Int J Clin Exp Med 2015;8(10):17644-17653
www.ijcem.com /ISSN:1940-5901/IJCEM0013399

Original Article

Application of intelligent optimal kV scanning technology (CARE kV) in dual-source computed tomography (DSCT) coronary angiography

Jun Zhang[1,2], Shaolei Kang[1], Dan Han[1], Xiaojie Xie[1], Yaming Deng[1]

[1]*Department of Medical Imaging, The First Affiliated Hospital of Kunming Medical University, Kunming 650032, China;* [2]*Department of Medical Imaging, Taizhou People's Hospital, Taizhou 225300, China*

Received July 25, 2015; Accepted September 10, 2015; Epub October 15, 2015; Published October 30, 2015

Abstract: This study aims to evaluate the applications and values of dual-source computed tomography (DSCT) intelligent optimal kV scanning technology (CARE kV) in coronary CT angiography (CCTA). 150 patients with normal body mass index were performed DSCT coronary angiography, then randomly divided into the "Semi", 120,100 and 80 kV Group, and the 2 "on" groups, with 30 patients in each group. The first 5 groups used the reference voltage as 120 kV, and the reference current as 400 mAs, while the other group used the reference voltage as 100 kV, and the reference current as 400 mAs. The image quality, average CT value, image noise, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR) and radiation dose were comparatively analyzed among the 5 groups. The image quality scores of the five groups showed no significant difference ($P > 0.05$); the average CT values and image noises had significance ($P < 0.05$), while SNR and CNR showed no significant difference ($P > 0.05$). The 80 kV group showed the biggest noise, with the CT value as 700 HU, while the radiation dose was the lowest, followed by the on group. As for the patients with normal body mass index (BMI), CARE kV-"on" could obtain high-quality images and lower radiation dose for CCTA, while the operation was simple and convenient.

Keywords: Tomography, X-ray computer, coronary angiography, radiation dose, CARE kV

Introduction

Coronary heart disease (CHD) was exhibiting significantly increased incidence trend in our country, which seriously threats people's health, and it had already become one of the main causes of death [1]. Currently, the main imaging methods towards CHD included Intravenous Ultrasound (IVUS), coronary angiography (CAG), Magnetic Resonance images (MRI) and Optical Coherence Tomography (OCT), etc. The selective CAG was the "gold standard" in diagnosing CHD, but it was an invasive examination, not only cost highly, but also had certain risks, so it was not suitable to be used as a screening tool for CHD [2]. In recent years, Multi-slice Computed Tomography (MSCT) had obtained great progresses in examining CHD. The 64-slice coronary computed tomography angiography (CCTA) could exhibit the coronary artery plaques and diagnose the coronary stenosis, with rapid imaging speed while no invasion, its diagnostic sensitivity towards coronary stenosis (≥ 50%) was 93%, the specificity was 98%, and the positive and negative predictive values were 87% and 99%, respectively, therefore, it had become an effective method towards the clinical screening and diagnosis of CHD [3]. The dual-source CT (DSCT) used two sets of X-ray tube system and two detectors to acquire the CT images, thus the time resolution was greatly improved, the limitations of 64-slice CT on the clinical applications were thus broken, no β-blockers needed to be taken before the examination, while clear coronary images could be reconstructed, so it could be used as the preferred noninvasive coronary examination method [4].

As it was well known that the radiation dose of CT was significantly higher than conventional X-ray, while with more and wider application of CT, the ionizing radiation damages caused thereby had become a serious social problem

Table 1. Grouping of different scanning parameters

Group	Tube voltage	CARE kV	CARE Dose4D	Reference voltage	Reference current
A	120 kV	Semi	On	120 kV	400 mAs
B	100 kV	Semi	On	120 kV	400 mAs
C	80 kV	Semi	On	120 kV	400 mAs
D	-	On	On	120 kV	400 mAs
E	-	On	on	100 kV	400 mAs

of medicine [5]. According to foreign scholars [6], there existed relevance among age, gender, scan mode and cancer risk in CCTA, and it was a relatively stable cancer risk. With the aging process, different body organs would gradually reduce their radiosensitivities, and it often might take long period for one severe ionizing radiation to cause malignant transformation, and this incubation period also required a minimum of 12 years [7]. Therefore, how to reduce the radiation dose of CCTA and implement the personalized examination had become an important research topic of CCTA. Currently, there were a variety of methods to reduce the radiation dose of CCTA, such as reducing the tube voltage, tube current, and electrocardiopulse tube current regulation technology [8], these technologies still exhibited limited abilities in reducing the radiation dose. Therefore, how to effectively reduce the radiation dose of CCTA was important.

Besides the wide tube voltage selection range such as 70 kV and 80 kV, the second generation DSCT also provided the CARE kV technology, the CARE kV technology was namely the intelligent optimal tube voltage scanning technology, which could automatically determine the optimized tube voltage and tube current according to the examination purpose and the subject's body shape, thus realizing the optimal personalized examination to reduce the dose, while improve the image qualities, it was the unique radiation dose reduction technique in DSCT [9]. This study investigated the feasibility of CARE kV towards CCTA, aiming to assess its impacts on reducing the radiation dose and improving the image qualities.

Materials and methods

General information

150 patients were performed CCTA from June 2012 to December 2012, including 59 males and 61 females, aged 36 to 84 years, with the mean age as (51.40 ± 11.10) years, the patients were randomly divided into 5 groups (group A-E) according to the scanning methods, with 30 patients in each group. The Inclusion criterion was that the patient should have body mass index (BMI) within normal range [10] (male: 20 kg/m^2 ≤ BMI < 25 kg/m^2, women: 19 kg/m^2 ≤ BMI < 24 kg/m^2). No medication was administrated to control the heart rate before the examination, and all patients signed the informed consent. Exclusion criteria: with heart, renal dysfunction; could not hold the breath cooperatively; with severe arrhythmias; allergic to iodine contrast agent; after bypass surgery, with obvious heart enlargement and the chest wall was too thick. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Kunming Medical University. Written informed consent was obtained from all participants.

DSCT coronary scanning

The second-generation dual-source CT (Siemens Definition Flash, Siemens Medical Solutions, Forchheim, Germany) was used, together with the prospective ECG triggering sequence for the scanning: collimation: 64 × 2 × 0.6 mm, FOV: 150 mm × 150 mm~180 mm × 180 mm, the pitch was automatically set according to the changes of heart rate (range 0.2 to 0.5), the scanning range was from 1 cm below the tracheal carina to the heart diaphragmatic surface, the scan length (LEN) was given by the computer. One dual high-pressure syringe (SCT211, Medrad, INC. America) was adopted, and the contrast agent was 50~70 mL of iopromide (Injection® 370 mg/mL, Bayer Healthcare, Germany), followed by 30~40 mL of saline subsequently, and the flow rate was 5.0 mL/s. Region of interest (ROI) of the contrast tracer method (bolus tracking) was at the aortic root, when 100 HU was reached, the scanning was delayed for 6 s. The groupings of different scanning parameters were shown in **Table 1**.

Image processing and analysis

The thickness of reconstructed image was 0.75 mm, with the pitch as 0.4 mm, and the convolution kernel was set as smoother B26f. The evaluation of coronary calcium plaque and stent set the reconstructed image thickness as 0.60

Table 2. Comparison of age, heart rate, BMI and LEN among the 5 groups ($\bar{x}$ ± s, n = 30)

Group	Age (years)	Heart rate (times/min)	BMI (kg/m^2)	LEN (cm)
A	56.40 ± 3.34	76.30 ± 3.22	21.50 ± 2.32	15.30 ± 1.32
B	57.12 ± 2.76	75.22 ± 3.78	21.10 ± 2.78	15.57 ± 1.12
C	56.56 ± 3.78	77.80 ± 2.99	22.10 ± 2.52	15.11 ± 1.62
D	58.60 ± 2.54	75.50 ± 3.38	21.30 ± 2.26	15.38 ± 1.24
E	57.30 ± 3.65	77.50 ± 3.26	22.70 ± 2.21	15.28 ± 1.23
Chis-Square	2.056	2.574	4.821	0.345
P	0.354	0.245	0.208	0.442

Table 3. Actual selection of tube voltage and tube current in group D&E ($\bar{x}$ ± s, n = 30)

Tube voltage (kV)	Group D		Group E	
	N (cases)	Tube current (mAs)	N (cases)	Tube current (mAs)
70	0	-	0	-
80	6	185.4 ± 32.3	23	222.8 ± 38.5
100	21	265.4 ± 33.4	7	259.4 ± 36.4
120	3	320.3 ± 35.5	0	-

mm, the pitch as 0.3 mm, and the convolution kernel as smoother B46f. The best-phase data were transmitted into the processing workstation (syngo MMWP, version 2008A; Siemens Medical Solutions) for the multiplanar reconstruction (MPR), maximum intensity projection (MIP), curved planar reformation (CPR), and volume rendering (VR) to obtain multi-directional coronary images.

Subjective assessment of image qualities

According to the standards of American Heart Association (AHA), namely the modified coronary 15-segment method [11, 12], the image quality scoring was divided into 4 grade [13]: grade I, the coronary artery was clearly displayed, with small image noise, continuous and complete lumen, without stepped artifacts, the image quality was excellent, recorded as 4 points; grade II, the image noise was small, the wall had mild artifacts or CPR exhibited mild stepped artifacts, while would not affect the diagnosis, the image quality was good, recorded as 3 points; grade III: the image noise was relatively large, the wall exhibited moderate artifacts or CPR exhibited moderate stepped artifacts, while the diagnosis could still be made, the image quality was moderate, recorded as 2 points; grade IV: the image noise was large, the coronary artery dislocated in the reconstruction image, the wall exhibited severe artifacts, and the diagnosis could not be performed, the image quality was poor, recorded as 1 point. Only the vessel with luminal diameter larger than 2 mm was evaluated, the heavily calcified vessel segments were not evaluated. Two experienced radiologists performed the evaluation with the double-blind method, and the image should be read together when a common consensus could not be obtained.

Objective assessment of image qualities

The axial CT values were measured towards the three layers of aortic root (upper, middle and lower, near the opening of left main stem), with ROI set as 1 cm^2, and the standard deviation of average CT value was set as the image noise. Measurement of signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) [14]: 2 mm^2 ROIs were placed at 9 coronary sites, including the left main coronary artery, proximal segment of anterior descending branch, distal segment of anterior descending branch (away from the second diagonal branch opening), proximal segment of the first diagonal branch, proximal segment of circumflex branch, distal segment of circumflex branch (away from the second obtuse marginal branch opening), proximal segment of the first obtuse marginal branch, proximal segment of right coronary artery and distal segment of right coronary artery (before posterior descending branch opening). Calculation formula [15]: SNR = CTlumen/image noise; CNR = (CTlumen-CTconnective tissue)/image noise; CTlumen was the average CT value of each segment, CTconnective tissue was the average CT value of 2 mm^2 ROIs of the surrounding fat tissues (placed at the perivascular tissues of left main stem opening).

Analysis of radiation dose

The radiation dose only referred to CCTA, while not included those for the positioning image, coronary artery calcium integration and automatic tracking technology. The volume CT dose index (CTDIvol) and the dose length produce

Table 4. Displaying situations of different segments under different tube voltages [segment (%)]

Group	Cases	Excellent (4 points)	Good (3 points)	Middle (2 points)	Poor (1 point)	Sum
A	30	205 (48.7)	205 (48.7)	11 (2.6)	0 (0)	421
B	30	209 (49.4)	205 (48.5)	9 (2.1)	0 (0)	423
C	30	211 (49.6)	205 (48.1)	10 (2.3)	0 (0)	426
D	30	217 (50.7)	201 (46.9)	10 (2.4)	0 (0)	428
E	30	220 (51.2)	201 (46.7)	9 (2.1)	0 (0)	430

The image quality scores among the 5 groups were compared with the multi-sample nonparametric Kruskal-Wallis test, the difference was not statistically significant (Chis-Square = 0.634, P = 0.105 > 0.05).

(DLP) were given by the computer. The effective dose (ED) was calculated according to the formula ED = K × DLP, among which K was the conversion factor, the average chest value used 0.014 mSv/(mGy·cm), proposed in the European CT quality standard guidelines [16].

Statistical analysis

SPSS17.0 statistical software package was used. The age, heart rate, BMI, LEN and image quality of the 5 groups were compared, and performed the multi-sample nonparametric Kruskal-wallis test; the image noise, average CT value, CNR, SNR, CTDIvol, DLP and ED of the 5 groups were performed the single-factor analysis of variance. The Kappa test was performed to evaluate the intergroup consistency, with Kappa > 0.7 considered as better consistency, 0.4 ≤ Kappa ≤ 0.7 considered as medium consistency, and Kappa < 0.4 considered as poor consistency, and P < 0.05 considered as statistical significance.

Results

General information

The multi-sample nonparametric Kruskal-wallis test was used for the comparison, the results revealed that there was no statistically significant difference in age, heart rate, BMI and LEN among the five groups (P > 0.05, **Table 2**), indicating that these 5 groups were comparable.

Actual selection of tube voltage and tube current

Group D selected (100 kV, 265.4 ± 23.4 mAs) to scan 21 patients, accounting for 70% (21/30); selected (80 kV, 115.4 ± 12.3 mAs) to scan 6 patients, accounting for 20% (6/30); selected (120 kV, 320.3 ± 35.5 mAs) to scan 3 patients, accounting for 10% (3/30). Group E selected (80 kV, 122.8 ± 18.5 mAs) to scan 23 patients, accounting for 76.7% (23/30); selected (100 kV, 259.4 ± 26.4 mAs) to scan 7 patients, accounting for 23.3% (7/30) (**Table 3**).

Comparison of CCTA image quality scores

In **Table 4**, Group A had a total of 421 coronary segments accepted the scoring (among which 11 segments had the diameter < 2 mm, 3 segments exhibited heavily calcified coronary arterial wall, thus seriously affecting the evaluation, and excluded, and 15 segments showed no image because of anatomic variations), the image qualities of a total of 410 segments were evaluated as excellent and good (97.4%). Group B had a total of 423 coronary segments accepted the scoring (among which 9 segments had the diameter < 2 mm, 2 segments exhibited heavily calcified coronary arterial wall, thus seriously affecting the evaluation, and excluded, and 16 segments showed no image because of anatomic variations), the image qualities of a total of 414 segments were evaluated as excellent and good (97.9%). Group C had a total of 426 coronary segments accepted the scoring (among which 9 segments had the diameter < 2 mm, 2 segments exhibited heavily calcified coronary arterial wall, thus seriously affecting the evaluation, and excluded, and 13 segments showed no image because of anatomic variations), the image qualities of a total of 416 segments were evaluated as excellent and good (97.7%). Group D had a total of 428 coronary segments accepted the scoring (among which 13 segments had the diameter < 2 mm, 2 segments exhibited heavily calcified coronary arterial wall, thus seriously affecting the evaluation, and excluded, and 7 segments showed no image because of anatomic variations), the image qualities of a total of 418 segments were evaluated as excellent and good (97.6%). Group E had a total of 430 coronary segments accepted the scoring (among which 9 segments had the diameter < 2 mm, 2 segments exhibited heavily calcified coronary arterial wall, thus seriously affecting the evaluation, and excluded, and 9 segments

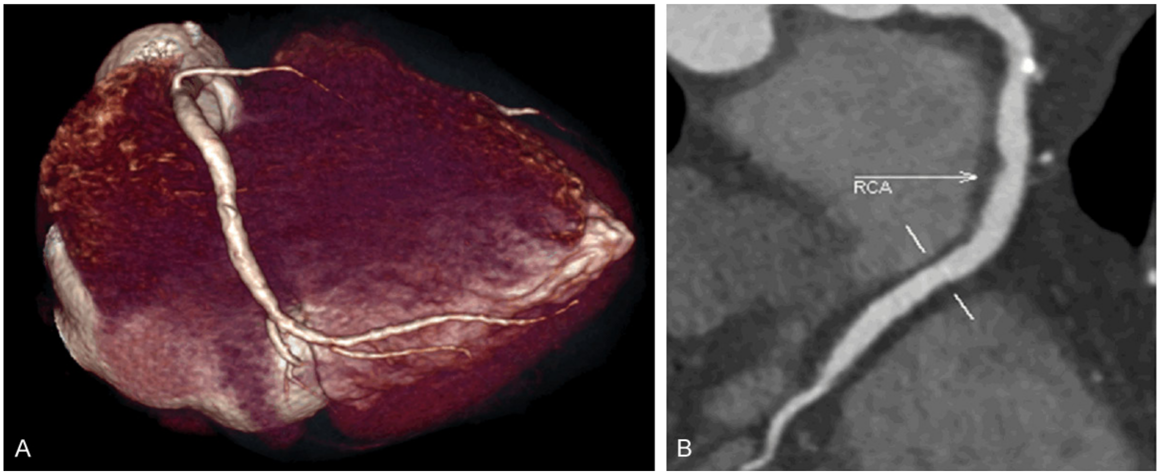

Figure 1. Male, 38 years old, BMI (22.4 kg/m^2), performed group A scanning program. Tube voltage 120 kV, tube current 342 mAs, the image quality was evaluated as 4 points. A. VR image clearly showed the middle segment of RCA; B. CPR image clearly showed the small soft spots in the middle segment of RCA.

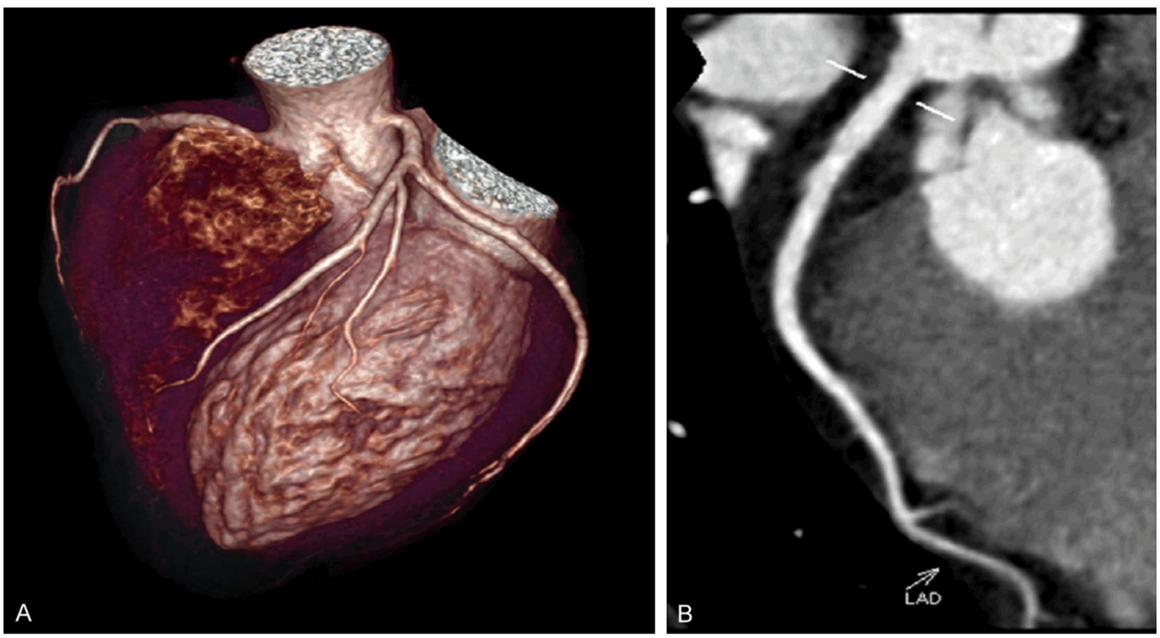

Figure 2. Male, 41 years old, BMI (22.9 kg/m^2), performed group B scanning program. Tube voltage 100 kV, tube current 283 mAs, the image quality was evaluated as 4 points. A. VR image clearly showed the whole LAD and CX; B. CPR image clearly showed that the LAD lumen was unobstructed.

showed no image because of anatomic variations), the image qualities of a total of 421 segments were evaluated as excellent and good (97.9%). The difference in excellent and good image qualities among the five groups was not statistically significant ($P > 0.05$). The image quality scores among the 5 groups were compared with the multi-sample nonparametric Kruskal-wallis test, and the scores were (3.42 ± 0.63) points, (3.41 ± 0.54) points, (3.49 ± 0.33) points, (3.45 ± 0.43) points and (3.48 ± 0.81) points, respectively, the difference was not statistically significant (Chis-Square = 0.634, $P = 0.105 > 0.05$) (**Figures 1-5**), and the consistency between the two reviewers was good (Kappa = 0.72, $P < 0.05$).

Objective assessment of image qualities

The comparison of average value CT, image noise, SNR and CNR were performed the F test. Group C exhibited the highest average CT value

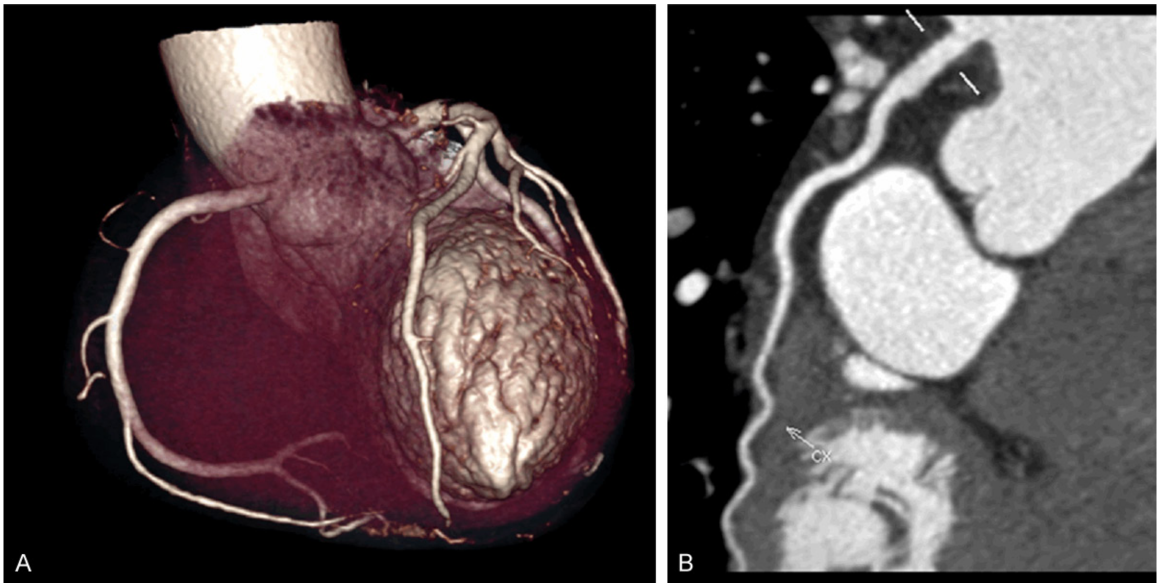

Figure 3. Male, 41 years old, BMI (22.9 kg/m^2), performed group C scanning program. Tube voltage 80 kV, current 241 mAs, the image quality was evaluated as 4 points. A. VR image clearly showed the whole RCA and the middle- and distal segments of LAD; B. CPR image clearly showed that the CX lumen was unobstructed.

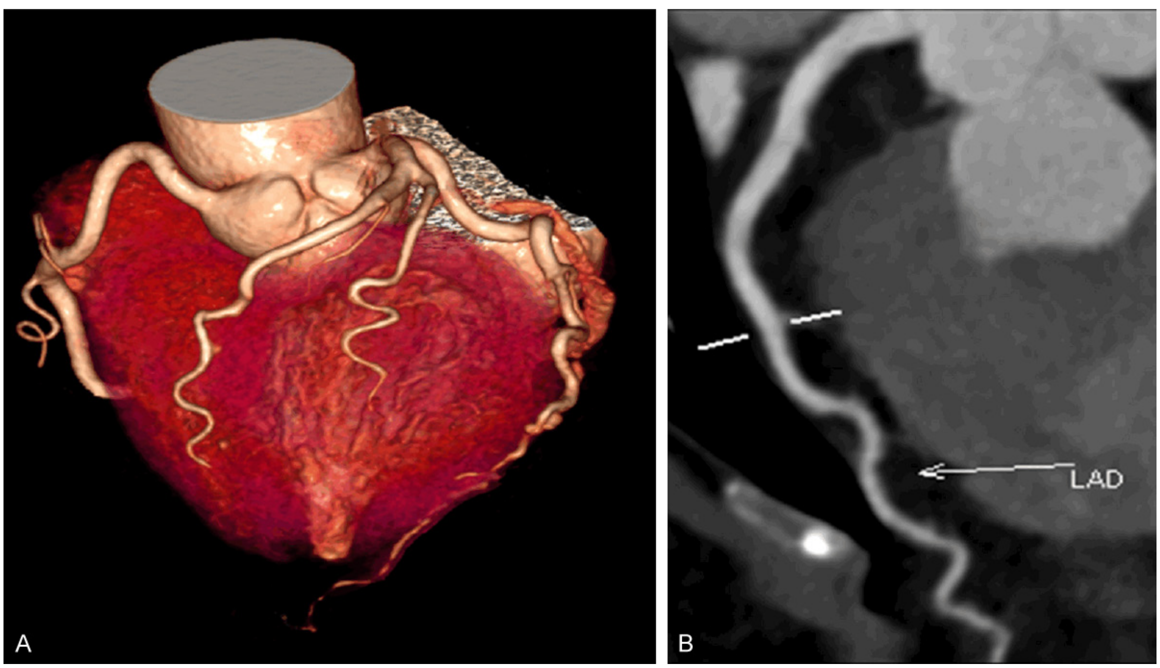

Figure 4. Female, 43 years old, BMI (24.8 kg/m^2), performed group D scanning program. Tube voltage 100 kV, tube current 293 mAs, the image quality was evaluated as 4 points. A. VR image clearly showed the whole LAD and CX; B. CPR image clearly showed the LAD lumen was unobstructed.

and image noise, and the differences of pair-wise comparison were statistically significant ($P < 0.05$, **Table 5**), the difference in SNR and CNR among the 5 groups was not statistically significant ($P > 0.05$, **Table 5**).

Comparison of radiation doses

The comparison of CTDIvol, DLP and ED were performed the F test, group C exhibited the lowest CTDIvol, DLP and ED, and the differences of

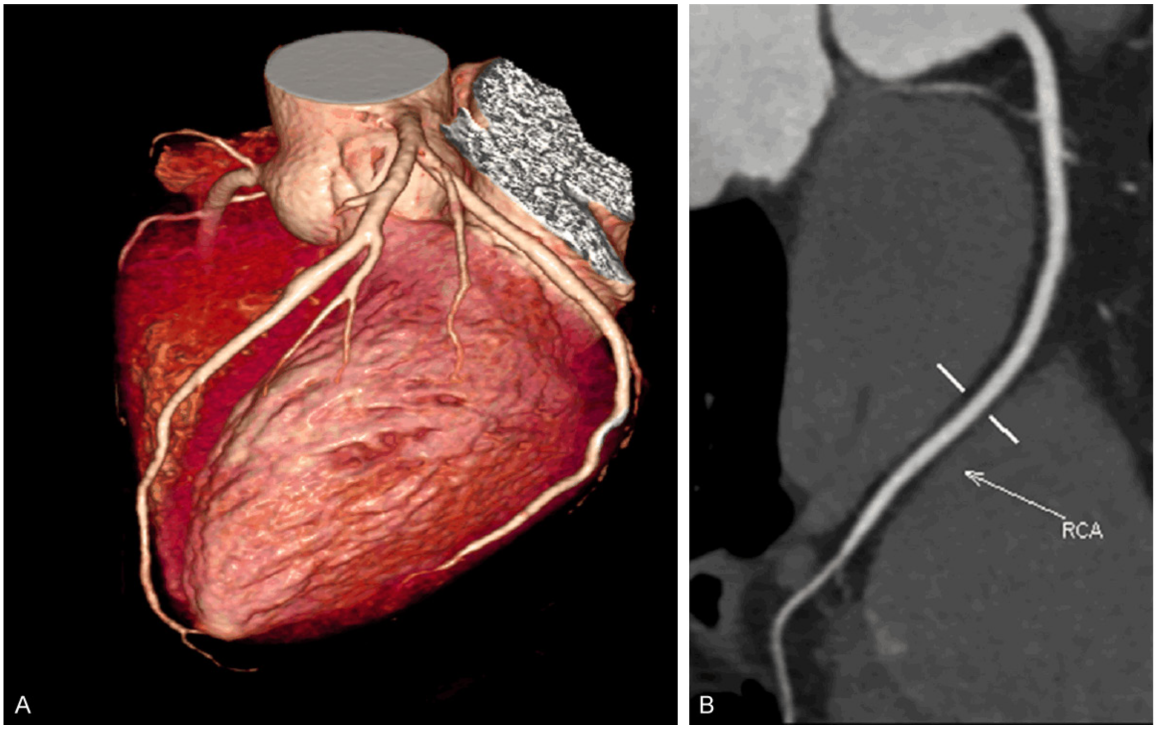

Figure 5. Male, 36 years old, BMI (23.5 kg/m^2), performed group E scanning program. Tube voltage 100 KV, tube current 273 mAs, the image quality was evaluated as 4 points. A. VR image clearly showed the whole LAD and CX; B. CPR image clearly showed the small soft spots in the proximal and middle segments of RCA.

Table 5. Comparison of average CT value, image noise, SNR and CNR among the 5 groups ($\overline{x}$ ± s, n = 30)

Group	Average CT value (HU)	Image noise (HU)	SNR	CNR
A	486.19 ± 82.43	25.29 ± 12.23	17.44 ± 4.30	22.32 ± 3.43
B	553.60 ± 71.22	32.40 ± 12.25	16.30 ± 4.80	20.32 ± 4.11
C	742.20 ± 90.20	45.90 ± 14.43	15.70 ± 4.90	18.41 ± 4.34
D	506.43 ± 81.11	28.24 ± 11.29	16.20 ± 4.20	21.76 ± 3.54
E	561.12 ± 81.23	34.43 ± 12.34	16.33 ± 4.44	20.41 ± 4.54
F	3.430	4.332	4.435	3.654
P	0.013	0.012	0.535	0.353

pairwise comparison were statistically significant (P < 0.05, **Table 6**).

Discussion

The development of low-dose CT technology had gone through four generations: the first generation was characterized by "lower radiation dose, while lower image quality", namely basing on ensuring the basic diagnostic requirements of image quality, the reduction of radiation dose was realized simply through reducing kV and/or mAs. The second generation was characterized by "reducing the radiation dose, while remaining the image quality basically unchanged", which was represented by the technology that could eliminate the "invalid" radiation dose outside the scanning range, so that the image quality could be remained unchanged while the radiation dose was reduced simultaneously. The third generation was characterized by "reducing the radiation dose, while remaining the image quality unchanged", represented by various multi-image spaces-based iterative reconstruction algorithms. The fourth generation was characterized by "reducing the radiation dose, while improving the image quality", the CARE kV technology was representative [17], which could automatically determine the optimal tube voltage and current according to the examination purpose and the subject's body shape, thus achieving the optimal radiation dose while higher image qualities.

The CARE kV technology [18, 19] could automatically determine the subject's body shape

Table 6. Five groups CTDIvol, DLP and ED comparison ($\overline{x}$ ± s, n = 30)

Group	CTDIvol (mGy)	DLP (mGy*cm)	ED (mSv)
A	44.65 ± 3.23	662.14 ± 53.57	9.29 ± 1.31
B	29.24 ± 4.23	449.71 ± 67.14	6.29 ± 1.36
C	14.40 ± 3.62	199.12 ± 59.29	2.75 ± 1.53
D	27.31 ± 4.46	402.71 ± 67.86	5.69 ± 1.23
E	19.34 ± 4.31	271.29 ± 65.09	3.80 ± 1.33
F	1.236	2.122	2.332
P	0.015	0.005	0.004

according to the positioning image, than according to the preset level of image quality, as well as the examination purpose and the subject's body shape, the CT system could automatically calculate the reference value and changing curve of tube current required under different tube voltages, and calculate the CTDIvol for the comparison. When CARE kV was set to "On", the computer could automatically select the tube voltage from low to high according to the positioning image and the preset level of image quality, if the hardware of CT tube system allowed (mainly towards the size of tube current), the lowest tube voltage would be selected for the scanning, otherwise, the second lowest tube voltage would be selected. For example, if 70 kV tube voltage-corresponding tube current did not exceed the limit, 70 kV tube voltage would be selected for the scanning, if it exceeded the restrictions, the CT system would automatically consider 80 kV. The CARE kV technology also provided the "Semi" function, namely the "semi-automatic" feature, especially targeting the multi-phase examination or reviewing examination to ensure the consistency of tube voltage, thus ensuring the comparability of image CT values obtained in different phase or before-and-after examination. The tube voltage was fixed, the computer could adjust the tube current according to the positioning image and the preset level of image quality. Finally, this technology also offered the "Off" function, namely completely shutting down the radiation dose-adjustment technology. In short, when applying the CARE kV technology, the reference value of tube current changed with the changes of tube voltage automatically, eliminating the tedious calculations and dependence on physicians' experience [20]. In this study, the patients of group D and E exhibited normal BMI, group D was selected 100 kV (24 cases), 80 kV (9 cases) and 120 kV (7 cases) for the scanning, and group E was selected 80 kV (29 cases) and 100 kV (11 cases) for the scanning, suggesting that the actual scanning tube voltage were determined according to the preset levels of image quality, then to the subject's body shape [21], consistent with the foreign researches. However, the CARE kV technology made the whole tube voltage shifting downwards, in addition to lowering the radiation dose, it could also enhance the attenuation of iodine-containing tissue towards X-rays, therefore, the coronary CT value would be increased, so it might affect the exhibition of coronary small soft spots.

In this study, the pairwise comparison of average coronary CT values among the 5 groups showed statistically significant differences, among which group C (80 kV) exhibited the highest average CT value, followed by group E (reference voltage 100 kV, reference current 400 mAs), group B (100 kV), group D (reference voltage 120 kV, reference current 400 mAs) and group A (120 kV). It might because group E was opened the CARE kV technology, most patients were administrated 80 kV (29 cases) and 100 kV (11 cases), while most patients in group D were performed 100 kV (24 cases) after the adjustment, only 7 and 9 cases were performed 120 kV and 80 kV, respectively. Although the pairwise comparison of image noise among the 5 groups exhibited statistically significant differences, the difference in SNR and CNR was not statistically significant, consistent with Park et al [22], and the 5 groups all exhibited more than 97% cases with "excellent" image quality level, indicating that the CARE kV technology could ensure the image quality. Group C exhibited ED decreased by about 28% than group E, but the average CT value of group C reached 700 HU, not conducive to the detection of coronary small soft plaques, so the group C scanning program was not recommended in clinical work. Meanwhile, the radiation dose of group E was reduced by about 60% than group A (120 kV), with the average ED as only 3.8 mSv, consistent with Winklehner et al [23], indicating that the "On" mode of CARE kV could better ensure the image quality and reduce the radiation dose than the "Semi" mode. To sum up, as for the patients within normal BMI range, the group E scanning program (CARE kV "On", reference voltage 100 kV, reference current 400 mAs) could be recommended for CCTA, not only could obtain high-quality images and significantly reduce the radiation dose, but also could simplify the operations.

Of course, this study had some shortcomings: firstly, it did not use the coronary angiography as the reference standard to assess the diagnostic accuracy; secondly, this study did not select the patients with BMI greater than 25 kg/m^2. Furthermore, the scan quality reference was set as 120 kV (or 100 kV), 400 mAs. Although it was beneficial towards the quality control of several technicians during the operation, it did not set more personalized scanning solution according to BMI and chest thickness, etc., therefore the radiation dose might still be reducible, and the literature suggested BMI < 25, with the reference values as 100 kV, 320 mAs [15].

Acknowledgements

This study was supported by Yunnan provincial Natural Science Foundation (2008c0477m), Project of Scientific Research Fund of Yunnan Provincial Department of Education (Project number: 2010Y177); Graduate Innovation Fund of Kunming Medical College (2009N22), multicenter study of MSCT coronary angiography (Project number: NCT01164839). Project of innovation team Fund of Yunnan provincial (2014HC018).

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Dan Han, Department of Medical Imaging, The First Affiliated Hospital of Kunming Medical University, No. 295 Xichang Road, Kunming 650032, China. Tel: +86 871 65324888 2886; Fax: +86 871 65324888 2886; E-mail: danhandoc@163.com

References

[1] Fu F, Jin H and Feng Y. A rare case of single right coronary artery with congenital absence of left coronary artery in an adult: a case report. J Cardiothorac Surg 2015; 10: 57.

[2] Krupiński M, Urbańczyk-Zawadzka M, Laskowicz B, Irzyk M, Banyś R, Gruszczyńska K and Baron J. Computed tomography in the evaluation of the anomalous origin of the coronary artery: coexistence with other congenital heart disease in an adult population. Folia Morphol (Warsz) 2015; 74: 73-77.

[3] Varga-Szemes A, Meinel FG, De Cecco CN, Fuller SR, Bayer RR 2nd and Schoepf UJ. CT myocardial perfusion imaging. AJR Am J Roentgenol 2015; 204: 487-497.

[4] Sun K, Li K, Han R, Li W, Chen N, Yang Q, Du X, Wang C, Liu G, Li Y, Zhou M, Li L and Heidrun E. Evaluation of high-pitch dual-source CT angiography for evaluation of coronary and carotid-cerebrovascular arteries. Eur J Radiol 2015; 84: 398-406.

[5] Durhan G, Hazırolan T, Sunman H, Karakaya J, Karçaaltıncaba M, Aytemir K, Karaağaoğlu E and Akata D. Does coronary calcium scoring with a SCORE better predict significant coronary artery stenosis than without? Correlation with computed tomography coronary angiography. Eur Radiol 2015; 25: 776-784.

[6] Hell MM, Bittner D, Schuhbaeck A, Muschiol G, Brand M, Lell M, Uder M, Achenbach S and Marwan M. Prospectively ECG-triggered high-pitch coronary angiography with third-generation dual-source CT at 70 kVp tube voltage: feasibility, image quality, radiation dose, and effect of iterative reconstruction. J Cardiovasc Comput Tomogr 2014; 8: 418-425.

[7] Koplay M, Cimen D, Sivri M, Güvenc O, Arslan D, Nayman A and Oran B. Truncus arteriosus: Diagnosis with dual-source computed tomography angiography and low radiation dose. World J Radiol 2014; 6: 886-889.

[8] Madhok R and Aggarwal A. Comparison of 128-Slice Dual Source CT Coronary Angiography with Invasive Coronary Angiography. J Clin Diagn Res 2014; 8: RC08-11.

[9] Zimmerman SL, Kral BG and Fishman EK. Diagnostic quality of dual-source coronary CT examinations performed without heart rate control: importance of obesity and heart rate on image quality. J Comput Assist Tomogr 2014; 38: 949-955.

[10] Schmidkonz C, Marwan M, Klinghammer L, Mitschke M, Schuhbaeck A, Arnold M, Lell M, Achenbach S and Pflederer T. Interobserver variability of CT angiography for evaluation of aortic annulus dimensions prior to transcatheter aortic valve implantation (TAVI). Eur J Radiol 2014; 83: 1672-1678.

[11] Puchner SB, Ferencik M, Maurovich-Horvat P, Nakano M, Otsuka F, Kauczor HU, Virmani R, Hoffmann U and Schlett CL. Iterative image reconstruction algorithms in coronary CT angiography improve the detection of lipid-core plaque--a comparison with histology. Eur Radiol 2015; 25: 15-23.

[12] Kurata A, Kono A, Sakamoto T, Kido T, Mochizuki T, Higashino H, Abe M, Coenen A, Saru-Chelu RG, de Feyter PJ, Krestin GP and Nieman K. Quantification of the myocardial area at risk using coronary CT angiography and Voronoi algorithm-based myocardial segmentation. Eur Radiol 2015; 25: 49-57.

[13] Meinel FG, Canstein C, Schoepf UJ, Sedlmaier M, Schmidt B, Harris BS, Flohr TG and De Cecco CN. Image quality and radiation dose of low tube voltage 3rd generation dual-source coronary CT angiography in obese patients: a phantom study. Eur Radiol 2014; 24: 1643-1650.

[14] Paul JF. Individually adapted coronary 64-slice CT angiography based on precontrast attenuation values,using different kVp and tube current settings: evaluation of image quality. Int J Cardiovasc Imaging 2011; 27: 53-59.

[15] Ripsweden J, Brismar TB, Holm J, Melinder A, Mir-Akbari H, Nilsson T, Nyman U, Rasmussen E, Rück A and Cederlund K. Impact on image quality and radiation exposure in coronary CT angiography: 100 kVp versus 120 kVp. Acta Radiol 2010; 51: 903-909.

[16] Hausleiter J, Martinoff S, Hadamitzky M, Martuscelli E, Pschierer I, Feuchtner GM, Catalán-Sanz P, Czermak B, Meyer TS, Hein F, Bischoff B, Kuse M, Schömig A and Achenbach S. Image quality and radiation exposure with a low tube voltage protocol for coronary CT angiography results of the PROTECTION II Trial. JACC Cardiovasc Imaging 2010; 3: 1113-1123.

[17] Lu C, Wang Z, Ji J, Wang H, Hu X and Chen C. Evaluation of a Chest Circumference-Adapted Protocol for Low-Dose 128-Slice Coronary CT Angiography with Prospective Electrocardiogram Triggering. Korean J Radio 2015; 16: 13-20.

[18] Holmquist F, Hansson K, Pasquariello F, Bjork J and Nyman U. Minimizing contrast medium doses to diagnose pulmonary embolism with 80-kVp multidetector computed tomography in azotemic patients. Acta Radiol 2009; 50: 181-93.

[19] Gordic S, Husarik DB, Desbiolles L, Leschka S, Frauenfelder T and Alkadhi H. High-pitch coronary CT angiography with third generation dual-source CT: limits of heart rate. Int J Cardiovasc Imaging 2014; 30: 1173-1179.

[20] Dey D, Achenbach S, Schuhbaeck A, Pflederer T, Nakazato R, Slomka PJ, Berman DS and Marwan M. Comparison of quantitative atherosclerotic plaque burden from coronary CT angiography in patients with first acute coronary syndrome and stable coronary artery disease. J Cardiovasc Comput Tomogr 2014; 8: 368-374.

[21] Ghoshhajra BB, Engel LC, Károlyi M, Sidhu MS, Wai B, Barreto M, Shanmugam U, Hoffmann U, Brady TJ, Kalra M and Abbara S. Cardiac computed tomography angiography with automatic tube potential selection: effects on radiation dose and image quality. J Thorac Imaging 2013; 28: 40-48.

[22] Park YJ, Kim YJ, Lee JW, Kim HY, Hong YJ, Lee HJ, Hur J, Nam JE and Choi BW. Automatic Tube Potential Selection with Tube Current Modulation (APSCM) in coronary CT angiography: Comparison of image quality and radiation dose with conventional body mass index-based protocol. J Cardiovasc Comput Tomogr 2012; 6: 184-190.

[23] Winklehner A, Goetti R, Baumueller S, Karlo C, Schmidt B, Raupach R, Flohr T, Frauenfelder T and Alkadhi H. Automated attenuation-based tube potential selection for thoracoabdominal computed tomography angiography: improved dose effectiveness. Invest Radiol 2011; 46: 767-773.