Acta Transitional Medicine *An International Scientific Journal*	ISSN: 2521-8662	Volume 3	Issue 1	Pp.52-57	March 2020

OPTIMIZATION OF IMAGE QUALITY AND RADIATION DOSE VIA HIGH-PITCH AORTIC CT ANGIOGRAPHY WITH INDIVIDUAL DOSE OF CONTRAST AGENT

Haidong Chen , Zhenjie Yu , Rungen Zhan, Weicheng Lin , Rong Zhou , Jiamin Li *

Department of Radiology, Zhuhai People's Hospital (Zhuhai Hospital affiliated with Jinan University), Zhuhai, 519000, P.R. China.

**Corresponding Author: Li Jiamin: jml2019@126.com; 1Department of Radiology, Zhuhai People's Hospital（Zhuhai Hospital affiliated with Jinan University), Zhuhai, 519000, P.R. China.*

Abstract: Objective: To improve the distal aortic image quality and reduce the whole radiation dose of high-pitch dual-source CT angiography using individual dose of contrast agent. **Material and Methods:** A total of 91 consecutive patients undergoing clinically indicated CT angiography (CTA) of the thoracoabdominal aorta on a dual-source scanner using either conventional dual-source CT angiography mode (n=47) or high-pitch dual-source CT angiography mode (n =44) during the arterial phase. For the high-pitch group, the delayed imaging time was the peak time of the femoral artery. The dose of contrast agent, contrast enhancement and signal noise ratio (SNR) were evaluated objectively. Subjective rating of the image quality throughout the thoracoabdominal aorta was assessed by two independent readers. Scanner-reported dose-length product values were used to estimate effective dose values. **Results:** Compared to conventional method, dual-source high-pitch aortic CT angiography dramatically shortened the total examination time by 78％ to 1.47±0.14 min. In the conventional group, there were 5 patients who had poor imaging of the distal arteries due to abdominal aortic aneurysm, so they needed additional re-scan. However, in the high-pitch group, all patients could obtain good images that meet the diagnosis requirements with only one scan. The mean dose of contrast agent decreased by 21.6% to 62.68±5.98 ml($P<0.001$) in high-pitch group. Furthermore, the volume CT dose index, dose-length product and effective dose in high-pitch group were significantly lower than those in conventional group, reduced by 70.3%, 66.8% and 66.1% respectively (all $P < 0.001$). At the level of abdominal aorta, mean CT values, SNR and subjective rating were higher in high-pitch group compared to conventional group (all $P < 0.05$), whereas at the level of aortic root, there was no significant difference of SNR between two groups($P>0.05$), the incidence of aortic root motion artifacts in the high-pitch group was significantly lower than that in the conventional group($P<0.05$), and subjective rating was still much higher in high-pitch group than that in conventional group($P<0.05$). **Conclusion:** High-pitch dual-source CT angiography using individual dose of contrast agent can not only effectively reduce the effective radiation dose, but also improve the image quality of the aortic root and distal end.

Keywords: Dual-source CT, High-pitch, CT angiography, Aorta, individual dose of contrast agent

Introduction

Computerized tomography (CTA) has been established as the standard imaging method for the assessment of aortic disease[1]. However, because the examination requires intravenous injection of contrast agent, patients (including those with unstable hemodynamics) undergoing CTA may be at risk of contrast-induced nephropathy[2]. Moreover, in clinical situations where both the thoracic aorta and the descending aorta of the abdominal aorta need to be evaluated, there may be conflicting imaging goals, namely to minimize motion artifact from the root and ascending aorta, optimally enhancing the thoracic and abdominal aorta including large branch vessels, and radiation burden[3]. However, depending on the clinical situation, especially for patients who are treated or suspected of abdominal aortic aneurysm, supplementary unenhanced or delayed collection is required[4]. However, multiple collections will also increase the patient's accumulated radiation dose.

The high-pitch resolution provided by dual-source

CT, which is almost twice that provided by single-source CT scanners, is very valuable in cardiac imaging applications[5, 6] Nowadays, there are some researches aimed at improving image quality and reducing radiation dose. Long Jiang Zhang et al.[7]studied that when the total aortic CTA at 70 kVp and the pitch increased to 3.4, the dose was reduced by more than 80% compared to 120 kVp and 1.2 pitch. Tevfik F Ismail et al. [8]reported that taking the peak time of the aortic root as the time of coronary angiography in coronary CTA. However, so far, there are few studies on using a pitch = 3.4 scan for improving the poor visibility of distal arteries caused by aortic disease.

Materials and methods

Subject Population

This prospective study was approved by our institutional review board, and all patients signed informed consent. From 2018 to 2019, 91 patients (69 men and 22 women; mean age 59.2 years) with suspected or known aortic disease were included in this study. After informed consent, 47 patients were randomly selected to use the conventional CTA scan mode, and 44 patients were used the high-pitch and contrast agent individualized scan mode. Exclusion criteria: those who are allergic to iodine contrast medium; patients with severe liver and kidney dysfunction and cardiac dysfunction; pregnant; lactating women and patients under 18 years of age.

CT Imaging Protocol

In all examination, we used Siemens SOMATOM Definition Flash dual-source CT scanner, MEDRAD Stellant D dual-tube high-pressure syringe, and used Bayer Univision (370mgI/ml) as a contrast agent, which is injected through the elbow vein. First, perform continuous positioning imaging of the patient’s chest and abdomen (from the entrance of the chest cavity to below the pubic symphysis), and then perform an enhanced scan.

The high-pitch group adopted 100kVp, effective mAs 370, pitch 3.4, and CARE Dose 4D function was enabled. The contrast agent personalization plan was as follows. The first step is to inject 15ml of contrast agent and 20ml of saline at a rate of 5ml/s and measure the average peak time of bilateral femoral arteries (PT, s). The second step is to calculate the required contrast agent dose according to the patient's femoral artery peak time: $\frac{\mathrm{PT}}{2}(\mathrm{PT,s}) \times 4\mathrm{m/s}$(The part with PT less than 1s was calculated as 1s). Finally, the contrast agent needed by the individual plus 50 ml of physiological saline was injected at a rate of 4 m/s. Scan delay time is PT value, set iterative reconstruction (SAFIRE, Stength =1).

The regular scan group used 120 kVp, effective mAs 220, pitch 1.2, and CARE Dose 4D function was enabled.100ml of contrast agent and 50ml of physiological saline were injected under high pressure, and the injection flow rate was 5ml/s. Using contrast medium tracking technology (Bolus Tracking) and setting the region of interest (ROI) on the 12th thoracic plane of the aorta. The trigger threshold was 100 Hu, and the arterial phase enhancement scan was performed after a 6-second delay after the trigger.

In the equipment three-dimensional card, the volume data of each patient is reorganized by types such as MPR, VR and MIP, and the image is comprehensively analyzed.

Objective Image Analysis

The objective evaluation of image quality includes the average CT value and signal noise ratio (SNR) after blood vessel enhancement. The assessment blood vessels include the aortic root and the same level as the superior vena cava, pulmonary artery, left atrium and descending aorta, as well as the carotid artery at the carotid root level and the femoral arteries on both sides of the symphysis pubis level. When measuring, the area of attention (ROI) was set in the central area of the blood vessel lumen, avoiding the blood vessel wall, calcification, metal stents and artifact areas. The ROI of patients with aortic dissection was set in the true cavity. Calculate the determined SNR (SNR = average CT value/SD) by calculating the standard deviation (SD) of the CT value of the ROI area.

Subjective Analysis of Image Quality

Two Observers (5 and 1-year experience in reading aortic CTA) independently evaluated image quality in axial CTA images of the aorta by using by using a 4-point scale evaluating motion artifacts, noise level, and vessel visibility, where 4, no related artifacts or noise, excellent blood vessel enhancement, good definition of blood vessel edge; 3, with a little artifact or noise, the sharpness and enhancement of the blood vessel edge are good, but without limitation regarding the evaluation of aortic diseases; 2,moderate artifacts, slightly noisy, but no obvious faults, barely able to diagnose; and 1,poor quality with severe metal or motion artifacts rendering diagnostic interpretation impossible. The multiplanar reformation and maximum intensity projection were combined to evaluate overall image quality of each segment of the aorta by the same readers using the same four-point scale.

Estimation of Radiation Dose

The CTDIvol, DLP and total effective dose length product (DLP) during monitoring and scanning are automatically recorded by the machine.(The monitoring period referred to the scan detection level of the routine group and the period of monitoring the descending aortic threshold, and the period of measuring the peak time of the femoral artery in the high-pitch group. The scan period referred to the enhanced scan after the injection of contrast agent.)[9].

Calculate the effective dose (ED) according to DLP: ED = k × DLP, where k is the torso value 0.015

recommended by the European Commission (CEC)[9], which are recorded as ED during the monitoring period and ED during the scanning period. During the entire inspection process, the total DLP is the sum of the monitoring period DLP and the scanning period DLP; the total ED is the sum of the monitoring period ED and the scanning period ED.

Statistical analysis

The contrast enhancements of the CTA images were expressed as mean CT values ± standard deviation, and as medians with IQRs for non-parametric data. The Student's t test was used to compare the age, measured CT value, subjective analysis of image quality, SNR, CTDIvol, DLP and ED between the two groups. P values below 0.05 were considered statistically significant. The uniformity between the two physicians was tested using the kappa consistency.

Result

A total of 91 patients completed complete aortic CTA examination without any complications and were included in our study. There was no statistically significant difference in age between patients (conventional group, 58.11±14.35 years; high-pitch group, 60.39±12.66years, P>0.05). Compared with the conventional group, the average scan time of CTA was 6.69±0.98min, and the scan time of the high-pitch group was shortened by about 78% (1.47±0.14min, P<0.001). In the conventional group, 5 patients needed to be rescanned with contrast agent due to poor imaging of the distal artery. The high-pitch group could obtain images that meet the diagnostic requirements in only one scan(Figure 1). The mean dose of contrast agent decreased by 21.6% to 62.68±5.98 ml(P<0.001) in high-pitch group(Table 1).

Table 1The difference of age, contrast agent and the scanning time between two groups.

Variables	Convention Group(n=47)	High-pitch Group (n=44)	Mean Diff	P-value
Age (years)	58.11±14.35	60.39±12.66	-2.28	0.42
Contrast agent(ml)	80.00±0.00	62.68±5.98	-17.32	0.00
Scanning time(min)	6.69±0.98	1.47±0.14	5.22	0.00

Contrast agent:Total contrast agent used throughout the examination；

Scanning time:The total time spent in the entire inspection process.

Table 2 The difference of CTDIvol, DLP and ED between two groups.

Variables	Convention Group (n=47)	High-pitch Group (n=44)	Mean Diff	P-value
CTDIvol	11.19±2.69	3.32±0.28	7.87	0.00
DLP of monitoring	9.39±3.85	22.82±6.37	-13.43	0.00
DLP of scanning	764.03±211.71	239.43±28.59	524.60	0.00
Total DLP	773.23±211.95	262.25±26.92	510.97	0.00
ED of monitoring	0.14±0.06	0.34±0.10	-0.20	0.00
ED of scanning	11.46±3.18	3.59±0.43	7.87	0.00
Total ED	3.93±0.40	11.61±3.18	-7.68	0.00

CTDIvol: patients' volume CT dose index;

DLP of monitoring and ED of monitoring: DLP and ED values when monitoring aortic threshold or peak femoral time;

DLP of scanning and ED of scanning: DLP and ED values when scanning complete aorta;

Total DLP: Sum of DLP values for monitoring and scanning; Total ED:Sum of ED values for monitoring and scanning.

Comparing the arteries between the two groups, the degree of aortic enhancement in the high-pitch group was greater than that in the conventional group. Among them, the end enhancement degree of the high-pitch group (470.88±84.38HU) increased most obviously, which was up to 32% (P <0.001) compared with the conventional group (355.43±107.17HU). Comparing the arteries between the two groups, the degree of aortic enhancement in the high-pitch group was greater than that in the conventional group. Among them, the end enhancement degree of the high-pitch group (470.88±84.38HU) increased most obviously, which was up to 32% (P <0.001) compared with the conventional group (355.43±107.17HU). The contrast enhancement and SNR of the superior vena cava, left atrium, and pulmonary artery that may affect the diagnosis of aortic disease were not significantly different between the two groups (P>0.05)(Figure 2).

Subjective evaluation of image quality. The two doctors' evaluations are in good agreement (> 75%). The evaluation results are shown in Figure 3. The overall image score of the high-pitch group (3.77±0.37) was significantly higher than that of the conventional group (3.06±0.47) (P<0.001), especially in the aortic root and abdominal aorta.

The radiation dose comparison is shown in Table 2. The CTDIvol of the large pitch group was 70.3% lower than that of the conventional group (P<0.001).Although the DLP and ED of the large pitch group were higher than those of the conventional group during the monitoring period, they were significantly lower during the scanning period (P <0.001). Therefore, compared with the conventional group, the total DLP and ED of the high-pitch group were reduced by 66.8% and 66.1%, respectively (P <0.001).

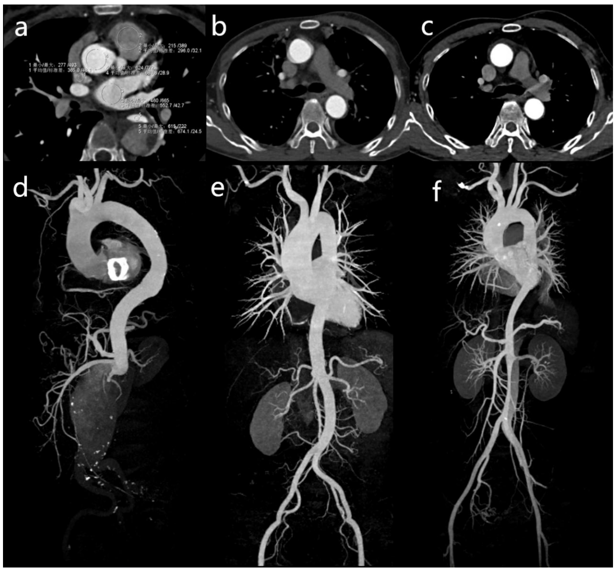

Figure 1 a)Setting the position of the ROI at the level of the aortic root and measuring the CT value of each vessel cavity.b. There are pulsation artifacts in the aortic root of the conventional plan; c) In the same patient, there is no pulsation artifact in the same part of the aortic root in high-pitch mode. d)Using conventional plan, the enhancement effect of the distal aorta is poor, and supplementary scanning is required; e,f)Using the large-pitch program, patients with aortic dissection, the aortic root dilates, and the aorta and femoral artery are strengthened uniformly.

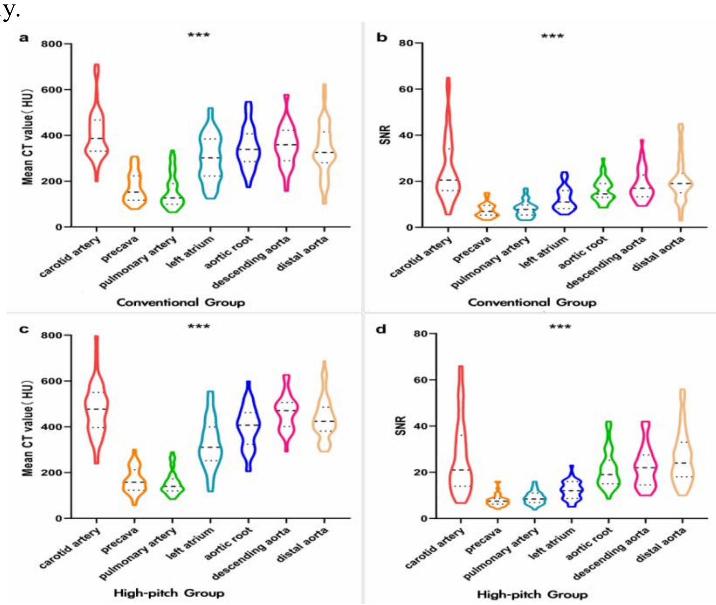

Figure 2 The average CT value and signal-to-noise ratio of each segment of the artery in the conventional group are shown in a and b, respectively. And the average CT value and signal-to-noise ratio of each segment of the artery in the high-pitch group are shown in c and d, respectively.

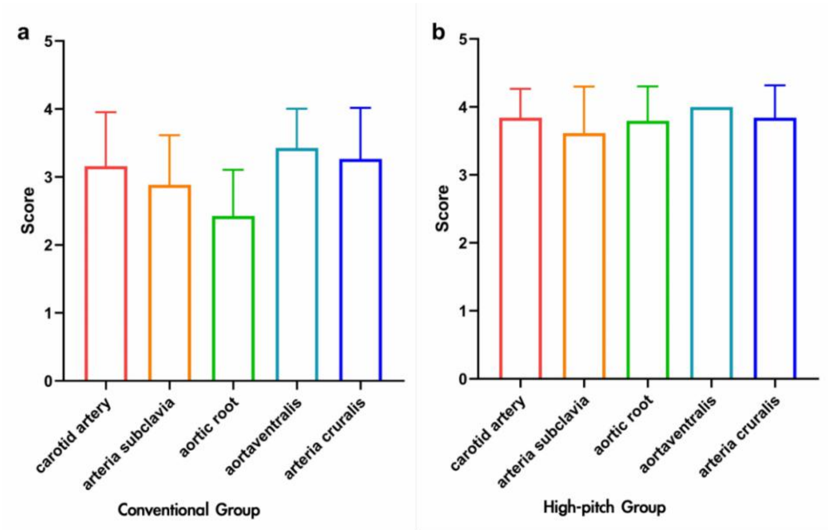

Figure 3 The subjective scores of the images in the conventional group and the high-pitch group are a and b, respectively.

Discussion

Compared with the traditional single-source multi-slice spiral CT, the gantry rotation time of the second-generation dual-source CT is 0.28s, and the time resolution is as high as 75ms[10].With its double-tube super-large instantaneous output power and high heat capacity, it can perform a flash spiral scan mode with a maximum pitch of 3.4, which can not only complete the scan ultra-fast, but also reduce the radiation dose to the patient[5, 6]. Iterative reconstruction algorithm is the first choice for post-processing to reduce CT radiation dose. A large number of studies have shown that the iterative reconstruction algorithm can reduce the radiation dose by 50%(8-10). Tevfik F Ismail et al. reported that the peak time of the aortic root was used as the delayed scan time to optimize the time of contrast agent delivery and image acquisition[8]. This study explored the application of the Flash Cardio scanning solution for the second-generation dual-source CT coronary artery imaging and realized virtual ECG (=60bpm) gating by activating and configuring the ECG Monitor Demo mode option. The above met the "Flash Check" test requirements to achieve the maximum spacing (spacing = 3.4) scanning. At the same time, the peak time of the femoral artery is used to determine the personalized optimization contrast medium plan and the time of image acquisition and combined with iterative technology to perform the entire aortic CTA scan.

The aortic root is prone to artifacts that affect the diagnosis [7]. Dual source CT with high-pitch and no ECG triggering provided accurate motion-artifact-free imaging of the ascending aorta [11]. In this study, the 3.4 high-pitch scan mode was used. Compared with the conventional group, the high-pitch group had a higher CT value of the aortic root, but there was no difference in SNR. However, the subjective score of the high-pitch group was significantly higher than that of the conventional group. The reason for this phenomenon may be that the aortic roots in the high-pitch group have almost no motion artifacts, and the personalized contrast agent program delays the imaging time to the time when the peak of the femoral artery appears, which reduces the pulmonary artery and superior vena cava contrast agent concentration.. Thereby reducing the influence of peripheral blood vessels on the diagnosis of aortic diseases. Therefore, in this study, the high-pitch group obtained good images that meet the diagnostic requirements.

This personalized contrast agent program is mainly aimed at solving the problem of obtaining the best enhancement effect of the distal aorta in CTA. Previous reports that high-pitch scan can improve the visualization of the distal aorta in CTA[7].In the objective evaluation of image quality, the enhancement degree of the descending aorta and distal abdominal aorta of the high-pitch group was significantly better than that of the conventional group ($P < 0.001$). In particular, the average CT value of the distal abdominal aorta increased more significantly, which is similar to Tevfik F Ismail et.al research results[8]. In the routine group, 5 patients due to distal aortic disease (abdominal aortic aneurysm, abdominal aortic dissection, etc.) caused poor enhancement of the distal arteries and were unable to provide images that meet the diagnostic requirements, so they needed to be supplement scanned.The patients with distal aortic disease in the high-pitch group could obtain enhanced images with good contrast after only one examination, without the need for supplementary contrast agents and supplementary scans. It can be seen that, based on the individual hemodynamic characteristics of the patient, the method of taking the femoral artery peak time as an important parameter for the calculation of individual contrast medium and the method of image acquisition time will help to further improve the enhancement effect of the distal aorta and reduce the contrast medium dose.

This study also evaluated the radiation dose during aortic CTA examination to further explore the advantages and disadvantages of conventional scanning and high-pitch scanning. During the monitoring period, the DLP and ED of the high-pitch group were higher than those of the conventional group. However, during the entire scanning period, the DLP and ED of the high-pitch group were significantly reduced, which completely made up for the deficiency of the monitoring period. Compared with the conventional group, the total DLP and ED of the high-pitch group were reduced by 66% and 60%, respectively. Previous reports have shown that the combination of high-pitch and iterative technology can reduce the effective radiation dose by about 50%[4, 12, 13]. The reduction of radiation dose will help to improve the cumulative radiation dose of patients with aortic disease who require multiple follow-ups.

There are still some shortcomings in this study. First, the height and weight of the patients were not included in the analysis as factors affecting the study. Second, the contrast-to-noise ratio (CNR) of the image was not evaluated. And further research is needed to further reduce and optimize the combination of optimal tube voltage and lower contrast rate.

Compared with the conventional CTA examination method, when the dual-source CT high-pitch mode is combined with the individualized contrast agent program for aortic scanning, it can not only effectively reduce the effective radiation dose, but also improve the image quality of the aortic root and distal end.

References

[1] Zhang LJ, Li X, Schoepf UJ, Wichmann JL, Tang CX, Zhou CS, Lu GM: Non-Electrocardiogram-Triggered 70-kVp High-Pitch Computed Tomography Angiography of the Whole Aorta With Iterative Reconstruction: Initial Results. *J Comput Assist Tomogr* 2016, 40(1):109-117.

[2] Stacul F, van der Molen AJ, Reimer P, Webb JAW, Thomsen HS, Morcos SK, Almén T, Aspelin P, Bellin M-F, Clement O *et al*: Contrast induced nephropathy: updated ESUR Contrast Media Safety Committee guidelines. *European radiology* 2011, 21(12):2527-2541.

[3] Bolen MA, Popovic ZB, Tandon N, Flamm SD, Schoenhagen P, Halliburton SS: Image quality, contrast enhancement, and radiation dose of ECG-triggered high-pitch CT versus non-ECG-triggered standard-pitch CT of the thoracoabdominal aorta. *AJR American journal of roentgenology* 2012, 198(4):931-938.

[4] Hachulla A-L, Ronot M, Noble S, Becker CD, Montet X, Vallée J-P: ECG-triggered high-pitch CT for simultaneous assessment of the aorta and coronary arteries. *J Cardiovasc Comput Tomogr* 2016, 10(5):407-413.

[5] Rubin GD, Shiau MC, Leung AN, Kee ST, Logan LJ, Sofilos MC: Aorta and iliac arteries: single versus multiple detector-row helical CT angiography. *Radiology* 2000, 215(3):670-676.

[6] Sommer WH, Albrecht E, Bamberg F, Schenzle JC, Johnson TR, Neumaier K, Reiser MF, Nikolaou K: Feasibility and radiation dose of high-pitch acquisition protocols in patients undergoing dual-source cardiac CT. *AJR American journal of roentgenology* 2010, 195(6):1306-1312.

[7] Zhang LJ, Zhao YE, Schoepf UJ, Mangold S, Felmly LM, Li X, Tang CX, Zhou CS, Qi L, Lu GM: Seventy-Peak Kilovoltage High-Pitch Thoracic Aortic CT Angiography without ECG Gating: Evaluation of Image Quality and Radiation Dose. *Acad Radiol* 2015, 22(7):890-897.

[8] Ismail TF, Cheasty E, King L, Naaseri S, Lazoura O, Gartland N, Padley S, Rubens MB, Castellano I, Nicol ED: High-pitch versus conventional cardiovascular CT in patients being assessed for transcatheter aortic valve implantation: a real-world appraisal. *Open Heart* 2017, 4(2):e000626.

[9] Menzel HG, Harrison JD: Doses from radiation exposure. *Ann ICRP* 2012, 41(3-4):12-23.

[10] Hu C, Wang J, Xu K, Yuan Y, Wang X, Xie L, Li S: Dual-source computed tomography for evaluating coronary stenosis and left ventricular function. *Exp Ther Med* 2013, 6(4):961-966.

[11] Liu Y, Xu J, Li J, Ren J, Liu H, Xu J, Wei M, Hao Y, Zheng M: The ascending aortic image quality and the whole aortic radiation dose of high-pitch dual-source CT angiography. *J Cardiothorac Surg* 2013, 8:228.

[12] Yin W-H, Lu B, Li N, Han L, Hou Z-H, Wu R-Z, Wu Y-J, Niu H-X, Jiang S-L, Krazinski AW *et al*: Iterative reconstruction to preserve image quality and diagnostic accuracy at reduced radiation dose in coronary CT angiography: an intraindividual comparison. *JACC Cardiovasc Imaging* 2013, 6(12):1239-1249.

[13] Oda S, Utsunomiya D, Funama Y, Katahira K, Honda K, Tokuyasu S, Vembar M, Yuki H, Noda K, Oshima S *et al*: A knowledge-based iterative model reconstruction algorithm: can super-low-dose cardiac CT be applicable in clinical settings? *Acad Radiol* 2014, 21(1):104-110.