

Original Research Article**Non-Invasive Computed Tomographic Coronary Angiography for Patients with Suspected Coronary Artery Disease**

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Dr Vijay ThakurEmail: vijay31thakur@gmail.com, Phone No-9418465894**ABSTRACT**

Introduction: 64 Slice CT is useful non-invasive screening tool in evaluation of patients suspected of CAD with excellent temporal and spatial resolution. Excellent image quality is obtained by lowering heart rate <60 bpm. Atherosclerotic plaques causing stenosis can be differentiated into calcified, non-calcified and mixed density types which allow further planning for management of CAD.

Objective: Our study aimed at quantification of coronary calcium by 64 slice MDCT and its implication for determining risk of cardiovascular events, detection of CAD and significant coronary artery stenosis (>50% narrowing of lumen).

Material & Methods: Our study included 60 patients suspected of CAD in pre-test clinical evaluation. All these patient were subjected to Calcium-scoring (by Agatston method, AJ-130, using Smart score 4.0 software) and Coronary Angiography on 64 Slice MDCT Scanner using 3D Workstation with vessel analysis software (Cardiac IQ Express 4.0, GE Healthcare).

Observations: CTCA detected significant CAD in about one-third of study population who were clinically suspected of having CAD on basis of symptoms and stress tests. No obstructive CAD was present in two-third of patients and CTCA prevented them to undergo cost-extensive Invasive Coronary Angiography (ICA). The atherosclerotic plaques causing stenosis could be differentiated into Calcified, non-calcified and mixed density, which helped in further planning for management of CAD.

Conclusion: CTCA is better than calcium score in evaluation of CAD. Patient with zero calcium score can harbour significant CAD which is reliably detected on CTCA. Therefore, CTCA is an excellent non-invasive tool in work-up of patients of CAD.

Keywords: CAD-coronary artery disease, CTCA- computed tomographic coronary angiography, ICA – invasive coronary angiography, CAC –coronary artery calcification, MDCT-multi-detector computed tomography, CS-Calcium score.

INTRODUCTION

World over, coronary artery disease (CAD) is the major cause of morbidity and mortality. Coronary artery calcification (CAC) has been shown to be a predictive marker of coronary atherosclerotic disease. The presence and extent of CAC correlates with the overall magnitude of coronary atherosclerotic plaque burden and with the development of subsequent coronary events^[1]. Although coronary calcium is a sensitive indicator of atherosclerosis but it is not specific for detection of relevant coronary artery stenosis (91.8% sensitivity, and 55% specificity). Therefore evaluation of CAD is mandatory with Coronary angiography^[2]. Conventional invasive coronary angiography (ICA) is the diagnostic Gold-Standard for evaluation of known or suspected CAD. The risk of adverse events are small but serious and potentially life threatening sequelae may occur with ICA, therefore it should be restricted to stringent clinical indications.^[3]

The 64 slice MDCT is the alternative imaging modality which allows non-invasive visualization of coronary arteries^[4]. Recent studies show high sensitivity (94%) and specificity (97%) for detection of coronary stenosis with CT angiography using 64 slice scanners. With high negative predictive value it can reliably exclude CAD in patient with equivocal clinical presentation who may otherwise undergo a cost extensive ICA.

In modern MDCT scanners, artefacts due to motion and severe vessel wall calcification can be reduced by use of beta-blockers (maintaining HR <60 bpm) and by choosing several reconstruction intervals relative to cardiac cycle respectively.

The present study aims at providing benefits of MDCT to the patients that include, predicting the risk of CAD by calcium scoring, cost effectiveness, no need of hospitalization, minimal or no risk during or after the procedure and identifying the cause of stenosis as non-calcified or calcified plaque. Evaluation of non coronary structures and cardiac morphology are the additional advantages of CTCA compared to ICA.

MATERIAL AND METHODS

This was a Hospital based prospective study carried out over a period of one year. The study included 60 patients presenting with angina on exertion with positive stress test (i.e Tread mill test) for inducible ischemia and patients with atypical chest pain with positive stress test. Coronary stents, bypass grafts, cardiac arrhythmias, pregnant females, deranged renal functions and elevated heart rate with contraindication to beta-blockers formed exclusion criteria. Consent was obtained from all eligible patients before being included in the study. All these patients were subjected to Calcium scoring and Coronary angiography using 64-MDCT (Light Speed VCT-Xte, GE Medical Systems). An initial non-enhanced ECG-gated CT was performed for Calcium score using predefined parameters. Then a contrast enhanced scan for coronary angiography was performed.

Coronary calcium scoring was done by using Agatston method (AJ-130), using Smart Score 4.0 software. Calcium score was calculated for LMA, LAD, LCX, RCA and PDA. The total calcium score was interpreted as per Table-1.

Coronary CT Angiography (a)-Segmentation:- the coronary arteries were segmented according to the guidelines of American Heart Association (AHA) as per Table-2.

(b) Quantification of Stenosis:- MDCT angiograms were assessed on Three dimensional Workstation (Advantage Windows Version 4.5 GE Healthcare) using vessel analysis software (Card IQ Express 4.0, GE Healthcare). Coronaries were analysed with different visualization techniques such as MIP, MPR and VR. Each vessel was analysed atleast in two planes, one parallel and one perpendicular to the course of vessel. Multiple longitudinal, tranverse and oblique views were analysed as per requirements. Axial source data was analysed in all cases. Coronary arteries were analysed down to the level of 1.5 mm. Quantification of stenosis was done as per Table -3

c)-**Number of Vessels involved:** The obstructive disease was classified as single, two or three vessel disease. Three main vessels taken for characterization were RCA ,LAD and LCX . Left main artery (LMA) involvement was taken separately into consideration whenever it was present.

d)-**Plaque Characterization:** Atherosclerotic plaques causing obstructive lesions were classified as Non-Calcified , Calcified or Mixed density plaques based on CT attenuation values as per Table-4 .

OBSERVATIONS & STATISTICAL ANALYSIS

The data was presented as frequency and percentages for comparison and discussion. Out of 60 patients 39 (64%) were males and 21 (36%) were females with male to female ratio of 1.8 : 1. Fifty Seven (94%) patients had angina while 3 (6%) patient had atypical chest pain. Stress test was positive in all patients.

Calcium score and CAD: Calcium scoring was done in all cases. Calcium score was zero in 32 (54%) patients while it was <100 in 13 (21%) patients , between 101-400 in 12 (20%) patients and 3 (5%) patients had calcium score >400 . Out of 32 patients with zero Calcium score , 4 (13%) patients were found to have obstructive CAD on CTCA while 3 (9%) showed non-obstructive CAD and no CAD was seen in 25 (42%) patients. Table-5.

CT Coronary angiography

In 51 (85%) patients CTCA was performed with Retrospective ECG –gating method while in 9 (15%) patients, Prospective ECG-gating method was used because of persistently low (<60bpm) Heart Rate. Very good to excellent image quality were obtained in all cases. Fifty eight (94%) of cases showed normal origin and course of Coronary arteries while 2 (6%) cases revealed anomalous origin of RCA from left coronary sinus with inter-arterial course between aorta and main Pulmonary trunk.(Figure-2) Ramus intermedius was present in (10%) of cases. Right Coronary

dominance was present in 52 (87%) cases, Left coronary dominance in 6 (10%) cases and co-dominance was observed in 2 (3%) cases.

CTCA and CAD; No CAD was seen in 26 (43%) cases, 22 (37%) patients had significant / obstructive CAD while 12 (20%) patients had non obstructive CAD. Total 35 obstructive segment were identified on CTCA in 22 patients which comprised of 20 mixed density , 4 calcified and 11 non-calcified plaques (Table-6). Twenty of 35 (57%) obstructive segments showed moderate i.e (50-70%) stenosis , 11 (32%) segments showed critical /severe (70-99%) stenosis and 4 (11%) segments revealed complete occlusion

Distribution of obstructive lesions: Out of 35 stenotic lesions , 14 (40%) were in LAD , (12 in proximal and 2 in middle segment), 13 (37%) in RCA (4 in Proximal and 9 in middle segment) and 8(23%) lesions were seen in LCX (6 in Proximal and 2 in the middle segment) (Table-7)

Distribution of non-obstructive lesions: there were total 37 non-obstructive lesions in 12 patients. 7 (19%) were seen in RCA, 2 (5%) in LMA, 20 (54%) in LAD and 8 (22%) in LCX. Of these, 14 (38%) were mixed density,10 (27%) were non-calcified and 13 (35%) were calcified plaques.(Tables-7)

In 9 out of 22 patients with obstructive CAD, Calcium score was <100 while 13 patients had Calcium score >100. Amongst these 5 of 9 (56%) patients showed single vessel disease whereas 4 of 9 (44%) had two vessel involvement. No three vessel involvement was seen in this group. Out of 13 patients with Calcium score >100 , 7 (54%) had single vessel involvement two and three vessel involvement was seen in 3 (23%) cases each. LMA was not involved in any of the patients. Multiple vessel involvement increased with increasing Calcium score (Table -7).

Table-1 Interpretation of calcium score

Total calcium score (AJ-130)	Atherosclerotic plaque burden	Probability of significant CAD (next 10 years)	Implications of cardiovascular risks
0	No plaque	Very unlikely, <5%	Very low
1-10	Minimal	Very unlikely, <10%	Low
11-100	Mild	Mild or minimal stenosis likely, < 20%	Moderate
101-400	Moderate	Non-obstructive CAD highly likely, obstructive disease possible, 20-90%	Moderately high
>400	Extensive	High likelihood (>90%) of atleast one coronary artery stenosis	High

Table-2. AHA Segments of coronary arteries

Name of artery	Segment
RCA	1 Proximal
	2 Middle
	3 Distal
LMA	5
LAD	6 Proximal
	7 Middle
	8 Distal
Diagonals	9 1st
	10 2nd
LCX	11 Proximal
	13 Middle
	15 Distal
Marginals	12 1st
	14 2nd
PDA	4a
PLB	4b
RIB	16
Total	17 Segments

Table -3 Quantification of stenosis

Percentage luminal narrowing	Grade of stenosis
No narrowing	No stenosis or CAD
<50 %	Non-significant (mild) stenosis or non-obstructive CAD
50-70%	Obstructive CAD with moderate stenosis
>70%-99%	Obstructive CAD with severe or critical stenosis

Table-4 Plaque Assessment

Fibrous / non-calcified plaques	91±22HU
Calcified plaques	391±156 HU
Mixed density plaques	Variable density

Table -5 Relationship of calcium scores with CAD

Calcium score	Obstructive CAD No (%age)	Non obstructive CAD No (%age)	No CAD No (%age)	Total No (%age)
0	4 (7)	3 (5)	25 (42)	32 (54)
1-100	5 (8)	8 (13)	0 (0)	13 (21)
101-400	10 (17)	2 (3)	0 (0)	12 (20)
>400	3 (5)	0 (0)	0 (0)	3 (5)
Total	22 (37)	13 (21)	25 (42)	60 (100)

Table-6 Plaque types versus CAD

Types of plaques	Non-obstructive CAD No (age)	Obstructive CAD No (age)
Non-calcified/fibrous	10 (27)	11 (35)
Calcified plaques	13 (35)	4 (11)
Mixed density plaques	14 (38)	20 (54)
Total	37 (100)	35 (100)

Table -7 Relationship of Calcium score and number of vessels involved

Vessels involved	Patients with calcium score <100		Patients with Calcium score >100	
	No	% age	No	% age
Single	5	56	7	54
Two	4	44	3	23
Three	0	0	3	23
Left main	0	0	0	0
Total	9	100	13	100



Figure-1 (a) and (b). 57 Years Male with chest pain and positive stress test ,Calcium scor; zero . (a) Straight luminal view of LAD showing normal caliber and opacification . (b) Angiographic view reveals normal main coronary arteries and their branches with right coronary dominance.



Figure-2 . (a) ,(b) and (c) . 60 Years Male with angina and positive stress test , Calcium score-394 . (a) Straight luminal view of LAD showing calcified plaques in proximal segment causing stenosis >70% . (b) Curved MPR of OM1 ; showing non-calcified plaques in proximal part causing < 50% stenosis , (c) Angiographic view showing calcified plaques causing stenosis of proximal segment of LAD

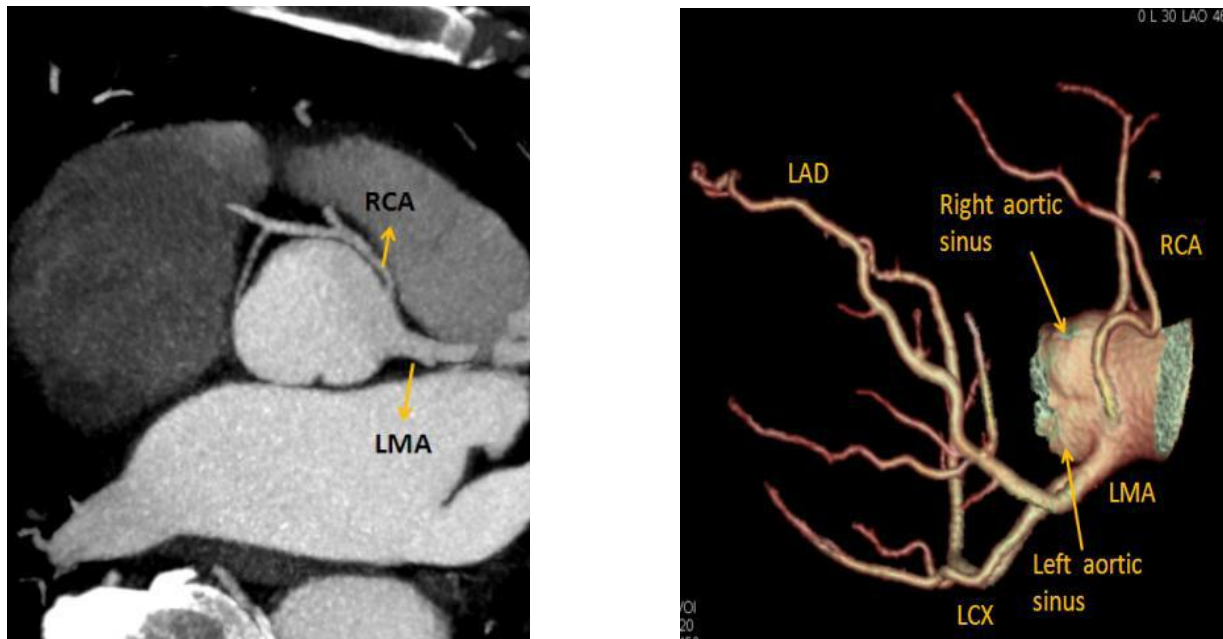


Figure-3 (a) and (b) . 56 Years Female with angina and positive stress test , Gating : Prospective ; Calcium score-zero (a) Axial image at level of aortic cusps and (b) Tree VR image showing anomalous origin of RCA from left aortic sinus with interarterial course between aorta and pulmonary artery .

DISCUSSION

Coronary calcification has been used as marker of coronary atherosclerosis, at the same time it affects the accuracy of CTCA by causing artifacts. With the advent of 16 slice, 64 slice and higher version MDCT scanners, the number of non-evaluable segments have reduced significantly and accuracy has improved .

Age and sex distribution: The age of patients in our study ranged from 35-75 years. There were 39 (64%) Males and 21 (36%) Females with Male to Female ratio of 1.8 : 1. Most 26 (45%) patients were in age group of 51-60 years. Our study population showed almost similar age and sex distribution as in study of 1764 patients of suspected CAD by Haberl et al ^[5].

Calcium scoring: In our study Calcium score was zero in 32 (53%) patients, between 1-100 in 13 (22%) patients , 101-400 in 12 (20%) patients and > 400 in 3 (5%) patients. Our results were almost comparable to study of 203 patients by Earls JP et al ^[6]. Their results were ; Calcium score of zero in 45.8% patients, score of 1-10 in 11.1% patients, 11-100 in 22.2% cases and 101-400 in 6.9% cases where as 13.9% patients showed calcium score >

400. Slight difference in results may be due to difference in size of study population.

Arad Y et al (2005) ^[7] and Mohlenkamp et al ^[8] in their studies observed that coronary calcification was a strong and independent predictor of CAD in all age groups and the risk of CAD increased with the increasing calcium score. It was also found to predict the risk of CAD events independently of standard risk factors. Coronary calcification was also found to be present more frequently with advancing age. Budoff MJ et al ^[9] observed that patients with low absolute CAC were low- risk, regardless of age, sex, and race/ethnicity percentile rank. Persons with an absolute CAC > 400 were high-risk regard;less of percentile rank. Our study also showed increased incidence of obstructive CAD with increasing calcium scores (table-5).

Coronary artery anatomy, origin, course variants and dominance

RCA originates from right coronary sinus and Left Main Coronary Artery (LMCA) originates from left coronary sinus. Left coronary artery generally bifurcates into LAD and LCX. Sometimes it trifurcates and an additional central branch known as Ramus intermedius (RIB) is formed. RCA runs in the right AV groove , LCX runs in the left AV

groove and LAD runs in inter-ventricular groove anteriorly. In our study, 58 (97%) cases showed normal origin and course of both right and left coronary arteries and their branches. Only 2(3%) cases showed anomalous origin of RCA from left coronary sinus with anomalous inter-arterial course between aorta and pulmonary trunk. (Figure-3). The prevalence of coronary artery anomalies reported by Pannu H K et al.^[10] is 0.85% . Kosar P et al^[11] reported 0.5% prevalence of RCA originating from left coronary sinus..**Ramus intermedius:** We found RI to be present in 6(10%) of cases however Kosar P et al showed RI in 31% cases in a study of 700 patients. Difference in prevalence may be due to the fact that our study comprised of 60 patients only.

Coronary artery dominance on CTCA: Right coronary artery dominance was observed in 52 (87%) of cases in our study. Six (10%) cases showed left coronary artery dominance whereas 2(3%) cases showed co-dominance. Similarly Kosar P et al in a study of 700 patients with suspected CAD, reported right coronary artery dominance in majority (76%) of cases. Left coronary dominance was seen in 9.1% cases while 14.9% cases showed co-dominance.

Coronary artery disease on CTCA: Obstructive CAD is defined as > 50% diameter narrowing in any segment of coronaries. The reduction in diameter of < 50% is taken as non-obstructive CAD. (Figure-2) Most authours ^{[7][12]} used similar criteria for defining CAD . In our study 22 (37%) cases were diagnosed to have obstructive CAD, Eight (13%) cases revealed obstructive lesions only and 14 (24%) cases showed co-existent obstructive and non-obstructive lesions.

Non-obstructive lesions were detected in 12 (20%) cases. No CAD was present in 26 (43%) of cases. (Figure-1) Almost similar results were seen in a study of 63 patients by Ovrehus KA et al.^[13] where they reported obstructive CAD in 32 % of cases and CAD was excluded in 55 % of cases by CTCA. The accuracy was determined with invasive coronary angiography.

Obstructive coronary artery disease: In our study total 35 obstructive lesions / segments were identified. Of these, 20 (57%) segments showed moderate stenosis followed by critical stenosis in 11 (32%) segments and occlusions was seen in 4 (11%) of segments. Laber et al ^[14] in a study of 59 patient with stable angina, found 29 obstructive lesions by CTCA. Like in our study, they reported 22 (76%) of lesions causing moderate stenosis while remaining 7 (24%) of lesions were found to cause severe /critical stenosis .

Number of vessels involved: In our study , out of 22 patients with obstructive disease ,13 (59%) patients were having single vessel disease , two vessel disease was seen in 6 (27%) of patients while remaining 3 (14%) patients had 3 vessel involvement. Left main vessel involvement was not seen in any of the patients. Likewise single vessel involvement was seen in majority i.e 73 % of cases in a study by Choi EK et al^[15]. The cause for difference in percentage may be due the reason that sample size in author's study was large and 1000 cases were included.

Distribution of obstructive lesions: A total of 35 obstructive lesions were detected ion CTCA in our study. Majority i.e 14 (40%) of these were present in LAD followed by 13 (37%) in RCA and 8 (23%) lesions were in LCX (Table-7) Similar pattern of involvement was reported by Ropers D et al [16] in a study of 77 patients where majority i.e 36 % of obstructive lesions were seen in LAD followed by 29 % in RCA. Further , most i.e 12 (34%) of obstructive lesions in our study involved proximal segment of LAD , followed by middle segment of RCA 9 (26%) and proximal segment of LCX 6 (17%) .(Table-7)

Choi et al (2008) ^[15] studied 1000 patients of suspected CAD with CTCA. They found that majority i.e 61 % of obstructive lesions were located on Left main or proximal segment of LAD.

Non-obstructive coronary artery disease: In our study, a total of 37 non-obstructive lesions were detected in 12 patients with suspected CAD. Of these, 7 (19%) lesions were seen in RCA,

LMA showed 2 (5%) lesions and 20 (54%) lesions were located in LAD while LCX showed 8 (22%) lesions. Min J K et al ^[17] in a study of 1127 patients with suspected CAD found that most of non-obstructive lesions were present in LAD as in our study.

Plaque characteristics:- in our study majority of coronary artery lesions comprised of mixed density plaques i e 20 (54%) in case of obstructive CAD and (14)38% in case of non-obstructive CAD (table-5). Our results are in agreement with the study of 161 patients by Hausleiter et al ^[18] .they observed that most 43 (46%) lesions of coronary arteries were mixed density plaques.

Calcium score and coronary artery disease: In our study 32 (54%) patients had zero calcium score. Out of 32 patients, 4 (13%) patients were diagnosed to have obstructive CAD on CTCA, and 3 (9%) patients showed non-obstructive CAD while remaining 25 (42%) patients were shown to be free from CAD . An increase in incidence of obstructive as well as non-obstructive CAD was noted with increasing calcium scores. Further, number of vessels involved by obstructive lesions also increased with increasing calcium scores. (Table-4).

Kelly JL et al (2008) ^[19] studied 794 patients of suspected CAD and found 45% of cases with zero calcium score , however CTCA in these patients revealed obstructive CAD in 5.2 % of the cases . Therefore , significant stenosis may be present in patients with no coronary calcification . In another study of 1795 patients by Vilegenthart R et al ^[20] it was observed that the incidence of CAD increases with increasing calcium score as seen in our study. They also calculated multivariate-adjusted relative risk of coronary events which was 3.1 for calcium score of 10-400, 4.6 for calcium score of 401-1000 , and 8.3 for calcium score of > 1000 .

CTCA in diagnostic work up of patients with CAD

It has been found in different studies that CTCA is a reliable diagnostic test to detect or rule out significant / obstructive stenosis in patients with

suspected CAD. It helps in selecting patients who need to undergo ICA and the cost associated with hospital stay and diagnostic work up is reduced significantly. Sixty four slice MDCT is a useful tool in diagnosing significant CAD. Coronary calcium score as well as stenosis grading on CTCA are useful prognostic indicators.

CONCLUSION

Coronary artery disease (CAD) is an important cause of morbidity and mortality . Coronary artery calcification has been shown to be a predictive marker of coronary atherosclerotic disease and 64 slice CT is an excellent imaging modality for detection of coronary artery calcification and stenosis . Incidence of obstructive coronary artery disease increases with increasing calcium score and 64 slice CT allows non-invasive visualization of coronary arteries . CTCA detects obstructive CAD in significant number of patients and normal CTCA confidently rules out possibility of obstructive CAD and thereby obviates the need for cost-extensive and invasive coronary angiography. Atherosclerotic plaques causing coronary stenosis can be differentiated into calcified, non-calcified and mixed density types which allow further planning for management of CAD . CTCA is better than calcium score in evaluation of CAD .Patients with zero calcium score can harbor significant CAD which is reliably detected by CTCA. Therefore, CTCA should be included in the routine work up of patients with CAD before selecting them for ICA .

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