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Diagnostic accuracy of multislice computed tomography coronary angiography is improved at low heart rates

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Abstract

Purpose: Assess the effect of heart rate on diagnostic accuracy for the detection of significant coronary artery stenosis using 16-row multislice computed tomography (MSCT). *Material and methods*: About 120 patients (105 males; 59 ± 11 years) with suspected coronary artery disease who underwent conventional coronary angiography (CA) and MSCT-CA were retrospectively enrolled for the study. Patients underwent a MSCT-CA (Sensation 16, Siemens, Germany), with the following protocol: collimation 16 × 0.75 mm, gantry rotation time 420 ms, feed/rotation 3.0 mm, kV 120, mAs 400–500. The protocol for contrast material administration was 100 ml of Iodixanol (Visipaque 320 mg l/ml, Amersham, UK) at 4 ml/s and the delay was defined with a bolus tracking technique. In all patients the mean heart rate (HR) during the scan was used as a criteria to divide the population in two groups of 60 patients each. In one group (Low HR) the 60 patients with lower heart rates, and in the other group (High HR) the patients with higher heart rates. In the two groups diagnostic accuracy (per coronary segment) for the detection of significant stenosis (≥50% lumen reduction) was evaluated in vessels ≥2 mm of diameter using quantitative CA as reference standard. The difference in diagnostic accuracy were compared with a Chi^2 test and a $p < 0.05$ was considered significant. *Results*: There was no significant difference between the two groups regarding age, gender, weight, mean intravascular attenuation, and calcium score. Overall 1310 (652 for Low HR and 658 for High HR) segments with 219 (105 for Low HR and 114 for High HR) significant lesions were available for the analysis. The average heart rate was 52 ± 4HU and 63 ± 5HU for Low HR and High HR, respectively ($p < 0.001$). The sensitivity and specificity were 92 and 96% for Low HR and 90 and 92% for High HR ($p < 0.05$). There were 22 vs. 44 false positives, and 8 vs. 12 false negatives in the Low HR and High HR, respectively. *Conclusion*: Increasing HR significantly deteriorates diagnostic accuracy in MSCT-CA.

Introduction

Significant coronary artery stenosis can be reliably detected with multislice computed tomography coronary angiography (MSCT-CA) [1–3]. The increased number of detector rows and faster gantry rotation of the generation with 16 detector rows compared to the previous generations with four detector rows have improved the diagnostic performance. Nevertheless, HR remains a relevant issue able to influence the diagnostic performance [4, 5].

The aim of our study was to compare diagnostic accuracy of 16-row MSCT-CA in the detection of significant coronary artery stenosis in two groups of patients with different HR.

Material and methods

We retrospectively enrolled for the study 120 patients (105 males 59 ± 11 years) who previously underwent both conventional coronary angiography (CA) and MSCT of the coronary arteries (calcium score and coronary angiography) to compare the diagnostic accuracy of either techniques to detect coronary artery disease. Inclusion criteria were: regular heart rate with sinus rhythm, and the ability to hold the breath for 20 s. Exclusion criteria were: contra-indications to intravenous administration of iodinated contrast material, patients with previous bypass surgery. Age, gender, weight, and mean heart rate during the scan were collected. A single oral dose of 100 mg metoprolol was administered 1 h before the scan if the heart rate was ≥65 beats/min.

A calcium score scan was performed with the following parameters: collimation 16 × 1.5 mm, gantry rotation time 420 ms, feed/rotation 6.0 mm, effective slice width 3mm, increment 1.5 mm, kV 120, eff. mAs 150.

The MSCT-CA scan (Sensation 16, Siemens, Germany) was performed with the following parameters: collimation 16 × 0.75 mm, gantry rotation time 420 ms, feed/rotation 3.0 mm, effective slice width 1 mm, increment 0.5 mm, kV 120, eff. mAs 400–500. The protocol for contrast material administration was 100 ml of Iodixanol (Visipaque 320 mg/ml, Amersham, UK) at 4 ml/s and the delay was defined with a bolus tracking technique.

Three standard temporal windows were set at −350 ms, −400 ms, and −450 ms before the next *R* wave for ECG-gated retrospective reconstruction by a single observer. The same observer, a radiologist with 3 years of experience in this field, selected the dataset with least residual motion for the final evaluation.

For the evaluation, coronary arteries were divided into segments according to the AHA classification [6]. A single observer, unaware of the MSCT results, classified all coronary segments as < 2 and ≥2 mm diameter using a quantitative coronary angiography (CA) algorithm (CAAS, Pie Medical, The Netherlands). Only segments classified as ≥2 mm were considered for comparison with MSCT. The severity of coronary stenoses was quantified in two orthogonal views, and a stenosis was classified as significant if the mean lumen diameter reduction was ≥50%.

Coronary calcium score was assessed with a dedicated software application (CaScore, Siemens, Germany). The overall Agatston score was recorded in each patient. Two observers with 3 years of experience in this field, blinded to the results of conventional coronary angiography, independently evaluated all MSCT-scans. All branches (> 2 mm lumen diameter) of the coronary tree were evaluated for the presence of significant (≥50% diameter reduction) obstructive stenoses. Segments with stents were excluded from analysis. Maximum intensity projections were used to identify coronary lesions and multiplanar reconstructions to classify lesions as significant or not-significant. Disagreements were resolved by consensus.

The median (57 bpm) of the mean HR during the scan in overall patients was found and used to divide the population in two groups of 60 patients each. In the first group (defined as: Low HR) were clustered all the patients with the lower mean HR, and in the second group (defined as: High HR) the patients with the higher mean HR.

Interval data were expressed as mean and standard deviation. Diagnostic accuracy was expressed

Table 1. Patients data.

	Low	High
Number of patients	60	60
Mean age (years)	58 ± 11	59 ± 10
Male/Female	54/6	51/9
Mean heart rate (bpm)*	52 ± 4	63 ± 5
Mean calcium score (Agatston score)	213 ± 452	379 ± 675
Mean weight (kg)	71 ± 8	71 ± 10

bpm = beat per minute. *$p < 0.01$.

Table 2. Diagnostic accuracy of low heart rate group vs. high heart group (per segment).

AHA	Segment	*n*		SDS		Sensitivity		Specificity		PPV		NPV	
		L	H	L	H	L	H	L	H	L	H	L	H
1	RCA proximal	57	58	15	14	100 (78–100)	100 (76–100)	95 (83–99)	100 (91–100)	88 (63–99)	100 (76–100)	100 (91–100)	100 (91–100)
2	RCA middle	48	52	13	19	100 (75–100)	95 (73–98)	91 (76–98)	88 (71–96)	81 (54–97)	82 (59–96)	100 (89–100)	97 (82–99)
3	RCA distal	41	46	3	5	100 (29–100)	80 (28–99)	100 (90–100)	93 (80–98)	100 (29–100)	57 (18–96)	100 (90–100)	97 (86–99)
4	PDA	37	37	1	2	100 (2–100)	50 (1–99)	100 (90–100)	97 (85–99)	100 (2–100)	50 (1–99)	100 (90–100)	97 (85–99)
5	Left main	58	59	1	4	100 (2–100)	100 (39–100)	100 (93–100)	100 (93–100)	100 (2–100)	100 (39–100)	100 (93–100)	100 (93–100)
6	LAD proximal	58	59	18	20	94 (72–99)	90 (68–95)	98 (86–99)	80 (63–90)	94 (72–99)	69 (48–91)	98 (86–99)	94 (79–99)
7	LAD middle	52	53	18	17	94 (72–99)	100 (80–100)	97 (84–99)	81 (63–91)	94 (72–99)	71 (48–92)	97 (84–99)	100 (88–100)
8	LAD distal	47	51	3	2	33 (0–95)	100 (15–100)	98 (87–99)	94 (83–98)	50 (1–99)	40 (5–95)	96 (84–99)	100 (92–100)
9	1st diagonal	41	38	3	5	67 (9–98)	40 (5–92)	90 (75–97)	82 (64–93)	33 (4–90)	25 (3–87)	97 (85–99)	90 (73–97)
10	2nd diagonal	27	22	1	0	100 (2–100)	NA	96 (80–99)	96 (77–99)	50 (1–99)	0 (0–99)	100 (86–100)	100 (83–100)
11	LCX proximal	50	55	10	8	90 (55–99)	88 (47–97)	95 (83–99)	87 (74–95)	82 (48–98)	54 (25–91)	97 (86–99)	98 (87–99)
12	1st marginal	51	48	7	9	86 (42–99)	89 (51–99)	96 (84–99)	95 (82–99)	75 (34–98)	80 (44–98)	98 (87–99)	97 (86–99)
13	LCX middle	47	48	9	6	100 (66–100)	67 (22–97)	90 (75–97)	98 (87–99)	69 (38–94)	80 (28–99)	100 (89–100)	95 (84–99)
14	2nd marginal	30	25	2	3	50 (1–99)	100 (29–100)	96 (81–99)	91 (70–98)	50 (1–99)	60 (14–96)	96 (81–99)	100 (83–100)
15	PLB	8	7	1	0	100 (2–100)	NA	100 (59–100)	100 (59–100)	100 (2–100)	NA	100 (59–100)	100 (59–100)

The values of diagnostic accuracy are expressed in percentage and between brackets the 95% confidence intervals. L = low heart rate group; H = high heart rate group; *n* = absolute number of segments; AHA = American Heart Association segmental classification; SDS = absolute number of significantly diseased segments (≥50% lumen reduction at Quantitative Coronary Angiography); RCA = right coronary artery; PDA = posterior descending artery; LAD = left anterior descending; LCX = circumflex; PLB = postero-lateral branch; NA = not assessable.

Table 3. Diagnostic accuracy of low heart rate group vs. high heart group.

Overall	Low HR	High HR
Sensitivity	92 (85–97)	90 (82–93)
Specificity	96 (93–97)	92 (89–94)
PPV	82 (73–91)	70 (61–83)
NPV	99 (97–99)	98 (95–98)

The values of diagnostic accuracy are expressed in percentage and between brackets the 95% confidence intervals. PPV = positive predictive value; NPV = negative predictive value; HR = heart rate.

in percentage with 95% confidence intervals. The differences in demographics were tested with an unpaired *T* test. The differences in diagnostic accuracy were tested with a non-parametric Cramer's *V* test. A $p < 0.05$ was considered significant.

Results

There were no significant differences between the two groups regarding age, gender, body weight and Agatston Calcium score (Table 1). The mean HR during the scan for the overall population was 57 ± 7 bpm. After sorting the population in the two groups the resulting mean HR was 52 ± 4 bpm and 63 ± 5 bpm ($p < 0.001$) for Low HR and High HR, respectively.

Overall, 1310 coronary segments (mean = 10.9 segments/patient) ≥2 mm were available for the comparison between MSCT-CA and CA (Table 2). Of these, 652 (50%) were available in Low HR and 658 (50%) in High HR. There were 219 significant coronary lesions available for analysis. Of these, 105 (49%) in group Low HR and 114 (51%) in group High HR.

The overall sensitivity, specificity, positive and negative predictive value for the detection of significant stenosis were 92, 96, 82 and 99% for Low HR and 90, 92, 70 and 98% for High HR ($p < 0.05$ – Table 3). The difference in diagnostic accuracy between the two groups was not significant when segments were compared separately ($p > 0.05$).

Discussion

In our experience image quality in MSCT-CA is reduced with the progressive increase in heart rate. This has been previously reported on 4-row MSCT equipments [4, 5].

Our study confirms these observations. In fact, a higher HR determines a significant reduction in overall diagnostic accuracy. In the population of patients that we retrospectively enrolled the other parameters that could have affected diagnostic accuracy (e.g. demographics, coronary calcifications, etc) were all not significantly different. The

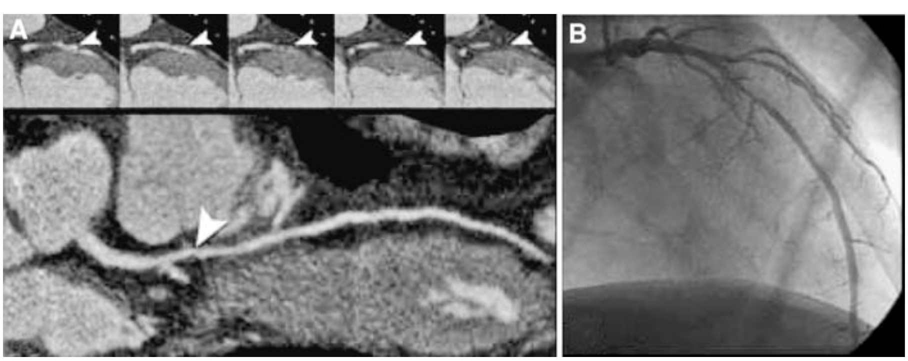

Figure 1. Example of lesion missed at CT because of motion artifact. The patient underwent the scan with a heart rate of 75 bpm. The CT images (A) performed in longitudinal curved multiplanar reconstruction (A – lower image) and in longitudinal multiplanar (A – upper images) show a vessel wall thickening of the proximal left anterior descending artery (arrowheads). The conventional coronary angiography instead demonstrates a significant lesion of the proximal segment of the same vessel (B).

difference was more evident in terms of false negatives (Figure 1). More significant lesions were missed in the group with higher HR. From the clinical point of view, a missed lesion is more important than a false positive, especially if MSCT-CA is used to pre-select patients for CA (Figure 1).

In a paper from Hoffmann et al. the Authors state that heart rates ranging around 60 bpm provide degradation of the image quality when compared to heart rates ranging around 50 bpm [7]. Lower heart rates then are always preferable especially when the heart rate variability is limited.

One limitation of the current study is that the population was enrolled retrospectively. Nevertheless, the scan protocol was homogenous in the study population and the two groups that were derived from it were also homogeneous. Another limitation is related to the fact that very high HR (e.g. >80 bpm) were not present in the population.

Despite improvements of the temporal resolution at higher heart rates, we have shown that diagnostic accuracy is significantly higher at lower HR, and deteriorates at higher HR. The use of negative cronotropic agents to temporarily reduce HR before the data acquisition remains still a cornerstone of MSCT-CA, especially when the entire coronary tree needs to be visualized. Further development aimed at a reduction of rotation time may progressively reduce the need of negative cronotropic agents.

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