Utility of Variable Helical Pitch CT Scanning Technique for CT Angiography of Aortoiliac and Lower Extremity Arteries

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Aims and objectives

CT angiography of aortoiliac and lower extremity arteries is useful for the evaluation of arterial diseases, including peripheral arterial occlusive disease (PAOD) (1-5). CT angiography for the evaluation of PAOD needs to cover a wide area from the abdomen to the legs because patients with PAOD have an increased risk of abdominal aortic aneurysm and renal artery stenosis (6, 7). It is important to optimize the scan parameters and the scan delay of CT angiography to obtain the adequate arterial enhancement with minimal venous overlap for a wide area.

The bolus transit speed from the aorta to the peripheral arteries would vary widely among individuals, and may be reduced in patients with PAOD (5, 8, 9). It is expected that the bolus transit speed in the peripheral arteries is slower than that in aorta, especially in patients with PAOD. Thus, applying the slower scan speed for the lower extremity segment compared with that for the abdominal segment would be useful to avoid outpacing the bolus and to improve the delineation of peripheral arteries.

Variable helical pitch (VHP) CT scanning technique allows a switching of helical pitch during a single scan. The scan speeds for the abdominal segment and for the lower extremity segment can be switched by using this technique. The image quality of CT angiography is expected to be improved, especially in patients with a slower blood flow speed in the legs compared with that in the aorta.

The purpose of this study was to evaluate the utility of VHP CT scanning technique for CT angiography of aortoiliac and lower extremity arteries.
**Methods and materials**

**Patients**

This prospective study was approved by our institutional review board, and written informed consent was obtained from all patients. Twenty-four patients (14 men and 10 women, age range, 26 to 84 years; mean age, 68.8 years) who were referred for CT angiography of aortoiliac and lower extremity arteries at our hospital between March 2013 and March 2014 were enrolled in this study. Their vascular diseases confirmed by CT angiography are summarized in Table 1.

<table>
<thead>
<tr>
<th>Vascular Disease</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAOD</td>
<td>9</td>
</tr>
<tr>
<td>PAOD (post angioplasty with stent placement)</td>
<td>9</td>
</tr>
<tr>
<td>No vascular disease</td>
<td>5</td>
</tr>
<tr>
<td>Stenosis of lower extremity arteries</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 1**: Patient vascular disease confirmed by CT angiography.

PAOD = peripheral arterial occlusive disease

**CT Examination and data analysis**

CT was performed using a 320-slice CT scanner (AquilionONE, Toshiba Medical Systems, Otawara, Japan).

Two test injection scans were performed to calculate the bolus transit speeds. As the first test bolus, 12 mL of contrast material (Iopamiron 300, Bayer Yakuhin, Osaka, Japan) was injected at a rate of 3 ml/s followed by 20 mL of saline flush at a rate of 3 ml/s. The first test scan was performed in combination with a bolus tracking technique to measure the arrival time of contrast material at the abdominal aorta and at the arteries of lower extremity concurrently. Real-time, low-dose serial monitoring scan was performed at the level of the upper abdomen starting from 8 seconds after the initiation of contrast material injection, and the CT number was monitored with a region of interest (ROI) cursor placed in the abdominal aorta. The trigger threshold level was set at an increase of 50 HU over the baseline CT number. Immediately after reaching the trigger level, the following serial monitoring scan was started at the level of the tibial diaphysis every 2 seconds, and continued until 70 seconds after the initiation of contrast material injection. The second test scan was performed at the level of the femoral diaphysis every 2 seconds from 10
to 70 seconds after the initiation of contrast material injection using the same injection parameters as for the first test scan.

ROIs were placed in the bilateral anterior or posterior tibial arteries on the first test scan images and in the bilateral superficial or deep femoral arteries on the second test scan images respectively, and time-density curves were obtained for both of these regions. The time elapsed from the initiation of contrast material injection to peak enhancement was calculated as T-femoral and T-tibial for the superficial or deep femoral artery and the anterior or posterior tibial artery, respectively. When the time to peak enhancement was different for the bilateral arteries, the longer time was used. The time elapsed from the initiation of contrast material injection to reaching the trigger threshold level of the bolus-tracking technique was also calculated as T-aorta. Then, aorto-femoral bolus transit speed (AFTS) and femoro-tibial bolus transit speed (FTTS) were calculated using the following equations, where $D_1$ and $D_2$ represented the distances between the table positions of two monitoring scans ($D_1$: upper abdomen and femoral diaphysis, $D_2$: femoral diaphysis and tibial diaphysis) (Fig. 1 on page 8).

$$\text{AFTS} = \frac{D_1}{T_{\text{femoral}} - T_{\text{aorta}}}$$

$$\text{FTTS} = \frac{D_2}{T_{\text{tibial}} - T_{\text{femoral}}}$$
Fig. 1: AFTS and FTTS were calculated using T-aorta, T-femoral and T-tibial, that were measured at the level of the upper abdomen, the femoral diaphysis and the tibial diaphysis, respectively.

References: - Suita/JP

The CT angiographic scan was started in the craniocaudal direction from the supracleiac aorta to the ankles with a delay time of T-aorta + 5 seconds after injection of 70 mL of contrast material followed by 20 mL of saline flush at the same injection speed as used for the test injection. The scan protocol for the CT angiographic scan was selected from the two protocols with different table speeds; Protocol A (patients with FTTS of 35 mm/s or more) and Protocol B (patients with FTTS of less than 35 mm/s). The table speeds
of CT for aorto-femoral area and femoro-tibial area were switched by VHP technique, and were set at 40 and 32 mm/s for Protocol A and at 40 and 20 mm/s for Protocol B, respectively. Scan parameters are summarized in Table 2.

<table>
<thead>
<tr>
<th>Test Scan #1</th>
<th>Test Scan #2</th>
<th>CT Angiography Protocol A</th>
<th>CT Angiography Protocol B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Type</td>
<td>Volume, Axial</td>
<td>Helical</td>
<td>Helical</td>
</tr>
<tr>
<td>Beam Collimation (mm)</td>
<td>40 x 1, 5 x 1</td>
<td>0.5 x 32</td>
<td>0.5 x 32</td>
</tr>
<tr>
<td>Rotation Time (sec)</td>
<td>0.5, 0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Tube Voltage (kVp)</td>
<td>120, 120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Tube Current (mA)</td>
<td>50, 50</td>
<td>AEC (SD = 15)</td>
<td>AEC (SD = 15)</td>
</tr>
<tr>
<td>Helical Pitch for</td>
<td></td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Aorto-Femoral Area</td>
<td></td>
<td>1</td>
<td>0.625</td>
</tr>
<tr>
<td>Helical Pitch for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femoro-Tibial Area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table Speed for</td>
<td></td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Aorto-Femoral Area (mm/sec)</td>
<td></td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td>Table Speed for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femoro-Tibial Area (mm/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Scan parameters of the test Scans and CT angiographic scan.
Image analysis

Three-dimensional (3D) maximum intensity projection (MIP) images were created using a computer workstation (Advantage Workstation 4.4, GE Healthcare, Milwaukee, WI) from the axial 0.5 mm-thick images for each examination. A radiologist with 10 years' experience in abdominal radiology reviewed the CT angiographic images referring to both the axial images and the 3D images, and evaluated visualization of arteries and venous overlap for each of the 3 segments (the abdominal, the iliofemoral and the leg segment) using a 3-point scale: 1, poor visualization of arteries and/or severe venous overlap; 2, moderate visualization of arteries and/or faint venous overlap; 3, good visualization of arteries without venous overlap.

Statistical analysis

The Pearson's product-moment correlation coefficient test was used to evaluate the correlation between AFTS and each of T-aorta, T-femoral and T-tibial, as well as FTTS and each of T-aorta, T-femoral and T-tibial. A P value of less than 0.05 was considered as statistically significant.
Fig. 1: AFTS and FTTS were calculated using T-aorta, T-femoral and T-tibial, that were measured at the level of the upper abdomen, the femoral diaphysis and the tibial diaphysis, respectively.

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Results

AFTS and FTTS

AFTS and FTTS ranged from 20.5 to 61.4 and from 16.6 to 82.4 mm/s, respectively. FTTS was slower than AFTS in 16 patients with FTTS of less than 41 mm/s, whereas FTTS was faster than AFTS in 8 patients with FTTS of more than 41 mm/s (Fig. 2 on page 13). Twelve of 24 patients were scanned with Protocol A, whereas the other 12 patients were scanned with Protocol B.
**Fig. 2:** AFTS and FTTS of 24 patients. FTTS was slower than AFTS in 16 patients, whereas FTTS was faster than AFTS in the other 8 patients.

*References:* - Suita/JP

The Pearson's product-moment correlation coefficient and corresponding P value for the correlation between AFTS and each of T-aorta, T-femoral and T-tibial were #0.59 and 0.002, #0.88 and less than 0.001 and #0.73 and less than 0.001, respectively.

The Pearson's product-moment correlation coefficient and corresponding P value for the correlation between FTTS and each of T-aorta, T-femoral and T-tibial were #0.38 and 0.07, #0.39 and 0.06 and #0.76 and less than 0.001, respectively. Thus, only T-tibial had an excellent significant negative correlation with FTTS (**Fig. 3** on page 13).

![Scatter diagram showing the correlation between T-tibial and FTTS. The Pearson's product-moment correlation coefficient for T-tibial and FTTS was $-0.76$ ($P < 0.001$).](image)

*References:* - Suita/JP
The results of subjective image analysis are shown in Table 3.

<table>
<thead>
<tr>
<th>Score</th>
<th>Protocol A (n = 12)</th>
<th>Protocol B (n = 12)</th>
<th>Total (n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abdominal Segment</td>
<td>Iliofemoral Segment</td>
<td>Leg Segment</td>
</tr>
<tr>
<td>3</td>
<td>12 (100%)</td>
<td>12 (100%)</td>
<td>24 (100%)</td>
</tr>
<tr>
<td></td>
<td>(75%)</td>
<td>(92%)</td>
<td>(96%)</td>
</tr>
<tr>
<td>2</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>4 (17%)</td>
</tr>
<tr>
<td></td>
<td>(25%)</td>
<td>(8%)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>1 (4%)</td>
</tr>
</tbody>
</table>

| Table 3: Rating of image quality of CT angiographic images. |

For the abdominal and iliofemoral segments, images were rated as good quality (a score of 3) in almost all patients (100% and 96%, respectively). For the leg segment, images were rated as good quality in 9 of 12 patients (75%) scanned with Protocol A and in 10 of 12 patients (83%) scanned with Protocol B (Fig. 4 on page 14). Only the image of one patient scanned with Protocol B was rated as poor quality for the leg segment.
Fig. 4: CT angiographic image of a 74-year-old man with obstruction of right superficial femoral artery scanned using Protocol B (AFTS and FTTS were 34.1 and 19.9 mm/s, respectively). Arterial enhancement was prominent for both aortoiliac and lower extremity areas.

References: - Suita/JP
Fig. 2: AFTS and FTTS of 24 patients. FTTS was slower than AFTS in 16 patients, whereas FTTS was faster than AFTS in the other 8 patients.

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Fig. 3: Scatter diagram showing the correlation between T-tibial and FTTS. The Pearson's product-moment correlation coefficient for T-tibial and FTTS was #0.76 (P < 0.001).
**Fig. 4:** CT angiographic image of a 74-year-old man with obstruction of right superficial femoral artery scanned using Protocol B (AFTS and FTTS were 34.1 and 19.9 mm/s, respectively). Arterial enhancement was prominent for both aortoiliac and lower extremity areas.

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Conclusion

FTTS was slower than AFTS in 16 of 24 (67%) patients in this study. In order to simplify the procedure and to decrease the number of test injection technique, we regarded the time elapsed from initiation of contrast material injection to reaching the trigger threshold level of the bolus-tracking technique as T-aorta, which would be earlier than peak enhancement of aorta. It is expected that AFTS used in this study would be faster than the actual aorto-femoral bolus transit speed, hence FTTS might be slower than "actual" AFTS in most patients. Thus, to slow down the table speed in the lower-extremity segment using VHP technique would be useful to obtain the sufficient enhancement of arteries for a wide area, especially in patients with slow FTTS.

Although our scan protocols yielded CT angiographic images of good quality in most patients, procedure would be somewhat complex and time-consuming. Each test scan needs contrast material and saline flush, and amount of contrast material available for the CT angiographic scan is thus decreased. Moreover, repeated test scans would cause an additional radiation exposure, although low-dose scan is used. Our results indicated that FTTS had a significant negative correlation with T-tibial. Thus, FTTS would be estimated by a single test scan at the tibial level, and the test scan at the femoral level would be skipped. When the time to peak enhancement of tibial arteries is long, FTTS is expected to be slow, and slower scan speed should be selected for the lower-extremity area. Further study will be needed to confirm the usefulness of single test scan protocol with VHP technique.

In conclusion, VHP would be useful technique for CT angiography of aortoiliac and lower extremity arteries, especially in patients with slow FTTS.
References


