· Original article ·

Low dose, high-pitch dual-source CT coronary angiography in patients with atrial fibrillation: is it possible?

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【**Abstract**】 **Objective** The objective was to attempt to rule out whether high-pitch spiral acquisition dual-source computed tomography coronary angiography (CTCA) can be performed in patients with atrial fibrillation at low dose. **Methods** Ten patients with atrial fibrillation who were admitted for a first diagnostic coronary angiogram were screened for participation. All patients underwent dual-source CT. Patients were performed CTCA using the prospectively ECG-gated high-pitch mode and retrospective ECG gating spiral acquisition respectively with their permissions. The start phase for image acquisition of the most cranial slice was selected at 20%-30% of the R-R interval in all patients. **Results** Image qualities of prospectively ECG-gated high-pitch mode were rated as being excellent in 7 cases of all the patients and only 3 cases' image qualities were graded score 2. By using retrospective ECG gating spiral acquisition mode, non-diagnostic image quality (score 3) occurred in 4 patients which were observed in RCA and 1 patient in LCX. The estimated radiation dose ranges from 0.68 to 1.887 mSv in flash mode and the radiation dose of spiral mode were very high ranging from 14.92 to 29.308 mSv. **Conclusions** Our case series suggest that patients with atrial fibrillation rhythm can be performed CTCA with high-pitch spiral acquisition mode. 20%-30% of the RR interval window for data acquisition for high-pitch dual-source CTCA may probably obtain good image quality with low doses.

【**Key words**】 Coronary angiography; Atrial fibrillation; Dual-source CT; High pitch

Introduction

Electrocardiography (ECG)-synchronized computed tomography coronary angiography (CTCA) is a non-invasive tool with a high diagnostic accuracy for the detection of coronary arterial stenosis [1-5]. The effective radiation doses of CTCA could be lowered down to 1.5-2.5 mSv with the first generation of dual-source CT[6]. Recently, the second generation of dual-source CT systems was introduced, providing high detector coverage with the use of two 128-section detectors[7-8]. This dual-source CT system also allows CTCA examinations to be performed at high-pitch values of up to 3.4[9]. In the high-pitch acquisition mode that is unique to dual-source CT, the second detector system can be used to fill these gaps. By combining high-pitch and large detector coverage, the CTCA acquisition time is reduced to a quarter of a second, allowing depiction of the entire heart within a single heart beat [8,10-11].

Studies had indicated that high-pitch dual-source CTCA provides a high diagnostic accuracy for the assessment of coronary stenosis with low dose of below 1 mSv[11-12]. However, regular sinus rhythm and heart rates ≤60 beats per minute has been considered a prerequisite for an adequate examination [11]. Atrial fibrillation are not fit to CTCA

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with high-pitch spiral acquisition mode[11]. To our knowledge, it has not yet been investigated whether good image quality can be acquired in high-pitch dual-source CTCA yields at atrial fibrillation rhythm. In this study, we attempted to rule out whether high-pitch spiral acquisition dual-source CTCA can be performed in patients with atrial fibrillation at low dose.

Subjects and methods

1. Patients

Ten patients with atrial fibrillation who were admitted for a first diagnostic coronary angiogram were screened for participation. All patients were symptomatic, but at low to intermediate likelihood of coronary artery stenosis based on clinical assessment, with no previously known coronary artery disease, previous coronary artery stent implantation, or coronary artery bypass grafts and had been referred for CTCA to rule out haemodynamically relevant coronary artery lesions. Patients with renal failure, known allergy to contrast agent were not considered for CTCA.

2. Premedication

All patients continued taking their baseline beta-receptor antagonist medication at the time of CTCA. 25-50 mg orally metoprolol (AstraZeneca) was administered for reducing the heart rate.

3. Dual-source CT protocol and image reconstruction

All patients underwent dual-source CT (Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany). Patients were performed CTCA using the prospectively ECG-gated high-pitch mode (flash mode) and retrospective ECG gating spiral acquisition (spiral mode) respectively with their permissions. If patients do not agree with being scanned twice (flash mode and spiral mode), flash mode were performed for CTCA. All patients received a single dose of 2.5 mg nitroglycerin. Then, 60 ml of Iohexol (Omnipaque 350, 350 mg/ml, Bayer Schering Pharma) was injected at a flow rate of 6 ml/s followed by 60 ml of saline solution. Contrast-agent application was controlled by bolus-tracking in the ascending aorta (signal attenuation threshold 100 HU). Data acquisition was initiated with a mean delay of 6 s after reaching the threshold. CT parameters were as follows: detector collimation 2 mm ×64 mm ×0.6 mm, slice acquisition 2 mm ×128 mm ×0.6 mm by means of a z-flying focal spot, gantry rotation time 280 ms, pitch 3.4, tube current time product 320 mAs per rotation, and tube voltage 100 kV[13]. CTCA was performed from 2 cm below the level of the tracheal bifurcation to the diaphragm. A craniocaudal imaging direction was chosen, and the start phase for image acquisition of the most cranial slice was selected at 20%-30% of the R-R interval in all patients. Images were reconstructed with a slice thickness of 0.6 mm, a reconstruction increment of 0.4 mm, and using a soft-tissue convolution kernel (B26f). In the case of vessel wall calcifications, additional images were reconstructed using a sharp-tissue convolution kernel (B46) to compensate for blooming artefacts.

4. CTCA data analysis

Coronary segments were defined according to a reporting system of the American Heart Association (AHA)[14]. The right coronary artery (RCA) was defined to include segments 1-4, the left main artery (LM) to consist of segment 5, the left anterior descending artery (LAD) to include segments 6-10, and the left circumflex artery (LCX) to include segments 11-15. The intermediary artery was designated as segment 16, if present, and considered to belong to the LAD.

5. Assessment of coronary artery motion artefacts

For the assessment of coronary artery motion artefacts, two experienced readers evaluated all coronary artery segments on cross-sectional source images and multiplanar reformations applying a semi-quantitative three-point scale: score 1 (excellent image quality, no motion artefacts), score 2 (moderate, however diagnostic image quality with minor blurring of the vessel wall) and score 3 (non-diagnostic image quality due to severe blurring or doubling of the vessel wall).

6. Estimation of radiation dose

The effective radiation dose delivered at chest CT was calculated by applying a method proposed by the European Working Group for Guidelines on Quality Criteria for CT using the dose -length product (DLP) and a conversion coefficient of 0.017 mSv/(mGy × cm)[15].

Results

The age ranges from 50 to 84 and heat rate ranges from 56 to 121 beats per minute. The body mass index of the study patients were 19.8-30.2 kg/m^2. Three patients did not agree with being scanning twice by two mode respectively and performed scanning by flash mode only.

Table 1 Coronary artery image quality of flash mode and spiral mode

Cases	Age (year)	BMI (kg/m^2)	HR (beats/min)	Image Quality Score of flash mode				Image Quality Score of spiral mode				Radiation dose (mSv)	
				RCA	LM	LAD	LCX	RCA	LM	LAD	LCX	flash mode	spiral mode
Cases 1	54	19.8	103	2	1	2	1	3	1	1	1	1.853	21.08
Cases 2	64	20.1	121	1	1	1	2	–	–	–	–	0.68	–
Cases 3	73	21.6	56	1	1	1	1	3	1	1	1	0.952	14.92
Cases 4	40	28.9	80	1	1	1	1	3	1	1	3	0.918	21.306
Cases 5	74	25.3	98	1	1	2	1	3	1	1	1	0.901	29.308
Cases 6	54	30.2	67	1	1	1	1	1	1	1	1	1.887	14.65
Cases 7	55	29.3	81	1	1	1	1	1	1	1	1	0.935	15.15
Cases 8	57	24.2	97	1	1	1	1	–	–	–	–	0.989	–
Cases 9	84	23.5	68	1	1	1	1	–	–	–	–	0.697	–
Cases 10	50	26.4	68	1	1	1	1	3	1	3	1	0.85	27.013

1. Motion artefacts

Image qualities of flash mode were rated as being excellent (score 1) in 7 cases of all the patients and only 3 cases′ image qualities were graded score 2. By using spiral mode, non-diagnostic image quality (score 3) occurred in 4 patients which were observed in RCA and 1 patient in LCX (Table 1). Examples of the typical cases were displayed in Figure 1,2.

2. Radiation dose estimates

The estimated radiation dose ranges from 0.68 to 1.887 mSv in flash mode and high-pitch dual-source CTCA resulted in a radiation dose of below 1 mSv in 8 patients. However, the radiation dose of spiral mode were very high ranging from 14.92 to 29.308 mSv.

Discussion

There are three scan mode in high-pitch mode of dual-source CT: spiral acquisition of data with retrospective ECG gating, prospectively ECG-triggered axial acquisition (sequential mode) and prospectively ECG-triggered high-pitch spiral acquisition[16]. In spiral mode, radiation exposure is high and effective radiation doses as high as 30 mSv have been reported. In sequential mode, radiation exposure can be reduced substantially, and in some series average doses as low as 2.1-4.1 mSv have been reported[6,17-19]. The high-pitch mode of dual-source CT permits imaging of the entire heart within one heart beat by continuous and fast movement of the table during CT acquisition. It provides a high diagnostic accuracy for the assessment of coronary stenoses with low dose of below 1 mSv[11].

Leschka et al[11] found 99% evaluable coronary segments in CTCA performed in flash mode in patients with heart rates 60 beats per minute when triggering the initiation of the imaging at 60% of the R-R interval and a sensitivity of 94% and a specificity of 96% for the detection of significantly coronary artery stenosis. Recently, Goetti et al[8] suggested that a systolic window for data acquisition for high-pitch dual-source CTA in patients with high heart rates (≥70 beats per minute) significantly improves the quality of coronary artery imaging. However, there

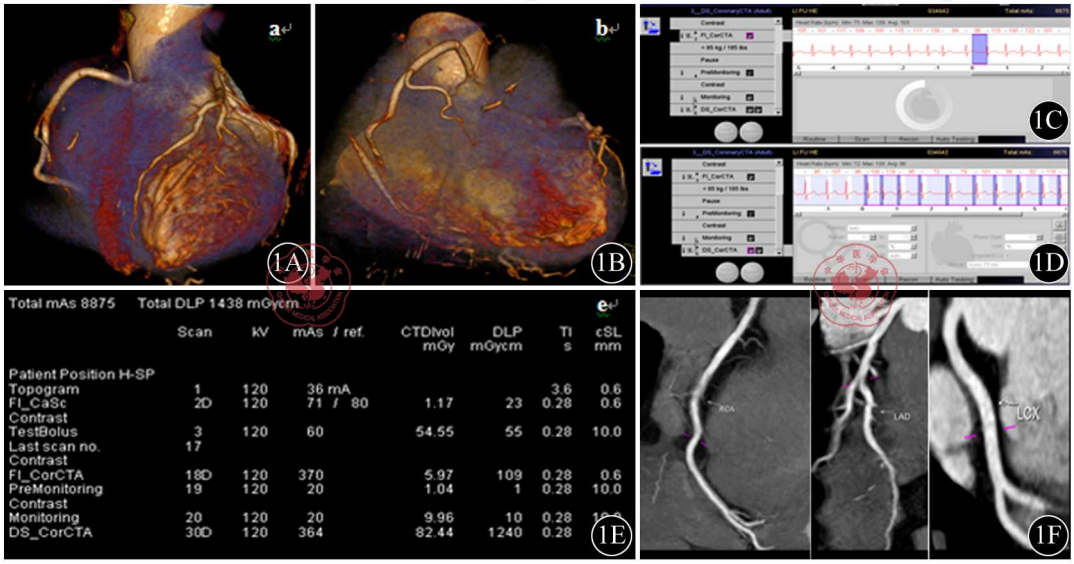

Figure 1 CTCA using two modes respectively in a 54-year-old man (heart rate 103 bests/min) . Volume rendered image of flash mode (1A) delineate the three-dimensional course of the coronary arteries and show minor motion artefacts in coronary arteries. Volume rendered image of spiral mode (1B) show the motion artefacts of RCA are serious. CTCA performed with flash mode show ECG-triggered acquisition scanning completed before the next R wave (1C). ECG-triggered acquisition of spiral mode in several cardiac cycles (1D) . The estimated effective dose of flash mode is 1.853 mSv and the dose of spiral mode is 21.08 mSv (1E). Curved multiplanarre construction of flash mode show minor motion artefacts in RCA,LAD and LCX (1F)

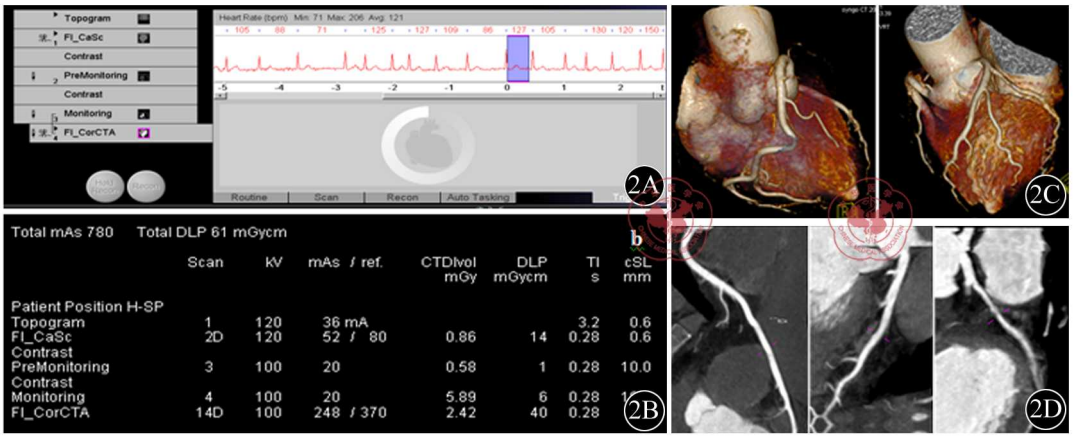

Figure 2 High-pitch dual-source CTCA in a 64-year-old woman (heart rate 121 beats/min) . ECG-triggered acquisition of flash mode show scan time is 233 ms and the RR interval is 253 ms, flash scanning completed between two RR intervals (2A). The estimated effective dose is 0.68 mSv (2B). Volume rendered image show image quality is good (2C). Curved multiplanarre construction of flash mode show image quality of RCA and LAD are excellent and minor motion artefacts in LCX (2D)

have not any reports about CTCA with flash mode in patients with atrial fibrillation rhythm .

In patients with atrial fibrillation ,the later R wave can facilely fall into the scan range of CTCA because the R - R interval is absolutely irregular which can result in motion artefacts . To avoid motion artefacts ,the scanning must complete before the next R wave. We suggested two methods could be applied :one is reducing heart rate ,the other is scanning earlier as far as possible . Araoz et al[20] reported that optimal image sharpness of the coronary arteries a - chieved at 35%-40% of the R-R interval in patients with heart rates >70 beats per minute. According Araozet and Robert Goetti's results ,we suggested CTCA with high-pitch spiral acquisition mode set at 20%-30% of the R-R in-

terval in patients with atrial fibrillation rhythm would probably obtain good image quality .

In these 10 patients,we perform CTCA with flash mode set at 20%-30% of the R-R interval in patients with atrial fibrillation rhythm. We found that image quality of CTCA with flash mode in patients with atrial fibrillation were good in most of our cases. However,there were 5 cases non-diagnostic image quality in spiral mode. It implied that high-pitch spiral acquisition mode not only could obtain good image quality ,but also probably surpass spiral mode in image quality.

Based on the results of our report ,the follow in conclusions can be drawn :first,patients with atrial fibrillation rhythm can be performed CTCA in one heart beat with high -pitch spiral acquisition mode. Second,in patient with atrial fibrillation,good cardiac image acquisition should begin at 20%-30% of the R-R interval because it is probably that the later R wave fall into the scan range of high -pich spiral mode in acquisition at 60% of the R-R. Third,the radiation doses of high-pich spiral mode in acquisition mode were very lower .

Our results is only a cases series with 10 patients. The cases are very few to perform a statistic analysis. Future studies with larger patient populations are needed to confirm our preliminary experience as described in this cases series.

Conclusion

Our case series suggest that patients with atrial fibrillation rhythm can be performed CTCA with high -pitch spiral acquisition mode. 20%-30% of the R-R interval window for data acquisition for high -pitch dual-source CTCA may probably obtain good image quality with low doses .

(本文中文文题:心房颤动患者的低剂量、大螺距双源 CT 冠状动脉成像的可行性研究)

References

[1] Husmann L,Herzog BA,Burger IA,et al. Usefulness of additional coronary calcium scoring in low-dose CT coronary angiography with prospective ECG-triggering impact on total effective radiation dose and diagnostic accuracy. Acad Radiol,2010,17:201-206.

[2] Ropers D,Pohle FK,Kuettner A,et al. Diagnostic accuracy of noninvasive coronary angiography in patients after bypass surgery using 64-slice spiral computed tomography with 330-ms gantry rotation. Circulation,2006,114:2334-2341.

[3] Carrascosa P,Capunay C,Deviggiano A,et al. Accuracy of low-dose prospectively gated axial coronary CT angiography for the assessment of coronary artery stenosis in patients with stable heart rate. J Cardiovasc Comput Tomogr,2010,4:197-205.

[4] Xu Y,Tang L,Zhu X,et al. Comparison of dual-source CT coronary angiography and conventional coronary angiography for detecting coronary artery disease. Int J Cardiovasc Imaging,2010,26 Suppl 1:75-81.

[5] Zhang LJ,Wu SY,Wang J,et al. Diagnostic accuracy of dual-source CT coronary angiography:The effect of average heart rate,heart rate variability,and calcium score in a clinical perspective. Acta Radiol,2010,51:727-740.

[6] Scheffel H,Alkadhi H,Leschka S,et al. Low-dose CT coronary angiography in the step-and-shoot mode:diagnostic performance. Heart,2008,94:1132-1137.

[7] Petersilka M,Bruder H,Krauss B,et al. Technical principles of dual source CT. Eur J Radiol,2008,68:362-368.

[8] Goetti R,Feuchtner G,Stolzmann P,et al. High-pitch dual-source CT coronary angiography:systolic data acquisition at high heart rates. Eur Radiol,2010,20:2565-2571.

[9] Donati OF,Burg MC,Desbiolles L,et al. High-pitch 128-slice dual-source CT for the assessment of coronary stents in a phantom model. Acad Radiol,2010,17:1366-1374.

[10] Hausleiter J,Bischoff B,Hein F,et al. Feasibility of dual-source cardiac CT angiography with high-pitch scan protocols. J Cardiovasc Comput Tomogr,2009,3:236-242.

[11] Leschka S,Stolzmann P,Desbiolles L,et al. Diagnostic accuracy of high-pitch dual-source CT for the assessment of coronary stenoses:first experience. Eur Radiol,2009,19:2896-2903.

[12] Alkadhi H,Stolzmann P,Desbiolles L,et al. Low-dose,128-slice,dual-source CT coronary angiography:accuracy and radiation dose of the high-pitch and the step-and-shoot mode. Heart,2010,96:933-938.

[13] Lell M,Marwan M,Schepis T,et al. Prospectively ECG-triggered high-pitch spiral acquisition for coronary CT angiography using dual source CT:technique and initial experience. Eur Radiol,2009,19:2576-2583.

[14] Austen WG,Edwards JE,Frye RL,et al. A reporting system on patients evaluated for coronary artery disease. Report of the Ad Hoc Committee for

Grading of Coronary Artery Disease,Council on Cardiovascular Surgery,American Heart Association. Circulation,1975,51:5-40.

[15] European Commission. European Guidelines on Quality Criteria for Computed Tomography. Report EUR,1999:16262.

[16] Wolf F,Leschka S,Loewe C,et al. Coronary artery stent imaging with 128-slice dual-source CT using high-pitch spiral acquisition in a cardiac phantom:comparison with the sequential and low-pitch spiral mode. Eur Radiol,2010,20:2084-2091.

[17] Duarte R,Fernandez G,Castellon D,et al. Prospective Coronary CT Angiography 128-MDCT Versus Retrospective 64-MDCT:Improved Image Quality and Reduced Radiation Dose. Heart Lung Circ,2011,20:119-125.

[18] Hirai N,Horiguchi J,Fujioka C,et al. Prospective versus retrospective ECG-gated 64-detector coronary CT angiography:assessment of image quality,stenosis,and radiation dose. Radiology,2008,248:424-430.

[19] Earls JP,Berman EL,Urban BA,et al. Prospectively gated transverse coronary CT angiography versus retrospectively gated helical technique:improved image quality and reduced radiation dose. Radiology,2008,246:742-753.

[20] Araoz PA,Kirsch J,Primak AN,et al. Optimal image reconstruction phase at low and high heart rates in dual-source CT coronary angiography. Int J Cardiovasc Imaging,2009,25:837-845.

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