Low dose runoff CTA: what protocol is preferred without special reconstruction algorithms?

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Purpose

MDCT angiography is an accurate, non-invasive technique for assessing the presence and extent of peripheral arterial occlusive disease. The sensitivity and specificity of MDCT angiography are 95% and 96%, respectively [1]. The diagnostic applications of MDCT angiography have extremely improved considerably because of its high spatial resolution, the use of fast contrast material injection rates, novel reconstruction algorithms and postprocessing tools. However MDCT angiography has some critical disadvantages such as sensitivity to number of artifacts and especially radiation dose that is a persistent problem with modern MDCT.

A strategy for reducing radiation dose at CTA involves lowering the tube voltage or tube current. Recent studies showed statistically significant decreasing of radiation dose while reducing tube voltage or current without deterioration of vascular enhancement and image quality [2,3].

But some of these studies have potential limitation, they were performed in patients with normal or slightly elevated body mass index (BMI<25). Whether results of these studies are applicable to populations of larger patients should be verified. In addition two main types of low-dose protocols should be compared.

Recently new reconstruction algorithms such as iterative reconstruction have become widespread. Iterative reconstruction is an alternative to filtered back projection (FBP) reconstruction methods. Investigations to determine image quality at thoracic and coronary CT using these methods had already demonstrated decreased image noise and its potential for radiation dose reduction [4-8]. But in most cases special reconstruction algorithms is an expensive option for MDCT and in some cases could not be used with previous generation of CTs. This is an important limitation factor. However low-dose protocol should be used despite of absence of special reconstruction algorithms.

The purpose of our study was to compare two low-dose scanning protocols reconstructed using standard algorithm (FBP), and to estimate their effects on the signal, noise, effective radiation dose (ED), quality of acquired data.
Methods and Materials

This prospective study was approved by the institutional review board and informed consent was obtained from all patients.

90 consecutive patients with clinically indicated CTA were enrolled in the study and randomized into three groups based on CTA protocols: first (120kV 200mAs), second (80kV 200mAs) and third (120 kV 50mAs). Exclusion criteria were renal dysfunction and allergy to iodine. All had suspected lesions of aorta and peripheral vessels.

Examination protocols

CTA examinations were performed on a 256-MDCT (Brilliance iCT, Philips Healthcare, Cleveland, OH). First group (n=30) was examined with following parameters: tube potential 120 kV, tube current 200 mAs, collimation was decreased up to 64x0,625 for optimization of scan time, rotation time 0,5 s; pitch 0,98. Second group of patients (n=30) was examined with tube potential 80 kW, tube current 200 mAs. Tube potential in third group was 120 kV, but the tube potential was 50mAs.

All patients received 80 ml of contrast media (350mg/ml) at a flow rate 5 ml/s. Bolus of CM followed by 30 ml of saline bolus. Synchronization between the bolus of CM and CT acquisition was achieved using a bolus-tracking system. Monitoring of bolus was performed on the level of abdominal aorta. The trigger threshold was set at 100 HU, delay before acquisition start was 8 sec.

CT Data were reconstructed with 0,9 mm slice thickness and 0,45 reconstruction interval. CT images in all groups were reconstructed from raw data only with the filtered back projection (FBP).

To evaluate objective image quality the mean intraarterial attenuation and image noise were measured in main three segments: aorto-iliac, femoropopliteal and lower leg. Attenuation levels of right and left segments were averaged. The density and the noise within the psoas major was measured to calculate contrast-to-noise ratio (CNR). Radiation doses were also compared among the groups. We recorded the scanner-generated CTDI volume (CTDIvol), dose length product (DLP). Effective dose (ED) was calculated using weighted coefficient 0,015.

For visual evaluation axial images, thin-slab maximum intensity projections and volume rendered images were used. All data sets were interpreted by two radiologists with 5 and 12 years of experience. Radiologists were blinded to protocols used. They visually evaluated all data by consensus using 3 point scale.

Images were classified so that
3 (excellent) = excellent visualization of arteries with no or minimal streak artifacts, no image noise with preserved spatial resolution, grade of the stenosis could be easily evaluated;

2 (fair) = acceptable visualization of arteries with artifacts, image noise is high, the lumen contour is partially obscured due to image noise and impaired spatial resolution, but the grade of the stenosis can be assessed still.

1 (poor) = insufficient visualization, noise is very high, spatial resolution is impaired, stenosis could not be evaluated.

All data were reported as the mean±SD. Two-tailed (paired and unpaired) Student's t-test was performed for analysis of continuous variables with normal distributions. The Mann-Whitney U-test was used to compare visual scores. We used a statistical software package (SPSS 21, version 21.0.0.0; SPSS, Chicago, IL). Two-tailed p<0.05 was considered statistically significant.
Results

90 patients were enrolled in this study: 78 men and 12 women. Mean age in first, second and third group was 63±14,5 61±13,8 and 62±11,2 years, respectively (p=0,696). Mean body weight was 81,3±12,69, 77,4±12,8 and 79,5±16,14 kg, respectively (p=0,773). Mean height - 1,69±0,27m, 1,7±0,3 and 1,70±0,43m, respectively (p=0,859). The BMI ranged from 21 to 38 kg/m² and were not significantly different between groups (p=0,17, 0,614, 0,297, respectively). The mean intraarterial attenuation in 1, 2, 3 group was 315±6HU, 448±76HU, 334±33HU, respectively, but significantly higher in the second group (p=0,0003). Noise in the second group (64±20HU) was significantly higher than that in the third group (45±14HU, p=0,0002), and first group (29±8,5HU, p=0,0002). The CNR in the second (6,64±2,3) and third (6,36±2,1) group was significantly lower than that in the first group (11,7, p=0.0001).

Visual scores for the three arterial segments are summarized in Table 1. There was a significant difference in visual scores for the aorto-iliac segment between standard and low-dose protocol (p=0,029 120kV vs. 80kV; p = 0,035 120 kV vs. 120 kV 50 mAs). Visual scores for femoropopliteal and lower leg were not significantly associated with the protocol used (p<0,0001). There were two cases of poor visualization in the aorto-iliac segment in the second group (80kV protocol, patient's BMI 34 and 37 kg/m², respectively) and one case of poor visualization in the aorto-iliac segment in the third group (120 kV 50 mAs protocol, patient's BMI 37 kg/m²).

Effective dose was 27,1±5,9mZv, 8,1±1,8mZv and 6,4±1,02mZv, respectively, differences were significant (p<0,0001).
**Table 1:** Visual scores of investigated segments

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Fig. 1: Axial CT scan on a level of aorto-iliac segment performed with 120 kV 200 mAs protocol. Effective dose is 27.2 mZv. Image quality is excellent, image noise is low. Stenosis can be easily evaluated. Patient BMI 34 kg/m2.

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Fig. 4: Same patient with BMI 34. Thin-slab MIP reconstruction. 120kV 200mAs,

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Fig. 3: Axial CT scan on a level of aorto-iliac segment performed with 80kV 200 mAs. Effective dose is 9.63 mZv. Image quality is poor, image noise is very high, spatial resolution is impaired. Image quality is insufficient to assess a grade of stenosis. Patient’s BMI is 34 kg/m².

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**Fig. 5:** Same patient as on fig.4. 80kV 200mAs, BMI 34kg/m2 Volume rendered image. Image quality is too low.

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Fig. 7: Axial CT scan on a level of aorta segment performed with 80kV 200 mAs. Image noise is high, quality is fair, but sufficient to assess structures and small vessels. Patient's BMI is 27 kg/m2.

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Fig. 6: Same patient as on fig.5. Axial CT scan on a level of iliac arteries performed with 80kV 200 mAs. Effective dose is 8.25 mZv. Image quality is fair due to high image noise. Image quality is sufficient to assess a grade of stenosis. Patient's BMI is 27 kg/m2.

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**Fig. 8:** Same patient as on fig. 6. Thin-slab MIP reconstruction. 80kV 200 mAs. Effective dose is 8.25 mZv. BMI is 27 kg/m². Occlusion of the left common iliac artery. Excellent visualisation of main and small arteries on the level of femoropopliteal and lower leg segment.

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**Fig. 9:** Thin-slab MIP reconstruction. 80kV 200 mAs. Effective dose is 8.43 mZv. BMI is 21 kg/m². Occlusion of the left common and superficial iliac artery. Excellent visualisation of main and small arteries on the level of aorto-iliac, femoropopliteal and lower leg segment. Image quality is sufficient to assess a grade of stenosis.

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**Fig. 10:** Axial CT scan on a level of iliac arteries performed with 120kV 50mAs. Effective dose is 4.97mZv. Image quality is poor due to very high image noise. Image quality is insufficient to assess a grade of stenosis. Patient’s BMI is 37 kg/m2. Patient after aortobifemoral bypass surgery.

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**Fig. 11:** Same patient as on fig.10. Thin-slab MIP reconstruction. 120kV 50mAs. Effective dose is 4,97mZv. BMI is 37 kg/m2. Poor visualisation of main and small arteries on the level of aorto-iliac and femoropopliteal segment. Visualisation of lower leg segment is good.

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Conclusion

Some reports have investigated the feasibility of MDCT for the assessment of patients with PAOD, authors reported high degree of accuracy in the evaluation of the site and degree of stenosis, with results comparable with those of DSA. Some studies revealed that diagnostic quality of images can be achieved with a lower radiation dose. They showed high sensitivity, specificity, accuracy, PPV and NPV for detecting of significant stenosis using low-dose protocols [2,3].

Our results shows average radiation dose reduction up to 70% achieved using "80kV" and 77% using "50mAs" protocol providing sufficient image quality. A significant change of image quality was observed in both low-dose protocols, especially in the aorto-iliac segment. Most of patients with BMI more than 30 kg\m^2 in the second group had fair image quality. Decreasing of visual scores in the third group was observed mainly in patients with BMI > 28 kg\m^2, while in the second group visual scores mainly decreased in patients with BMI > 24 kg\m^2. However the quality of images was sufficient for assessment of stenosis. In the second group 30% of patients with normal BMI (18-25 kg \m^2), 62% of overweight patients (BMI 26-29 kg\m^2) and 78% (22% had poor quality) of obese patients (BMI>30 kg\m^2) had fair visual scores of aorto-iliac segment. In third group 14%, 55%, 70% studies had fair quality on the level of aorto-iliac segment, respectively. There was no statistically significant difference in visual scores between two low dose protocols (p=0.533), as well as comparing BMI subgroups (p=0.554, 0.845, 0.779 for subgroups with normal weight, overweight and obese patients, respectively). But we should take into account that the mean radiation dose was significantly (p<0.0001) higher in the second group than in the third group (8.1±1.8mZv and 6.4±1.02mZv, respectively).

There was a tendency of decreasing of visual scores in the second group compared to the third group. It is associated with significantly higher values of intraarterial attenuation and noise in the second group. Application of the low-dose protocols in obese patients (BMI>30) is limited, especially in evaluation of aorto-iliac segment due to higher noise and attenuation levels, that strongly reduce spatial resolution. Both low dose protocols can be applied to patients with normal BMI and to overweight patients. However, studies performed with the use of 80kV protocol had a strong tendency to reduce the quality in patients with a BMI> 24kg\m^2. While at 50mAs protocol such limitation is observed in patients with BMI>28 kg\m^2. This allows us to recommend it as the preferred protocol for low-dose runoff CTA in the absence of special reconstruction algorithms.
Fig. 9: Thin-slab MIP reconstruction. 80kV 200 mAs. Effective dose is 8.43 mZv. BMI is 21 kg/m². Occlusion of the left common and superficial iliac artery. Excellent visualisation of main and small arteries on the level of aorto-iliac, femoropopliteal and lower leg segment. Image quality is sufficient to assess a grade of stenosis.

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Fig. 12: Axial CT scan on a level of renal arteries performed with 120kV 50mAs. Effective dose is 4.43mZv. Image quality is good. Image noise is high. Image quality is sufficient to assess a grade of stenosis. Patient's BMI is 30 kg/m².
Fig. 13: Same patient as on fig.12. Axial CT scan on a level of iliac arteries performed with 120kV 50mAs. Effective dose is 4.43mZv. Image quality is fair. Image noise is high. Image quality is sufficient to assess a grade of stenosis. Patient's BMI is 30 kg/m2. Patient after aortofemoral bypass surgery. Occlusion of the right common and superficial iliac artery.

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**Fig. 14:** Same patient as on previous fig. Thin-slab MIP reconstruction. 80kV 200 mAs. BMI is 30 kg/m². Occlusion of the right common and superficial iliac artery, right and left femoral artery. Excellent visualisation of main and small arteries on the level of femoropopliteal and lower leg segment.

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**Fig. 15:** Axial CT scan on a level of iliac arteries performed with 120kV 50mAs. Effective dose is 4.83mZv. Patient's BMI is 22kg/m². Image quality is excellent. Image noise is low. Image quality is sufficient to assess a grade of stenosis. Stenosis of the right superficial iliac artery.

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**Fig. 16:** Same patient as on fig.15. Multiplanar reconstruction on a level of aorto-iliac segment. Image quality is sufficient to assess a grade of stenosis.

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Fig. 17: Same patient as on fig 15. Thin-slab MIP reconstruction. 120kV 50mAs. BMI is 22 kg/m². Excellent visualisation of main and small arteries on the level of aorto-iliac, femoropopliteal and lower leg segment. Image quality is sufficient to assess a grade of stenosis.

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