Multi-detector CT angiography for the assessment of anterior spinal artery and artery of Adamkiewicz patency in patients suspected of having thoracic aortic pathology

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Objective To evaluate the visualization of the anterior spinal artery (ASA) and the artery of Adamkiewicz (AKA) as well as the affecting factors for the detection rate using multidetector row CT (MDCT). Methods Ninety-nine consecutive patients (31 women and 68 men; age range, 25-90 years; average age 61.3 years) with suspicion for thoracic aortic lesions necessitating surgical intervention (31 aortic aneurysm, 45 dissection, 5 intramural hematoma, and 18 normal), underwent 16-slice MDCT angiography from the aortic arch to the aortic bifurcation. Transverse sections, multiplanar reformations (MPR) and thin maximum intensity projections (MIP) were used to assess the ASA and AKA. The level of the ASA and AKA origins and CT acquisition parameters were recorded. The contrast-to-noise ratio (CNR) of the image, an index of the mass of the T11 body (vertebral mass index), the subcutaneous fat thickness, and the CT value within the aortic arch and at the T11 level were measured. The detection of the ASA and AKA was evaluated relative to the acquisition parameters, scan characteristics, and aortic lesion type. Differences were assessed with Wilcoxon rank-sum and t tests. Results The ASA was visualized in 51 patients (52%) and the AKA in 18 patients (18%). The ASA was identified in 36/67 (54%) patients with 1.25 mm thickness and in 36/32 (47%) patients with 2.5-3.0 mm thickness. This difference did not achieve significance (P=0.13). The detection rate of the ASA and the AKA was influenced by vertebral mass index and the CNR (P<0.05). The amount of subcutaneous fat affected the detection rate of the ASA (P<0.05) but not the AKA. In CT scans with ASA detection, the mean CT values in the aorta at the arch and at T11 were 360 and 358 HU, respectively; whereas in CT scans without ASA detection, the CT values in the aorta at the arch and at T11 were lower (297 and 317 HU, respectively; both P<0.05). Conclusion The ASA and AKA were less frequently detected in our cohorts than previous reports. The visualization of the ASA and AKA was significantly affected by aortic enhancement, the "vertebral mass index", and the CNR. (J Geriatr Cardiol 2006;3(1)52-56)

Key Words: Aneurysm, aortic; arteries, Adamkiewicz; arteries, spinal; computed tomography (CT); angiography

Introduction

Damage to the spinal cord after the treatment of the descending thoracic and thoracoabdominal aortic aneurysms is an uncommon but devastating complication. Paraplegia has been reported to occur in 3.7% for thoracic aortic aneurysm and 5.6% for combined open surgery of abdominal aortic aneurysm and endovascular stent-graft repair of thoracic aortic aneurysm. The blood supply of the spinal cord is derived from three to ten intercostal and lumbar arteries, which coalesce to form the anterior spinal artery (ASA) and the two posterior spinal arteries. The ASA extends the length of the spinal cord. The artery of Adamkiewicz (AKA), which usually originates between the sixth intercostal and the second lumbar artery, is the principal arterial supply of the ASA in the lower thoracic and lumbar level.

Preoperative angiography has been advocated to prevent the ischemic injury of the spinal cord. Magnetic resonance angiography and multi-detector computed tomography (MDCT) have been proposed as alternative non-invasive techniques for the detection of the ASA and AKA. Substantial variations in the detection rate, 50-100% for the ASA, 68-90% for the AKA, have been reported and most of the published data were acquired in Japanese cohorts exclusively, to our knowledge. The purpose of this study was to evaluate the visualization of the ASA and AKA, the affecting factors for the detection rate using MDCT.

Materials and methods

Ninety-nine consecutive patients with known or suspected thoracic aortic disease and without aortic stent-grafts or surgical grafts between T5 and L2 underwent CT angiography from the thoracic inlet to the aortic bifurcation. There were 31 women and 68 men with ages that ranged from 25 to 90 years (61.3±13.4 years, mean ± s.d.). The final diagnosis in the thoracic aorta was aneurysm in 31, dissection in 45, intramural hematoma in...
5, and normal or atherosclerotic plaques in 18 patients.

Patients were scanned with 16-row MDCT scanners (LightSpeed 16 or LightSpeed Ultra, GE Medical System, Milwaukee, WI, and Sensation 16, Siemens Medical Solutions, Erlangen, Germany). All CT scans were obtained with 0.5 second rotation, 1–2.5 mm nominal detector widths, pitch of 1.3–1.7, 120 kV, and 254–440 mA. Transverse sections were reconstructed with 50% overlap relative to the effective section thickness and ranged between 0.6, and 1.5 mm intervals.

Iohexol (Amersham Health, Princeton, NJ) was administered through an antecubital vein with a dose of 120-150 mL (350mgI/mL) at a rate of 4-5 mL/sec. The scan delay was determined either by a preliminary 10 mL test injection or by direct bolus tracking using SmartPrep (General Electric Medical Systems) or CareBolus (Siemens Medical Solutions).

All observations were made retrospectively by two cardiovascular radiologists. To examine the ASA and AKA, transverse sections, coronal multiplanar reformations (MPR) and thin-slab (2-4 mm) maximum intensity projections (MIP) were generated and displayed on workstation (Advantage Windows 4.1, GE Medical Systems) with window and level settings selected to maximize arterial to background discrimination. The ASA and AKA were identified by maintaining the MIP-slab parallel to the anterior surface of the spinal cord at each vertebral level assessed from T5 to L5. An enhanced artery on the midline ventral surface of the spinal cord was interpreted as the ASA. At the same time, an artery originating from the aorta and coursing through the intervertebral foramen to join the AKA was a hairpin configuration was interpreted as the AKA.

To estimate the contrast-to-noise ratio (CNR) of the image, we measured the mean attenuation value within a 50 mm² region-of-interest in the aorta at the T11 level and subtracted that value from the mean attenuation within a 50 mm² region-of-interest in the spinal cord. This contrast value was divided by the standard deviation of the attenuation within the central portion of the spinal cord at the T11 level (50 mm² region-of-interest). The CT numbers were measured within an aortic region-of-interest at the level of T11. This level was chosen because 89% of AKA origins occurred between the T9 and T12 levels.

Following manual segmentation, the mass of the T11 vertebral body was estimated as the product of the volume of the segmentation and 1000 plus the mean CT number within the segmentation. We refer to this measure as the “vertebral mass index” because the “Body Mass Index” could not be obtained from retrospective study.

The length of the detected portion of the ASA, the level of origin of the AKA, the section thickness, were compared to the product of the tube current and the rotation time (mA·s), the degree of aortic enhancement within aorta at arch and T11 level, the T11 “vertebral mass index”, the CNR and the thickness of the subcutaneous fat measured along the mid-clavicular line.

The data were analyzed using a Kruskal-Wallis or Mann-Whitney U test for unpaired data, with a P value of less than 0.05 was considered to indicate a significant difference.

### Results

Among 51 patients (52%) whose ASA was visualized, the AKA was seen in 18 patients (18%). The ASA was shown in 22/31 (71%) patients with thoracic aortic aneurysms, 20/50 (40%) dissection and intramural hematoma patients, and 9/18 (50%) normal or atherosclerotic patients. The AKA was shown in 8/31 (26%) patients with thoracic aortic aneurysms, 5/50 (10%) dissection and intramural hematoma patients, and 5/18 (28%) normal or atherosclerotic patients.

The course of the ASA extended from T6 to L1-2 (Table 1). The AKA originated from T7 to T12, 13 were from left and 5 from right (Table 2). When the AKA was shown, the cranial portion of the ASA, distal to the junction with the AKA, was always visualized. The cranial portion of the ASA was visualized depending upon the level of its junction with the AKA. The cranial portion of the ASA was never detected when its junction with the AKA was cephalad to the superior endplate of the T9 vertebral artery. If the cranial portion was shown, there was no difference in diameter with the caudal portion of the ASA (Fig 3).

The scans were stratified into two groups according to the effective section thickness: <2.0 mm and 2.5–3.0 mm. The ASA was identified in 36/67 (54%) patients with <2.0 mm thickness, and the AKA was identified in 15/32 (47%) patients with 2.5-3.0 mm thickness (Fig. 1 and 2). This difference did not achieve significance (P=0.13).

<table>
<thead>
<tr>
<th>Superior Extent</th>
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<tbody>
<tr>
<td>T6</td>
<td>0</td>
</tr>
<tr>
<td>T7</td>
<td>0</td>
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<td>T10</td>
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<td>T11</td>
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Fig 1. MDCT scan obtained with 1.25mm scan thickness in a 73-year-old female with thoracic aneurysm. (a) Coronal MIP shows the AKA with a typical hairpin configuration, arising from the right T7 level, joins the ASA, which only the descending portion is seen. (b) Oblique MIP shows the AKA (arrowheads) originating from the right intercostal artery (small arrow) and joining the ASA (large arrows) (c) MPR images (from the ventral to the dorsal) show the continuity of the intercostal artery, the AKA and ASA. (d) Axial images show the ASA and AKA.

The aortic luminal attenuation at T11 was significantly higher ($P<0.05$) in the 52 CT scans that allowed ASA detection (358±62 HU) than in the 47 scans where the ASA was not visualized (317±68 HU). AKA visualization was also dependent on aortic luminal enhancement at T11, measuring 393±63 HU and 329±65 HU in patients with and without AKA visualization, respectively ($P<0.05$).

The mA•s values ranged from 127 mA•s to 220 mA•s, and did not affect the detection of the ASA ($P=0.84$) or the AKA ($P=0.89$). However, the detection of the ASA and the AKA was associated with a larger arterial CNR, less noise in the spinal cord, and a smaller "vertebral mass index" (Table 3). Thinner subcutaneous fat was associated with improved ASA detection, but not AKA detection.

Discussion

The ASA and AKA are the major blood supply of the spinal cord in the thoracolumbar region. The anterior two thirds of the spinal cord receive blood supply from the ASA and 75% of blood supply of the spinal cord comes from the ASA. It has been demonstrated that the ASA is a continuous structure throughout the length of spinal cord. The ASA and the AKA diameters are reported to be 0.5-1.2 mm in the thoracolumbar region. In order to prevent ischemic injury to the spinal cord, the anatomy of the blood supply of the spinal cord needs to be recognized before invasive treatment such as surgery or stent-graft placement in the descending thoracic and proximal abdominal aorta. Although selective angiography is recommended, it is time-consuming and hazardous.

The detection of the ASA and AKA using MDCT angiography has been assessed in three prior published investigations. Takase and colleagues were the first to publish a report of AKA detection using MDCT. They examined 70 patients with suspected thoracoabdominal vascular disease using 100 mL of contrast medium (300 mgI/mL) injected at 3.5 mL/sec and 2 mm thick MDCT sections to identify the AKA in 90% of patients. The artery of Adamkiewicz was...
successfully visualized in 24 of 30 patients (80%) with 1-mm thick, 4-row MDCT angiography in a study by Yoshioka et al. For these CT scans, a total of 2.5 mL/kg of contrast material (370 mgI/mL) was injected at 3 mL/sec. After injecting 100 mL of contrast medium (350 mgI/mL) at 5 mL/sec. Kudo, et al reported 100% ASA and 68% AKA detection on arterial phase abdominal MDCT scans (2 mm section thickness) in 19 patients with liver disease patients but without known thoracic aortic disease.11

In our study, the detection rate of the ASA and AKA with MDCT were 52% and 18%. This lower detection rate cannot be explained on the basis of CT technique, because the section thickness between our MDCT scans and those of the prior reports was similar and the quantity and the flow rate of contrast material in our study was the same or greater than in the prior reports.4,10,11

The detection of any structure in the body relates directly to the ratio of the contrast difference between the structure and its background to the noise.17 Assuming fixed acquisition and contrast material administration parameters, an increase in the body habitus as measured by “vertebral mass index” and subcutaneous fat thickness, for example, will reduce the CNR of a CT scan by both increasing the noise and decreasing arterial enhancement. Within our study population, the detection of the ASA and the AKA was affected significantly by the CNR. Moreover, we found independent and significant associations between both the level of aortic enhancement and the noise in the scan with ASA and AKA visualization.

We also investigated three scan parameters, section thickness and mA•s to determine how they affected ASA and AKA visualization. The detection rate was not significantly influenced by the section thickness or scan mA•s. In general, the thin sections typical of MDCT angiographic acquisitions have an important influence on the detection of small arteries due to the reduction in volume averaging when compared to thicker section acquisitions.18,19 The lack of association of section thickness with ASA visualization might be explained by the vertical course of the AKA, which minimizes the likelihood of longitudinal volume averaging, thus minimizing the impact of a 1.25 versus a 2.5-3 mm section. Although the majority of the AKA is vertical as well, its horizontal portions were not adversely affected by imaging with 2.5-3 mm section thickness and reconstructing with 1.6 mm increments. This further suggests that for MDCT sections with 1–3 mm thicknesses, spinal artery visualization is influenced primarily by CNR and not by volume averaging.

The lack of association of ASA and AKA visualization with mA•s is intriguing, as higher values will reduce image noise. This lack of association suggests that the influence of body habitus on ASA and AKA visualization dominates over whatever improvement in CNR that an increase in mA•s might provide. This statement presupposes that the selection of mA•s factors in our study was based upon body habitus, but because our recruitment was retrospective, we cannot make this assertion. Therefore, it remains to be shown whether a formalized scheme to increase CNR by increasing mA•s in patients with large body habitus might improve ASA and AKA visualization rates.

When analyzing MDCT data for ASA and AKA identification, we have found some visualization strategies to be particularly useful. Thin slab MIP is excellent for depicting the relationship between the ASA and AKA. When the ASA is not well-enhanced an overly thick slab may preclude visualization, so thin slabs (3-5 mm) are advised. To demonstrate the ASA, the slab angulation should be adjusted at different spinal levels to maintain a parallel orientation to the anterior surface of the spinal cord. Double oblique MIPs are needed to show the continuity of the intercostal artery, the AKA and the ASA. Curved MPR can be used to show the ASA and AKA as well.10,11 but may be difficult to implement because of the small diameter of these two vessels.

A limitation of our study is the absence of a reference standard, e.g. selective intercostal and lumbar angiography, to determine whether a lack of ASA or AKA visualization can be attributed to a limitation of the imaging modality or if the vessel is truly occluded. In fact, in the setting of aortic aneurysm, dissection and intramural hematoma, conventional angiographic visualization of the ASA is reported to occur in only 55-75%.3,5,20 Unfortunately, due to the complexity and risk, selective intercostal and lumbar angiography is an uncommon procedure, and a comparison of MDCT detection to angiographic detection is very difficult to attain in a clinical cohort. A key insight to be gleaned from our study is that body size appears to influence arterial detection with CT angiography.

In conclusion, MDCT visualization of the ASA and AKA appears to have greater dependence upon body habitus than

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**Table 3. Impact of measures of body habitus and image quality on AKA and ASA detection**

<table>
<thead>
<tr>
<th>Measure</th>
<th>AKA (Detected)</th>
<th>AKA (Not detected)</th>
<th>P value</th>
<th>AKA (Detected)</th>
<th>AKA (Not detected)</th>
<th>P value</th>
</tr>
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<tr>
<td>CNR</td>
<td>15.2±5.6</td>
<td>11.9±5.1</td>
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<td>9.1±2.4</td>
<td>7.1±2.2</td>
<td>.02</td>
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<tr>
<td>Noise in Spinal Cord (HU)</td>
<td>20.1±6.5</td>
<td>24.4±8.5</td>
<td>.04</td>
<td>21.5±7.2</td>
<td>25.9±8.8</td>
<td>.03</td>
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<tr>
<td>Vertebral Mass Index</td>
<td>7.5±2.2</td>
<td>8.8±2.3</td>
<td>.03</td>
<td>8.1±2.4</td>
<td>9.1±2.2</td>
<td>.04</td>
</tr>
<tr>
<td>Subcutaneous Fat Thickness (mm)</td>
<td>14.6±7.1</td>
<td>15.6±6.7</td>
<td>.59</td>
<td>13.7±5.6</td>
<td>17.1±7.4</td>
<td>.01</td>
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</tbody>
</table>

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scan acquisition or contrast-medium delivery parameters.

References