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Clinical application of flash spiral mode of high-pitch dual source CT in carotid, cardiac and cerebral vessels combined one-stop angiography

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Abstract. – OBJECTIVE: This study aims to evaluate the clinical application value of flash spiral mode of high-pitch dual source CT in carotid, cardiac and cerebral vessels combined one-stop imaging.

PATIENTS AND METHODS: A total of 100 consecutive patients were given carotid, cardiac and cerebral vessels combined one-stop imaging at flash spiral mode of high-pitch dual source CT. 27 patients received DSA examination of carotid and cerebral vessels, and 38 patients received digital subtraction angiography (DSA) examination of the coronary artery at the same time. Carotid, cardiac and cerebral vessels combined one-stop imaging was compared with "golden standard", DSA image.

RESULTS: The overall satisfaction rate of coronary arteries, extracranial segment of the carotid artery (CA-E), intracranial segment of the carotid artery (CA-I), and cerebral vessels (anterior, middle, and posterior cerebral artery) were 93%, 99%, 95% and 97% respectively, and the positive rate of hemadostenosis was consistent with DSA. The kappa value indicating consistency of cerebral, carotid and coronary artery vessels was 0.78382, 0.80654, 0.82398, respectively.

CONCLUSIONS: The method of carotid, cardiac and cerebral vessels combined one-stop imaging by flash spiral mode of high-pitch dual source CT can provide high image quality. It comprehensively evaluates stenosis of carotid, cardiac and cerebral vessels, which is of great importance for early intervention in harmful events of the cardia and cerebrovascular disorder.

Key Words:
Coronary heart disease, Stroke, Tomography, X-ray computed, Angiography.

Introduction

Cardiovascular and cerebrovascular diseases mainly include coronary heart disease and stroke, frequently occur in middle-aged and elderly people, and represent a serious disease for human health. Atherosclerosis is the main cause of coronary heart disease and stroke[1-3]. Although non-invasive spiral CT angiography has become the main choice to accurately examine the lesions of coronary, head and neck arteries, it is yet controversial that a large amount of contrast medium results in the rise of radiation dose for the patient has to receive separate examination on coronary, head and neck arteries[4]. The second-generation dual source CT, with wide detector and fast rotation speed, improves the data collection, and makes it possible for one-stop scanning of head, neck and heart arteries. This study aimed to evaluate the clinical value of flash spiral mode of high-pitch dual source CT in carotid, cardiac and cerebral vessels combined one-stop angiography by comparing with DSA images.

Patients and Methods

Common Data

A hundred patients admitted in Rizhao People's Hospital were enrolled for carotid, cardiac and cerebral vessels combined one-stop imaging under the Flash large spiral mode of dual source CT. Inclusion criteria: patients with body mass index (BMI) <30 kg/m^2, weight (66.5±12.2) kg, heart rate ≤65 times/min (including patients who received drug intervention). Exclusion criteria: patients who were allergic to iodine contrast agents, with arrhythmia (atrial fibrillation, frequent ventricular premature beat), with severe hepatic and renal dysfunction, hemodynamic instability and breath-holding problem. All the patients had signed the informed consent regarding CTA examination. Among these 100 patients, 37 patients

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were suspected of cerebrovascular ischemia, 41 of coronary heart disease, 7 patients received carotid artery stenting, and 2 patients received coronary artery bypass graft. There were 66 male and 34 female patients with age ranging from the age of 38 to 86 (average age of 61.3±8.5). This study was approved by the Ethics Committee of Rizhao People's Hospital.

CT Scanning Technology

The data was collected by using second-generation dual-source CT (Definition Flash, Siemens Healthcare, Forchheim, Germany). The scan started from heart mediastinum to cranial apex. The rotating time of the tube: 280 ms. The collimation: 2 mm × 64 mm × 0.6 mm. The tube voltage: 100 kV. Real-time dynamic exposure dose (CARE Dose4D) was adopted to further adjust the tube current according to BMI, on the basis of tube voltage adjustment. The current range was 350-410 ma and the pitch was 3.4. At the aortic root level, the CT value of ROI was detected. When the value was greater than 100 Hu, the scan was automatically triggered after a delay of 4 s. The prospective ECG gated large pitch (flash spiral) scan mode was used, the R-R interval was 55% (default mode), and 60 ml was injected into the anterior cubital vein. The bolus tracking method was used to determine the concentration of iodide (370 mg/ml) and normal saline (50 ml) at the rate of (5-6) ml/s.

Image Reconstruction

Image reconstruction was performed by using two methods, including traditional filtered back projection (FBP) and recurrence CT protocol (RP) reconstruction. The thickness of both reconstruction methods was 0.6 mm, the reconstruction interval was 0.3 mm, and the convolution kernel was B26f and I26f, respectively. The image was post-processed by Circulation and 3D software. Multiplanar (MPR), thin maximum intensity projection (MIP), curved planar reformations (CPR), and volume rendering (VR) were mainly used for image reconstruction, and the blood vessels were analyzed combined with axial enhanced images.

DSA Examination in Positive Patients

Twenty-seven patients received head and neck angiography (DSA), and 38 patients received coronary angiography (DSA). The written informed consent had been signed before the examination. The examination was conducted within two weeks after dual source CT head, neck, and heart CTA.

Image Quality Analysis

Subjective image quality evaluation and criteria: the head and neck cardiovascular system was divided into four parts: coronary artery, extracranial segment of carotid artery, intracranial segment of carotid artery and cerebrovascular system. The image quality was evaluated by 0-3 score: excellent (3 points), clear vessel display, clear boundary, no artifacts; good (2 points), corresponding vessel with mild lumen blur, mild artifacts, which can be used for diagnosis; poor (1 point), severe vascular artifacts, which affects normal diagnosis; poor (0 points), corresponding vessel display is incomplete, continuity interruption, which cannot be diagnosed normally. Among them, images with 2-3 points indicate diagnostic value.

Diagnostic Standard of Angiostenosis and Its Levels

The stenosis rate of cerebral artery, carotid artery and coronary artery was calculated by North American symptomatic carotid endarterectomy test (NASCET) and international common diameter method. The stenosis rate D (%) = (1-A / b) × 100%, a = the diameter of the narrowest part in the cross section, B = the diameter of the distal normal vessel. The results were classified as follows: no stenosis (d = 0), Mild stenosis (D ≤49%), moderate stenosis (50% ≤D ≤69%), severe stenosis (70% ≤D ≤99%) and total occlusion (D = 100%). For the convenience of analysis, the cerebral arteries of 27 patients were divided into 162 vessels according to bilateral anterior, middle and posterior cerebral arteries, and the carotid arteries were divided into 54 vessels from the left and right sides. The coronary arteries were divided into 15 sections of vessels according to the American Heart Association Segment: right coronary artery was divided into RCA1, RCA2, RCA3 and RPD, while the left coronary artery was divided into LMA, LAD1, LAD2, LAD3, D1, and D2 and LCX was divided into LCX1, LCX2, OMB, and PD. Therefore, there were totally 532 sections in the coronary arteries of these 38 patients.

Calculation

Sensitivity also known as true positive rate = CTA true positive number / DSA positive number × 100%. Specificity also known as true negative rate = CTA true negative number / DSA negative number × 100%; Accuracy refers to the coincidence of CTA and DSA results = (CTA true positive number + true negative number) / (DSA pos-

itive + negative total number) × 100%. Positive predictive value = CTA true positive / (true positive + false positive) × 100%. Negative predictive value = CTA true negative / (true negative + false negative) × 100%. Kappa value = consistent number of stenosis detected by CTA and DSA / total number of stenosis detected × 100%.

Statistical Analysis

SPSS 17.0 statistical software (SPSS Inc. SPSS Statistics for Windows, Chicago, IL, USA) was used for data analysis. Kappa consistency test showed that kappa ≥0.75 indicated high consistency. The sensitivity, specificity, positive predictive value, negative predictive value and the Kappa value of the CTA were calculated based on the gold standard of DSA results to evaluate the reliability of dual source CTA in the diagnosis of carotid, cardiac and cerebral artery stenosis.

Results

The original data of 100 patients were processed for image generation. The overall satisfaction rates of coronary artery vascular, extracranial carotid artery (CA-E), intracranial carotid artery (CA-I) and cerebrovascular (anterior cerebral artery + middle cerebral artery + posterior cerebral artery) were 93%, 99%, 95% and 97%, respectively (Table I and Figure 1).

The overall coincidence of CTA and DSA in the diagnosis of 748 segments stenosis was 652 (87.2%). The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of dual source CT flash spiral mode CTA in the evaluation of carotid, cardiac and cerebral arteries stenosis were highly consistent with DSA as the gold standard control. The kappa values of consistency test were 0.78382, 0.80654 and 0.82398, respectively, which were all greater than 0.75, as shown in Tables II and III.

Discussion

Atherosclerosis is a type of systematic disease, 15-30% of which is implicated to cerebral artery, carotid artery, aorta, coronary artery and lower extremity artery at the same time[5]. Among these, the disease caused by coronary artery and head and neck artery atherosclerosis poses relatively great threat to human life. A large number of studies[6,7] showed that coronary heart disease caused by coronary atherosclerosis is closely related to stroke caused by head and neck atherosclerosis and both of them have common pathological changes. Wei et al[8] showed that the proportion of moderate and

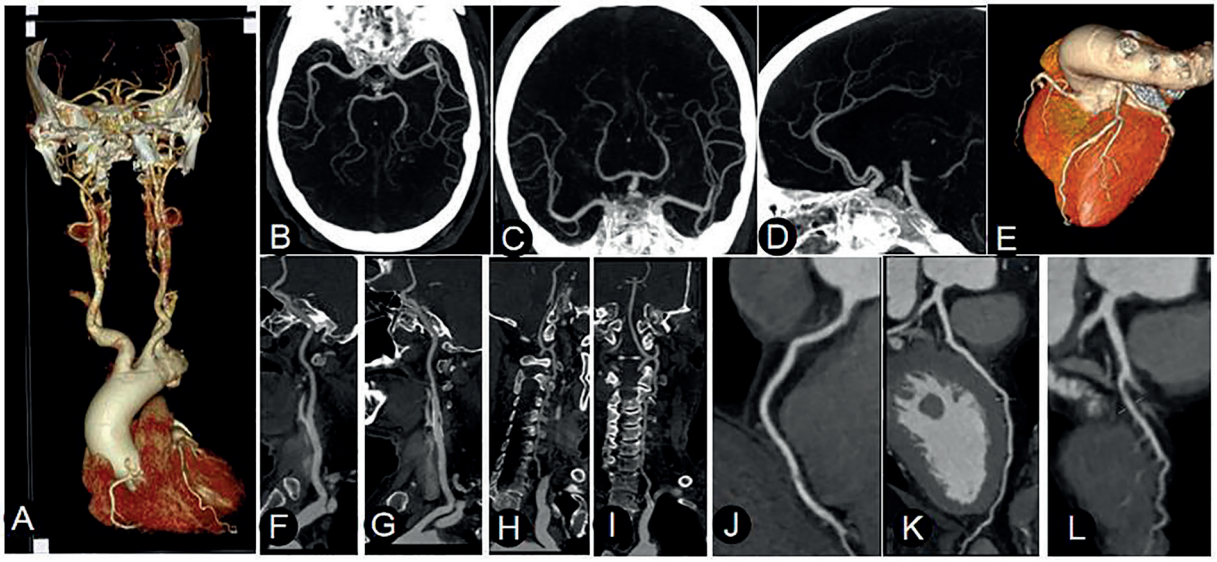

Figure 1. The carotid, cardiac and cerebral vessels combined one-stop imaging based on Flash large spiral scanning mode. The data of a 75-year-old male patients with heart rate of 65 bpm were used. Scanning time: 0.883 s, effective radiation dose: 1.22 msv, contrast agent: 55 ml. **A,** The VRT image of the carotid, cardiac and cerebral vessels**. B-D,** The image of MIP at cerebral vessels. **F-I,** The image of CPR at bilateral carotid artery and vertebral artery. **E,** VRT image of heart. **J-L,** The image of CPR at coronary artery.

Table I. The image quality assessment of carotid and cardiac and cerebral arteries combined one-stop imaging under the Flash large spiral mode of dual-source CT.

Part of blood vessel	Score				Summation of case number	Satisfaction rate of vascular evaluation
	3	2	1	0		
Coronary artery	71	22	5	2	100	93%
CA-E	93	6	1	0	100	99%
CA-I	77	18	5	0	100	95%
Cerebral vessel	84	13	3	0	100	97%

Table II. The contrast between DSA results of pate examination of 27 patients and diagnosis of stenosis in the coronary artery of 38 patients by dual-source CTA among these positive patients.

Dual source CTA	Cerebral vessel DSA						carotid artery DSA						Coronary artery DSA					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
A	52	3	3	0	0	58	11	1	0	0	0	12	377	10	3	0	0	390
B	8	30	5	0	0	43	3	10	1	0	0	14	30	59	6	1	0	96
C	2	3	49	0	0	54	1	2	12	1	0	16	1	1	16	3	0	21
D	0	0	0	6	0	6	0	0	2	7	0	9	0	2	4	17	0	23
E	0	0	0	0	1	1	0	0	0	0	3	3	0	0	0	0	2	2
F	62	36	57	6	1	162	15	13	15	8	3	54	408	72	29	21	2	532

Note: A, B, C, D, E shows different degree of vascular stenosis respectively. A shows the case number of normal; B shows the case number of mild degrees; C shows the case number of moderate degree; D shows the case number of severe degree; E shows the case number of occlusion in appropriate part of blood vessels; F is the summation of case number.

severe cerebral artery stenosis was as high as 92% in patients with coronary artery California risk score $\geq$ 2. With the aggravation of coronary artery stenosis, carotid artery and cerebral artery stenosis also worsened with parallelism. Therefore, a comprehensive and accurate evaluation of the severity of head and neck atherosclerosis and its relationship is of great significance for early clinical intervention and reduction of the incidence of cardiovascular and cerebrovascular diseases.

With the development of multislice spiral CT, CTA has become a noninvasive detection method for accurate diagnosis of coronary heart diseases and cerebral artery diseases[9]. Due to the influence of CT equipment hardware configuration, conventional CTA examination of coronary artery and head and neck artery requires prescription twice, scanning twice, with large amount of contrast agent, high radiation dose and relatively time-consuming operation. With the advent of the second-generation flash dual source CT, the time resolution is improved to 75 ms, the spatial resolution is 0.17 mm, the scanning speed is 45 cm/s, and the maximum pitch is 3.4, which can realize the prospective large pitch scanning, and there is still enough time to complete the head and neck pulse scanning after completing the cardiac imaging in a single cardiac cycle of 1/4S. In this study, dual source CT with large pitch mode was used for head and carotid artery one-stop imaging. The total amount of non-ionic contrast agent with concentration of 350 mg/ml was about 60 ml, and the average effective radiation dose was 1.38 ± 0.54 mSv. Compared to the study of Zhang et al[10], the effective radiation dose of 256 slice ICT combined cardio cerebrovascular imaging was reduced by 2/3. The results of dual source CT flash spiral mode combined one-stop scanning of cardiac and carotid and cerebral vessels were basically consistent with the finding of Sun et al[11].

This study showed that for patients with heart rate <65 beats/min, flash mode was used to collect data at 60% R-R interval, and the evaluable coronary segment rate was 93%, which was slightly lower than the data of Leschka et al[12] that the coronary segment rate was 99% by single coronary artery imaging with the same scanning mode. We propose that this study included pa-

tients with heart rate >65 beats/min, while drugs were applied to control the patients' heart rate below 65 beats/min before examination. In this study, the satisfaction rate of carotid and cardiac arteries reaches more than 95%, partially due to full preparation before examination and repeated communication with patients. Compared with DSA results, the results of head, neck and heart stenosis were basically consistent with DSA results ($p > 0.05$). The consistency of diagnosis of severe stenosis and occlusion with DSA was more than 95%. Compared with the images obtained by dual source CT single prospective scan or full dose coronary CTA as well as head and neck dual energy CTA, the noise of the images obtained by this technique has been increased. The iterative reconstruction (IR) of the original data further reduced the image noise significantly and improved the subjective image quality, which was in line with the previous results[13].

Although this study determined the feasibility of flash spiral mode of high-pitch dual source CT in carotid, cardiac and cerebral vessels combined one-stop angiography in a specific population (heart rate ≤65 beats/min, BMI <30), the following limitations still exist. First, the sample size of the study is small, for patients (BMI ≥30 kg/m^2) are not included. Second, the prospective ECG gated flash mode was used in this study. The sequence is sensitive to movement and prone to artifacts, especially in patients with high heart rate or under unstable state. Whether the dual source CT flash mode can be used for examination remains to be further investigated with the development of CT hardware. Thirdly, this technique can only reconstruct one diastolic phase of the cardiac cycle, whereas it is unable to edit ECG and analyze multi phases, which increases the uncertainty of diagnosis. In addition, iterative reconstruction is a time-consuming process.

Conclusions

To sum up, carotid, cardiac and cerebral vessels combined CTA imaging under the Flash large spiral mode of dual source CT functions as a rapid, effective and noninvasive detection method. This method ensures image quality and can reduce the dosage of radiation and contrast medium. For patients with heart rate of no more than 65 beats/min, it can comprehensively and accurately evaluate the severity of stenosis of carotid, cardiac and cerebral vessels and determine its clinical relationship, which provides reliable leads for early intervention and treatment in clinic.

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Table III. TExamination of sensitivity, specificity, positive and negative predictive values and accuracy of stenosis by dual-source CTA.

		Normal	Mild	Moderate	Severe	Occlusion	K value
Cerebral vessel	sensitivity	83.9%	83.3%	86.0%	100%	100%	0.78382
	specificity	94.0%	89.7%	95.2%	100%	100%	
	Positive predictive value	89.7%	73.2%	90.7%	100%	100%	
	Negative predictive value	90.4%	95.0%	92.6%	100%	100%	
	accuracy	77.9%	73.0%	81.2%	100%	100%	
Carotid artery	sensitivity	73.3%	92.3%	86.7%	87.5%	100%	0.80654
	specificity	97.4%	95.1%	92.3%	95.7%	100%	
	Positive predictive value	91.7%	85.7%	81.3%	77.8%	100%	
	Negative predictive value	90.5%	97.5%	94.7%	97.8%	100%	
	accuracy	70.7%	87.4%	79.0%	83.2%	100%	
Coronary artery	sensitivity	96.3%	81.9%	79.3%	86.4%	100%	0.82398
	specificity	90.4%	96.3%	99.2%	99.2%	100%	
	positive predictive value	97.0%	77.6%	85.2%	82.6%	100%	
	Negative predictive value	88.3%	97.1%	98.8%	99.4%	100%	
	accuracy	86.7%	78.2%	78.5%	85.6%	100%	

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Conflict of Interest

The Authors declare that they have no conflict of interests.

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