocardiographic gating, has emerged as an important diagnostic tool for evaluation of CABGs. (*Leschka et al, 2006*)

In a study done by *Frazier et al* in 2005 on 125 patients, angina recurred within 1 year in 24% of patients undergoing coronary bypass operations and within 6 years in more than 40%. A total of 25% of grafts are found to be occluded within 5 years after surgery. (*Frazier et al, 2005*)

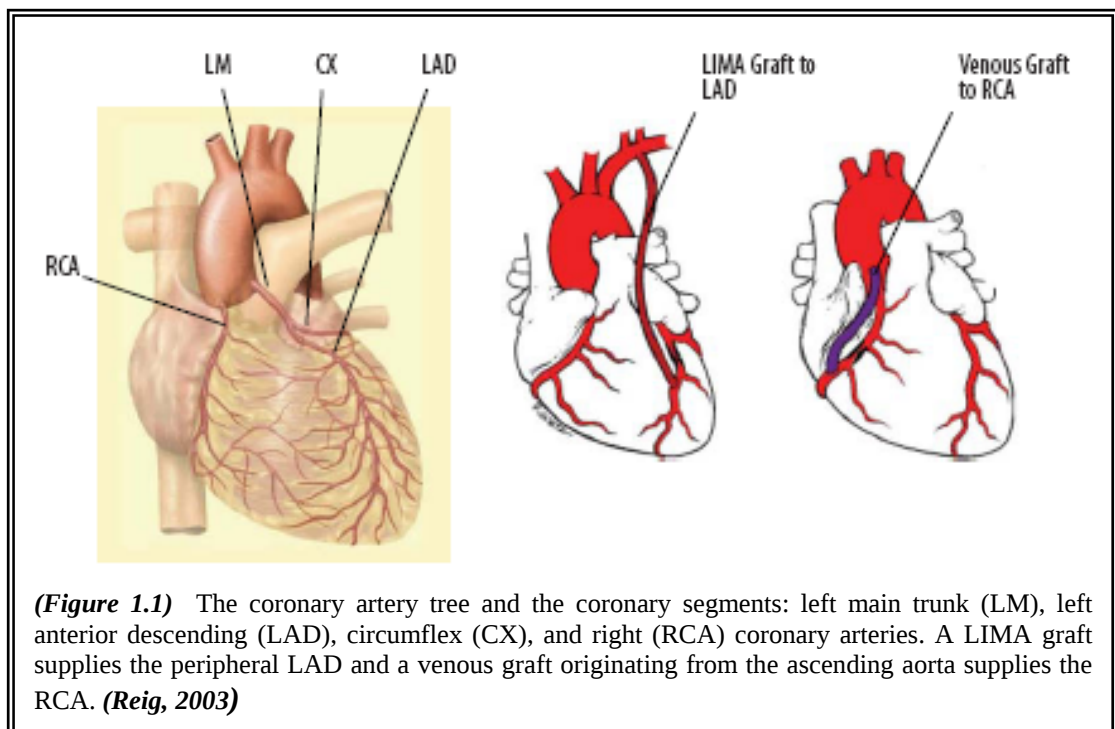
After coronary bypass operations, a variety of postoperative complications may occur. The most common is dyspnea and chest pain. Recurrent angina secondary to graft occlusion is always suspected in those patients. Owing to its improved spatial resolution compared with that of earlier-generation CT scanners and its ability to produce 3D and multiplanar images, multi-detector CT has assumed an integral role in the assessment of graft patency as well as other postoperative complications. In addition, the expanded capabilities of volumetric imaging may provide valuable information in preoperative planning for repeat CABG surgery. (*Nieman et al, 2003*)

Aim of Work

The aim of this study is to evaluate multi-detector row CT angiography as a less invasive technique in the assessment of the coronary arteries bypass graft (CABG). Those are high risk patients and they may not need to undergo much more invasive techniques (e.g. conventional angiography) to assess the patency of their grafts.

Introduction:

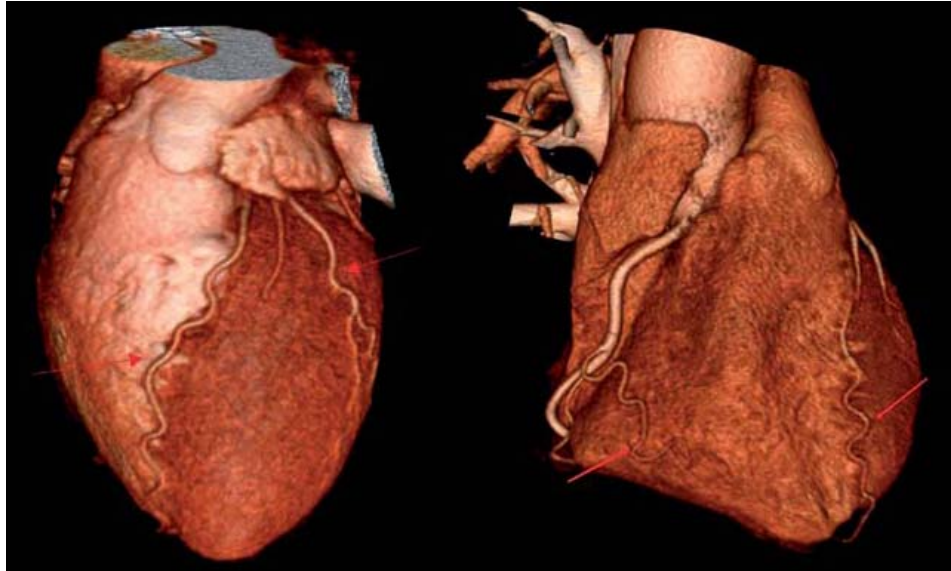
An adequate knowledge of the anatomy of coronary arteries (**Figure 1.1**) and its normal variants is an important point for the analysis of MDCT images. Nomenclature of coronary anatomy is frequently confusing, as a number of anatomical, clinical and radiological terms are used in combination. This conventional terminology is useful, however, as it has been applied in conventional coronary angiography, and it will be maintained. The heart is a highly differentiated blood vessel, with developed muscular walls. The vascular nutrition of myocardium is complex, with a number of anatomical normal variants that can involve even extracardiac vessels, such as bronchial, mammary and mediastinal arteries. (*Guillem et al, 2006*)



The coronary arteries are conductive vessels running through the epicardial surface of the heart, embedded in adipose tissue, and showing short segments of mild penetration into the myocardial tissue. As indicated by its name (from the latin *corona*: crown), coronary arteries are distributed over the heart as a crown-shape network, showing anastomotic communications between its different branches, particularly at the level of the base and the apex of the left ventricle. The connection between divisions of the same artery is known as homocollateral circulation, and the connection between different arteries is named heterocollateral circulation. Physiological collateral circulation acquires a relevant role in pathological circumstances. (*Petit et al, 1993*)

The radiologist interpreting coronary computed tomography angiography (CTA) should be familiar with coronary artery anatomy. It has a standard logical structure with some common variations and only a few rare abnormalities. In a conventional selective coronary angiography, blood in the chambers and coronary veins does not interfere with the visualization of the coronary arteries. In addition, myocardium and other soft tissues are hardly seen because of their low absorption of X-rays. Invasive selective coronary angiograms use projections performed in various orientations so that the cardiologist can perceive the 3D anatomy of the coronary arteries. This is quite different for imaging techniques such as CTA. In CTA the contrast agent is intravenously injected, which results in enhancement of the myocardium and blood in the cavities, and projection techniques such as maximum intensity projection (MIP) are therefore of limited use. Overlap of structures that obscure coronary imaging can be avoided by multi-planar reformation (MPR) using thin slices in any desired orientation. However, in that case much of the 3D information is not used. With modern post processing tools, such as MIP

or the volume-rendering technique (VRT), 3D impressions on a 2D surface can be created. These images look much like the gross anatomy of the heart, but they do not resemble the images known from invasive selective coronary angiography. (*Schoepf et al, 2005*)



(Figure 1.2) Coronary arteries of tortuous course (red arrows): this normal variant is frequently found in hypertensive patients. (*Reig, 2003*)

Macroscopical appearance of coronary arteries is variable in terms of diameter, which is larger in the left artery than in the right one in more than half of individuals, while the opposite occurs in nearly 20%. Also, the number of ramifications, its course —linear or sinusoid— (**Figure 1.2**), and the distance from the epicardial surface (**Figure 1.3**) is variable between individuals. Coronary arteries emerge from the aorta through the coronary ostia, located at the right (or anterior) and the left (or left posterior) sinuses of Valsalva. The coronary ostia are situated at the level of the sinotubular junction or slightly below it (56% of cases), followed by a high left orifice and a low right orifice or at the level of the junction (30% of individuals). (*Reig, 2003*)