Original Article

Detection of Coronary Bypass Graft patency by 256-Slice Multi-detector Computed Tomography

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OBJECTIVE. To evaluate the diagnostic accuracy of 256-slice Multi-detector Computerized Tomography (256-MDCT) in detection of coronary graft patency by comparison with the gold standard invasive coronary angiography (ICA).

MATERIALS AND METHODS. From January 2009 to April 2011, a total of 29 consecutive patients who had previously had CABG surgery were referred to us for assessment of graft patency. A total of 84 coronary bypass graft conduits (38 arterial graft conduits, 46 venous graft conduits) were studied, using 256-MDCT and ICA with iodine contrast intravenous injection. All patients underwent coronary angiography to either confirm result or PCI of graft disease. The diagnostic accuracy of the 256-MDCT for coronary bypass graft evaluation was assessed by comparing it to the ICA in terms of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

RESULTS. A total of 84 grafts were imaged using the 256-MDCT and all grafts were visualized. There was no statistical difference in diagnostic accuracy between MDCT and ICA regardless of the age, size or type of the bypass graft conduit (p value = 0.13). The sensitivity, specificity, positive predictive value, negative predictive value of 256-MDCT in coronary artery bypass graft assessment were 100%, 97.8% , 97.5% and 100 % respectively.

CONCLUSION. The 256-MDCT provides a high accuracy, reliability and feasibility for coronary bypass graft evaluation and the diagnostic accuracy is comparable to the gold standard ICA.

Coronary artery bypass graft surgery (CABG) has been used as an alternative to medical therapy, in treating symptomatic coronary artery disease patients for over forty years as an alternative option to medical therapy.[1] The superior outcome of CABG over medical treatment in terms of survival benefit is clearly documented in patients with left main or three vessels CAD, especially when the proximal left anterior descending (LAD) artery is involved.[2] However, graft degeneration does occur which leads to graft patency reduction to 81% in one year, 75% at 5 years and less than 50% at 15 years for venous graft occlusion.[3] Therefore, verification of graft patency is vital in management of symptomatic patients who have undergone CABG. Although the invasive coronary angiography (ICA) remains the gold standard in assessing graft vessel, a recent meta-analysis study has been shown that the 64-MDCT can offer a comparable result in non-invasive fashion.[4] To date, there has been no comparative study between ICA and 256-MDCT available in Thailand, we therefore conducted a retrospective study to assess the diagnostic accuracy of this new technology by comparing with ICA.

Materials and Methods

From January 2009 to April 2011, 29 CABG patients were referred to our services with suspicious recurrent symptoms of coronary artery disease and all of them had undergone both 256-MDCT scanning and ICA. The exclusion criteria for MDCT scanning were: patients with recurrent myocardial infarction, severe allergy to seafood and iodine contrast agent or serum creatinine levels > 1.5 mg/dL. All patients underwent coronary angiography to either confirm previously indeterminate results or to correct stenotic native coronary vessel or coronary bypass graft by percutaneous coronary intervention (PCI). The bypass graft images from both studies were analyzed and compared in terms of patency and severity of luminal diameter narrowing, i.e., no stenosis (0%), < 50% stenosis, ≥ 50% stenosis or occluded (100% stenosis). Significant stenosis was defined as luminal diameter is narrower ≥ 50% by comparing to the adjacent segments.[5]

CT coronary angiography (CTA)

CT studies were performed on 256-MDCT (Brilliance ICT 256-MDCT, Philips, Netherland) scanner with a 0.27s rotation time. A bolus of iodinated contrast injection volume was calculated by the formula of scan time (5 seconds (s) for coronary artery scanning) plus post threshold delayed time (~5 seconds) and multiplied by flow rate (4.5-6 ml/s) (Phillips company protocol). A contrast bolus was injected into antecubital vein at a flow rate of 4.5-6 ml/s. (Flow rate 6 ml/s of contrast injection was preferred if the patient's body weight > 90 kg), followed by 50 ml saline solution injection. The tracking position was placed at the ascending aorta and scan started automatically at 5 seconds after reaching the threshold (100 - 120 Hounsfield units, HU). Cardiac scanning covered from the aortic arch to 2-3 centimeters below the diaphragm using the following parameters; x-ray tube potential 120-140 KV, tube current 471 MA, slice collimation 128x0.625 mm^2, table speed of 44 mm/s, and pitch 0.16. The mean coronary scan time was of 5.0 s. The retrospective electrocardiographic gating was used for cardiac phase selection. The coronary scan data was completely obtained from two to three consecutive heart beats and the axial slices were reconstructed synchronized to the electrocardiography (ECG). The administration of beta-blockades to lower the heart rate depended on the physician if there were no contraindications. The slice thickness was of 0.67 mm. The CT data was independently and blindly analyzed by three experienced cardiac CT specialists. The vessel analysis was assessed on at least two planes, one parallel and one perpendicular to the course of the vessel.

Invasive coronary angiography (ICA)

ICA was performed by standard technique via femoral approach. At least two orthogonal views were taken for assessing each epicardial artery and coronary bypass graft. The angiograms were separately analyzed by experienced interventionists without prior review of the MDCT images. The angiography results were independently compared with the MDCT results.

Statistical analysis

By using ICA as the gold standard, images from CTA and ICA were compared and analyzed. The sensitivity, specificity, positive and negative predictive values were calculated. Chi-square test was used to analyze the differences between the 256-MDCT and the ICA results and statistical difference was considered when the p value was < 0.05.

Results

Of total 29 consecutive post CABG patients (93% were male), the mean age was 61 ± 27 years old. Most patients, 27 cases (93%) had multiple bypass grafts. The mean age of coronary bypass graft was 10.33 years (ranged 3-25 years). Of total 84 graft conduits, all grafts were obtained and analyzed by 256-MDCT.

Over half of conduits (53.6%) were saphenous vein graft (SVG) and the rest were taken from arterial conduit including left internal mammary artery (LIMA) 33.3% (28/84), right internal mammary artery (RIMA) 3.5% (3/84), left radial artery (LRA) 4.7% (4/84), right radial artery (RRA) 2.4% (2/84) and the gastroepiploic artery (GEA) 1.1%(1/84) (Table 1).

Almost half of the conduits (40/84, 47.6%) had some degree of luminal stenosis. Of these, 73.3% were venous, 17.9% were arterial bypass graft conduits [(10% (4/40) were LIMA , 2.5% (1/40) were RIMA , 5.0% (2/40) were left radial arterial, 10% (1/40) were GEA)]. The diameters of arterial grafts were 2.0-5.2 mm and of the venous 2.5-6.0 mm.

By comparison with ICA, the 256-MDCT demonstrated high sensitivity (100%) and high specificity (97.7%) for coronary bypass graft assessment regardless of the age, size or type of conduit. The positive predictive value was of 97.6%, the negative predictive value was of 100% and the total accuracy was of 98.8% (p = 0.13) (Table 2, 3).

According to the type of coronary bypass graft, the 256-MDCT also demonstrated high sensitivity and high specificity for both arterial and venous grafts (100% sensitivity for both arterial and venous bypass graft, 100% specificity for arterial bypass graft and 93.3% specificity for venous bypass graft) (Table 4-7). With 84 graft conduits, 134 anastomosis sites were obtained. 4.5% (6/134) of total anastomosis sites were stenosis which was lower than the vessel body. The diagnostic accuracy of the anastomosis site assessment was 100% in sensitivity, specificity, positive predictive value and negative predictive value with the *p* value =1.0 when compared against the ICA (Table 8, 9). A further comparison between our study and other meta-analysis studies of the 16-, 64-MDCT[4] revealed no significant difference in outcomes with the exception that the accuracy of the 256-MDCT in coronary bypass graft evaluation were higher than the 16-,64-MDCT which were reported in meta-analysis study (Table 10, 11). Almost all LIMA conduit (27/28, 96.4%) were of the in situ type. In 27 patients with multiple coronary bypass grafts, the patency of the LIMA graft (24/28, 85.7%) was higher than the SVG (14/46, 30.4%) regardless of the size, type and age of graft.

Table 1: Coronary bypass graft conduit characters.

Conduit type	Number of conduits (n = 84)	Size (mm in diameter)	Disease present
LIMA	28	3.2 ± 2.9	4 (4/28 = 14.3%)
RIMA	3	3.3 ± 0.7	1 (1/3 = 33%)
LRA	4	2.6 ± 0.7	2 (2/4 = 50%)
RRA	2	2.6 ± 0.5	0 (0/2 = 0)
GEA	1	2.3	1 (1/1 = 100%)
SVG	46	3.3 ± 1.2	32 (32/46 = 69.6%)
Total	**84**		**40 (47.6%)**

LIMA = left internal mammary artery RIMA = right internal mammary artery LRA = left radial artery
RRA = right radial artery GEA = gastroepiploic artery SVG = saphenous vein graft

Table 2: Correlative findings of 84 coronary bypass graft conduits between CT coronary angiography (CTA) and invasive coronary angiography (ICA).

Test	Disease present (ICA)	Disease absent
Positive (CTA)	40	1
Negative (CTA)	0	43

Table 3: Overall diagnostic accuracy of the 256-MDCT compared to the gold standard invasive coronary angiography (ICA).

Characteristic	Diagnostic Accuracy
Sensitivity	100%
Specificity	97.7%
Positive predictive value	97.6%
Negative predictive value	100%
Accuracy	**98.8% (*p* = 0.13)**

Table 4: Correlative findings of 38 arterial bypass graft conduits between CT coronary angiography (CTA) and invasive coronary angiography (ICA).

Test	Disease present (ICA)	Disease absent
Positive (CTA)	8	0
Negative (CTA)	0	30

Table 5: Overall diagnostic accuracy of the 256-MDCT compared to the gold standard invasive coronary angiography (ICA) in arterial bypass graft assessment.

Characteristic	Diagnostic Accuracy
Sensitivity	100%
Specificity	100%
Positive predictive value	100%
Negative predictive value	100%
Total accuracy	**100% (*p* = 1.0)**

Table 6: Correlative findings of 46 venous bypass graft conduits between CT coronary angiography (CTA) and invasive coronary angiography (ICA).

Test	Disease present (ICA)	Disease absent
Positive (CTA)	31	1
Negative (CTA)	0	14

Table 7: Overall diagnostic accuracy of the 256-MDCT compared to the gold standard invasive coronary angiography (ICA) in coronary venous bypass graft assessment.

Characteristic	Diagnostic Accuracy
Sensitivity	100%
Specificity	93.3%
Positive predictive value	96.8%
Negative predictive value	100%
Accuracy	**97.8% (*p* = 0.90)**

Table 8: Overall diagnostic accuracy of the 256-MDCT compared to the gold standard invasive coronary angiography (ICA) in 134 anastomosis sites of the coronary bypass graft assessment.

Test	Disease present (ICA)	Disease absent
Positive (CTA)	6	0
Negative (CTA)	0	128

Table 9: Overall diagnostic accuracy of the 256-MDCT compared to the gold standard invasive coronary angiography (ICA) in 134 anastomosis sites of the coronary bypass graft assessment.

Characteristic	Diagnostic Accuracy
Sensitivity	100%
Specificity	100%
Positive predictive value	100%
Negative predictive value	100%
Accuracy	**100% (*p* = 1.0)**

Table 10: Comparison of the overall diagnostic accuracy of the 256-MDCT to the gold standard invasive coronary angiography (ICA) in bypass graft assessment to the meta analysis studies of the 16-, 64-MDCT.[4]

Data	Grafts	Number	Sensitivity (%)	Specificity (%)
Meta analysis	Combined	777/84	88.7/**100**	97.5/**97.7**
(Jones CM. et al, Ann Thor Surg 2007)				
VS	Arterial	245/39	90.9/**100**	98.3/**100**
Bangkok Heart Hospital				
(Jan.2009-April 2011)	Venous	348/45	85.2/**100**	97.2/**93.3**

Table 11: Comparison between the accuracy of the 256-MDCT (Bangkok Heart Hospital) with 64-MDCT in bypass graft assessment studies of the others.

Data	Patient	MDCT	Grafts	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Pashka (Eur H J 2006)	31	64	96	97.8	89.3	90	87.7
Dikkers (J Cardio Imag 2006)	34	64	64	69	98.7	-	-
Meyer (J Am Coll 2007)	138	64	418	97	97	93	99
Bangkok Heart Hospital	**29**	**256**	**84**	**100**	**97.7**	**97.6**	**100**

Discussion

The emerging role of MDCT to verifying graft patency in patients non invasively

At least 30% of our new patients had CABG surgery long ago in other medical centers and presented without operative details. With no clues of sites or number of grafts taken, angiographers often use excessive amount of contrast agent in order to find or confirm the occlusion of aortocoronary bypass conduits. Therefore, acute kidney injury or CHF can be expected in patients who had impending kidney dysfunction or compromised left ventricle function. By intravenously injecting 50-70 ml of contrast, the 256-MDCT provides more complete information of the origin, number and entire length of coronary graft in one shot. In the case of post CABG patient who came with no known information about their coronary bypass graft surgeries, MDCT can provide this information. Our study showed 100% accuracy in evaluation of coronary bypass graft conduits of the 14 of 29 patients who were unable to provide us with any details of their previous coronary bypass graft operations.

A recent meta-analysis study[4] has shown comparable results between MDCT and ICA in 16 and 64 slice scanners. However, in tachycardic patients, motion artifacts do occur and beta-blockades are commonly required to reduce HR below 65 beat/min.[6-8] With shorter scan time, the 256 scanner could be used with a wider range of patients and heart rate lowering may not be required and also provides relatively higher accuracy than 16-, 64-MDCT (Table 10, 11) because of its higher temporal and spatial resolution. Our result also confirmed the role of 256-MDCT in assessing graft patency with the high accuracy (100% of sensitivity, 97.7% of specificity). Therefore, 256-MDCT can be reasonably proposed as an alternative tool using limited contrast and is comparable to the ICA in assessing graft patency.

Accuracy of severity assessment

Some artifacts can affect MDCT interpretation. The blurring of calcified arterial wall can lead to overestimation of stenotic severity. Comparing with our previous study,[9] (luminal stenosis detection by 256-MDCT between the native coronary artery and coronary bypass graft), we found that the diagnostic accuracy of coronary artery bypass graft was a bit higher than the native coronary artery. It may be due to the lesser rate of sub-intimal calcification which causes blooming artifacts in coronary bypass graft compared to the native coronary artery. Therefore, the accuracy of interpretation of graft vessel (sensitivity and specificity) was expected to be higher than for native arteries. Surgical clips also produced artifacts but to a lesser degree than calcified plaque since their scatter alignment was relatively parallel to the graft body.

By independent assessment for graft severity between ICA and MDCT, almost all agreed in 83/84 segments (98.8%) and the disparity was found only in one graft (1/84, 1.2%) since it was diagnosed as no stenosis by ICA but mild stenosis (< 40%) by MDCT. If we re-classified severity of graft stenosis into patent and occluded as aforementioned, the sensitivity, specificity, positive and negative predictive values of 256-MDCT were 100%.

Limitation

The major limitation was the relatively small patient numbers (who underwent both MDCT and ICA for coronary bypass graft evaluation). In studies with few cases, the numbers are also vulnerable to be discordant; if more than a few cases are in disagreement, this affects the statistical assessment. Also because this was a retrospective analysis, confounding factors could not entirely be excluded.

Conclusion

Our study confirms that the 256-MDCT offers a comparable result to those from the ICA in coronary bypass graft assessment. The high specificity and negative predictive value make the 256-MDCT scanner a reasonable option in excluding graft occlusion especially in patients with no operative detail. However, the fast MDCT is still not suitable for use as a screening tool because the exposure to radiation and contrast media is still an important issue of concern. No supporting data from large studies are yet available on this subject. In the near future, when techniques using dosages with the least possible radiation exposure, are better developed, it will not take long to consider the role of the fast MDCT as a screening tool in coronary bypass graft stenosis evaluation.

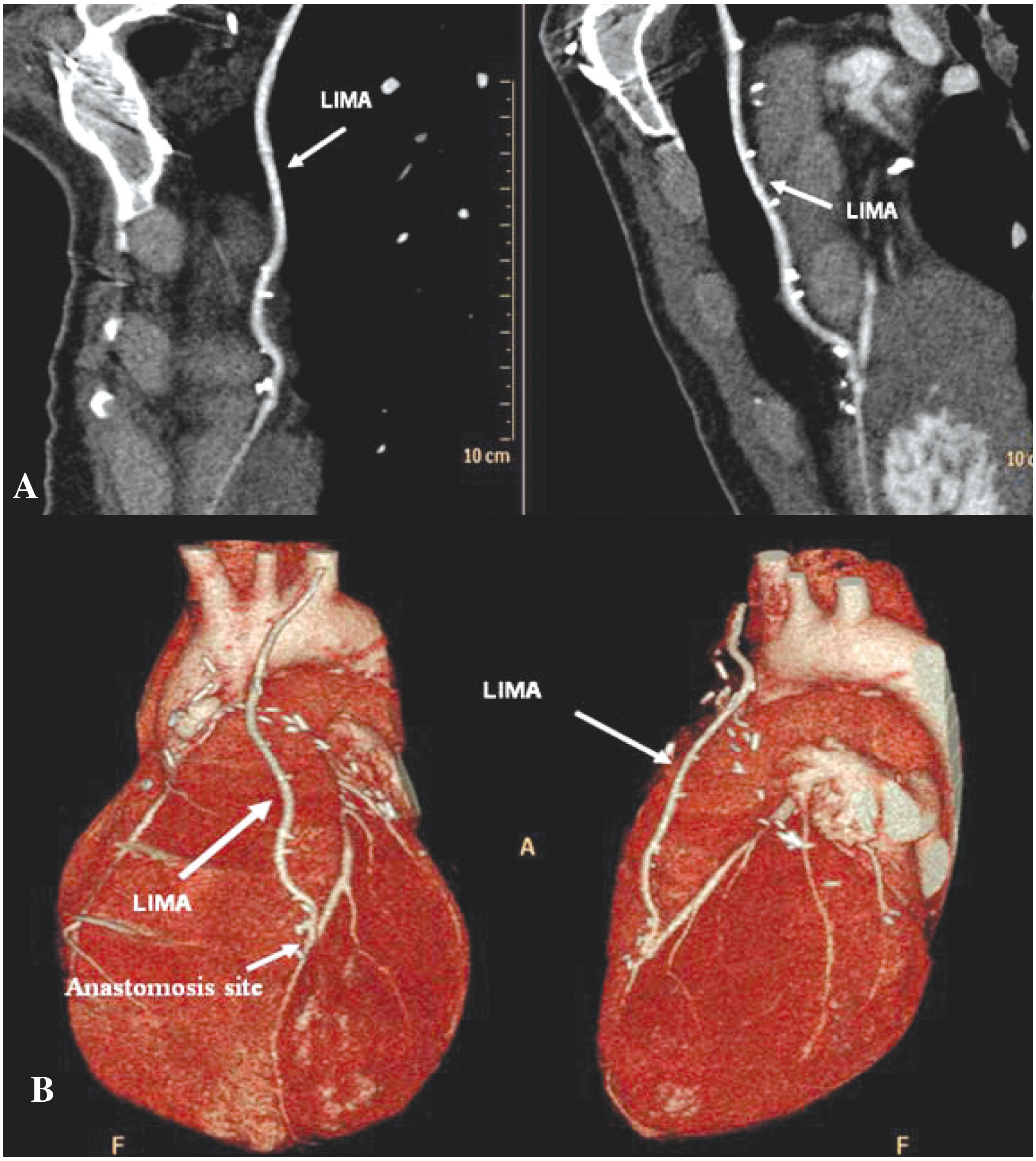

Figure 1: *Demonstration of LIMA graft to the LAD and its anastomosis site.*
A: *MPR images.*
B: *Volume rendering images.*
LIMA = left internal mammary artery
LAD = left anterior descemding
MPR = multiplanar reconstruction

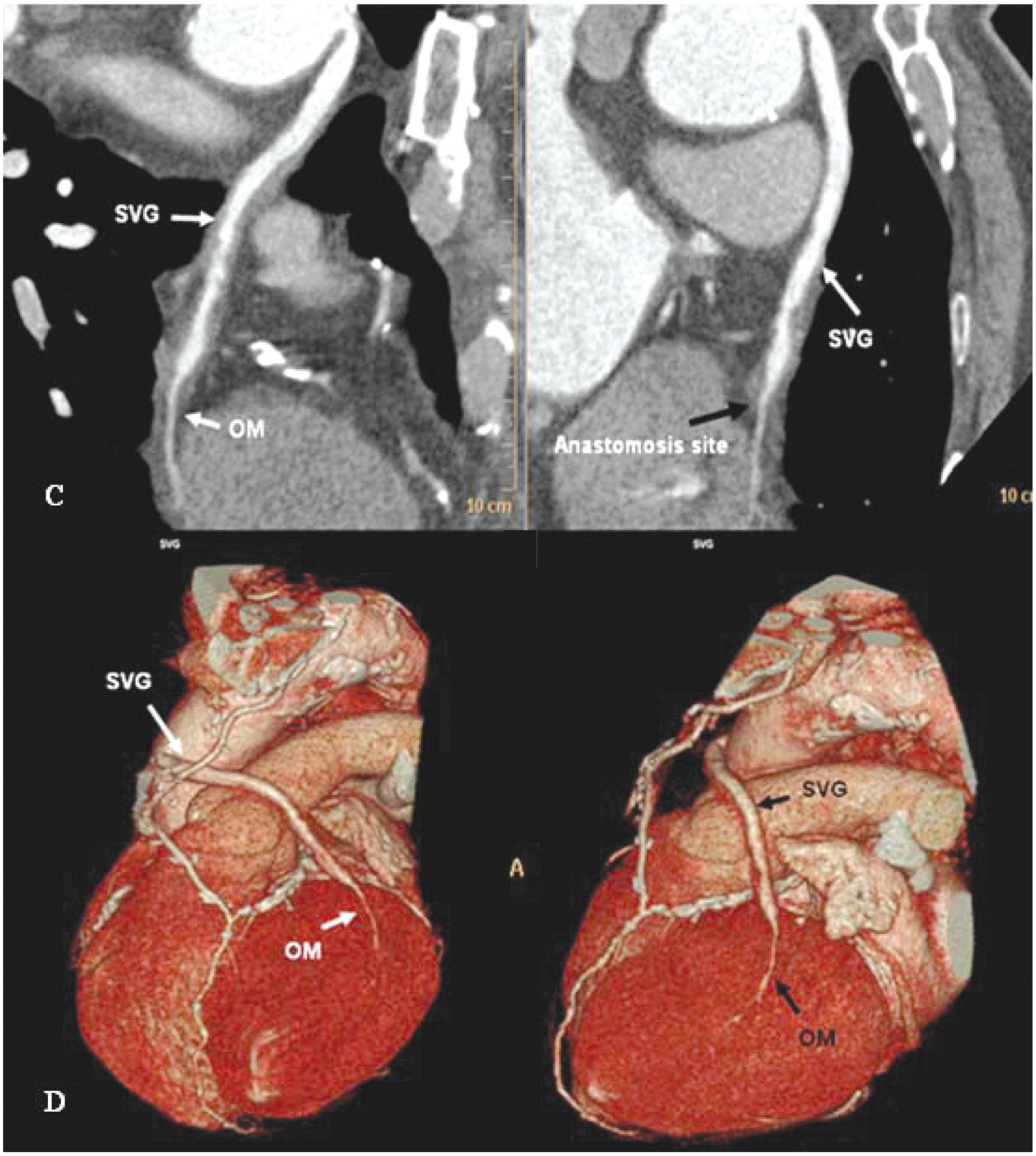

__Figure 2:__ Demonstration of SVG to the OM and its anastomosis site.
__C:__ MPR images shows the distal stenosis of the SVG.
__D:__ Volume rendering images.
SVG = saphenous vein graft
OM = obtuse marginal branch
MPR = multiplanar reconstruction

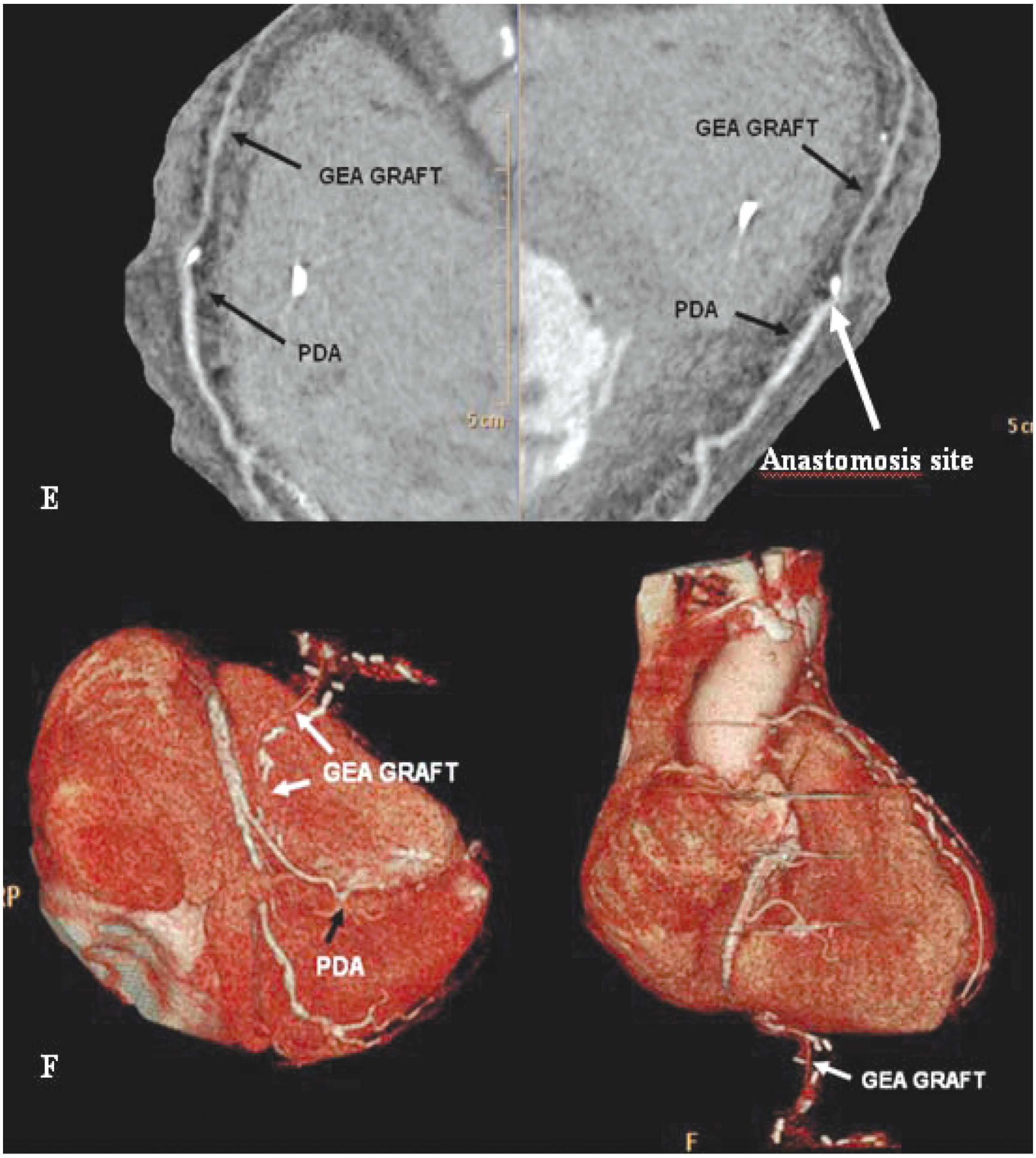

Figure 3: *Demonstration of the GEA to the PDA and its anastomosis site.*
E: *MPR images shows the patent of the GEA graft.*
F: *Volume rendering images.*
GEA = Gastroepiploic arterial graft
PDA = Posterior descending artery
MPR = multiplanar reconstruction

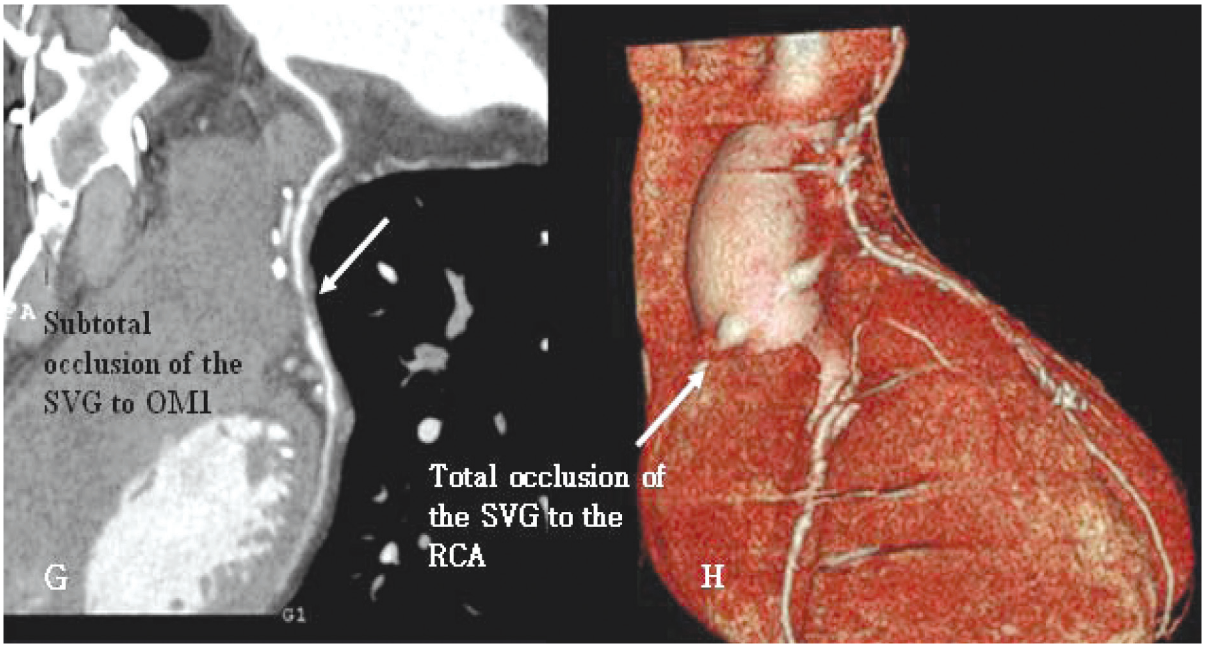

Figure 4: *Demonstration of graft vessel stenosis.*
G: *MPR images.*
H: *Volume rendering image.*
MPR = multiplanar reconstruction
SVG = saphenous vein graft
OM = obtuse marginal branch
RCA = right coronary artery

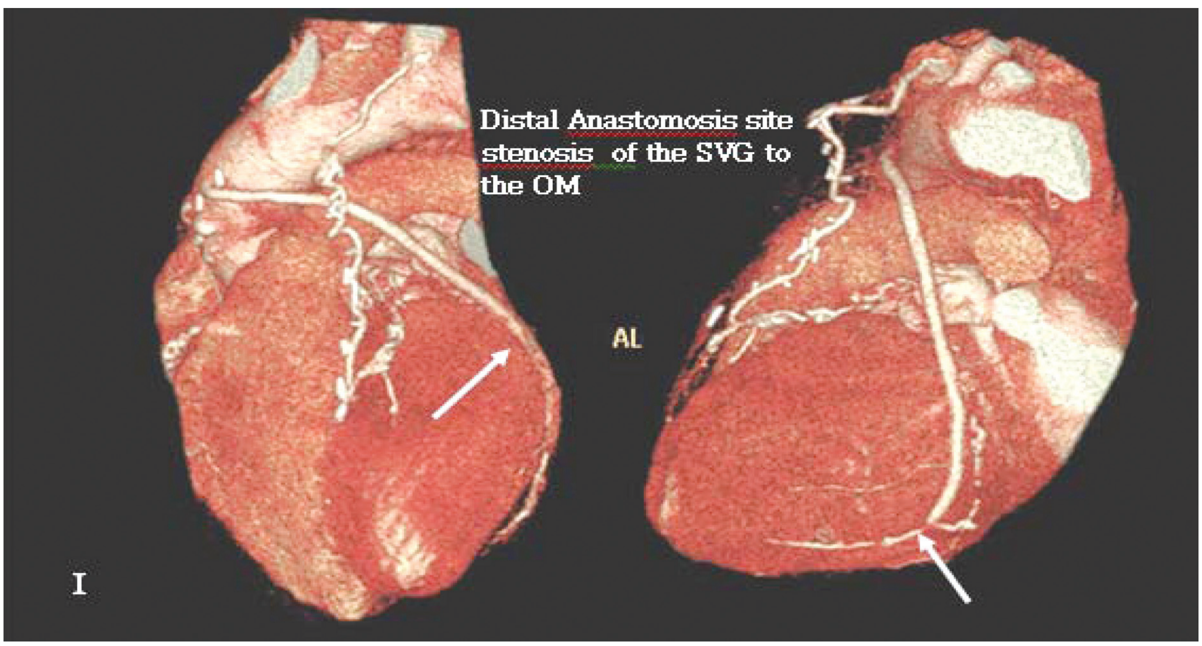

Figure 5: *Demonstration of distal anastomosis site stenosis of the SVG to the OM.*
SVG = saphenous vein graft
OM = obtuse marginal branch

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