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DIAGNOSTIC ACCURACY OF CORONARY CT ANGIOGRAPHY WITH SINGLE SOURCE 128-MULTISLICE CT IN PATIENTS WITH CORONARY ARTERY DISEASE

Radiodiagnosis

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ABSTRACT

Coronary catheter Angiography (CA) regarded as the "Gold standard" for coronary arterial assessment is invasive and associated with morbidity and mortality. Alternatively, non-invasive coronary CT Angiography (cCTA) with the help of multislice CT (MSCT) is capable of acquiring motion-free, high-resolution images in a single breath hold. Our aim was to assess the accuracy of cCTA using single source 128 MSCT for evaluating coronary artery disease (CAD) compared to CA. Thirty three patients with low to intermediate clinical suspicion were evaluated. cCTA showed a sensitivity, specificity, positive and negative predictive values of 100%, 93.3%, 94.7% and 100% respectively for detecting CAD. Two stenotic lesions with significant (>50%) diameter narrowing were missed by cCTA resulting in a sensitivity of 92.16% in the segment based analysis. The sensitivity for detecting non-significant lesions is 72.7%. Given the high sensitivity and negative predictive value, 128 MSCT can be effectively used to rule out significant CAD in patients with low to intermediate clinical suspicion.

KEYWORDS

Coronary artery disease, coronary CT angiography, catheter angiography

INTRODUCTION AND LITERATURE REVIEW

Catheter angiography (CA) is regarded as the 'gold standard' for evaluating atherosclerotic coronary arterial disease (CAD). It provides an accurate, reliable, reproducible evaluation of luminal status with opportunity for direct intravascular intervention. Despite being the gold standard, CA has limitations. It is invasive with an overall complication rate for adult procedures at 7.4/1000 and a mortality of 0.7/1000 (West, Ellis, Brooks, & Joint Audit Committee of the British Cardiac Society and Royal College of Physicians of London, 2006). Another major limitation is its inability to evaluate extra luminal changes and coronary calcium burden which may be partly offset with simultaneous use of intravascular ultrasound (IVUS) but at an increased cost (Doh et al., 2014).

Coronary CT angiography (cCTA) is an alternative modality for evaluating coronary arteries. It is considered an appropriate test by the American College of Radiology (ACR) for evaluating patients with low to intermediate risk of CAD, atypical chest pain, equivocal stress test, negative cardiac enzymes or with suspicion of coronary artery anomalies (Jacobs et al., 2006). Coronary CTA demonstrated high sensitivity and high negative predictive value for significant CAD making it ideal non-invasive test to rule out significant CAD in low risk population (Cury et al., 2013; Hoffmann et al., 2009). It has the added advantage of being incorporated into a 'triple rule out' test protocol in an emergency setting simultaneously ruling out pulmonary embolism and aortic dissection (Gruettner et al., 2013). Incidental chest or upper abdominal abnormalities that may or may not explain the current clinical findings are clear advantages for cCTA over CA (Teague, Rissing, Mahenthiran, & Achenbach, 2012).

ACR acknowledges the continuous change in technology in CT scanners which includes a significant jump in the number of slices acquired in a single rotation (from 4 to 640 multislice currently) and the use of more efficient detectors. cCTA with 64 detector CT has been shown to have better diagnostic performance and increased assessability of coronary segments compared to 4 detector row and 16 detector row CT in a meta-analysis by Vanhoenacker et al (2007) (Vanhoenacker et al., 2007). Recently, ACR revised the recommendations for minimum standards for cCTA highlighting the role of higher detector row CT machines in an attempt to improve diagnostic quality and reducing radiation exposure (Jacobs et al., 2006). The recommendations included the use of MSCT(multislice CT) with detector rows 64 and above, ECG synchronization, in plane resolution of ≤ 0.5 x 0.5mm, z-axis (longitudinal) resolution of ≤ 1mm, temporal resolution of ≤ 250ms, automated tube current modulation. The standards may be set higher as the modern, technically more capable and cost effective machines become more widely available.The 64 multidetector CT (MDCT)is possibly the widely used scanner and the workhorse in many dedicated cardiac centers. Now, there is increasing availability of higher MDCT's (128, 256, 320 MSCT) with wider anatomical coverage achieved by increasing the detector rows, dual source or dual focal spots (Hsiao, Rybicki, & Steigner, 2010).

Our literature search yielded very few studies that have directly compared performance of 128 MSCT to CA (Table.1) (Chaosuwannakit, Kiatchoosakun, & Makarawate, 2012; Madhok, 2014; Sato, Horii, Yoshimura, Yagi, & Aoyama, 2017; Takagi et al., 2018). Sato et al (2017) demonstrated the diagnostic performance of dual source 128 MSCT to be comparable to CA in patients with very high Agatston score (>400). The segment based sensitivity, specificity, positive predictive value, negative predictive value and accuracy were 92.2%, 87.5%, 69.6%, 97.3% and 88.6% respectively (Sato et al., 2017). In a very recent retrospective study by Takagi et al (2018), the segment based sensitivity, specificity, positive predictive value, negative predictive value and accuracy were 95%, 96%, 79%, 99% and 96% respectively. In our study, we aimed to reassess the accuracy of cCTA using single source 128 MSCT compared to CA for evaluating CAD in patients with low to intermediate risk and significant stenosis. We also aimed to evaluate the coronary segmental assessability by cCTA.

Table.1: Studies comparing 128 MSCT versus CA:

Study	Configuration	Coronary segment based for >50% luminal narrowing			
		Sensitivity	Specificity	Positive predictive value	Negative predictive value
Chaosuwannakit et al (2012)	128 MDCT	98%	99%	94%	99%
Madhok et al (2014)	128 slice dual source system	95.26%	95.12%	88.46%	98.08%
Sato et al (2017)	128 slice dual source system	92.2%	87.5%	69.6%	97.3%
Takagi et al (2018)	128 MDCT – ultra high resolution CT; single source	95%	96%	79%	99%

MATERIAL AND METHODS

After approval from the Institution Ethics Committee (IEC), a prospective study was undertaken at our institute from February 2015 to July 2016. Our inclusion criteria were patients referred from the cardiology out-patient with clinically determined low to intermediate risk for CAD based on Morise risk score (Morise, Haddad, & Beckner, 1997). Exclusion criteria were patients with acute coronary syndrome with elevated enzymes and positive ECG findings, patients with coronary stents or bypass grafts, allergy to contrast medium and renal insufficiency (serum creatinine concentration > 1.5 mg/dl). Written informed consent was obtained from all patients.Based on the above criteria, thirty-three patients (n=33) formed the study group.

CORONARY CT ANGIOGRAPHY (cCTA):

All patients received oral Metoprolol 25mg and Alprazolam 0.5mg at bedtime for two days prior to cCTA and oral Metoprolol 50-100mg on the day of examination depending on preprocedural heart rate. Optimal heart rate considered for the study was < 65/min. Breath hold training was given before the procedure. All patients were scanned on a single source 128 MSCT (SOMATOM Definition AS+, Siemens, Erlangen, Germany) within a week prior to CA. Non-contrast CT was acquired from the level of the carina till the base of the heart for evaluating coronary calcified plaques followed by cCTA acquisition after injecting 70 ml of nonionic contrast (Ultravist) at 5ml/ sec with concentration of 370mgI/ml. Prospective ECG gating was used for cCTA image reconstruction. For cCTA the scan parameters were, collimation - 0.6 mm, slice thickness- 0.6 mm, image matrix- 512 x 512, tube rotation time- 0.3 sec, kVp- 120, automatic exposure control for tube current modulation with CARE. The images were reviewed on a dedicated 3D workstation (Syngo.via, Siemens). Coronary calcium score was calculated from the non-contrast acquisition using the Agatston method (Agatston et al., 1990). For cCTA, axial images were reconstructed as Multi-planar Reconstruction (MPR), Maximum Intensity Projection (MIP), Curved Planar Reconstruction (CPR) and Volume Rendering Technique (VRT) and stored for review.

CORONARY CATHETER ANGIOGRAPHY (CA):

Conventional CA was performed according to standard techniques with acquisition of standard views after coronary artery injections. Image data were stored for review.

DATA ANALYSIS

cCTA image interpretation was performed by two radiologists (B.W and P.R). The inter-reader disagreement were resolved by consensus. Segments were scored as having significant CAD if there was ≥50% diameter reduction of the lumen and non-significant if there was <50% diameter reduction of the lumen. A modified 15 segment model for the coronary arteries was used in our study (Austen et al., 1975). The following segments were identified: *Right coronary artery* (RCA) was subdivided in a *proximal, middle, and distal parts; posterior descending artery* (PDA); posterior lateral branch; the *left main coronary artery* (LM); the *left circumflex artery* (LCX) was divided into *proximal and distal* parts; *obtuse marginal* (OM1 and OM2) branches from left circumflex artery, the *left anterior descending artery* (LAD) was divided into *proximal, middle, and distal* parts; the *diagonal* (DI and D2) branches from LAD. Coronary artery analysis was performed in all vessels with a diameter down to 1.5 mm, including those vessels distal to complete occlusion. The data was tabulated on a MS-Excel (2007). All the statistical analysis was done using MedCalc ®v12.5 for windows statistical software and Stata/MP 13.0 for Windows (Statacorp LP, USA, 2013).

CA image data was evaluated by an experienced cardiologist (M.K). The coronary artery segmentation and criteria for stenosis were similar to that used in cCTA. Coronary artery analysis was performed in all vessels with a diameter down to 1.5 mm, including those vessels distal to complete occlusions.

RESULTS

The study group included 33 patients - 20 males (61%) and 13 females (39%). Mean age was 58 years with range-25-84 years.

Coronary calcium score (Table.2):

CT Coronary calcium score (CCS) for each patient was graded according to Agatston scoring guidelines and summarized in Table.2. The CCS ranged from 0 to 540 with a mean of 84. About 19 out of the 33 patients (57.6 %) had a score of <1.Only 2 out of the 33 patients had a score > 400 placing them in a high risk category.

Table 2. Coronary calcium score

Calcium Score (CAD grade)	No. of study subjects (percentage)
0 or <1 (No evidence of CAD)	19 (57.57)
1-10 (Minimal)	2 (6.06)
11-100 (Mild)	4 (12.12)
101-400 (Moderate)	6 (18.18)
>400 (Severe)	2 (6.06)

Coronary artery Dominance:

About 78.8% of our patients (26 out of 33) showed right sided dominance.

Diagnostic performance of cCTA versus CA:

To assess the diagnostic performance of cCTA as compared with gold standard CA. Patients were classified as positive for the presence of CAD, if there was a luminal narrowing ≥50% in any coronary artery segment by CA, which is regarded as the standard of reference. The analysis was expressed as receiver operator curve (ROC) (Figure.1). The sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, positive predictive value and negative predictive value for detecting significant coronary artery disease by cCTA in symptomatic patients were 100%, 93.33%, 15.00, 0, 94.74% and 100.00% respectively. Analysis of paired proportions between cCTA and CA by applying McNemar's test showed no significant difference between the two tests. (p value =1.000 and 95% CI of -2.88% to 3.03%). With respect to lesion detection by cCTA , analysis by applying paired samples t- test also showed no significant difference between two tests (p value = 0.4138; 95% CI of -0.3145 to 0.1327).

Coronary artery segment assessability :

There was a statistically significant decrease in the number of segments that could be assessed by cCTA (394 segments) compared to CA (418 segments).

Significant Vs Non-significant lesion analysis (Table.3):

For significant lesion (> 50% luminal narrowing) coronary CTA showed a sensitivity of 92.16% and positive predictive value of 100%. For non-significant stenosis (<50% narrowing), coronary CTA shows a sensitivity of 72.73%, specificity of 97.69%, positive predictive value of 44.44% and negative predictive value of 99.3%.

Table 3. Coronary CTA for significant Vs non-significant lesion.

Parameters	Significant lesion, >50% luminal narrowing (with 95%CI)	Non-significant lesion, <50% luminal narrowing (with 95%CI)
Sensitivity	92.16% (81.12 to 97.82%)	72.73% (39.03 to 93.98%)
Specificity	NA	97.69% (95.79 to 98.89%)
Positive Likelihood Ratio	NA	31.49% (15.46 to 64.15%)
Negative Likelihood Ratio	NA	0.28% (0.11 to 0.73%)
Disease Prevalence	100% (93.02 to 100%)	2.48% (1.24 to 4.39%)
Positive Predictive Value	100% (92.45 to 100%)	44.44% (21.53 to 69.24%)
Negative Predictive Value	0% (0 to 60.24%)	99.3% (97.96 to 99.85%)

Segment based analysis (Table.4):

The diagnostic performance of coronary CTA was statistically analyzed based on coronary artery segments. It showed highest sensitivity (100%) for distal LCX, D1, OM1 and mid RCA vessels.

Table 4. Segment based diagnostic performance of cCTA

VESSEL	SENSITIVITY	SPECIFICITY	PLR	NLR	PPV	NPV
LM	72.73%	97.69%	31.49%	0.28%	44.44%	99.30%
LAD-P	77.78%	95.83%	18.67%	0.23%	87.50%	92.00%
LAD-M	90.00%	95.65%	20.7%	0.1%	90.00%	95.65%
LAD-D	50.00%	100.00%	NA	0.5%	100.00%	96.87%
LCX-P	80.00%	100.00%	NA	0.2%	100.00%	96.55%
LCX-D	100.00%	92.31%	13%	0	77.78%	100.00%
D1	100.00%	96.87%	32%	0	50.00%	100.00%
D2	NA	100.00%	NA	NA	NA	100.00%
OM1	100.00%	100.00%	NA	0	100.00%	100.00%
OM2	NA	100.00%	NA	NA	NA	100.00%
PLB	0	100.00%	NA	1	NA	96.97%
RCA-P	100.00%	81.82%	5.5%	0	73.33%	100.00%
RCA-M	87.50%	96.00%	21.87%	0.13%	87.50%	96.00%
RCA-D	100.00%	100.00%	NA	0	100.00%	100.00%
PDA	NA	100.00%	NA	NA	NA	100.00%

Figure1:

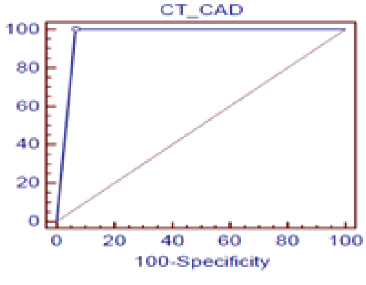
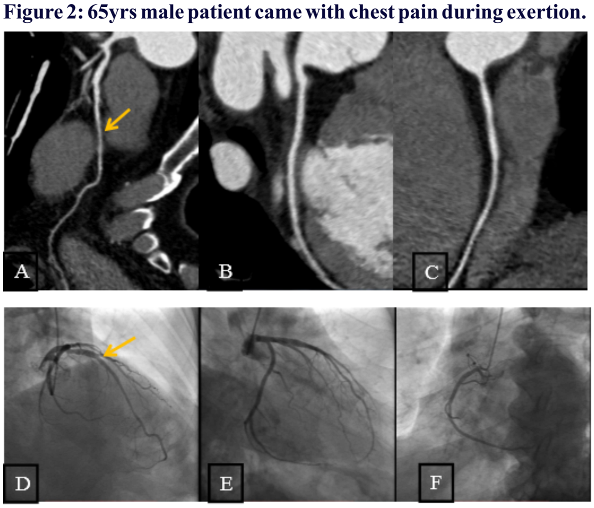


Figure.1: Receiver Operator Curve (ROC) - Diagnostic performance of cCTA expressed against CA

cCTA diagnostic performance: Sensitivity = 100% (95% CI: 81.47% to 100.00%); Specificity = 93.33% (95% CI: 68.05% to 99.83%); Positive Likelihood ratio = 15.00 (95% CI: 2.26 to 99.64); Negative Likelihood ratio = 0; Positive Predictive value = 94.74% (95% CI: 73.97% to 99.87%); Negative predictive value = 100.00% (95% CI: 76.84% to 100.00%)

Figure 2: 65yrs male patient came with chest pain during exertion.

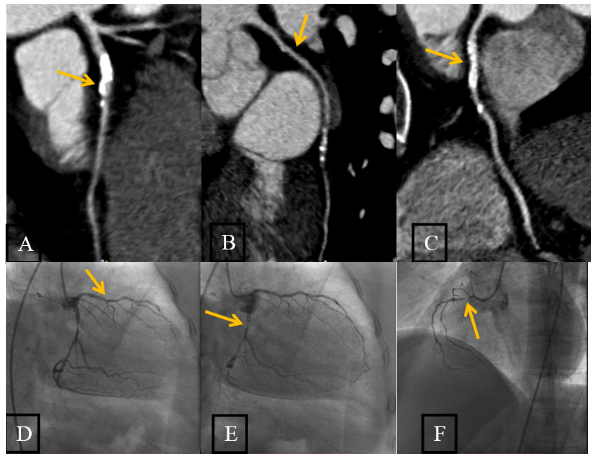


There is non significant (<50%) narrowing (arrow)of mid LAD with normal distal segment opacification. Otherwise rest of the coronary vessels are normal.

cCTA curved MPR images of LAD (A),LCX (B) & RCA (C) and its branches respectively.

CA images of LAD (D),LCX (E) & RCA (F) and its branches respectively.

Figure 3: 54yrs old male presented with chest pain

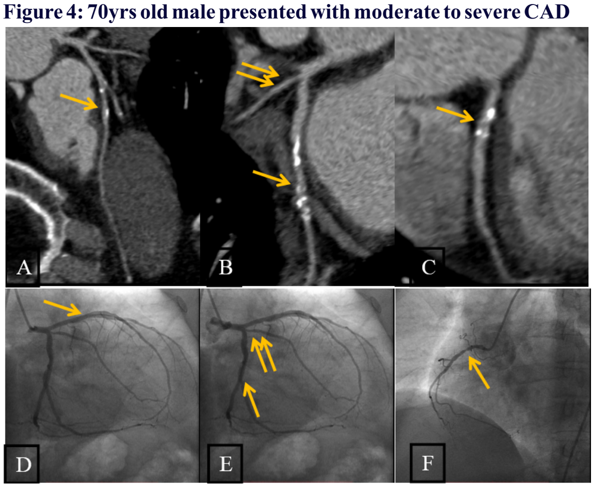


There is non significant (<50%) narrowing of proximal LAD with significant narrowing(>50%) of proximal LCX and proximal RCA.

cCTA curved MPR images of LAD (A),LCX (B) & RCA (C) and its branches respectively.

CA images of LAD (D),LCX (E) & RCA (F) and its branches respectively.

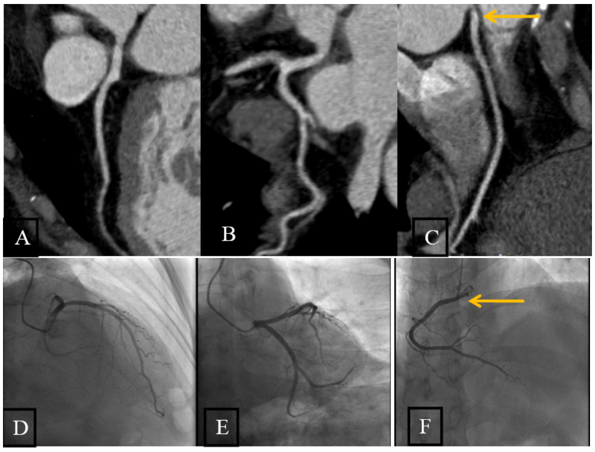
Figure 4: 70yrs old male presented with moderate to severe CAD



cCTA reveals non significant narrowing(<50%) in mid LAD(A) & distal LCX(B) and significant narrowing (>50%) of proximal RCA(C).Proximal Ramus(double arrow) appears normal(B)

CA reveals normal proximal LAD and distal LCX(D).Proximal Ramus shows non significant narrowing(<50%)(E) and there is significant narrowing(50%) of proximal RCA(F)

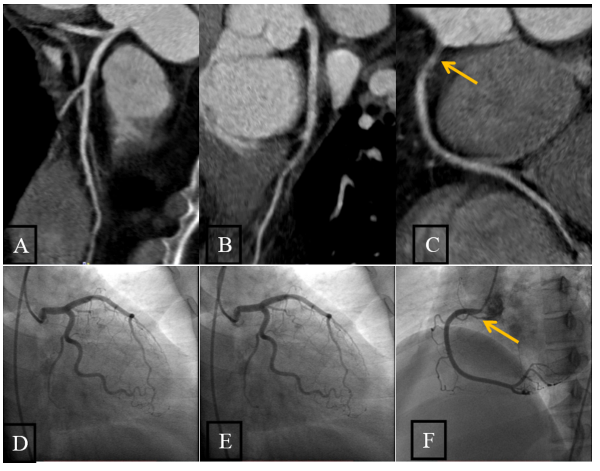
Figure 5: 36yrs old male presented with chest pain



cCTA reveals non significant narrowing(<50%) in proximal RCA(C).LAD (A) & LCX (B)are normal.

CA reveals normal LAD (D) & LCX (E).No narrowing seen in proximal RCA (F).

Figure 6: 43yrs old female presented with chest pain with palpitation



cCTA reveals significant narrowing(>50%) in proximal RCA(C).LAD (A) & LCX (B) are normal.

CA reveals normal LAD(D) & LCX(E).No narrowing seen in proximal RCA(F).

DISCUSSION

Cross-sectional imaging of the coronary arteries with CTA still remains a challenge (Ghekiere et al., 2017). Patient factors that limit CT imaging are continuous motion, heart rate, small vessel size (2-4mm), significant change in orientation of coronary arteries from section to section with respect to the axial plane and patient anatomy. Machine related limiting factors are scanning time (indirectly reflects breath hold time), quality of the contrast injection, image noise, spatial and temporal resolution and presence of artifacts. These limitations are only partly overcome by pharmacological intervention like the use of beta blockers and by several technical advances in current modern CT scanners.The 128 MSCT we utilized in our study comfortably satisfied the ACR recommendations for evaluating low to intermediate suspicion CAD. The 'z' axis flying focus technology in the X-ray tube imparted the capability to acquire 128slices in a single rotation (426 slices in a sec) with 64 detector rows. The gantry rotation time of 0.3 sec, temporal resolution of 150ms and spatial resolution of 0.33mm3 were also within the recommendations. Absence of dual source in our scanner placed a limitation on our temporal resolution which is 4 to 5 times compared to the temporal resolution of CA.

With respect to the outcome of our study, the observed high sensitivity and negative predictive value for detecting significant CAD (>50% narrowing in any of the coronary vessels) in a symptomatic patient were not unexpected using 128 MSCT. But segment based comparison to CA does reveal shortcomings in cCTA. There was complete agreement with CA in 16 out of 33 patients on the segment based analysis.There was overcall of non-significant stenosis in 9 segments and in all cases the stenosis was thought to be less than 25%. Two significant stenosis (>50% luminal diameter narrowing) involving LAD segments in two patients were missed by cCTA (Figure.2). cCTA also missed non-significant stenosis in 4 segments, two of them in LAD, one in right coronary mid segment and one in posterolateral ventricular branch. Calcium score did have a relation to the number of lesions detected. But significant lesions were present in 5 patients with a calcium score of <1.

LIMITATION:

Our prospective study is limited by a small sample size. Selection bias could not be avoided in our single institution study conducted at tertiary level center. Further we did not analyze the radiation dose accrued by our patients after cCTA and CA in our study.

CONCLUSION:

Single source 128 multislice cCTA is well suited as a non-invasive technique for ruling out significant coronary artery disease in patients with low to intermediate pretest risk.However, significant lesions can occasionally be missed by cCTA which can be related to both patient factors and technical restraints. Judicious use of stress tests, catheter angiography and clinical acumen should guide appropriate management to avoid false reassurance.

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