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Low-dose CT coronary angiography with a novel IntraCycle motion-correction algorithm in patients with high heart rate or heart rate variability

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Aims Motion artefacts due to high or irregular heart rate (HR) are common limitations of coronary computed tomography (CT) angiography (CCTA). The aim of the study was to evaluate the impact of a new motion-correction (MC) algorithm used in conjunction with low-dose prospective ECG-triggering CCTA on motion artefacts, image quality, and coronary assessability.

Methods and results Among 380 patients undergoing CCTA for suspected CAD, we selected 120 patients with pre-scanning HR $>$70 bpm or HR variability (HRv) $>$10 bpm during scanning irrespective of pre-scanning HR or both conditions. In patients with pre-scanning HR $<$65 or $\geq$65 bpm, prospective ECG triggering with padding of 80 ms (58 cases) or padding of 200 ms (62 cases) was used, respectively. Mean pre-scanning HR and HRv were 70 $\pm$ 7 and 10.9 $\pm$ 4 bpm, respectively. Overall, the mean effective dose was 3.4 $\pm$ 1.3 mSv, while a lower dose (2.4 $\pm$ 0.9 mSv) was measured for padding of 80 ms. In a segment-based analysis, coronary assessability was significantly higher ($P < 0.0001$) with MC (97%) when compared with standard (STD) reconstruction (81%) due to a significant reduction ($P < 0.0001$) in severe artefacts (54 vs. 356 cases, respectively). An artefact sub-analysis showed significantly lower number of motion artefacts and artefacts related to chest movement with MC (16 and 4 cases) than with STD reconstruction (286 and 24 cases, $P < 0.0001$ and $P < 0.05$, respectively). The number of coronary segments ranked among those of excellent image quality was significantly higher with MC ($P < 0.001$).

Conclusions The MC algorithm improves CCTA image quality and coronary assessability in patients with high HR and HRv, despite low radiation dose.

Keywords Motion correction algorithm • Computed tomography coronary angiography • Radiation exposure

Introduction

Although a good diagnostic performance of coronary computed tomography angiography (CCTA) has been demonstrated, beam-hardening artefacts resulting from calcified plaques and motion artefacts due to high heart rate (HR) and HR variability (HRv) during scanning may significantly reduce CCTA diagnostic performance.[1,2] Previous studies demonstrated that high HR and HRv are the primary causes of coronary artery unassessability because of motion artefacts.[2–5] Therefore, CCTA guidelines[6] encourage the use of HR-control drugs, including beta-blockers and ivabradin before scanning.[7] However, contraindications to these drugs or

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lack of response to treatment make it impossible to obtain ideal HR values in a sizable number of patients. For this reason, several technologies have been introduced in clinical practice for improving diagnostic performance in high HR patients. They include dual-source computed tomography (CT), high-pitch CT, and 320-detector row CT.[8–10] Lately, a vendor-specific motion-correction (MC) algorithm (GE Healthcare, Waukasha, WI, USA) has been developed with the aim of compensating for coronary motion blurring. To our knowledge, only one previous study assessed the diagnostic performance of the new MC algorithm in conjunction with retrospective ECG-triggering CCTA in a small patient population referred for transcatheter aortic valve implantation.[11] The primary aim of our study was to evaluate the impact of the MC algorithm, when compared with standard (STD) reconstruction, on motion artefacts, image quality, and coronary assessability of low-dose CCTA performed with prospective ECG triggering in a large patient population with suspected coronary artery disease (CAD). Moreover, as secondary aim, we evaluated the diagnostic accuracy of CCTA performed with MC algorithm and STD reconstruction in comparison with invasive coronary angiography (ICA) as gold standard imaging technique.

Methods

Study population

Between September 2012 and April 2013, 410 consecutive patients undergoing CCTA for suspected CAD (chest pain and multiple cardiovascular risk factors in 135, new onset chest pain in 142 and unconclusive or equivocal stress test in 133) were considered for inclusion in this study. Exclusion criteria were contraindications to contrast medium, impaired renal function (creatinine clearance <60 mL/min), inability to sustain a 15-s breath-hold and cardiac arrhythmias (atrial fibrillation or flutter, severe ventricular arrhythmias). A total of 30 patients were excluded due to breath-holding inability (6 patients), impaired renal function (15 patients), and cardiac arrhythmias (9 patients). In the remaining 380 patients, in the case of resting HR >65 bpm before CCTA, metoprolol was intravenously administered with a titration dose up to 25 mg to achieve a target HR of ≤65 bpm. Among the 380 patients, only those with pre-scanning HR >70 bpm after metoprolol administration or HRv >10 bpm during the scan irrespective of HR before scanning or with both these conditions were considered for analysis. Therefore, the analytic study population consisted of 120 patients. Pre-test probability of CAD was determined using the Diamond and Forrester method.[12] Of the 120 patients prospectively enrolled, 64 patients underwent to ICA in the 6 months following CCTA. Among the 64 patients, we performed a complete CCTA diagnostic accuracy analysis vs. ICA in the 39 patients who were referred for an otherwise clinically indicated non-emergent ICA regardless of the CCTA results, in order to exclude from the diagnostic accuracy analysis the ICA likely CCTA driven. However, in order to not ignore the impact on the CCTA diagnostic accuracy of the remaining 25 patients, we also evaluated the diagnostic accuracy of CCTA vs. ICA in a patient-based analysis in all the 64 patients. Written informed consent was obtained from all patients, and the study protocol was approved by the institutional ethics committee.

Imaging protocol

In all patients, CCTA was performed with a Discovery HDCT scanner (GE Healthcare, Milwaukee, WI, USA) using the following parameters: slice configuration 64 × 0.625 mm, gantry rotation time 350 ms, prospective ECG-triggering (SnapShot Pulse, GE Healthcare, Milwaukee, WI, USA).[13] Moreover, in all patients, the coronary calcium score (CCS) was assessed with a dedicated software application (CaScore Package; GE Healthcare) and the overall Agatston score was recorded. In patients with HR of <65 bpm before scanning and after metoprolol, we used prospective ECG-triggering with padding of 80 ms, corresponding to two distinct mid-diastolic phases using a reconstruction interval of 10% (i.e. 70 and 80% of R-R cycle). In patients with HR ≥ 65 bpm before scanning and after metoprolol, we used prospective ECG triggering with padding of 200 ms, corresponding to four distinct diastolic phases (i.e. 45–75% of R-R cycle). Irrespective of the padding used for the acquisition, in case of HR ≤ 70 bpm before scanning and after metoprolol, only patients with HRv > 10 bpm during the scan were used for analysis, as previously described (58 patients with padding 80, 62 patients with padding 200). The post-processing algorithm statistical iterative reconstruction (ASIR) was employed for image reconstruction.[14] A body mass index (BMI)-adapted scanning protocol was used: BMI < 20 kg/m^2, tube voltage and tube current of 100 kVp and 500 mA, respectively; 20 ≤ BMI < 25 kg/m^2, 100 kVp and 550 mA; 25 ≤ BMI < 30 kg/m^2, 100 kVp and 600 mA; 30 ≤ BMI < 35 kg/m^2, 120 kVp, and 650 mA. All patients received an 80-mL bolus of Iomeprol-400 (Iomeron 400 mg/mL, Bracco, Milan, Italy) through an antecubital vein at an infusion rate of 5 mL/s, followed by 50 mL of saline solution at same flow rate.

MDCT image reconstruction and analysis

STD reconstructions were generated for two distinct mid-diastolic phases (i.e. 70 and 80% of R-R cycle) when padding of 80 ms was used and for four distinct diastolic phases (i.e. 45–75% of R-R cycle) when padding of 200 ms was used, as typically done in standard CCTA studies. To generate MC reconstructions, raw CCTA data were processed off-line using an advanced coronary MC technique. Briefly, after cardiac multiphase reconstruction and automated coronary vessel tracking, the MC algorithm (Snapshot Freeze, GE Healthcare) uses information from adjacent cardiac phases within a single cardiac cycle to characterize vessel motion (both path and velocity), determine actual vessel position at the prescribed target phase, and adaptively compensate for any residual motion at that phase. This approach works on a per-vessel and per-segment basis to correct for differing degrees of motion for each voxel of coronary vessel.[11] The MC images were also reconstructed at two distinct end-diastolic phases or four distinct diastolic phases in case of padding of 80 or 200 ms, respectively. Two experienced readers performed a blinded analysis of all studies for both MC and STD reconstructions in terms of image quality, presence of artefacts, CCTA assessability in a segment-based model, and presence of significant stenoses, defined as narrowing of the coronary lumen exceeding 50%. For any disagreement on data analysis between the two readers, consensus agreement was achieved. Both readers had 10 years of experience and were Level III equivalent.[15] Studies were evaluated with a standard 18-segment model accordingly with the Society of Cardiovascular Computed Tomography guidelines.[6] In all patients, CCTA data sets were analysed using a vessel analysis software (CardioQ3 Package, GE Healthcare). For each coronary segment, image quality was ranked as excellent (no artefacts), good (minor artefacts, good diagnostic quality), adequate (moderate artefacts, acceptable for routine clinical diagnosis), or poor/non-evaluable/non-diagnostic (severe artefacts impairing accurate evaluation, segment classified as non-evaluable) .[16,17] Segments classified as excellent, good, and adequate were considered evaluable/diagnostic. The causes of impaired image quality were classified as beam-hardening artefacts generated by large coronary calcifications, motion artefacts related to high HR or HRv during scanning, artefacts related to chest movement or non-compliance with breath holding, slice misalignment artefacts due to premature heart beats during the scan and artefacts due to impaired signal/image-to-noise ratio.

Radiation dose parameters

The effective dose (ED) of CCTA was calculated according to the European Working Group for Guidelines on Quality Criteria in CCTA.[18] The dose-length product (DLP), defined as total radiation energy absorbed by patient's body, was measured in mGy × cm in each patient. The ED was calculated as the DLP times a conversion coefficient for the chest ($K = 0.014$ mSv/mGy cm).[18]

Invasive coronary angiography

Conventional ICA was performed by standard technique. Angiograms were analysed with a quantitative coronary angiography software (QantCor, QCA, Pie Medical Imaging, Maastricht, the Netherlands) by two interventional cardiologists with 20 years of experience blinded to CCTA results. The severity of coronary stenoses was quantified in two orthogonal planes, and a stenosis >50% was classified as significant.

Statistical analysis

Statistical analysis was performed using SPSS 13.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean ± SD, and discrete variables as absolute numbers and percentages. Paired Student's *t*-test was used to test differences in continuous variables between the two groups, and the χ^2 test was used to study differences regarding categorical data. $P < 0.05$ was considered statistically significant. Coronary assessability (number of coronary segments evaluable/total number of coronary segments) was calculated. An estimation of accuracy [sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)] was calculated on a segment-based model and on a patient-based model, based on a 50% threshold against the standard of ICA findings. On a patient-based analysis, patients with at least one detected stenosis >50% in a native coronary artery were classified as 'positive'. We also perform a segment-based analysis, including all segments for analysis with non-evaluable segments censored as 'positive'. The diagnostic performance between the two groups was compared using the pairwise McNemar's test. The intra- and inter-observer variability for the assessment of image quality and for the detection of significant disease on CCTA images were tested with a *K* test. As concern the power calculation of the sample size, assuming a 20% frequency of severe artefacts in the segment-based analysis with the STD evaluation, a sample size of at least 1800 evaluable coronary segments yielded more than 90% power to deem as significant (with $P < 0.05$) a reduction of 5% (from 20 to 15%) with MC algorithm.

Results

Clinical characteristics of study patients and CCTA data

Clinical characteristics, HR before and during scanning, CCTA CAD extension and ED are reported in *Table 1*. The mean echocardiographic left ventricle ejection fraction (LVEF) was 55%, without patients with an LVEF of ≤50%. The mean pre-test likelihood of CAD was intermediate (38%). Thus, our study patients represent the typical population with low-to-intermediate CAD likelihood usually referred for CCTA with an appropriate indication. Accordingly, prevalence of obstructive CAD was 33 and 10% of patients had only multivessel CAD. The mean pre-scanning HR and mean HRv and maximum HR during scanning were high (70 ± 7, 10.9 ± 4, and 79 ± 10 bpm, respectively). The mean CCS was 253 ± 153. The mean overall ED of CCTA was 3.4 ± 1.3 mSv, while a lower dose (2.4 ± 0.9 mSv) was measured in patients with padding 80 msec.

Table 1 Clinical characteristics of study patients and CCTA data

Patients (number)	120
Age, (years)[a]	61 ± 10
Male/Female	84/36
BMI[a]	26 ± 3.6
Hypertension (≥140/90 mmHg)	56
Hypercholesterolaemia (>200 mg/dL)	45
Diabetes mellitus	12
Current smoking	36
Family history of CAD	32
Echocardiographic LVEF	55.5 ± 3.1
Serum creatinine (mg/dL)[a]	1 ± 0.2
Pre-test likelihood of CAD	36%
Metoprolol	
Acute (intravenous)	90
Chronic (oral administration)	47
Average dose (mg)	
Acute[a]	14.2 ± 7.7
Chronic[a]	75 ± 12
HR before study (bpm)[a]	70 ± 7.1
HRv during study (bpm)[a]	10.9 ± 4.4
HR during study (bpm)[a]	74 ± 8.2
Maximum HR during study (bpm)[a]	79 ± 10.8
Agatston score[a]	253 ± 153
CAD extension (>50% stenosis)	
0-vessel, *n* (%)	80 (67%)
1-vessel, *n* (%)	28 (23%)
2-vessel, *n* (%)	12 (10%)
3-vessel, *n* (%)	0 (0%)
Effective dose (mSv)	
CCS	0.85 ± 0.08
CCTA padding 80	2.38 ± 0.92
CCTA padding 200	4.34 ± 1.43
CCTA all patients	3.42 ± 1.26

CAD, coronary artery disease; HR, heart rate; HRv, heart rate variability; LVEF, left ventricle ejection fraction.
[a]Data are expressed as mean ± standard deviation.

Artefacts, image quality, and coronary assessability

Coronary assessability, prevalence of artefacts and, specifically, of severe artefacts impairing adequate evaluation of coronary lumen (segment classified as unevaluable) for STD and MC reconstruction are reported in *Table 2*. In a segment-based analysis, the overall coronary assessability was significantly higher ($P < 0.0001$) using the MC algorithm when compared with STD reconstruction (97 vs. 81%, respectively) due to a significantly lower number of severe artefacts (54 vs. 356 segments, $P < 0.0001$). In a sub-analysis of severe artefacts, we found a significantly lower number of severe motion artefacts and severe artefacts related to chest movement with MC (16 and 4 segments) than with STD reconstruction (286 and 24 segments, $P < 0.0001$ and $P < 0.05$, respectively). The overall number of artefacts was also significantly lower with MC (68 vs. 458 segments,

$P < 0.0001$). Analysing all artefacts, a significantly lower number of motion and slice misalignment artefacts and artefacts related to chest movement were found with MC vs. STD evaluation ($P < 0.0001$, $P < 0.05$ and $P < 0.05$, respectively). In a patient-based analysis, the prevalence of patients with at least one coronary segment classified as non-assessable was significantly lower with MC (38/120 patients, 31%) than after STD reconstruction (94/120 patients, 78%). Differences between MC and STD evaluations in terms of image quality score are reported in *Table 3*. The number of coronary segments with excellent image quality was significantly higher with MC vs. STD reconstruction, while the number of segments with poor image quality was significantly lower with MC vs. STD ($P < 0.001$). The Kappa value for classifying coronary segments as evaluable/diagnostic vs. non-evaluable was 0.97 for intra-observer agreement and 0.94 for inter-observer agreement with the MC evaluation and 0.88 for intra-observer agreement, 0.86 for inter-observer agreement with the STD. *Figure 1* depicts multiple motion artefacts impairing assessment of a right coronary artery and the improvement after MC algorithm. *Figure 2* shows multiplanar reconstructions of a left anterior descending artery with a mixed plaque displaying a severe motion artefact, well corrected by MC, facilitating stenosis detection and assessment.

Table 2 **Comparison of assessability and artefacts between standard reconstruction and MC algorithm**

	No.	Assessability, *n* (%)	Artefacts, *n* (%)	BH (*n*)	MA (*n*)	SM (*n*)	CM (*n*)	S/N (*n*)
Standard								
Coronary segments	1838	1482 (81%)	456 (25%)	39	360	23	31	3
MC algorithm								
Coronary segments	1838	1784 (97%)*	68 (4%)*	32	19*	9†	6†	2
	No.	Assessability *n* (%)	Severe Artifacts *n* (%)	Severe BH (*n*)	Severe MA (N)	Severe SM (*n*)	Severe CM (*n*)	Severe S/N (*n*)
Standard								
Coronary segments	1838	1482 (81%)	356 (19)%	32	286	14	24	0
MC algorithm								
Coronary segments	1838	1784 (97%)*	54 (3%)*	28	16*	6	4†	0

BH, beam-hardening artefacts, presence of high-density artefacts generated by large calcification; CM, artefacts related to chest movement or non-compliance of breath hold; MA, motion artefacts due to high HR or high HRv during study; MC, motion correction algorithm; SM, slice misalignment related to premature ventricular beats; S/N, impaired image signal/image noise ratio.

*$P < 0.0001$ MCA vs. standard; $^{\dagger}P < 0.05$ MCA vs. standard.

Diagnostic accuracy

CCTA diagnostic accuracy in a segment-based analysis (using only evaluable coronaries for the analysis), measured in the 39 patients that underwent to a clinically indicated non-emergent ICA after CCTA, is shown in *Table 4*. Sensitivity, NPV, and accuracy of CCTA were significantly higher with MC than with STD evaluation (82, 98, and 98 vs. 50, 96, and 95%, respectively, $P < 0.05$). *Table 4* also reports a segment-based model using all segments for the analysis, with non-evaluable segments censored as positive. Similarly, CCTA sensitivity, specificity, PPV, and accuracy were significantly higher with MC vs. STD evaluation (98, 86 and 98 vs. 93, 62, and 94%, respectively, $P < 0.01$). In a patient-based analysis, sensitivity, specificity, NPV, PPV, and accuracy were 100% with MC evaluation and 76, 87, 78, 87, and 79%, respectively, with STD assessment. Sensitivity, NPV, and accuracy were significantly higher with MC vs. STD evaluation ($P < 0.01$). A patient-based analysis, performed in all 64 patients underwent to ICA in the 6 months following CCTA, including the remaining 25 patients with CCTA positive for at least one >50% stenosis, showed sensitivity, specificity, NPV, PPV, and accuracy of 100, 94, 100, 98, and 98%, respectively, with MC evaluation and 90, 78, 78, 90, and 86%, respectively, with STD assessment. Sensitivity, NPV, and accuracy were significantly higher with MC vs. STD evaluation ($P < 0.05$). The Kappa value for detecting significant coronary artery stenoses with CCTA was 0.90 for intra-observer agreement and 0.87 for inter-observer agreement with the MC evaluation and 0.85 for intra-observer agreement, 0.84 for inter-observer agreement with the STD.

Discussion

Although the literature demonstrated good CCTA diagnostic accuracy for significant coronary stenoses detection, impaired image quality due to high HR, and radiation exposure are still recognized limitations of this imaging tool. Indeed, high HR and HRv during

Table 3 Comparison of image quality score between standard reconstruction and MC algorithm

	No.	Excellent, *n* (%)	Good, *n* (%)	Adequate, *n* (%)	Poor, *n* (%)
Standard					
Coronary segments	1838	845 (46%)	301 (16%)	336 (18%)	356 (19%)
MC algorithm					
Coronary segments	1838	1120 (61%)*	365 (20%)	299 (16%)	54 (3%)*

*$P < 0.001$ MC algorithm vs. standard.

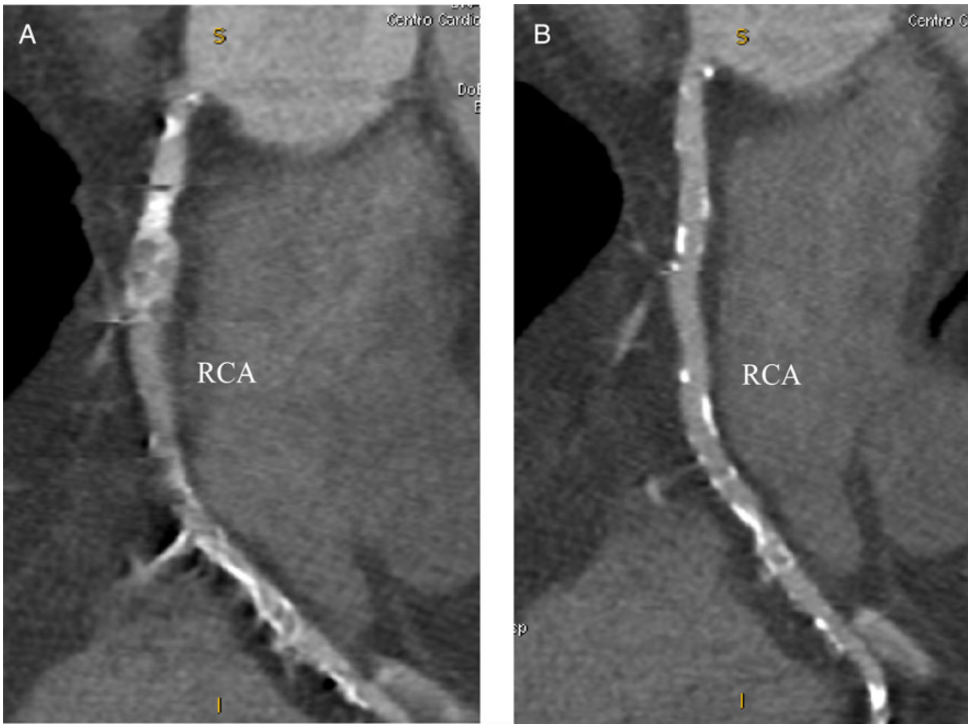

Figure 1 Right coronary artery imaging by prospective ECG-triggering (40% of R-R cycle) CCTA performed with standard reconstruction (*A*) and motion-correction algorithm (*B*) in a patient with heart rate variability of 21 bpm (from 67 to 88 bpm) during the scan. Note the marked correction of multiple motion artefacts achieved with the new algorithm.

scanning have been found to be the main reasons of coronary artery unassessability, while motion artefacts alone account for up to 12% of coronary segments considered not assessable.[2–5] Regarding radiation exposure, prospective ECG-triggering for image acquisition and the ASIR algorithm for image reconstruction have been shown to allows a significant reduction of CCTA effective dose, without impairing diagnostic accuracy.[13,14,19,20] To the best of our knowledge, our study, together with a recent study of Fuchs *et al.*, is the first to evaluate the impact of a new MC algorithm, in conjunction with prospective ECG-triggering and ASIR, on CCTA motion artefacts, image quality, and coronary assessability. Our aim was to assess whether this could improve image quality at high HR despite low radiation exposure. The main findings of our study are: (i) post-processing with the MC algorithm significantly improves coronary assessability when compared with STD reconstruction due to a significant reduction of severe artefacts with a marked improvement of image quality score; (ii) these results were obtained with low radiation exposure (mean ED 3.4 ± 1.3 mSv), which was reduced still further (2.4 ± 0.9 mSv) in patients undergoing scanning with padding of 80 msec. A sub-analysis of severe artefacts showed a significantly lower number of severe motion artefacts and severe artefacts due to chest movement with MC vs. STD reconstruction. Overall, the MC algorithm was able to reduce all artefacts (including all degrees, minor, moderate and severe) and was associated with a significantly lower number of motion and slice misalignment artefacts and artefacts related to chest movement. These results may be explained by the peculiar MC algorithm technology, which is based on characterization of vessel motion (path and velocity). This

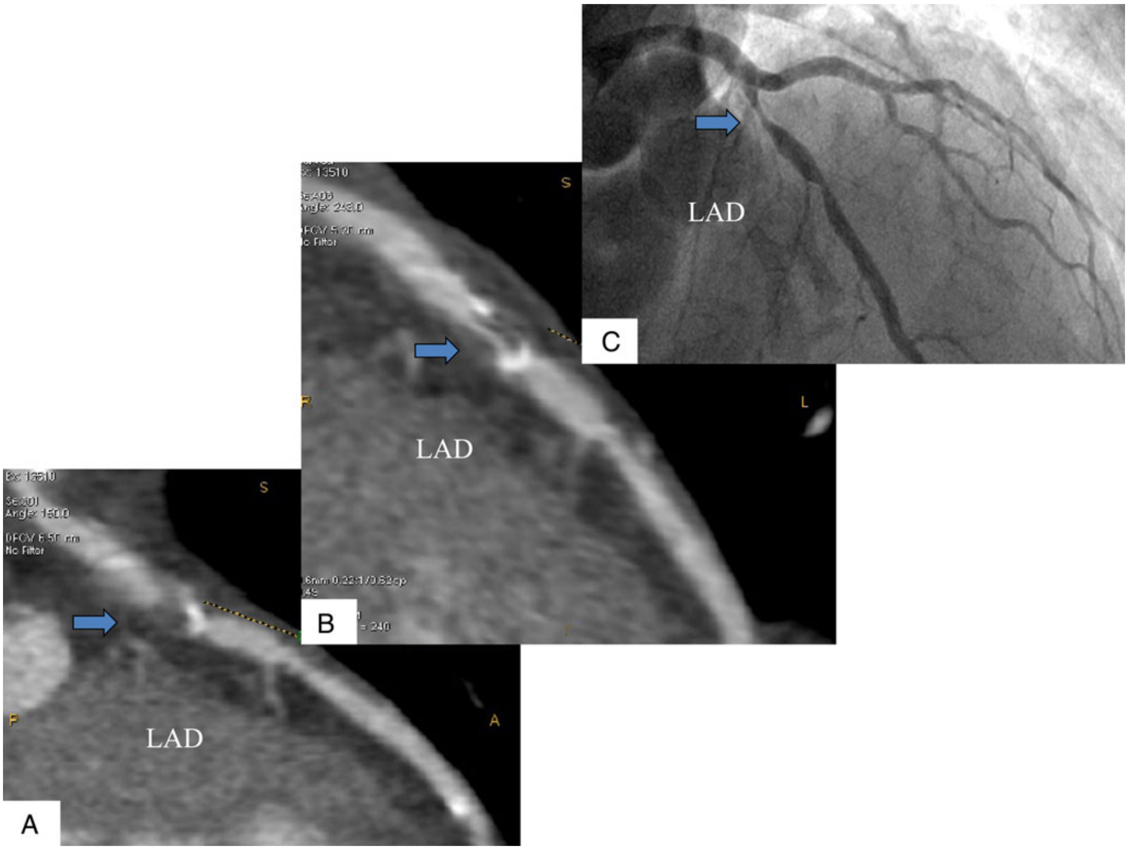

Figure 2 CCTA multiplanar standard reconstruction (50% of R-R cycle) of a left anterior descending coronary artery showing a severe motion artefact due to high heart rate (77 bpm) during the scan impairing the evaluation of a mixed atherosclerotic lesion (*A*, arrow). The MC algorithm allowed artefact correction and appropriate assessment of the coronary stenosis severity (*B*, arrow) that was confirmed by invasive coronary angiography (*C*, arrow).

Table 4 **Comparison of the diagnostic accuracy of CCTA in the two groups: segment-based analysis**

	N	TN	TP	FN	FP	Se (95% CI)	Sp (95% CI)	NPV	PPV (95% CI)	Accuracy (95% CI)
Segment-based analysis (using evaluable segments only)										
Standard	448	412	16	16	4	50% (45–55)*	99% (98–100)	96.3% (94–98)*	80% (62–97)	95.5% (94–97)*
MC algorithm	512	446	36	8	2	81.8% (78–85)	99.6% (99–100)	98.3% (97–99)	94.7% (88–100)	98% (97–99)
	N	TN	TP	FN	FP	Se (95%CI)	Sp (95%CI)	NPV (95%CI)	PPV (95%CI)	Accuracy (95%CI)
Segment-based analysis (using all segments, with not evaluable segments censored as positive)										
Standard	526	412	26	16	72	61.9% (57–66)$^{\psi}$	85.1% (82–88)$^{\psi}$	96.3% (94–98)	26.5% (18–35)$^{\psi}$	83.3% (80–86)$^{\psi}$
MC algorithm	526	466	36	8	16	81.8% (78–85)	96.7% (95–98)	98.3% (97–99)	69.2% (57–82)	95.4% (94–97)

FN, false negative; FP, false positive; NPV, negative predictive value; PPV, positive predictive value; Se, sensitivity; Sp, specificity; TN, true negative; TP, true positive.
*$P < 0.05$ Standard vs. MC algorithm; $^{\psi}P < 0.01$ Standard vs. MC algorithm.

allows determining the actual vessel position at the prescribed target phase and adaptively compensating for any residual motion at that phase, with a specific effect on motion artefacts due to high HR-HRv. Because this approach characterizes motion within a single heart cycle, it is less susceptible to beat-to-beat inconsistencies, heart period, or gantry period resonance points, which can limit multisector (i.e. multiple heart cycle) reconstruction.[11] The favourable effect of the MC algorithm, in terms of a significant reduction of artefacts due to either chest movement or slice misalignment caused by premature heart beat, is not surprising. Indeed, these artefacts are not related to HR or HRv, but are caused by anomalous or excessive coronary motion during the scan due to chest movement or premature cardiac beat, respectively. All together, the MC algorithm features contributed to markedly improve CCTA image quality, and in particular to achieve a statistically significant increase of the number of coronary segments ranked excellent in image quality. Our findings are consistent with the results of a recently published study of Fuchs *et al.*[21] that evaluated the impact of MC algorithm on image quality and interpretability of low-dose CCTA performed with prospective ECG-triggering, showing a significant improvement of both image quality and overall coronary evaluability (from 78 to 88%). However, the HR conditions of the latter are more favourable in comparison with the present study, in terms of lower mean maximum HR during scanning (73 bpm) and HRv (3 bpm only). Moreover, in the subgroup of patients who performed a clinically indicated non-emergent ICA regardless of the CCTA results, the diagnostic accuracy of CCTA was significantly improved with MC than with STD evaluation in both per-segment and per-patient analysis. As concern radiation exposure, the improvement of coronary assessability in patients with high HR and HRv was obtained with a mean ED of 3.4 mSv only. This is a clinically relevant achievement and adds further data to the previous study by Leipsic *et al.* which was the first to evaluate the coronary arteries with MC algorithm.[11] Indeed, using retrospective ECG-triggering, they demonstrated results similar to ours in terms of image quality and coronary assessability improvement but with an associated radiation exposure of 13.2 mSv. This value is higher than that reported in previous studies performed with different scanners (dual-source CT, high-pitch CT, 320-detector CT) in the setting of high HR patients.[8–10] Therefore, this novel MC approach is also advantageous from a dose perspective, because it can be applied to both retrospective and prospective-triggered CCTA. Moreover, as opposed to the multisector technique, the new approach simply requires a relatively small window of data within one heart cycle to support multiphase reconstruction for subsequent MC processing.[11]

In conclusion, in a subset of patients with high pre-scanning HR, and elevated HRv and high mean maximum HR during scanning, CCTA with MC reconstruction achieved good image quality, very high coronary assessability and was associated with low radiation exposure.

Study limitations

In interpreting these data, some limitations should be considered. First, this is a single-centre study that enrolled a relatively small population. Therefore, our results may not necessarily reflect the patient population of other centres. Second, because it was not the primary aim of our study, we did not compare the diagnostic accuracy of CCTA with MC algorithm in all study population (120 patients) but only in the subgroup of 39 patients who underwent to ICA in the 6 months following CCTA in whom ICA was otherwise clinically indicated, regardless of the CCTA findings. Although further 25 patients underwent to ICA in the 6 months following a CCTA positive for at least one >50% stenosis, we did not include the latter in the main diagnostic accuracy analysis because they underwent to ICA on the basis of CCTA findings only, without a clinical indication. Third, on the basis of our standard preparation for CCTA, our patients were pre-treated with intravenous metoprolol in case of resting HR >65 bpm before CCTA. Therefore, although only patients with high HRv during scanning or patients with HR immediately before scanning >70 bpm were considered for the analysis, patients with very high HR without pretreatment with beta-blockers were not included in the study. For all these reasons, an international multicentre study will be needed to test the diagnostic performance of CCTA with the MC algorithm as compared to ICA in a larger cohort of patients without pre-treatment with β-blockade. In this regard, the rationale and design of the ViCTORY (Validation of an Intracycle CT Motion CORrection Algorithm for Diagnostic AccuracY) trial, which has these features, has been recently published.[22] Fourth, we have to mention that MC is a post-processing algorithm designed to remedy the relatively low temporal resolution of the scanner used in the study (64-slice CT with standard gantry rotation time of 350 ms). However, it is important to note that the latter scanner generation is the most widely used in the clinical practice anywhere.

Conflict of interest: D.A. and G.P. are on speaker bureau of GE Healthcare. G.P. is on speaker bureau of Bayer, HeartFlow and Medtronic.

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IMAGE FOCUS

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Pseudo-aneurism with systolic compressive effect on the left coronary artery: a rare complication after infective endocarditis

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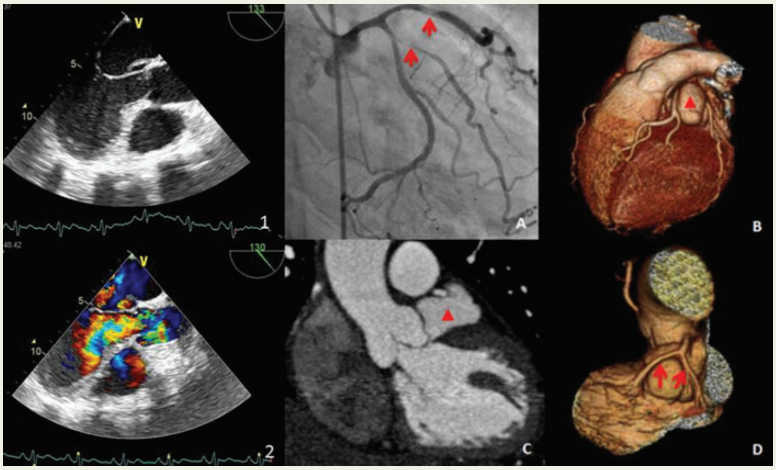

A 54-year-old-female, with a history of diabetes, was admitted with prolonged high fever, prostration, and temporal and spatial disorientation. Complementary study by transoesophageal echocardiography revealed an oscillating 0.4 cm^2 intra-cardiac mass adherent to the left coronary sinus and mild aortic regurgitation. Blood cultures were positive for methicillin-sensitive *Staphylococcus aureus* and the patient commenced antibiotherapy with flucloxacillin for 6 weeks and gentamicin for 5 days. Repeated transoesophageal echocardiography was suggestive of a ruptured abscess and worsening of the aortic regurgitation (moderate aortic regurgitation) (*Panels 1* and *2*). Further investigation with invasive coronary angiography (see Supplementary data online) ruled out obstructive atherosclerotic disease and revealed systolic narrowing of the left main trunk, proximal left anterior descending, proximal left circumflex artery, and 1^{a} left marginal artery, suggestive of extrinsic compression (red arrows in *Panel A*). Computed tomography coronary angiography (CTCA) showed a large cavity (46 × 30 × 24 mm) adjacent to the left coronary sinus, communicating through a narrow neck with the left ventricular outflow tract, just below the aortic annulus at the level of the mitral-aortic curtain, consistent with pseudo-aneurysm, that appeared to exert compressive systolic effect on the left coronary artery (pseudo-aneurysm—red triangles in *Panel B and C*; compressive systolic effect—red arrows in *Panel D*). The patient was referred to the Department of Cardiac Surgery. During surgery, the presence of a pseudo-aneurysm at the level of the mitral-aortic curtain was confirmed, and the entrance orifice was closed with a bovine pericardium patch. In the follow-up visit, the patient was asymptomatic.

Supplementary data are available at *European Heart Journal – Cardiovascular Imaging* online.