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BRIEF ARTICLE

Low-dose CT coronary angiography using iterative reconstruction with a 256-slice CT scanner

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Abstract

AIM: To explore whether computer tomography coronary angiography (CTCA) using iterative reconstruction (IR) leads to significant radiation dose reduction without a significant loss in image interpretability compared to conventional filtered back projection (FBP).

METHODS: A consecutive series of 200 patients referred to our institution to undergo CTCA constituted the study population. Patients were sequentially assigned to FBP or IR. All studies were acquired with a 256-slice CT scanner. A coronary segment was considered interpretable if image quality was adequate for evaluation of coronary lesions in all segments ≥ 1.5 mm.

RESULTS: The mean age was 56.3 ± 9.6 years and 165 (83%) were male, with no significant differences between groups. Most scans were acquired using prospective ECG triggering, without differences between groups (FBP 84% *vs* IR 82%; P = 0.71). A total of 3198 (94%) coronary segments were deemed of diagnostic quality. The percent assessable coronary segments was similar between groups (FBP 91.7% ± 4.0% *vs* IR 92.5% ± 2.8%; P = 0.12). Radiation dose was significantly lower in the IR group (2.8 ± 1.4 mSv *vs* 4.6 ± 3.0 mSv; P < 0.0001). Image noise (37.8 ± 1.4 HU *vs* 38.2 ± 2.4 HU; P = 0.20) and signal density (461.7 ± 51.9 HU *vs* 462.2 ± 51.2 HU; P = 0.54) levels did not differ between FBP and IR groups, respectively. The IR group was associated to significant effective dose reductions, irrespective of the acquisition mode.

CONCLUSION: Application of IR in CTCA preserves image interpretability despite a significant reduction in radiation dose.

Key words: Low-dose computer tomography coronary angiography; Iterative reconstruction

Core tip: A consecutive series of 200 patients referred to our institution to undergo computer tomography coronary angiography (CTCA) were sequentially assigned to filtered back projection (FBP) or iterative reconstruction (IR). The percent assessable coronary segment was similar between groups. Radiation dose was significantly lower in the IR group. Image noise and signal density levels did not differ between FBP and IR groups. The IR group was associated to significant effective dose reductions, irrespective of the acquisition mode. Our findings suggest that application of IR in CTCA preserves image interpretability despite a significant reduction in radiation dose.

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INTRODUCTION

With a large body of evidence accumulated within the past decade, computer tomography coronary angiography (CTCA) has earned a role in diagnostic algorithms of patients at intermediate risk of coronary artery disease[1-3]. However, the high effective radiation dose related to CTCA scans remains a limitation and has been the foundation of most of the criticisms received. Indeed, the recently published Prospective Multicenter Study on Radiation Dose Estimates of Cardiac CT Angiography I and Ⅱ (PROTECTION I and Ⅱ) reported a wide range of effective radiation doses according to the acquisition technique, therefore encouraging the application of dose reduction techniques such as prospective ECG-triggering, tube current modulation, and/or high pitch helical scanning[4,5] .

In the past few years, iterative reconstruction (IR), an alternative to conventional image reconstruction filtered back projection (FBP), has gained interest in order to attempt to attenuate the increase in image noise related to tube current modulation and low tube voltage acquisitions[6]. IR has the ability to reduce image noise by iteratively comparing the images obtained to a modeled projection. Thus, it can be used to reconstruct images with similar image quality despite a significant reduction in tube current, resulting in a reduction in overall radiation dose. This has particular interest in CTCA studies in order to attempt to overcome the main limitation of the technique for cardiovascular purposes[7-11]. The aim of our investigation was to explore whether CTCA using IR can achieve a substantial effective dose reduction without a significant loss in image interpretability.

MATERIALS AND METHODS

The present was a single-centre, investigator-driven, observational, prospective study that aimed to explore whether IR of CTCA scans leads to a significant radiation dose reduction without impairment of image interpretability. For that purpose, a consecutive series of patients referred to our institution to undergo CTCA constituted the study population. Patients were assigned to FBP or, sequentially, to IR. Inclusion criteria included adult patients ($\geqslant$ 18 years), without a history of contrast related allergy, renal failure, or hemodynamic instability, that were referred to CTCA to exclude coronary artery disease. Baseline heart rate, arrhythmia, or body mass index did not impact the enrollment decision. Patients with pacemakers or implantable devices were excluded. The institution's Ethics Committee approved the study protocol, which complied with the Declaration of Helsinki, and written informed consent was obtained from all patients.

CTCA acquisition

All studies were acquired with a 256-slice CT scanner (Philips Healthcare, Cleveland). Patients with a heart rate of > 65 beats/min received 50 mg oral metoprolol one hour prior to the scan or 5 mg intravenous propralonol if needed in order to achieve a target heart rate of less than 60 bpm. A dual phase protocol with 70 mL of iobitridol (Xenetix 350TM, Guerbet, France) followed by a 50-mL saline flush was injected through an arm vein after administration of 0.4 mg of sublingual nitroglycerin. A bolus tracking technique was used to synchronize the arrival of contrast at the level of the coronary arteries with the start of the scan. Scanning parameters were as follows. Rotation time 270 ms; tube voltage in FBP with body mass index (BMI) < 25 kg/m^2: 100 kV, BMI > 25 kg/m^2: 120 kV; tube voltage in IR with BMI < 20 kg/m^2: 80 kV, BMI 20-30 kg/m^2: 100 kV, BMI > 30 kg/m^2: 120 kV. Tube current was adjusted according to the scan protocol and BMI (range 170-1200 mA). Prospective ECG-triggering axial scanning was used when possible based on heart rate. ECG-based tube current modulation was performed for all helical studies.

CTCA analysis

Image analysis and coronary segment interpretability were assessed by consensus of two experienced level 3-certified coronary CTA physicians using dedicated software (Comprehensive Cardiac Analysis, Philips Healthcare) on a CT workstation (Brilliance Workspace, Philips Healthcare, Cleveland, OH, United States), blinded to the acquisition mode. A coronary segment was considered interpretable if image quality was adequate for evaluation of coronary lesions in all segments $\geqslant$ 1.5 mm.

Slice CT images were reconstructed preferably at end diastole using axial planes, multiplanar reconstructions, and maximum intensity projections at 1 mm slice thickness. Image noise and signal density for both FBP and IR (iDoseTM, level 5, Philips Healthcare) reconstruction algorithms were evaluated. The signal density and noise were evaluated using standardized regions of interest of 10 mm^2 within the aortic root at the level of the left main coronary artery on axial images, being the signal density defined as the mean Hounsfield units and the signal noise as the mean standard deviation of the signal density. Studies were evaluated using the previously reported 17-segment model, and effective dose radiation estimates were calculated using the dose-length product[12].

Statistical analysis

Discrete variables are presented as counts and percentages. Continuous variables are presented as mean ± SD, or median (25th, 75th percentile) for variables with non-Gaussian distribution. Comparisons between groups were performed using independent Student's t test, or χ^2 tests as indicated. We explored correlations between continuous variables using Pearson correlation coefficients. A two-sided P value of less than 0.05 indicated statistical significance. Statistical analyses were performed with the use of SPSS software, version 13.0 (Chicago, IL, United States).

RESULTS

A consecutive series of 200 patients referred to undergo CTCA constituted the study population (FBP, n = 100) and (IR, n = 100). The mean age was 56.3 ± 9.6 years

Table 1 Demographical characteristics, acquisition parameters, radiation dose and image quality

	FBP	IR	*P* value
Age (yr)	55.6 ± 9.1	56.0 ± 10.1	0.67
Male	85 (85)	80 (80)	0.35
Body mass index (kg/m^2)	27.2 ± 2.7	26.3 ± 3.4	0.03
Body mass index ≥ 30	15 (15)	13 (13)	0.68
Heart rate (bpm)	58.3 ± 7.0	58.2 ± 6.4	0.88
Acquisition technique			
Prospective (axial)	84 (84)	82 (82)	0.71
Retrospective (helical)	16 (16)	18 (18)	
Tube voltage (kV)	119.0 ± 4.4	109.0 ± 10.4	< 0.0001
Percent 80-100 kV	5 (5)	54 (54)	< 0.0001
mAs in prospective	203.1 ± 15.4	195.7 ± 26.8	< 0.0001
mAs in helical	943.2 ± 119.5	870.1 ± 122.8	< 0.0001
Radiation dose (mSv)			
Total	4.6 ± 3.0	2.8 ± 1.4	< 0.0001
Prospective (axial)	3.4 ± 2.4	2.4 ± 0.7	< 0.0001
Retrospective (helical)	10.3 ± 3.9	5.2 ± 1.6	< 0.0001
Image quality			
Attenuation level (HU)	461.7 ± 51.9	462.2 ± 51.2	0.54
Image noise (HU)	37.8 ± 1.4	38.2 ± 2.4	0.20
Signal to noise ratio	12.2 ± 1.4	12.1 ± 1.4	0.28
Coronary assessment (%)	91.7 ± 4.0	92.5 ± 2.8	0.12

Data are expressed as absolute numbers (percentage) or mean ± SD. FBP: Filtered back projection; IR: Iterative reconstruction.

and 165 (83%) were male, with no significant differences between groups. The mean heart rate was 58.3 ± 7.0 bpm for the FBP group and 58.2 ± 6.4 bpm for the IR group (*P* = 0.88). Patients assigned to IR had a significantly lower body mass index (26.3 ± 3.4 kg/m^2 *vs* 27.2 ± 2.7 kg/m^2; *P* = 0.03), despite both groups had similar proportion of patients with BMI ≥ 30 kg/m^2 (Table 1). Most scans were acquired using prospective ECG triggering, without difference between groups (FBP 84% *vs* IR 82%; *P* = 0.71).

A total of 3198 (94%) coronary segments were deemed of good diagnostic quality. The percent of assessable coronary segments was similar between groups (FBP 91.7% ± 4.0% *vs* 92.5% ± 2.8%; *P* = 0.12). Image noise (37.8 ± 1.4 HU *vs* 38.2 ± 2.4 HU; *P* = 0.20) and signal density (461.7 ± 51.9 HU *vs* 462.2 ± 51.2 HU; *P* = 0.54) levels did not differ between FBP and IR groups, respectively. The median effective radiation dose was 3.35 mSv (interquartile range 2.45-3.35). The IR group was associated to significant effective dose reductions, irrespective of the acquisition mode (helical or axial). Prospective scans with IR exhibited the least radiation doses (Table 1).

We found no significant relationships between radiation dose and the percent of interpretable segments (*r* = -0.01, *P* = 0.85). In turn, we found a significant, albeit weak, correlation between the effective radiation dose (mSv) and the signal to noise ratio (*r* = 0.25, *P* < 0.001), as well as between the mA and the signal to noise ratio (*r* = 0.31, *P* < 0.001).

DISCUSSION

In the past decade, CTCA has rapidly emerged as a non-invasive diagnostic tool with the ability to identify obstructive coronary disease, and has gained a role in different risk stratification and diagnostic algorithms. Moreover, it has demonstrated a significant prognostic value independent of traditional risk factors and functional tests[13-17]. Notwithstanding, one of the main challenges of CTCA is the relatively high radiation dose related to the technique[18-20]. Several different strategies have been proposed in order to attempt to decrease effective radiation dose, including tube modulation and prospective (axial) scanning[21-24]. One of the latest developments aimed at lowering dose radiation is IR.

The main finding of our investigation was that compared to conventional FBP, IR in CTCA preserved image interpretability despite a significant reduction in radiation dose. Compared to FBP, IR achieved a 50% dose reduction in helical scans, and a 29% dose reduction in prospective scans, being these results within the range of previous findings in different populations[7]. Such significant reduction might be attributed to the fact that more than half of the IR scans were performed using low voltage (80-100 kV), whereas within the FBP group only 5% of the scans were performed using 100 kV.

Tube current reduction with FBP, a commonly used dose reduction strategy, leads to an increment in image noise. In turn, IR consists in synthesized projection data that are compared to real data in an iterative manner, resulting in a significant reduction of image noise[6]. By reducing image noise, IR allows tube current reduction and, consequently, effective dose reduction. This explains the significantly larger dose reduction in helical compared to axial scans using IR.

A number of limitations must be recognized. Despite patients were sequentially assigned to FBP or IR, randomization was not performed, leading to an expected significantly higher body mass index of FBP patients, although it should be stressed that no significant differences were observed regarding the number of obese patients (BMI ≥ 30 kg/m^2). Furthermore, coronary angiography was not performed in order to evaluate the diagnostic accuracy of each technique; therefore our results should do not allow making assumptions in this regard and should be limited to the image interpretability.

Application of IR in CTCA preserves image interpretability despite a significant reduction in radiation dose, being this mainly attributed to the use of lower voltage scans.

COMMENTS

Background

In the past decade, computer tomography coronary angiography (CTCA) has rapidly emerged as a non-invasive diagnostic tool with the ability to identify obstructive coronary disease, and has gained a role in different risk stratification and diagnostic algorithms. Moreover, it has demonstrated a significant prognostic value independent of traditional risk factors and functional tests.

Research frontiers

Several different strategies have been proposed in order to attempt to decrease effective radiation dose, including tube modulation and prospective (axial) scanning. One of the latest developments aimed at lowering dose radiation is iterative reconstruction (IR).

Innovations and breakthroughs

The main finding of this investigation was that compared to conventional filtered back projection, IR in CTCA preserved image interpretability despite a significant reduction in radiation dose.

Applications

Application of IR in CTCA preserves image interpretability despite a significant reduction in radiation dose, being this mainly attributed to the use of lower voltage scans.

Peer review

In principle, it is a solid work on a state-of-the-art scientific topic. However, there are numerous minor typing errors as well as grammatical mistakes throughout the entire manuscript that need to be corrected prior to possible publication.

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