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Calcification at orifices of aortic arch branches is a reliable and significant marker of stenosis at carotid bifurcation and intracranial arteries

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ABSTRACT

Purpose: Simple rating scale for calcification in the cervical arteries and the aortic arch on multi-detector computed tomography angiography (MDCTA) was evaluated its reliability and validity. Additionally, we investigated where is the most representative location for evaluating the calcification risk of carotid bifurcation stenosis and atherosclerotic infarction in the overall cervical arteries covering from the aortic arch to the carotid bifurcation.
Method: The aortic arch and cervical arteries among 518 patients (292 men, 226 women) were evaluated the extent of calcification using a 4-point grading scale for MDCTA. Reliability, validity and the concomitant risk with vascular stenosis and atherosclerotic infarction were assessed.
Results: Calcification was most frequently observed in the aortic arch itself, the orifices from the aortic arch, and the carotid bifurcation. Compared with the bilateral carotid bifurcations, the aortic arch itself had a stronger inter-observer agreement for the calcification score (Fleiss' kappa coefficients; 0.77), but weaker associations with stenosis and atherosclerotic infarction. Calcification at the orifices of the aortic arch branches had a stronger inter-observer agreement (0.74) and enough associations with carotid bifurcation stenosis and intracranial stenosis. In addition, the extensive calcification at the orifices from the aortic arch was significantly associated with atherosclerotic infarction, similar to the calcification at the bilateral carotid bifurcations.
Conclusions: The orifices of the aortic arch branches were the novel representative location of the aortic arch and overall cervical arteries for evaluating the calcification extent. Thus, calcification at the aortic arch should be evaluated with focus on the orifices of 3 main branches.

1. Introduction

Calcification at the carotid bifurcation has been shown to correlate with over 50% of the cases of stenosis at the origin of the internal carotid artery (ICA) [1]. A similar relationship has been demonstrated between the degree of coronary artery calcification and the severity of atherosclerosis and cardiovascular events [2,3]. Several studies have also shown correlations between cardiovascular events and calcifications in the aortic arch, abdominal aorta, and ICA origin [4–9]. Although many clinical researchers have perceived that calcifications at the ICA origin or the aortic arch are important, they have paid little attention to calcifications in other cervical arteries. Thus, we investigated the following questions: Does calcification at the aortic arch or the ICA provide a representative measure of overall cervical artery calcification? If not, which is the most representative and clinically significant segment associated with ICA stenosis or atherosclerotic infarction, among the exhaustively assessed cervical arteries located between the aortic arch and the ICA?

For assessing calcification and measuring luminal stenosis at the arteries, multi-detector computed tomography angiography

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(MDCTA) is a more robust technique than conventional digital subtraction angiography or magnetic resonance angiography [10–13]. Therefore, we sought to establish a simple and clinically useful rating scale for calcification in the cervical arteries and the aortic arch, using multidirectional maximum-intensity-projection reconstruction (MIP) sequences of MDCTA. The second purpose was to identify representative locations, within the cervical arteries, associated with a risk of ICA stenosis or atherosclerotic infarction.

2. Materials and methods

2.1. Study population

Consecutive 520 patients underwent MDCTA between 2009 and 2012 were enrolled in this study, except 2 patients whose imaging data were unavailable due to inadequate contrast opacification. The main reasons for the MDCTA examination are definite diagnosis of arterial stenosis or ruptured aneurysms, and follow-up after treatment for carotid stenosis or aneurysms. Among the 518 studied patients (292 men and 226 women; mean age, 67.5 years; standard deviation of age, 13.0), 171 were diagnosed with ischemic stroke, 132 with hemorrhagic stroke, and the other 215 without stroke (non-stroke). Ischemic stroke were classified 4 subtypes using the A-S-C-O classification system; atherosclerosis (104 patients), small vessel disease (11 patients), cardiac source (25 patients), and other cause (31 patients including 22 patients with transient ischemic attack) [14]. At the initial diagnosis of ischemic stroke, 163 patients (95%) underwent diffusion-weighted and fluid attenuated inversion recovery MR images and MR angiography. Eight patients with cardiac pacemaker were diagnosed with ischemic stroke on the basis of the neurological assessments and evaluation of brain CT plain scan and CTA. The duration of conducting MDCTA from stroke onset or initial presentation was within 10 days in the 474 patients (92%).

Cervical ICA stenosis was defined as stenosis at the ICA origin, and similarly, intracranial stenosis was defined as stenosis of the major intracranial arteries, including the intracranial ICAs, or anterior, middle or posterior cerebral arteries. The degree of stenosis was calculated using mean percent stenosis ratios determined by MDCTA, and was divided into the following 3 categories: <29 (mild), 30–69 (moderate), 70–99% (severe), according to the methods of the North American Symptomatic Carotid Endarterectomy Trial (NASCET) [15]. Among 115 patients diagnosed with cervical ICA stenosis, 28 had undergone carotid artery stenting (CAS), and 2 had undergone carotid endarterectomy (CEA). Fourteen out of the 28 patients who had undergone CAS had received MDCTA examination prior to CAS; therefore, their treated ICA sites were evaluated for calcification or percent stenosis using initial pre-treatment MDCTA. The other 14 had undergone MDCTA only after CAS for follow-up, and they could not be evaluated them because of the presence of metallic stents. Therefore, the calcification locations were treated as missing values. Laboratory data and risk factors associated with arteriosclerosis, such as hypertension, hypercholesterolemia, diabetes, atrial fibrillation, cigarette smoking, and heavy alcohol use, were reviewed by retrospective examination of patient medical records. The study design and protocol were approved by the hospital's ethical committee for human research.

2.2. Scan techniques

All patients or their family members signed an informed consent form before MDCT examination. All were confirmed to have the appropriate indications for the use of iodinated contrast material. All CT examinations were performed with a 64-row MDCT scanner (Aquilion 64, Toshiba Medical, Tokyo, Japan). The CT parameters were: matrix, 512 × 512; field of view, 20–24 cm; maximum tube current, 230 mA, 120 kV; and section thickness, 1.6 mm. A helical scan automatically started from the aortic arch at the time of maximum enhancement of that site, and then proceeded to the vertex. Arterial enhancement was provided by intravenous administration of nonionic iodinated contrast material (40–50 mL, Iopamiron 300, Bayer HealthCare, Osaka, Japan), which was administered at a rate of 4.0 mL/s. The helical axial source images were processed to semi-automatically create MIP, three-dimensional, volume-rendering reconstruction (3D VR), and multiplanar reformatted reconstruction (MPR) images using a workstation (Ziostation, Ziosoft, Tokyo, Japan) (Fig. 1). The arterial calcification was evaluated using 360-degree MIP images.

2.3. Calcification measurements

Fig. 2 shows the calcification evaluation of the aortic arch and cervical arteries on a 4-point grading scale (0, none; 1, dot-like calcification; 2, calcification size > 3 mm and <180° of the cross-section of the arterial wall; 3, a semicircle or more of calcification at the arterial cross-sectional surfaces). Cervical arteries were divided into 16 segments: the origins and trunks of the brachiocephalic artery (2), the bilateral common carotid arteries (4), the bilateral ICAs (4), the bilateral subclavian arteries (4), and the origins of bilateral vertebral arteries (2). The aortic arch was defined as the curved portion between the ascending and descending aorta, except the orifices of the 3 branches which usually originate from the aortic

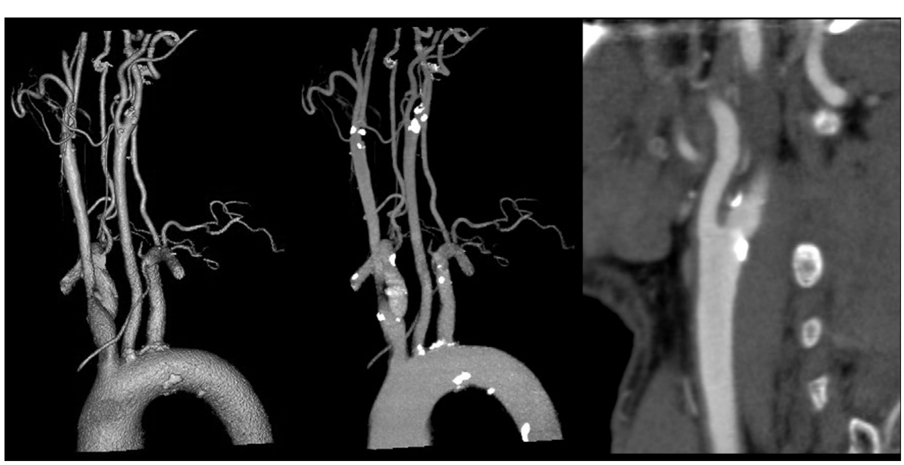

Fig. 1. Representative case of multi-detector computed tomography angiography (MDCTA). Left, a three-dimensional, volume-rendering reconstruction (3D VR) image; middle, a multidirectional maximum-intensity-projection reconstruction (MIP) image; and right, a multiplanar reformatted reconstruction (MPR) image.