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Low kV and Low Concentration Contrast Agent with Iterative Reconstruction of Computed Tomography (CT) Coronary Angiography: A Preliminary Study

Authors' Contribution:
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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The aim of this study was to evaluate the image quality and radiation dose of CT coronary angiography (CTCA) with low kV, low concentration contrast agent, and iterative reconstruction.

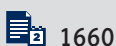
Material/Methods: Ninety cases were randomly divided into 3 groups according to contrast agent concentration: group A 270 mg/ml (100 kV), group B 350 mg/ml (120 kV), and group C 370 mg/ml (120 kV), with 30 cases per group. Tube current was 200–250 mAs. Collimator width was 128×0.6 mm. Rotation speed was 0.27 s. The CT value of the left and right coronary arteries and the ascending aortic root was measured. The SNR and CNR of the images were calculated to evaluate the image quality objectively. The CTDI, DLP, and contrast injection were recorded.

Results: There were no significant differences in sex, age, weight, height, and BMI among the 3 groups. There was no statistically significant difference between left and right coronary artery and ascending aortic root CT value, background noise, SNR, and CNR. Compared to B and C, the ED in group A decreased by about 27.58% and 28.21%, respectively. The total amount of iodine in group A was decreased by about 21.27% and 24.83%, respectively compared with groups B and C.

Conclusions: Low kV and low concentration contrast agent combined with iterative reconstruction for CTCA imaging produced image quality consistent with that of conventional CTCA and significantly reduced the dosage of the radiation and injected iodine.

MeSH Keywords: **Cardiovascular Agents • Radiology Department, Hospital • Tomography Scanners, X-Ray Computed**

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Background

Computed tomography coronary angiography (CTCA) is an effective and noninvasive way to diagnose and evaluate the plaque and stenosis of coronary arteries (CA). However, the potential harm of CT and iodine contrast agent is increasingly concerning. Prospective ECG-gating can remarkably reduce radiation agent dosage [1,2]. Using low kV scanning will further decrease radiation agent dosage and enhance vascular CT value, but has a higher noise-for-image quality. Low-concentration contrast agent reduces the intake of iodine, and possibly decreases its vascular concentration [3]. Iterative reconstruction can increase image quality by reducing noise [4]. This study evaluated the image quality and radiation dose of CT coronary angiography (CTCA) with low kV, low concentration contrast agent, and iterative reconstruction.

Material and Methods

Object

All 90 cases were selected from June 2016 to December 2016, and were underwent CTCA in our hospital. Exclusion criteria were: arrhythmia, heart rate >72 bpm, allergy for contrast agent, hyperthyroidism, renal or heart dysfunction, and body mass index (BMI) >25 kg/m². Postoperative pacemaker and coronary artery bypass grafting were also excluded in order to reduce metal artifact. All patients were randomly divided into 3 groups according to contrast agent concentration: group A 270 mg/ml, group B 350 mg/ml, and group C 370 mg/ml (30 cases per group).

CTCA and image reconstruction

Philips Brilliance 256 iCT was used for scanning. Breathing training was performed before scanning, diagnostic processes, and possible adverse effects of contrast agent. The scanning area of prospective ECG-gating was from 1 cm below the trachea carina to 1 cm below the left diaphragm. The direction was from head to feet. The injecting scheme was: 40 ml normal saline was injected after 50–60 ml contrast agent (4.5–5.5 ml/s); thresholding method; target area was descending aorta; and the trigger CT value of automatic scanning was 100 HU. Parameters of group A were 100 kV and 200–250 mAs. Parameters of group B and C were 120 kV and 200–250 mAs. Iodose3 was used for iterative reconstruction. The collimator width was 128×0.625 mm. The rotational speed of the X-ray tube was 0.27 s/round. The prior time phase center of iterative reconstruction was 75%. Time window width was 10%.

Image analysis and evaluation

The image was then reconstructed and analyzed by Philips EBW (Extended Brilliance Workspace). After volume rendering (VR), multiplanar reconstruction (MPR), curved planar reconstruction (CPR), maximum intensity projection, MIP, the straightened vascular image was matched with the original image. The image quality was valued subjectively and objectively.

Subjective assessment

Segments of CA were defined according to American Heart Association (AHA) criteria. The quality of image was assessed by 2 double-blinded, experienced radiologists. Score standard of evaluation was: 4, no motion artifact, no obvious noise, bright blood vessel; 3, no motion artifact, slight obscures around blood vessel, bright blood vessel; 2, little motion artifact, but enough for assessment, obvious obscures around blood vessel, visible blood vessel; and 1, severe motion artifact, overlapping blood vessels, serious obscures around blood vessel, undistinguishable vessels and surrounding components, dark blood vessels. Images with a scores of more than 1 were chosen for further diagnosis.

Objective assessment

Left and right CA and ascending aorta root were set as target areas. The target in left and right CA was located in 2/3 area of CA lumen. The target area of ascending aorta root was 100±5 mm². The average value of 3 continuous layers was used for assessment. Plaques were avoided during measurement. Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were measured and calculated. In the same layer of target areas, the CT value of 100±5 mm² target area in the muscle around spine and prethoracic air was measured. Vascular CT value was measured as the intensity of signal. Noise standard deviation of prethoracic air was measured as background noise.

SNR=signal intensity/background noise; CNR=(signal intensity–CT value of muscle beside the spine)/background noise.

Dosage of radiation and iodine

The scanning length (L, cm), CT dose index-volume (CTDI_{vol}, mGy), dose length product (DLP, DLP=L×CTDI_{vol}), and effective dose (ED, mSv; ED=k×DLP, k=0.014) for every case were recorded [5]. The volume (40–50 ml) and concentration of contrast agent in every case were also recorded and used for calculating the volume of iodine. Volume of iodine (mg)=Concentration (mg/ml)×Volume of injected contrast agent (ml).

Table 1. Comparison of general data among groups.

Index	Group A (30 cases)	Group B (30 cases)	Group C (30 cases)
Sex (Male/Female)	17/13	18/12	17/13
Age	56.67±14.92	56.36±14.71	57.17±13.93
Height	167.34±6.75	168.24±6.96	167.50±6.40
Weight	60.11±6.76	59.50±6.43	60.96±6.72
BMI	21.47±2.57	21.02±2.12	21.72±1.98

Statistical analyses

SPSS 16.0 was used for statistical analyses. Continuous variables are shown as average ± standard deviation. Age, DLP, effective dosage, signal intensity, noise, SNR, and CNR were analyzed and compared by ANOVA. The quality of image among groups was compared by Kappa analysis. $P < 0.05$ was considered as a significant difference.

Results

General data

All cases successfully underwent CTCA. The general data is shown in Table 1. There was no significant difference among groups in sex, age, weight, height, or BMI.

Comparison of image quality (Figure 1)

There were 1223 fragments of CA in total. The subjective assessment by 2 radiologists was uniform (Table 2). For the first radiologist, the images with a score of more than 1 accounted for 99.02%, 98.77%, and 99.02% in the 3 groups, respectively. For the second radiologist, the proportion was 99.02%, 99.01%, and 99.02%, respectively. The objective assessment is presented in Table 3. In scanning scheme, there was no significant differences in CT value, background noise, SNR, CNR of left and right CA, or ascending aorta root among groups.

Comparison of radiation and iodine dose

The radiation and iodine dose is shown in Table 4. There was no significant difference in scanning length and mAs among groups. However, both DLP and ED were significantly different among groups. DLP in group A was 120.01 ± 13.48 mGy×cm, which is remarkably lower than in group B and C ($P < 0.05$). Furthermore, ED in group A was notably reduced by 27.58% and 28.21% compared to group B and C, respectively ($P < 0.05$). The total volume of injected contrast agent was not significantly different. Nevertheless, the contrast agent concentration in group A was low. The iodine volume in group

A was 21.27% and 24.83% lower than in group B and C, respectively ($P < 0.05$).

Discussion

CTCA, as a noninvasive method of diagnosis, can test coronary artery stenosis, and show the properties of coronary plaque, and is increasingly used, but high radiation dose has been a problem. Recently, with the application of contrast agent, its risk in CTCA has also been a concern. Previous studies always focused on a single or double concentration in CTCA [6,7]. Therefore, the present study prospectively compared different concentrations of contrast agent, scanning parameters on image quality, and radiation and iodine dose. Our results suggest that CTCA with low kV (100 kV), low concentration of contrast agent (270 mg/ml), and iterative reconstruction can produce good image quality and remarkably reduce radiation dose and iodine in contrast agent.

With the application of CTA, the use of contrast agent has become more popular, but it has some risks, such as contrast-induced nephropathy (CIN). Low concentration and volume of contrast agent can reduce the corresponding risk; 40–60 ml contrast agent following normal saline is usually the main optimized scheme, compared to 70–100 ml contrast agent directly [3,8]. The advantages of low concentration of contrast agent are: 1) Isotonic low concentration contrast agent has the same osmotic pressure of plasma, reducing stickiness and the risk of cardiovascular parameters, hematologic system, endothelial system, and kidney. 2) During scanning, it decreases artifact from precava or right intracardiac high concentration contrast agent. 3) A large trocar is not required, which makes connecting the trocar and high-pressure injector easier and reduces the risk of exosmosis. 4) Low concentration decreases intravascular sclerosis. However, in the same condition of the same contrast agent volume and flow rate, a lower concentration will reduce intravascular CT value, which influences image quality and diagnosis.

According to the ALARA (as low as reasonably achievable) standard, it is preferable to have less radiation dosage. There are

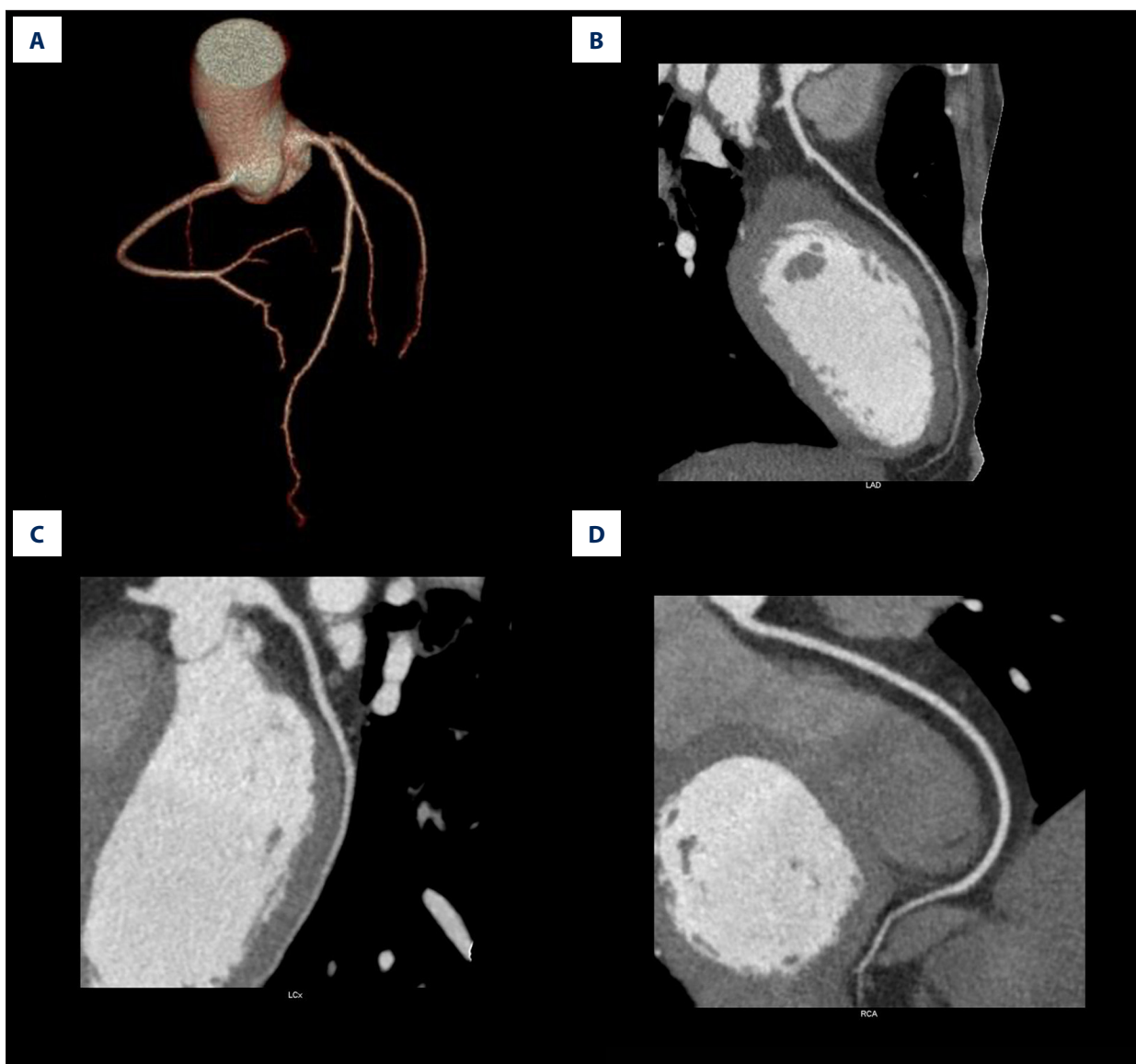


Figure 1. CTCA image with 100 kV, 270 mg/ml contrast agent. (A) VR; (B-D) CPR image of LAD, LCx, and RCA, respectively.

Table 2. Comparison of subjective assessment of image quality.

Observer	Score	Group A	Group B	Group C
Radiologist 1	4	210 (51.22%)	208 (51.36%)	215 (52.70%)
	3	164 (40.00%)	158 (39.01%)	158 (38.72%)
	2	32 (7.80%)	34 (8.40%)	31 (7.60%)
	1	4 (0.98%)	5 (1.23%)	4 (0.98%)
Radiologist 2	4	205 (50.00%)	207 (51.11%)	210 (51.47%)
	3	170 (41.46%)	159 (39.26%)	161 (39.46%)
	2	31 (7.56%)	35 (8.64%)	33 (8.09%)
	1	4 (0.98%)	4 (0.99%)	4 (0.98%)

Table 3. Comparison of objective assessment of image quality.

Index	Group A	Group B	Group C	
CT value (HU)	LCA	442.99±85.56	445.06±85.69	448.31±84.67
	RCA	441.76±85.14	444.60±85.22	447.91±84.63
	Ascending aorta root	442.49±85.03	444.70±85.45	447.98±84.60
SNR	LCA	55.92±17.85	53.71±15.13	52.18±13.48
	RCA	55.76±17.73	53.64±15.03	52.13±13.48
	Ascending aorta root	55.86±17.81	53.66±15.06	52.14±13.47
CNR	LCA	50.48±16.72	48.58±14.56	46.96±13.03
	RCA	50.31±16.60	48.52±14.46	46.92±13.04
	Ascending aorta root	50.42±16.69	48.53±14.49	46.92±13.03

Table 4. Comparison of radiation and iodine dose.

Index	Group A	Group B	Group C
Scanning length (cm)	18.29±0.94	18.34±0.91	18.41±0.95
DLP (mGy×cm)	120.01±13.44	165.71±14.18	167.14±14.64
ED (mSv)	1.68±0.67	2.32±0.70	2.34±0.62
mAs	215.24±8.41	220.14±8.94	221.15±8.72
Xontrast agent volume (ml)	46.10±4.48	45.16±4.64	44.70±4.09
Iodine (g)	12.45±1.16	15.81±1.32	16.54±1.42

methods to effectively reduce radiation dosage, such as reducing voltage and current, ECG-pulsing modulation technique, and prospective ECG-gating [3]. Prospective ECG-gating has almost 20% the radiation dosage of retrospective ECG-gating, and acquires a higher-quality image [9,10]. Reducing voltage is the most common approach because effective radiation dose is positively associated with current and voltage. In this study, radiation dose decreased by 27.58% and 28.21%, which is lower than the 30–40% reported in previous studies [11].

Although low kV increases noise, CNR is improved; therefore, low kV is beneficial to improve intravascular CT value during CTA because increased photoelectric effect will raise the detection rate of iodine. When the voltage is reduced from 120 kV to 100 kV, the CT value of iodine increases by 17% [11,12]. Therefore, low kV combined with low-concentration contrast agent can obtain the same CT value as with the usual scheme. Furthermore, low kV also needs a low concentration of iodine, otherwise the high concentration of contrast agent will increase banded artifacts and reduce image quality. In this study, there was no significant difference in CT value between group A with 100 kV and the other groups, which proves that low kV can enhance intravascular CT value.

In iterative reconstruction, the collected data is routinely compared with a model, after which, photonic and electronic noise is corrected. Therefore, CNR increases and spatial resolution remains the same [13]. Therefore, iterative reconstruction remarkably reduces noise and improves image quality [4,14,15]. This is also why low kV in this study can collect images with the same quality as with the traditional scheme.

The present study has some limitations. First, all cases had BMI below 25 kg/m². Whether our technique can work in obese subjects needs to be confirmed. Second, only the image quality was evaluated, and the diagnostic accuracy of CA plaque was ignored. Lastly, except for iDose3, the effect of different levels of iterative reconstruction algorithm on image quality needs to be further studied.

Conclusions

Low kV and low-concentration contrast agent combined with iterative reconstruction for CTCA imaging obtains image quality consistent with the conventional CTCA and significantly reduces the dosage of radiation and injected iodine.

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