Takayasu arteritis: assessment of coronary arterial abnormality using coronary CT angiography.

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Purpose

Background

Takayasu arteritis (TA) is an idiopathic systemic inflammatory disease involving the aorta and its major branches [1]. The cardiac involvement in TA is also important, and includes myocardial involvement, aortic valvular regurgitation and coronary vessel stenosis that produced consequently the myocardial infarction, heart failure or sudden death [1-2, 6]. Coronary involvement in TA is not rare, detected in approximately 10% to 30% of the cases with TA on conventional coronary angiography [2, 7-8].

To dates, CT or MR angiography has been utilized for the imaging of aorta and its branches, carotid, and lower extremity arteries in TA [9]. In our knowledge, the coronary CT angiography (CCTA) finding in TA patients have not been reported.

Purpose

1. To report the spectrum of imaging findings and their incidence in TA on CCTA

2. To assess the discrepancies of the clinical factors between the coronary arterial involved and non-involved groups.

3. Furthermore, we proposed the low-dose CT angiography protocol for the comprehensive evaluation of aorta and coronary arterial systems in TA.
Methods and Materials

Patients

68 patients who underwent CCTA among the 204 patients who diagnosed with TA in our center (cardiac and vascular center in Samsung Medical Center, Seoul, Korea) between September 1994 and March 2009.

56 females and 12 males; age range, 14-74 years; mean age, 46.9 years

• 37 patients (+): suspicious of a cardiac origin such as dyspnea on exertion or chest pain
• 31 patients (-): underwent CCTA for screening of coronary artery disease

Diagnosis of TA was based on the 1990 American College of Rheumatology criteria [12], requires at least 3 of the following: disease onset at age 40 years or younger, claudication of the extremities, a decreased brachial artery pressure, a systolic blood pressure difference between both arms more than 10 mmHg, bruit over the subclavian arteries or aorta, and angiographic evidence of narrowing or occlusion of the entire aorta, its primary branches or large arteries in the proximal upper or lower extremities.

Image acquisition and analysis

A total 76 coronary-aorta CT angiographic examinations were performed in 68 TA patients. 67 examinations were obtained using a dual-source CT system, and 9 examinations were performed with a 64-slice MDCT system (Table 1 on page 6).

The images were assessed for stenosis of the coronary ostium and coronary arterial luminal abnormalities like stenosis or aneurysm formation.

1. Stenosis of the coronary ostium

-Mild (< 50% stenosis) and significant (#50%) stenosis.

-Measured the thickness of ascending aortic wall adjacent to right coronary ostium at axial images

2. Stenosis of the coronary vessels

-Mild (< 50% stenosis) and significant (#50%) stenosis.
- Characteristics of stenosis; whether or not showed atherosclerotic plaque.

3. Coronary artery aneurysms; defined as segments that have a diameter that exceeds the diameter of normal adjacent coronary segments by 1.5 times and involve less than 50% of the total length of the vessel [13-15].

4. Aortic valvular regurgitations; checked in reconstructed multiplanar images during diastolic phases.

**Clinical analysis**

We retrospectively reviewed clinical history of TA, co-morbid disease, laboratory findings and clinical disease activities.

1. Clinical history

   - The age of the first diagnosis and disease follow duration

   - History of myocardial infarction, coronary stent insertion, coronary arterial bypass graft (CABG)

   - Echocardiographic record for aortic valvular regurgitation

2. Co-morbid diseases

   - Hypertension (blood pressure persistently higher than 140/90 mmHg or currently taking antihypertensive medication)

   - Diabetes mellitus (fasting glucose level of 126 mg/dl or more as assessed at least once or currently taking oral hypoglycemic agents or insulin)

   - History of smoking

3. Laboratory findings

   - Lipid profile (total cholesterol, LDL and HDL level); achieved within a month of CT study

   - Erythrocyte sedimentation rate (ESR), high sensitivity-C reactive protein (hs-CRP) level; checked within a day before CT study.
4. Clinical disease activities

-Active disease were classified clinically as satisfying of two or more features of the following criteria of

i) Systemic or vascular inflammation, such as fever, arthralgia, claudication and vascular pain,

ii) Elevated ESR (>21 mm/h) or CRP (>0.9mg/dl) level

iii) Thickened arterial wall (>3mm on axial scan) with mural enhancement on CT angiography.

**Estimation of radiation dose**

Radiation dose estimates for 67 CT examinations obtained with a dual-source CT scanner are expressed by using the volume CT dose index in milligrays, the dose-length product in milligray-centimeters and effective dose in millisieverts [18-19]. The effective radiation dose delivered at thoracic CT and thoracoabdominal CT was calculated with a method proposed by the European Working Group for Guidelines on Quality Criteria for CT by use of the dose-length product and conversion coefficient (k=0.017mSv/[mGy·cm]) [19].

**Statistics**

We used PASW® Statistics 18 (SPSS Inc., Chicago, Illinois) in the statistical analysis. The laboratory values are shown as the mean value±one standard deviation. Differences between the groups were examined by univariate analysis (independent t tests, Mann-Whitney U tests, #2 tests or Fisher exact tests as appropriate). P values less than 0.05 were considered statistically significant.
### Table 1: Image acquisition methods

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Number of examinations</th>
<th>Image acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSCT (N= 67)</td>
<td>35</td>
<td>High-pitch prospective ECG-triggered helical mode (\rightarrow) reconstructed for coronary arteries and aorta, respectively</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>Retrospectively ECG-synchronized helical mode with tube current modulation</td>
</tr>
<tr>
<td>64-MDCT (N=9)</td>
<td>9</td>
<td>ECG-nongated helical mode scan</td>
</tr>
</tbody>
</table>
Results

Coronary artery involvement

The specific numbers and proportions of the general characteristics of total TA patients and of the each classified group according to the presence of coronary arterial involvement are described in Table 2 on page 10 and Table 3 on page 10.

The analysis of coronary CT images revealed involvement of the coronary artery in 39 of 68 (57.4%) patients. The coronary arterial involved group showed a higher incidence of hypertension, a higher level of BMI and older age at the time of CT examination (p <0.05). The level of lipid profiles (total cholesterol, LDL, HDL), sex and other co-morbidity, diabetes mellitus and smoking history; were not generally different between two groups.

Three main CCTA features were detected:

i) Type 1, stenosis of the coronary ostium and proximal segments of coronary arteries (24 patients, 35.3% (24/68))

ii) Type 2, coronary arterial stenosis of other segments with or without plaques (21 patients, 30.8% (21/68))

iii) Type 3, coronary aneurysms (3 patients, 4.4% (3/68)).

Typical image findings of the each type are shown in Fig. 1 on page 11.

1. Type 1, stenosis of coronary ostium and proximal segments of the coronary arteries (N=24)

The mean wall thickness of the ascending aorta was significantly thicker than others (3.6 mm vs 2.2 mm, p=0.004). The mean wall thickness of the ascending aorta was thicker in mild ostial stenosis group than significant stenosis group (4.0 mm vs 2.5mm, p=0.032) (Table 4 on page 12 and Fig. 2 on page 12).

-15 patients (62.5%) were in the active state of disease and that were statistically significant higher proportion than no ostial stenosis group (17 of 44 patients, 38.6%, P=0.05).

-Mean BMI was significant higher than other patients (24.2 vs 22.0, p=0.007).
-Other laboratory findings and co-morbid diseases were not different from those of other groups of patients.

2. Type 2, coronary arterial stenosis of other segments (N=21)

11 patients had significant stenosis (≥50%) and 10 patients were observed mild (<50%) stenosis. 15 patients involved vessels showed atherosclerotic plaques with or without calcifications. In the remaining 6 patients vessels did not show definite plaques and there was segmental luminal narrowing with negative remodeling in each patient (Fig. 3 on page 12).

-Mean age at CT examination was higher than other patients (54.6 vs 43.5, p<0.001) and no difference in the TA onset age.

-7 patients (33.3%) had hypertension and 8 patients (38.1%) were men, these were statistically higher incidence than others (p=0.004 and p=0.003, respectively).

-4 patients (19%) were active state of TA, and this was significantly of low incidence (p=0.002).

3. Type 3, coronary aneurysm (N=3)

All 3 patients were female, and no one had co-morbid diseases (hypertension, DM, smoking). The mean age at checked CT was 41.0 years, two patients were active state of TA (Table 5 on page 13).

One patient underwent coronary arterial stent insertion after the CT diagnosis of coronary artery disease.

Aortic valve regurgitation

At echocardiography, aortic valvular regurgitation were found in 14 (20.6%) patients.

Valvular regurgitation of more than a mild degree was considered significant, all 12 patients having a significant regurgitation were detected at CTCA and remnant 2 patients were missed at CT.

10 patients were classified as active state of TA (68%); statistically higher prevalence than other patients (p=0.04).

Other finding of the CTCA
Previously inserted coronary arterial stent (3 patients), CABG (6 patients) and findings of the old myocardial infarctions (5 patients) were observed at coronary CT angiography (Table 6 on page 13). All the patients were associated with coronary arterial involvements, especially type 2.

**Radiation dose**

The high-pitch helical coronary and aorta CTA protocol yielded the significantly lower radiation dose than standard helical protocol implemented with the dual-source 128-MDCT system (Table 7 on page 14).
Table 2: General Characteristics of TA patients.

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<table>
<thead>
<tr>
<th>Clinical characteristics</th>
<th>All patients (N=68)</th>
<th>Coronary involved patients (N=39)</th>
<th>Coronary non-involved patients (N=29)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number (%)</td>
<td>Number (%)</td>
<td>Number (%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>56/68 (82.4)</td>
<td>30/39 (76.9)</td>
<td>26/29 (89.7)</td>
<td>0.178</td>
</tr>
<tr>
<td>Active disease*</td>
<td>32/68 (47.1)</td>
<td>19/39 (48.7)</td>
<td>13/29 (44.8)</td>
<td>0.755</td>
</tr>
<tr>
<td>Symptoms†</td>
<td>37/68 (54.4)</td>
<td>24/39 (61.5)</td>
<td>13/29 (44.8)</td>
<td>0.171</td>
</tr>
<tr>
<td>Co-morbidity‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>10/68 (14.7)</td>
<td>9/39 (23.1)</td>
<td>1/29 (3.4)</td>
<td>0.024</td>
</tr>
<tr>
<td>DM</td>
<td>6/68 (8.8)</td>
<td>4/39 (10.3)</td>
<td>2/29 (6.8)</td>
<td>0.635</td>
</tr>
<tr>
<td>Smoking</td>
<td>1/68 (1.4)</td>
<td>1/39 (2.6)</td>
<td>0/29 (0.0)</td>
<td>0.393</td>
</tr>
<tr>
<td>Total CHO (mg/dl)</td>
<td>164.76±34.88</td>
<td>163.38±35.49</td>
<td>166.62±34.57</td>
<td>0.708</td>
</tr>
<tr>
<td>LDL (mg/dl)</td>
<td>95.46±27.75</td>
<td>95.77±31.46</td>
<td>95.03±22.36</td>
<td>0.915</td>
</tr>
<tr>
<td>HDL (mg/dl)</td>
<td>52.86±14.06</td>
<td>51.13±13.69</td>
<td>55.21±14.44</td>
<td>0.240</td>
</tr>
<tr>
<td>BMI</td>
<td>22.68±2.8</td>
<td>23.56±3.01</td>
<td>21.71±2.23</td>
<td>0.015</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At checked CT</td>
<td>46.92±13.70</td>
<td>51.49±11.1</td>
<td>40.79±14.64</td>
<td>0.001</td>
</tr>
<tr>
<td>Disease onset</td>
<td>30.59±11.84</td>
<td>31.57±12.30</td>
<td>29.06±11.25</td>
<td>0.488</td>
</tr>
</tbody>
</table>
Table 3: General characteristics of the each types for coronary involvement. (N=48)

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![Fig. 1](image)

**Fig. 1:** There are typical images for the three types of the coronary arterial involvement of Takayasu arteritis. (A) type 1, stenosis of the coronary ostium and proximal segments of the coronary arteries. (B) type 2, the coronary arterial stenosis of other segments with or without plaques (C) type 3, coronary aneurysms.
Table 4: Comparison of wall thickness of the ascending aorta according to coronary ostial involvement of the TA. * The group with active disease were classified clinically as satisfying of two or more features of the following criteria of i) systemic or vascular inflammation, such as fever, arthralgia, claudication and vascular pain, ii) elevated ESR (>21 mm/h) or CRP (>0.9 mg/dl) level (14), iii) thickened arterial wall (>3 mm on axial scan) with mural enhancement on CT angiography (15).

Fig. 2: There are typical images for type 1, stenosis of coronary ostium in Takayasu arteritis. The wall thickness of the ascending aorta was thicker in mild ostial stenosis group (A) than significant stenosis group (B).
**Fig. 3:** There are typical images for the three types of the coronary arterial stenosis of Takayasu arteritis. (A) coronary arterial stenosis with calcified plaques. (B) coronary arterial stenosis with noncalcified fibrofatty plaques. (C) coronary arterial stenosis with negative remodeling, without any plaques.

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<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Hypertension/DM/Smoking</th>
<th>Total CHO (mg/dl)</th>
<th>LDL (mg/dl)</th>
<th>HDL (mg/dl)</th>
<th>BMI</th>
<th>Symptoms</th>
<th>Disease activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>56</td>
<td>-</td>
<td>155</td>
<td>70</td>
<td>69</td>
<td>21.3</td>
<td>+</td>
<td>Active</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>46</td>
<td>-</td>
<td>145</td>
<td>169</td>
<td>62</td>
<td>20.9</td>
<td>-</td>
<td>Inactive</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>21</td>
<td>-</td>
<td>132</td>
<td>77</td>
<td>45</td>
<td>19.1</td>
<td>-</td>
<td>Active</td>
</tr>
</tbody>
</table>

**Table 5:** Clinical findings of the three patients who had coronary arterial aneurysm.

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<table>
<thead>
<tr>
<th>Type of manifestations</th>
<th>Number of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary arterial involvement;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 1: Coronary ostial stenosis</td>
<td>24</td>
<td>35.3 (24/68)</td>
</tr>
<tr>
<td>Type 2: Coronary arterial stenosis</td>
<td>21</td>
<td>30.9 (21/68)</td>
</tr>
<tr>
<td>Type 3: Coronary aneurysm</td>
<td>3</td>
<td>4.4 (3/68)</td>
</tr>
<tr>
<td>Aortic valve regurgitation</td>
<td>12</td>
<td>17.6 (12/68)</td>
</tr>
<tr>
<td>Previous inserted coronary arterial stent</td>
<td>3</td>
<td>4.4 (3/68)</td>
</tr>
<tr>
<td>Previous done CABG</td>
<td>6</td>
<td>8.8 (6/68)</td>
</tr>
<tr>
<td>Finding of OMI</td>
<td>5</td>
<td>7.4 (5/68)</td>
</tr>
</tbody>
</table>
**Table 6:** CT findings of cardiac involvement in 42 patients.

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<table>
<thead>
<tr>
<th>Scanner system and acquisition mode</th>
<th>Tube Voltage (kV) (Number)</th>
<th>Mean CT dose Index (mGy)</th>
<th>Mean Dose-Length product (mGy x cm)</th>
<th>Mean Effective dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-pitch helical (N=35)</strong></td>
<td>120 (24)</td>
<td>5.17±0.88</td>
<td>348.6±61.27</td>
<td>5.92±1.09</td>
</tr>
<tr>
<td></td>
<td>100 (10)</td>
<td>2.95±0.52</td>
<td>221.1±53.84</td>
<td>3.75±0.91</td>
</tr>
<tr>
<td></td>
<td>80 (1)</td>
<td>1.38</td>
<td>90.0</td>
<td>1.53</td>
</tr>
<tr>
<td><strong>Total (mean)</strong></td>
<td></td>
<td><strong>305.0±72.1</strong></td>
<td><strong>5.18±1.22</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Standard helical (N=32)</strong></td>
<td>CTCA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 (5)</td>
<td>28.00±10.5</td>
<td>625.6±324.1</td>
<td>10.63±5.51</td>
</tr>
<tr>
<td></td>
<td>100 (26)</td>
<td>22.91±4.34</td>
<td>354.1±65.64</td>
<td>6.02±1.15</td>
</tr>
<tr>
<td></td>
<td>80 (1)</td>
<td>7.08</td>
<td>100.0</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td><strong>mean</strong></td>
<td><strong>22.88±4.42</strong></td>
<td><strong>380±85</strong></td>
<td><strong>6.47±1.64</strong></td>
</tr>
<tr>
<td></td>
<td>Aortography</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 (21)</td>
<td>12.37±4.31</td>
<td>787.66±254.77</td>
<td>13.39±4.17</td>
</tr>
<tr>
<td></td>
<td>100 (7)</td>
<td>11.36±6.21</td>
<td>554.2±199.34</td>
<td>9.42±3.38</td>
</tr>
<tr>
<td></td>
<td>80 (1)</td>
<td>2.54</td>
<td>133.0</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td><strong>mean</strong></td>
<td><strong>11.82±3.15</strong></td>
<td><strong>720.18±197.0</strong></td>
<td><strong>12.24±3.35</strong></td>
</tr>
<tr>
<td><strong>Total (mean)</strong></td>
<td></td>
<td><strong>1049.79±313.41</strong></td>
<td><strong>17.84±5.32</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Table 7:** Comparison of the mean radiation dose of each scans that produced by using a dual-source CT system.

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Conclusion

1. In our study, 57% of the TA patients were classified as having coronary arterial involvement in CTCA. This proportion is relatively high, compared with the previously reported studies (10%~30% on conventional coronary angiography).

2. The coronary arterial involved group showed a higher incidence of hypertension, a higher level of BMI and older age. And other clinical factors (level of lipid profiles, sex and other co-morbidity such as diabetes mellitus and smoking history) were not generally different between two groups.

3. Coronary arterial involvement in TA patients is unpredictable only consideration of cardiac symptoms.

The coronary involved group showed a more incidence of coronary symptoms than non-involved group, but no statistical difference between two groups.

Among the TA patients who performed CTCA with the purpose of screening, 48.4% were detected coronary arterial involvement.

4. CTCA provides many information on coronary arterial manifestation of TA and using the high-pitch dual-source CT angiography protocol yielded the significantly lower radiation dose.

5. We proposed the CTCA should be performed together with aorta CT angiography by using the high-pitch dual-source CTA protocol in TA patients, especially the patient with active disease, old age, hypertension and high BMI.

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