Low-tube-voltage MDCT angiography in patients with peripheral artery diseases: Comparison with standard-tube-voltage setting

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Purpose

Background
At CT angiography (CTA) of peripheral arteries, volumetric data can be acquired with thin collimation and a wide scan range from the abdomen to the legs. Three-dimensional (3D) reconstruction, including multiplanar reconstruction (MPR), maximum intensity projection (MIP), and volume rendering (VR), facilitate precise analysis of the lower extremity arteries. CTA is an accurate and noninvasive modality to assess presence and extent of peripheral arterial occlusive disease (PAOD) with sensitivity of 95% and specificity of 96% [1].

However, CTA of aortoiliac and lower extremity arteries involves high radiation exposure due to its wide scan range. Moreover, it might cause contrast-induced nephropathy because a considerable percentage of patients with PAOD potentially have impaired renal function [2]. One of the strategies for reducing both of the radiation exposure and contrast material volume at CTA includes lowering the tube voltage. Use of a low-tube-voltage technique drastically reduces the radiation dose [3]. Iodine attenuation increases as tube voltage decreases because the energy in the x-ray beam moves closer to the k-absorption edge of iodine. On the other hand, the lower tube voltage CT technique comes at the cost of greater image noise. The tube current-time product has to be increased to counteract the higher image noise.

Purpose
The purpose of this study were to investigate whether low-tube-voltage, high-tube-current CTA with reduced contrast material volume might provide sufficient vascular enhancement for evaluation of PAOD, and to compare the image quality and radiation dose of CTA performed under low-tube-voltage and high-tube-current setting with those performed under standard-tube-voltage setting.
Methods and Materials

Patient population (Fig. 1)

Between December 2008 and October 2009, we enrolled 80 patients (60 men, 20 women; mean age, 70.0 years, range 17-86 years). Twenty patients were examined with standard peak kilovoltage (kVp) (120-kVp group). The other 20 patients were examined with low kVp (80-kVp group) (Fig. 1).

CTA data acquisition (Fig. 2)

All CT examinations were performed with a 64-MDCT scanner (Brilliance 64, Philips Healthcare). The acquisition parameters for each protocol were shown in Fig. 2. To determine the optimal delay time for CTA, a test injection using a monitoring scan at the center of the scan range was performed for each protocol. A 20-gauge intravenous catheter placed in an antecubital vein; 10 mL of contrast material was injected at a rate of 5 mL/sec followed by 20 mL of saline flush at a rate of 5 mL/sec. Low-dose serial scan was performed at the center of the scan range every 2 seconds from 10 to 50 seconds after the initiation of contrast material injection. On the CT images obtained, regions of interest (ROIs) were placed in the distal femoral arteries in the center of the scan range, time-density curves were generated, and the time from the initiation of contrast material injection to peak enhancement was obtained.

The CTA examination was started in the craniocaudal direction from the suprarenal aorta to the ankles. The patients received 1.8 mL/kg and 1.2 mL/kg of contrast material (Iopamiron 300, Bayer HealthCare) in the 120-kVp and 80-kVp protocols, respectively. The injection duration of contrast material was determined as the time to peak enhancement on test injection because it was considered that the time to peak enhancement on test injection might be converted to that on CTA. The scanning delay time on CTA was determined by the following equation:

\[ T_a + T_{peak} - \frac{1}{2} T_{acquisition} \]

where \( T_a \) and \( T_{peak} \) are the arterial arrival time and the time to peak enhancement on test injection, respectively, and \( T_{acquisition} \) is the acquisition time of CTA.

Quantitative evaluation (Fig. 3)

The arterial attenuation values (in HU) were measured with the circular ROIs placed in the arteries as follows: (1) the juxta-renal abdominal aorta (ROI-1), (2) the aortic bifurcation (ROI-2), (3) the right and left common femoral arteries (ROI-3 and -4, respectively), (4) the right and left mid-superficial femoral arteries (ROI-5 and -6, respectively), and (5) the right and left mid-posterior tibial arteries (ROI-7 and -8, respectively). To compare the
density of the column of opacified blood, the mean arterial attenuation was calculated as the average of the mean attenuation values from ROI-1 to ROI-8 for each patient. To compare the uniformity of the opacification of the column of opacified blood, the difference between the maximum and minimum attenuation values along the z-axis was calculated for each patient.

**Visual evaluation (Fig. 4-8)**

Three arterial segments were qualitatively evaluated for diagnostic quality and rated based on the visualization of the arteries and venous contamination. Image findings were classified as follows: 3 (good), excellent visualization of arteries and with no or minimum venous contamination; 2 (fair), sufficient visualization of arteries and with moderate venous contamination, which did not interfere with arterial evaluation; and 1 (poor), insufficient visualization of arteries and with severe venous contamination. Representative cases are shown in Fig. 5-8.

**Radiation Dose**

We recorded the volume CT dose index (CTDI\text{vol}) for scans obtained at 80 and 120 kVp. We also recorded the scan range and calculated the DLP on the basis of the CTDI\text{vol} and scan range. In this study, we did not estimate the effective radiation dose because converting coefficient for lower legs has not been published.

**Statistical analysis**

All data were reported as mean ± SD. The two-tailed Student's t test was used to investigate the intergroup differences in scanning delay, acquisition time, arterial attenuation, the difference between the maximum and minimum attenuation values. The Mann-Whitney U test was used to verify visual evaluation results.
Patients

<table>
<thead>
<tr>
<th></th>
<th>80 kV (n=20)</th>
<th>120 kV (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>72 ± 9</td>
<td>67 ± 13</td>
</tr>
<tr>
<td>Male</td>
<td>15/20 (75%)</td>
<td>12/20 (60%)</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>59.3 ± 12.6</td>
<td>59.6 ± 10.4</td>
</tr>
</tbody>
</table>

No significant difference between 2 groups (two t-test)

Fig. 0: Patient population in each group

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CT data acquisition

Machine: Brilliance 64 (Philips)
Collimation: 64 × 0.5-mm
Rotation speed: 500 msec
Tube current: 80 kV; 456 mA
120 kV; 290-410 mA (auto mA)
Beam pitch: (80kV) 0.391
(120kV) 0.798

Fig. 0: CTA data acquisition in each protocol

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■ Quantitative evaluation

The arterial attenuation values (in HU) were measured with 8 ROIs placed in the arteries from the juxta-renal abdominal aorta (ROI-1) to bil. posterior tibial arteries (ROI-7 and -8).

1.) To compare the density, the mean arterial attenuation was calculated as the average of the mean attenuation values from ROI-1 to ROI-8 for each patient.

2.) To compare the uniformity, the difference between the maximum and minimum attenuation values along the z-axis was calculated for each patient.

Fig. 0: Quantitative evaluation

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### Visual evaluation

The CTA images were divided into three segments: the aortoiliac, the femoropopliteal, and the lower leg segment.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (Good)</td>
<td>excellent visualization and with no or minimum venous contamination</td>
</tr>
<tr>
<td>2 (Fair)</td>
<td>sufficient visualization and with moderate venous contamination</td>
</tr>
<tr>
<td>1 (Poor)</td>
<td>insufficient visualization and with severe venous contamination</td>
</tr>
</tbody>
</table>

**Fig. 0:** Visual evaluation

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Fig. 0: 120-kVp CTA (score 3)

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70M. 80-kV CTA.
Oclusion of bilateral superficial femoral arteries

Score 3 (Good)

Fig. 0: 80kVp CTA (score3)

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Fig. 0: 80-kVp CTA (score 2)

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Fig. 0: 80-kVp CTA (score 1)

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Results

**CTA scanning (Fig. 1)**

The mean injection duration at 80-kVp protocol was significantly longer than that at 120-kVp protocol. The contrast material volume, injection rate at 80-kVp protocol were significantly lower than those at 120-kVp protocol.

**Radiation Dose (Fig. 1)**

The mean DLP at 80-kVp protocol were significantly lower than that at 120-kVp protocol (1025.7 ± 151.8 mGy·cm vs 1491.4 ± 254.9 mGy·cm; p<0.001).

**Quantitative evaluation (Fig. 2)**

The mean arterial attenuation from ROI-1 to ROI-8 was not significantly different between two protocols (80-kVp vs 120-kVp: 304.8 ± 60.2 HU vs 319.3 ± 40.9 HU). The mean difference between the maximum and minimum attenuation values along the z-axis was significantly different between two protocols (80-kVp vs 120-kVp: 76.6 ± 34.5 HU vs 52.8 ± 18.6 HU; p=0.01).

**Visual evaluation (Fig. 3-5)**

Visual evaluation scores in three arterial segments at two protocols are summarized in Fig. 3-5. No cases were judged to show poor visualization with either protocol in the aortoiliac and femoropopliteal segments. One case was judged to show poor visualization with 80-kV protocol in the lower leg segment due to severe venous contamination. Visual evaluation was not significantly associated with the protocol used in each arterial segment.
### CTA Scanning

<table>
<thead>
<tr>
<th></th>
<th>80 kV</th>
<th>120 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM volume (mL)</td>
<td>72.8 ± 14.7</td>
<td>105.2 ± 19.6*</td>
</tr>
<tr>
<td>Inj. duration (sec)</td>
<td>33.9 ± 7.6</td>
<td>27.5 ± 3.3*</td>
</tr>
<tr>
<td>Inj. rate (mL/s)</td>
<td>2.2 ± 0.5</td>
<td>3.9 ± 0.8*</td>
</tr>
<tr>
<td>DLP (mGy x cm)</td>
<td>1025.7 ± 151.8</td>
<td>1491.4 ± 254.9*</td>
</tr>
</tbody>
</table>

Note. CM = contrast material  
Inj. = injection  
DLP = Dose Length Product  
* P<0.01

**Fig. 0:** Results of CTA scanning

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## Quantitative Analysis

<table>
<thead>
<tr>
<th></th>
<th>80 kV</th>
<th>120 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean CT density</td>
<td>308.4 ± 60.2</td>
<td>319.3 ± 40.9</td>
</tr>
<tr>
<td>Max – Min (HU)</td>
<td>76.6 ± 34.5</td>
<td>52.8 ± 18.6*</td>
</tr>
</tbody>
</table>

*P<0.01

Note.
Max - Min = the difference between the maximum and minimum CT density of arteries along the z-axis

**Fig. 0:** Mean CT density and the difference between maximum and minimum CT density in two groups

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## Visual evaluation

Aortoiliac segment

<table>
<thead>
<tr>
<th>Score</th>
<th>80 kV</th>
<th>120 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (good)</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>2 (fair)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1 (poor)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

N.S (P = 0.78)

**Fig. 0**: Visual evaluation results in aortoiliac segment

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**Fig. 0:** Visual evaluation results in femoropopliteal segment

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<table>
<thead>
<tr>
<th>Score</th>
<th>80 kV</th>
<th>120 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (good)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>2 (fair)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 (poor)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

N.S
**Fig. 0:** Visual evaluation results in lower-leg segment

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Conclusion

Our study results were summarized as follows: First, vascular enhancement with 80-kVp CTA with reduced contrast material volume was comparable to that with 120-kVp setting. The mean attenuation value from the abdominal aorta to lower-extremity arteries was 305 HU with 80-kVp and 319 HU with 120-kVp setting, although the contrast material volume used was, respectively, 73mL and 105 mL. Second, there was no significant difference in the visual evaluation from the abdominal aorta to lower-extremity arteries between with 80-kVp and 120-kVp setting. Third, the radiation dose of 80-kVp CTA was significantly lower than that of 120-kVp CTA by approximately 30% (80-kVp vs 120-kVp: 1026 mGy·cm vs 1491 mGy·cm).

In conclusion, The 80-kV CTA with reduced contrast material volume provides vascular attenuation and image quality comparable to those obtained with the 120-kV CTA with conventional contrast material dose for evaluation of peripheral arteries.
References


Personal Information

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