ROLE OF MULTISLICE COMPUTED TOMOGRAPHY (MSCT) IN POSTOPERATIVE ASSESSMENT OF CORONARY ARTERY BYPASS GRAFT (CABG)

ESSAY

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BY

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٢٠٠٧

بسم الله الرحمن الرحيم

وَعَلَّمَ ءَادَمَ ٱلۡأَسۡمَآءَ كُلَّهَا ثُمَّ عَرَضَهُمۡ عَلَى ٱلۡمَلَٰٓئِكَةِ فَقَالَ
أَنۢبِـُٔونِي بِأَسۡمَآءِ هَٰٓؤُلَآءِ إِن كُنتُمۡ صَٰدِقِينَ ﴿٣١﴾ قَالُواْ سُبۡحَٰنَكَ
لَا عِلۡمَ لَنَآ إِلَّا مَا عَلَّمۡتَنَآۖ إِنَّكَ أَنتَ ٱلۡعَلِيمُ ٱلۡحَكِيمُ ﴿٣٢﴾

صدق الله العظيم

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REVIEW OF LITERATURE

Findings and potential clinical applications of CABG include **detection of significant coronary artery re-stenosis.** Over ٣٥ studies with more than ١,٥٠٠ patients have been performed to compare the diagnostic accuracies of electron beam CT (EBCT) and MDCT for the detection of hemodynamically significant stenosis. Studies with EBCT and early versions of MDCT scanners, equipped with ٤ detectors and a temporal resolution of ٢٥٠–٣٣٠ ms, demonstrated the ability of cardiac CT to detect significant coronary artery stenosis with moderate sensitivity and excellent specificity for both EBCT (٨٢٪ and ٨٧٪, respectively) and MDCT (٨١٪ and ٩١٪ respectively) compared with selective X-ray coronary angiography **(Hoffmann U et al, ٢٠٠٤).**

The current generation of ٦٤-slice MDCT scanners provides an in-plane resolution of ٠,٤ mm, a slice thickness of ٠,٦ mm, and a temporal resolution of ١٦٥ ms **(Flohr T et al, ٢٠٠٢).** The simultaneous acquisition of ٦٤ parallel cross sections enables the imaging of the entire coronary artery tree in a single breath hold (٢٠ seconds for ١٦-slice MDCT versus; ١٠ seconds for ٦٤-slice MDCT).

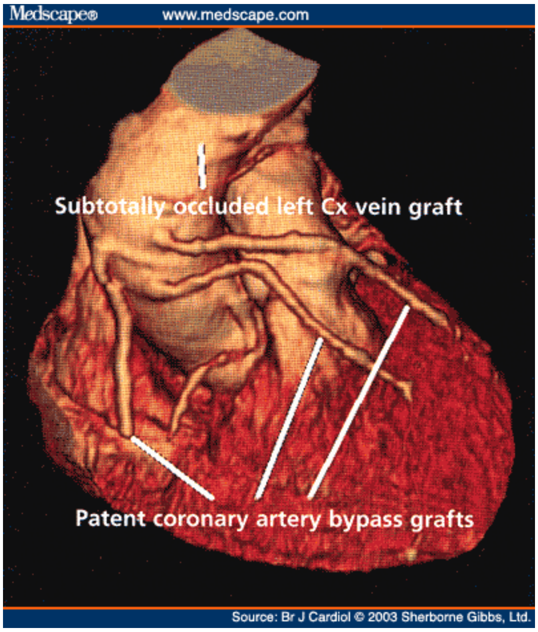

Figure ٤.١ *Three-dimensional reconstruction of the heart, coronary arteries and bypass grafts obtained by contrast-enhanced EBCT in a ٦٣-year-old man with vein grafts to the left anterior descending coronary artery (LAD), diagonal branch of LAD, left circumflex artery and right coronary artery. The study revealed patent vein grafts to the LAD, diagonal branch of LAD and right coronary artery. The saphenous vein graft to left circumflex (Cx) coronary artery was subtotally occluded* ***(Quoted from British Journal of Cardiology ٢٠٠٣).***

Recent studies have reported excellent diagnostic accuracy for ٦٤-slice MDCT in the detection of significant stenosis in smaller coronary artery segments and side branches as well (٨٦٪–٩٤٪ sensitivity and ٩٣٪–٩٧٪ specificity)**(Mollet et al, ٢٠٠٥).** A high negative predictive value of ٩٥٪–٩٧٪ suggests that ٦٤-slice MDCT can reliably rule out the presence of hemodynamically significant CAD) **(Leschka et al, ٢٠٠٥)**. The improvement is achieved through a significant decrease in the number of nonevaluable segments (٧٪), compared with ٢٠٪ nonevaluable segments for ١٦-slice MDCT **(Becker et al, ٢٠٠٢)**. The results also emphasize that low heart rates (٦٥ beats per minute) remain a prerequisite for excellent image quality in most patients **(Giesler et al, ٢٠٠٢).** Few studies have compared the degree of stenosis detected by quantitative coronary angiography with that detected by ١٦- or ٦٤-slice CT **(Kefer et al, ٢٠٠٥).** The overall correlation between the ٢ methods appears to be moderate, even for selected segments with high image quality. The sensitivities of ٦٤-slice MDCT for the detection of stenosis of less than ٥٠٪, stenosis of greater than ٥٠٪, and stenosis of greater than ٧٥٪ have been reported to be ٧٩٪, ٧٣٪, and ٨٠٪, respectively, and the specificity has been reported to be ٩٧٪ **(Leber et al, ٢٠٠٦).**

Also, MDCT is useful in **detection and characterization of coronary atherosclerotic plaque** in addition to the delineation of the coronary artery lumen **(Leber et al, ٢٠٠٤).** There is growing evidence that the presence, amount, and composition of noncalcified coronary atherosclerotic plaque and the degree of coronary remodeling in proximal segments can be assessed by MDCT.

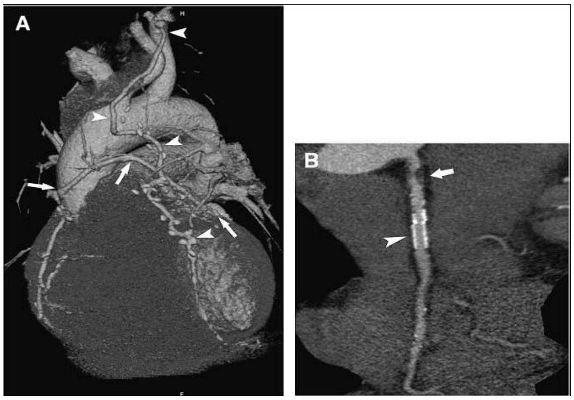

Figure ٤.٢: *(A) ٣-Dimensional volume rendered image of patient showing status after left internal mammary graft to middle segment of left anterior descending coronary artery (arrowheads). Operative clips are visualized parallel to course of graft. In addition, venous coronary bypass graft can be seen between aorta and left circumflex coronary artery (arrows). (B) Curved MPR image with sharp image filter reconstruction of right coronary artery in patient with percutaneous stent placement (arrowhead). Lumen of stent (٣,٥-mm diameter) is patent. There is no evidence of in-stent restenosis or neointimal hyperplasia. In addition, this patient has large noncalcified plaque that protrudes into lumen of proximal right coronary artery, causing significant stenosis (arrow)* ***(Quoted from Society of Nuclear Medicine, ٢٠٠٦).***

MDCT accurately detects calcified or mixed plaque with sensitivities and specificities above ٩٠٪. However, MDCT is less accurate for the detection of noncalcified plaques, with sensitivities and specificities ranging from ٦٠٪ to ٨٥٪ **(Achenbach et al, ٢٠٠٤),** but has the potential to further stratify noncalcified plaque into fibrous plaque and lipid-rich plaque **(Leber et al, ٢٠٠٣).**

MDCT is helpful in **testing for coronary artery calcification** using Ca-Scoring which has become a standard procedure using both EBT and MSCT technology **(Ulzheimer et al, ٢٠٠١).**

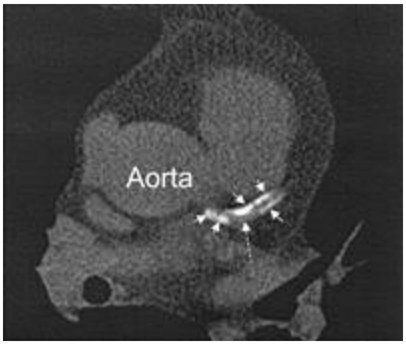

Figure ٤.٣: *A cross-sectional image through the aorta and the origin of the left coronary artery (dashed arrow). A moderate amount of calcification can be easily identified as bright signals (solid arrows)* ***(Quoted from Circulation, ٢٠٠٣).***

The most commonly used **scoring methods** in coronary calcium scoring are: **Agatston score, volume score and calcium mass**

Agatston score

The first score to establish the quantification of coronary calcifications with EBCT was introduced by **Agatston et al. in ١٩٩٠.** According to the Agatston method, **(Agatston et al. ١٩٩٠)** the regions of interest are defined by vessel and slice with the threshold option for pixels greater than ١٣٠ H to measure the area and peak density of plaques.

Depending on the peak density of the plaque, an area of at least ٠,٥٢ mm^{٢} (٢ pixels) is multiplied by one of the following cofactors: a factor of ١ for ١٣٠–١٩٩ H, a factor of ٢ for ٢٠٠–٢٩٩ H, a factor of ٣ for ٣٠٠–٣٩٩ H, and a factor of ٤ for densities greater than ٤٠٠ H. The total calcium score was calculated as the sum of the individual lesion scores in all coronary arteries.

$$\text{Agatston score} = \text{Inc} / \text{ST} \times \Sigma \text{area} \times \text{cofactor},$$

Where:
Inc is slice increment**; ST** is slice thickness, **area:** of vessel in region interest depending on peak density of plaque, **cofactor**: is a factor of ١ for ١٣٠–١٩٩ H, a factor of ٢ for ٢٠٠–٢٩٩ H, a factor of ٣ for ٣٠٠–٣٩٩ H, and a factor of ٤ for densities greater than ٤٠٠ H.

Volume score

The volume score represents the volume *V* of the calcification **(Kalender et al. ١٩٩٤).**

$$\text{volume} = \Sigma \text{area} \times \text{Inc}$$

Calcium mass

The third scoring method is the calcium mass and functions as a measure for the amount of calcium **(Ulzheimer et al, ٢٠٠١).**

$$\text{mass} = \Sigma \text{area} \times \text{Inc} \times \text{mean CT density}.$$

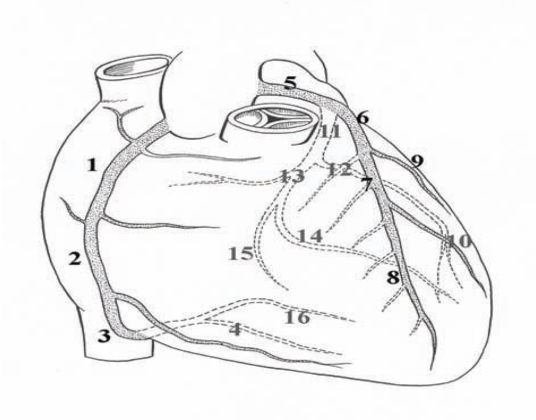

Figure ٤.٤: *١٧-segment coronary artery anatomy denotations*
(American Heart Association).

Table **٤,٢** *Readout from the Aquarius Workstation demonstrating calculation of the total Agatston score, the volume score, and the absolute mass score for each coronary artery and each individual calcified plaque*

Artery		Lesion	Score	Volume	Mean	Mass (mg)
LAD	Prox	9	98.55	78.57	380.10	27.78
LAD	Mid	11	6.36	3.67	175.50	0.60
LAD	Mid	10	12.72	10.87	299.25	3.03
LAD	Diag1	12	30.99	31.37	204.92	6.00
LCX	Prox	14	14.31	18.42	219.44	3.77
LCX	Prox	13	4.77	3.36	186.67	0.59
RCA	Prox	2	21.46	23.37	214.33	4.68
RCA	Prox	1	9.54	12.76	186.00	2.22
RCA	Mid	7	19.07	15.55	182.58	2.66
RCA	Mid	6	50.86	39.50	303.19	11.15
RCA	Mid	4	9.54	18.37	183.00	3.14
RCA	Mid	3	7.95	4.93	173.00	0.80
RCA		5	23.84	10.63	215.40	2.14
Coronaries total		13	309.94	271.35	258.48	68.55
LAD Total		4	148.61	124.47	314.35	37.41
LCX Total		2	19.07	21.78	211.25	4.36
RCA Total		7	142.26	125.09	221.94	26.78
Total:		13	309.94	271.35	258.48	68.55

(Measuring individual coronary calcified plaque, Eduardo et al.)

A positive test is considered if calcification is detected within the coronary arteries. Absolute Agatston scores of less than ١٠, ١١ to ٩٩, ١٠٠ to ٤٠٠, and above ٤٠٠ have been proposed to categorize individuals into groups having minimal, moderate, increased, or extensive amounts of calcification, respectively. The amount of calcification can give, to some extent, an indication of the overall amount of atherosclerosis.

It is well established that individuals with Agatston Scores above ٤٠٠ have an increased occurrence of coronary procedures (bypass, stent placement, and angioplasty) and events (myocardial infarction and cardiac death) within the ٢ to ٥ years after the test. Individuals with very high Agatston scores (over ١٠٠٠) have a ٢٠٪ chance of suffering a myocardial infarction or cardiac death within a year. Even among elderly patients (over ٧٠ years), who frequently have calcification, an Agatston Score above ٤٠٠ was associated with a higher risk of death.

In addition, a greater amount of calcification and a higher Agatston score increase the likelihood that coronary angiography will detect a significantly narrowed coronary artery stenosis.

A negative test is considered if no calcifications are detectable within the coronary arteries. Although this does not absolutely exclude the presence of atherosclerotic deposits within the coronary arteries, it does indicate that there is nothing more than minimal atherosclerosis, and the risk of a coronary event over the next ٢ to ٥ years is very low. The likelihood that a significant coronary artery narrowing is present is also very low.

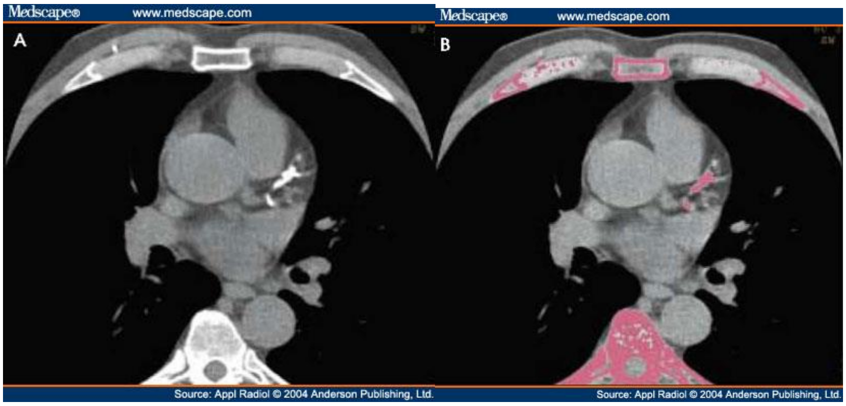

Figure ٤.٥: *(A) Prospectively ECG-gated multislice CT image reveals substantial calcification of the left anterior descending coronary artery. (B) Image obtained after applying automated ١٣٠ HU thresholding. Areas exceeding this density, including the coronary calcification, appear in pink* ***(Quoted from Applied Radiology, ٢٠٠٤)****.*

Coronary Artery Bypass Grafts imaging is facilitated by the axial course, comparatively large luminal dimensions, and relative lack of movement of at least the proximal segments of grafts. Mechanical CT imaging was used to determine the patency of CABGs more than ٢٠ years ago **(Moncada et al, ١٩٨٠).** Early studies with EBCT used the “flow mode” to measure time-density curves after bolus injection of contrast agent **(Stanford et al, ١٩٨٨).** Accuracy in determining CABG patency was improved with angiographic EBCT imaging. In ٣ studies, each including ٢٥ to ٤٥ patients, all grafts were assessable. The sensitivity for detecting CABG occlusion was ٩٥٪ to ١٠٠٪, and the specificity, ٨٩٪ to ١٠٠٪. The results obtained with ungated spiral scans at temporal resolution of ٧٥٠ milliseconds were similar **(Enzwieler et al, ٢٠٠).** A recent study of MSCT of ١٨٢ CABGs in ٦٥ patients reported a sensitivity of ٩٧٪ and a specificity of ٨٩٪ for detecting occlusions **(Ropers et al, ٢٠٠١)**.The detection of stenoses in CABGs by CTCA may be less successful than the detection of complete occlusion **(Ropers et al, ٢٠٠١)**.With EBCT the absence of slice overlap can cause gaps between image slices and decrease the quality of secondary off-axis image reconstructions, and with MSCT motion artifacts may occur **(Ropers et al, ٢٠٠١).** In particular, distal anastomoses and distal limbs of sequential grafts are difficult to image reliably with current CT technology. Artifacts from metallic clips may partially obscure the body of CABGs. ٣-D displays such as volume rendering are helpful in clarifying the complex anatomy in patients who have undergone several bypass operations.

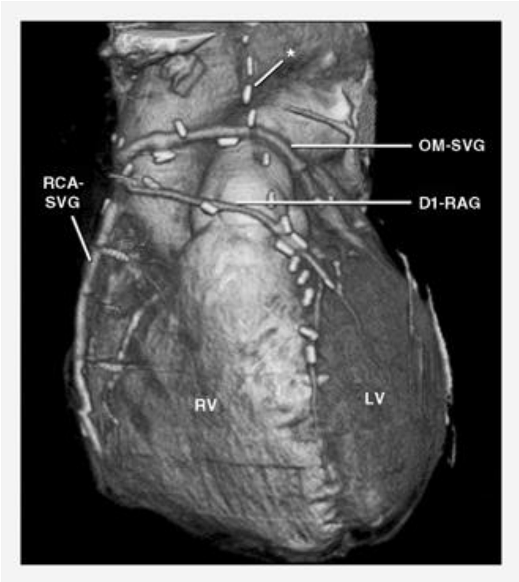

Figure ٤.٦: *Coronary artery bypass graft computed tomographic angiogram. *Occluded left internal mammary artery graft to the left anterior descending artery. D١-RAG, radial artery graft to first diagonal branch; LV, left ventricle; OM-SVG, saphenous vein graft to obtuse marginal branch; RCA-SVG, saphenous vein graft to right coronary artery; RV, right ventricle.* ***(Quoted from Gerber et al, ٢٠٠٦.)***

To image the entire course of CABGs, beginning with their proximal anastomosis in the ascending aorta, a longer distance must be covered in the craniocaudal direction than for imaging of the native coronary arteries, necessitating long breath holds. With EBCT, scanning time can be shortened by removing the slice overlap **(Knez et al, ١٩٩٦)** and administering atropine intravenously. With MSCT, scanning time can be shortened by