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Application of Dual-Source CT TurboFlash Coarse Pitch Scanning in Coronary Artery Imaging

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Abstract

Objective: To compare and analyze the image quality and radiation dose of three scanning modes of dual-source CT coronary artery retrospectively, and to discuss the application value of TurboFlash coarse pitch scanning mode. **Methods:** The imaging data of 100 patients who underwent CT coronary angiography (CCTA) using Siemens force CT retrospective gated triggering spiral scan (RES-SPIRAL), adaptive prospective gated triggering sequence scan (SEQ) and prospective coarse pitch scan (TurboFlash) retrospectively was collected. The image quality was evaluated by objective and subjective methods. The effective radiation dose of patients was compared and analyzed, and the indications of the three scanning modes were analyzed. The application value of dual-source CT TurboFlash coarse pitch scanning in coronary artery imaging was evaluated. **Results:** The results showed that the left main coronary artery, the right coronary artery and their tertiary branches could be clearly displayed in the three groups of images: the left anterior descending branch, the left circumflex branch, and their three-level branches. There was no statistical difference in subjective image quality among the three groups of pictures ($P > 0.05$). There was no statistical difference in objective evaluation indexes, such as CT value, SNR, CNR and Noise among the three groups ($P > 0.05$). The patient radiation dose results showed that the effective radiation dose ED of RES-SPIRA scan was (9.22 ± 1.33) mSv. The dose of SEQ was (2.88 ± 2.47) mSv, and the dose of TurboFlash was (0.51 ± 0.16) mSv. There was significant difference in comparison of the three groups ($P < 0.05$). RES-spiral scanning had the highest radiation dose and TurboFlash coarse pitch scanning (TurboFlash) had the lowest radiation dose. **Conclusion:** TurboFlash coarse pitch scanning is low in dosage, fast in speed and wide in adaptability. It is especially suitable for the elderly, children, coma and other

patients who cannot cooperate with breath-holding examination, as well as for the screening and examination of coronary artery diseases in asymptomatic population. Undoubtedly, it is a worthy method of heart coronary artery examination.

Keywords

Dual-Source CT, Coronary Computed Tomographic Angiography, Coarse Pitch Spiral Scanning, Image Quality, Radiation Dose

1. Introduction

Coronary Computed Tomographic Angiography (CCTA) is more and more widely used in the examination of cardiac coronary arteries, because it is fast, efficient, safe and non-invasive. At the same time, the radiation damage brought by CT examination to the subjects receives more and more attention [1]. Due to the rapid development of CT technology, technical means to reduce the radiation dose of CT have been continuously developed and widely used in clinical CT examination. Among them, there are continuous reports at home and abroad [2] [3] [4] that dual-source CT coarse pitch spiral scanning mode and prospective gated triggering sequence scanning mode can effectively reduce the radiation dose of cardiac coronary CT imaging. This paper retrospectively collected the image data of three types of coronary artery imaging scanning modes of the third-generation dual-source CT (SOMATOM Force CT, SIEMENS) to compare and study the image quality and radiation dose of these three modes, and discuss the application value of TurboFlash coarse pitch scanning mode.

2. Data and Methods

2.1. General Data

The imaging data of 100 cases of cardiac coronary artery examination using Siemens Somaatom Force CT from August 2016 to August 2018 were retrospectively collected. Among them, 25 cases were treated with RES-SPIRALs canning, including 15 males and 10 females, aged from 48 to 78 years, with an average age of (62.3 ± 11.8) years and a BMI range of (24.8 ± 3.8) kg/m^2; fifty patients received prospective sequence scan (SEQ) (36 males and 14 females) with a mean age of (64.74 ± 12.1) years old and a BMI range of (24.5 ± 3.5) kg/m^2 were enrolled; 25 patients receiving coarse pitch spiral received (TurboFlash), including 17 males and 8 females, with an age of 31 to 99 years old and an average age of (67.05 ± 15.94) years old and a BMI range of (25.3 ± 3.33.3) kg/m^2. There was no statistical difference in BMI among the three groups ($P > 0.05$). This study was approved by the local ethics committee.

2.2. Examination Methods

All cases received coronal artery scanning by Siemens third-generation dual-source

CT (Siemens, Germany). The patients adopted supine position, with foot-first mode and 4-lead electrocardiogram test in front of the chest. Medrad stellant CT special high pressure syringe was adopted. The contrast agent was 350 mg/ml nonionic contrast agent iohexol, with a dose of 45 to 60 ml, and a bolus injection rate of 5 ml/s. 20 ml saline was injected at the same speed before the bolus injection of contrast agent to test the patency of blood vessels. 50 ml saline was injected after the bolus injection of contrast agent. Contrast bolus intelligent tracking technology was adopted. The tracking point was set at the root level of the left main trunk of the ascending aorta. The ROI area was about 1 $mm \cdot m^2$, and the triggering threshold was 100 Hu. The triggering scan started 7 seconds after the enhancement of the region of interest reached the threshold. The scan range was 10 mm below the bifurcation of the trachea to the diaphragmatic surface of the heart. RES-SPIRAL and SEQ reference tubes had a voltage/tube current of 100 kV/ref 250 mAs, a ball tube rotation speed of 0.5 s, and a pitch of 1; collimation: 192 × 0.6 mm; thickness of reconstructed layer: 1 mm. TurboFlash adopted dual-source scanning. The reference voltage/tube currents of tube A and tube B were 100 kV/ref250 mAs and Sn150 kV/ref125 mAs. The tube rotation speed was 0.25 s, and pitch was 3.2; collimation: 2 × 192 × 0.6 mm; thickness of reconstructed layer: 1 mm. All three adopted CARE Dose4tube voltage and tube current intelligent modulation technology, and the third-generation iteration algorithm was used to reconstruct images. The actual tube voltage and tube current were automatically adjusted according to the patient's body mass index (BMI).

2.3. Image Quality Evaluation

The "coronary artery" function module in Syngo.via software was used for post-processing. Three-dimensional reconstruction was performed to obtain a coronary artery volume rendering (VRT) image, a maximum intensity projection (MIP) image, and a curved surface reconstruction (CIP) image.

Subjective evaluation: Syngo.via software was used to read the films at the workstation. Two senior imaging diagnostic doctors used double-blind method to make subjective evaluation on the cross-sectional images, VRT, MIP and CIP images of the above three groups respectively. If there were different opinions, they reached consensus through joint review and negotiation. The image quality of the coronary artery was analyzed by using the 15-segment method of the American Heart Association. The left main coronary artery (LMA), the left anterior descending coronary artery (LAD), the left circumflex coronary artery (LCX) and the right coronary artery (RCA) were scored with 5 grades [5]: 5 points, the image quality of the coronary artery was very good without artifacts. 4 points, the image quality is good, but there is subjective noise or some artifacts. 3 points, acceptable noise and artifacts with little effect on the diagnosis; 2 points, poor image quality, loud noise, and serious artifacts, resulting in a segment of the coronary artery that could not be used for diagnosis; 1 point, very poor image quality, causing at least two segments of the coronary artery unable

to be used for diagnosis (Figure 1).

Objective evaluation: Syngo.via software was used. CT values of circular region of interest (ROI) were measured at the proximal end of the left main trunk (LMA) and the proximal end of the right coronary artery (RCA) respectively. The CT values of the same location were measured repeatedly for 3 times and averaged. The ROI was placed in the center of the blood vessel and the diameter did not exceed 2/3 of the diameter of the blood vessel to be measured. The standard deviation (SD) of the aortic root CT value was set as image noise. The contrast noise ratio (CNR) = (CT blood vessel − CT fat)/SD. The signal-to-noise ratio (SNR) = CT blood vessel/SD. The CNR and SNR at the proximal end of LMA and RCA were calculated.

2.4. Radiation Dose Evaluation

Radiation dose data was automatically generated by the CT scanning system.

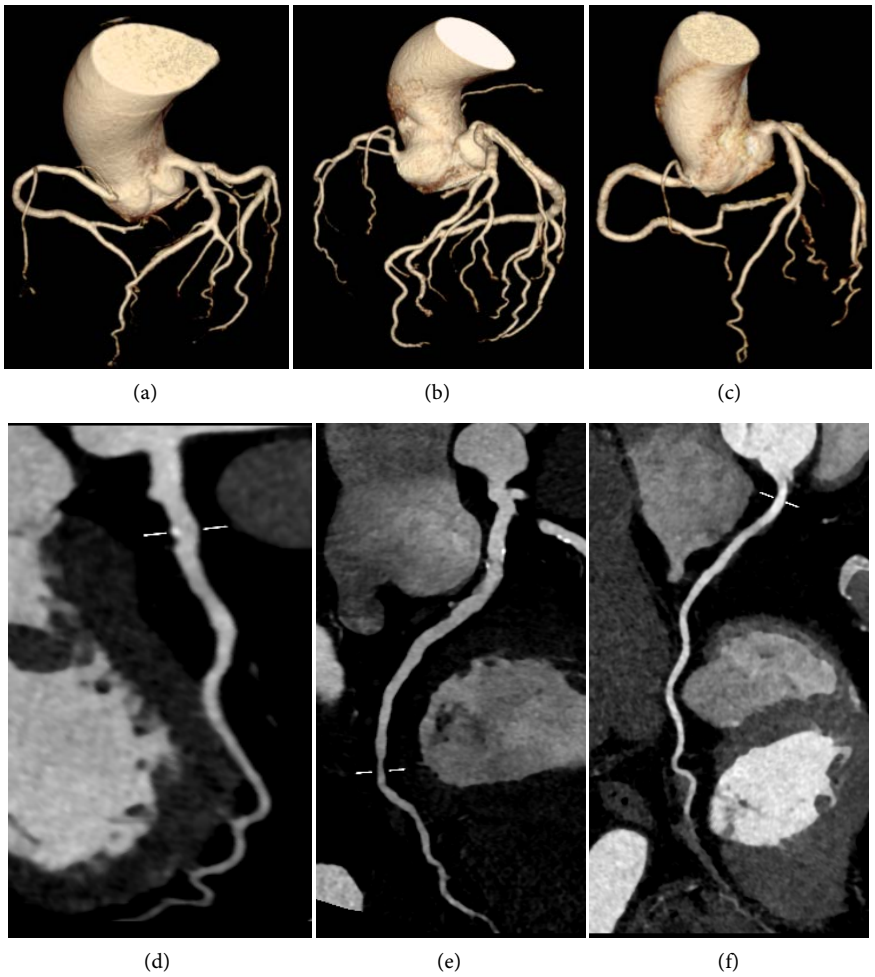

Figure 1. (a) to (c) were VRT images of coronary arteries obtained by RES-SPIRAL, SER and TurboFlash scanning modes respectively. Figures (d) to (f) were CPR images, and the effective radiation doses (ED) of the three scanning modes were 8 mSv, 2.1 mSv and 0.5 mSv respectively. However, there was no significant difference in subjective image quality scores of the three groups of images.

The radiation dose of coronary CTA in three scanning modes was only counted in this paper, excluding the radiation dose generated by calcification analysis and localization phase. CT volume dose index (CTDIvol) and dose length product (DLP), effective dose (ED) = DLP × absorption coefficient k [adult chest k = 0.014 mSv/(mGy × cm)] [6].

2.5. Statistical Analysis

SPSS 20 software was used for statistical processing. The measurement data of each group was expressed as mean standard deviation. Kruskal-Wallis test was used to compare the SNR, CNR, SD differences and subjective image scores of the three scanning methods. Single factor variance was used to analyze the radiation doses of the three scanning methods. $P \leq 0.05$ indicated that the difference was statistically significant. The consistency of the two images was analyzed by weighted Kappa. Kappa > 0.75 indicated good consistency. $0.40 \leq$ kappa ≤ 0.75 indicated relatively good consistency; Kappa < 0.40 indicated poor consistency.

3. Result

According to the comparison and analysis of the differences in SNR, CNR and SD of the images of the three scanning modes, there was no statistical difference in the objective image quality of the three groups of images ($P > 0.05$) (Table 1), and there was no statistical difference in the subjective image quality score ($P > 0.05$) (Table 2). The radiation doses of the three scanning modes were significantly different ($P < 0.05$) (Table 3). RES-SPIR scanning mode had the highest radiation dose and TurboFlash scanning mode had the lowest radiation dose.

4. Discussion

Compared with DSA, CCTA is fast, non-invasive, safe and efficient, and has been widely used in the examination of coronary arteries. At the same time, the radiation damage brought by traditional CCTA to patients is also receiving more and more attention. With the rapid development of CT technology, low-dose CCTA examination has become possible.

Table 1. Comparative analysis of CT values, SNR, CNR and SD of three CCTA scanning modes.

	RES-SPIRAL	SEQ	TurboFlash	P-value
LMA CT-Value	635.65 ± 172.68	642.5 ± 161.14	565.29 ± 190.78	P > 0.05
LMA SNR	20.88 ± 6.31	20.626 ± 6.95	20.79 ± 10.05	P > 0.05
LMR CNR	25.87 ± 7.34	25.57 ± 5.76	25.40 ± 6.9	P > 0.05
RCA CT-value	641.6 ± 165.35	642.5 ± 156.32	596.18 ± 189.21	P > 0.05
RCA SNR	21.12 ± 10.15	20.84 ± 11.29	20.65 ± 6.96	P > 0.05
RCA CNR	25.88 ± 7.01	25.79 ± 6.64	25.77 ± 7.08	P > 0.05
Noise	33.98 ± 7.69	34.75 ± 6.87	33.78 ± 7.24	P > 0.05

Table 2. Comparison and analysis of subjective image quality scores of images obtained by CCTA three scanning modes.

	Quality scores			χ^2-value	P-value
	RES-SPIRAL	SEQ	TurboFlash		
LAD	4.12 ± 0.33	4.13 ± 0.28	4.10 ± 0.34	2.328	0.298
LCX	4.08 ± 0.45	4.12 ± 0.41	4.09 ± 0.45	2.289	0.336
RCA	4.20 ± 0.34	4.17 ± 0.50	4.15 ± 0.37	4.367	0.278

Table 3. Comparative analysis of radiation doses of 3 CCTA scanning modes.

	RES-SPIRAL	SEQ	TurboFlash	P-value
N	25	50	25	
BMI (kg/m^2)	24.8 ± 3.8	24.5 ± 3.5	25.3 ± 3.3	>0.05
Gender	15 males and 10 females	36 males and 14 females	17 males and 8 females	-
Age	62.3 ± 11.8	64.74 ± 12.1	67.05 ± 15.94	>0.05
ED (mSv)	9.22 ± 1.33	2.88 ± 2.47	0.51 ± 0.16	<0.001
CTIvol (mGy)	40.54 ± 6.89	14.01 ± 9.77	1.99 ± 0.62	<0.001
DLP (mGy·cm)	658.46 ± 94.97	189.61 ± 124.81	36.68 ± 11.29	<0.001

The three scanning modes of the third-generation dual-source CT (Siemens, Germany) CCTA respectively are retrospective spiral scanning (RES-SPIRAL), adaptive prospective sequence scanning (SEQ) and coarse pitch spiral scanning (TurboFlash). RES-SPIRAL was to retrospective ECG-gating technology to acquire continuous spiral scanning data and synchronous data of heart movement by using synchronous acquisition technology of ECG and CT scanning. After scanning was completed, any time phase needed in the heart cycle could be selected to reconstruct according to the synchronously recorded electrocardiogram. Automatic pitch adjustment technology was adopted. The scanning mode can be applied to any heart rate and rhythm. With wide adaptability, it is suitable for any heart rate. Late ECG editing and cardiac function analysis is supported. In addition, this mode has fast scanning speed, and thus is suitable for long scanning range. But its disadvantage is that the radiation dose is too high. According to the research on Siemens second-generation dual-source CT by Guo Xiaowan *et al.*, the effective radiation dose of RES-SPIRAL scanning mode reached (13.33 ± 12.77) mSv, and the effective dose of this study also reached (9.22 ± 1.33) mSv based on the research of the second-generation dual-source CT.

SEQ scanning mode refers to the scanning process triggering by an R wave of the patient's ECG signal. X-ray exposure and data acquisition are started at a preset time point behind the R wave. Generally, X-ray exposure and data acquisition are started in the diastole with the lowest cardiac motility. During the acquisition process, the examination bed remained stationary. After the exposure

and data acquisition were completed, the examination bed was moved to the next scanning position and the scanning was delayed until the next triggering R wave appeared. The prospective R wave position is obtained from the average of the three R-R intervals, and the stepping and scanning are alternately carried out. The scanning is finished after the full volume data is acquired. Because Force CT uses adaptive technology, it can adjust the plan of scanning, data acquisition and examination bed movement according to the patient's heart rate changes. At the same time, Force CT adopts ECG-pulsing real-time tube current modulation technology. During diastole or systole, full-dose exposure can be used to obtain data for displaying coronary arteries, while the rest of the phases use low-dose exposure (about 20% of the full-dose). The obtained data can be used to dynamically display the movement of myocardium and valves, and can be used for cardiac function analysis. The advantages of SEQ scanning include: it is suitable for common arrhythmia, and the abnormal heart rhythm system can automatically adjust and evade, thus improving the success rate; it can be used for cardiac function analysis and later ECG editing; the radiation dose is lower than RES-SPIRAL scanning. The result of this study showed ED = (2.88 ± 2.47) mSv, which is 87.8% lower than RES-SPIRAL scanning mode; there is no statistical difference between high image quality and RES-SPIRAL scanning mode. However, its disadvantage is that it has high requirement for breath-holding: otherwise, faults and leakage will easily occur.

TurboFlash scanning is based on force dual-source CT coarse pitch/technology and machine performance of high time resolution (0.66 ms). Two sets of ball tubes, ball tube A and ball tube B, are used. Their arrangement position is equal to 95 degrees. In Flash mode, ball tube A and ball tube B use the same voltage to cooperate with the two sets of detectors (synchronous acquisition). The image data can be obtained by rotating about 1/4 turn, and the rotation speed is 0.25 seconds/turn. Its advantages are: the lowest radiation dose; with no need of breath-holding, it can be suitable for patients with high heart rate. Disadvantages: heart rate needs to be stable and regular; ECG editing is not supported; heart function analysis is not supported.

In recent years, there have also been reports on flash scanning mode. Qi Wang and other scholars [7] performed two-phase scanning in Flash mode on 47 patients with atrial fibrillation. The analysis found that the subjective image quality was excellent and the effective radiation dose was 0.64 to 1.97 mSv. It was believed that the results of coarse pitch acquisition were in good agreement with those of gold standard coronary angiography. Yuichiro Kanie and other [8] scholars retrospectively studied 142 children with congenital heart disease who underwent a coarse pitch heart scan under the control of Flash CT center less switch. The results showed that 80.5% of the coronary artery segments reached the diagnostic level of image quality. Age and heart rate did not affect the image quality of coronary artery imaging, and the effective radiation dose was at least 0.73 mSv. The study suggested that dual-source CT could complete coronary

CTA imaging with free breathing. Xia Yang *et al.* [9] used the coarse pitch scanning mode to evaluate the patency of coronary stents and received good results. This study found that among the cases completed by TurboFlash scanning mode, one was a deep coma patient, female, 69 years old, with a heart rate of 75 to 135 beats/min. The results showed that the images met the diagnostic requirements and excluded myocardial infarction. The effective radiation dose ED was 0.58 mSv. The lowest effective dose ED in this study was only 0.32 mSv. The average radiation dose of TurboFlash scanning mode was 88.99% lower than that of SEQ scanning mode.

To sum up, the three scanning modes of Force dual-source CT have their own advantages and disadvantages. We think that we should select the scanning mode according to the characteristics of the three scanning modes and the actual situation of the patients. From the perspective of late ECG editing and cardiac function analysis, there is no difference between SEQ and RES-SPIRAL, but the dose of SEQ is lower. For patients who can well cooperate with breath holding, the SEQ scanning mode should be preferred. For patients who do not have good respiratory coordination but require high image quality and need cardiac function analysis and ECG editing, RES-SPIRAL scanning mode can be selected. TurboFlash scanning mode is suitable for any heart rate because of its extremely fast scanning speed. There is no need to hold breath. There is no difference between the image quality of TurboFlash and that of the former two. For the elderly, infants, comatose patients and other subjects who cannot cooperate with holding breath, it should be the first choice; since the TurboFlash scanning mode has extremely low radiation dose, it has a broad development prospect to be popularized and applied in the screening and examination of coronary heart disease. However, since this scanning mode has a certain percentage of failure rate for patients with arrhythmia, and cannot realize ECG editing and cardiac function analysis, its advantages are limited to a certain extent.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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