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Clinical Study

Morphological differences between the aneurysmal and normal artery in patients with internal carotid–posterior communicating artery aneurysm

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ABSTRACT

The aim of this study was to identify image-based morphological parameters that correlated with the formation of internal carotid artery–posterior communicating artery (ICA–PcomA) aneurysms. Morphological parameters obtained from 3-dimensional digital subtraction angiography (3D-DSA) were evaluated from nine patients with ICA–PcomA aneurysms, including the diameter of the ICA (Dica) and PcomA (Dpcom), the angle between the ICA and the origin of the PcomA (Apcom), and the angle between the ophthalmic and communicating segments of the ICA (Aica). Measurements were performed on both sides of each patient. Parameters were analyzed with a paired-samples *t*-test for significance. In additional, receiver operating characteristic (ROC) analysis was performed on the significant parameter. Statistically significant differences were found between the aneurysmal (45.28 ± 29.07°) and control sides (79.22 ± 17.83°) for Apcom ($p = 0.020$). In the ROC analysis, the area under the curve value of Apcom was 0.852, and the threshold for optimal sensitivity and specificity was 52.25°. Therefore, the Apcom parameter was correlated with the formation of an ICA–PcomA aneurysm, and seems to be a promising morphological parameter for risk assessment of aneurysm formation.

1. Introduction

The evolution of an intracranial saccular aneurysm may be affected by a several factors. It is widely accepted that hemodynamics is important in the initiation, growth, and rupture of cerebral aneurysms. For a given geometry, Cebral et al.[1] showed that intra-aneurysmal hemodynamics do not vary significantly with physiological variations of flow rate, blood pressure, and waveform. Therefore, suitable parameters characterizing arterial geometry could capture the characteristic hemodynamics and potentially predict aneurysm formation. In this study, we defined four parameters to examine differences between the aneurysmal and normal artery in patients with an internal carotid artery–posterior communicating artery (ICA–PcomA) aneurysm. All parameters were obtained from three-dimensional digital subtraction angiography (3D-DSA).

2. Material and methods

2.1. Patient population

Informed consent was obtained from each patient prior to the clinical investigation. Because we reconstructed 3D data from rotational angiographic images in this study, we needed patients who had rotational angiographic images of sufficient quality for accurate segmentation and reconstruction. Nine consecutive patients who received both-side rotational angiography and showed a single-sided ICA–PcomA aneurysm met these criteria. All patients were female, and ranged in age from 47 years to 80 years (mean: 61.33 ± 12.51 years). The aneurysms were located on the left in five patients, and on the right in four patients. Five patients were admitted to our department for acute subarachnoid hemorrhage (SAH), three for a headache with ptosis, and one for a health examination.

2.2. Image acquisition

Cerebral angiography was carried out by interventional neurosurgeons within 72 hours of SAH onset. All catheter angiograms were performed by standard transfemoral catheterizations of the cerebral vessels and digital subtraction imaging was performed with a Philips Allura Xper FD 20 unit (Philips Medical Systems; Best, The Netherlands). The 2D views from the angiogram are shown in Fig. 1. For 3D-DSA, contrast material (Iohexol 300) (GE Healthcare; Shanghai, China) was automatically administered using a power injector (Mark V ProVis Pedestal) (Medrad; Indianola, PA, USA) into the ICA at 2.5 mL/s to a total amount of 22.5 mL. The C-arm was rotated 180° within 8 s at an exposure rate of 15 frames/s. The injection started 2.0 s before the acquisition of the first opacified image to provide entire filling of the selected arteries during rotational angiography. A total of 120 images were

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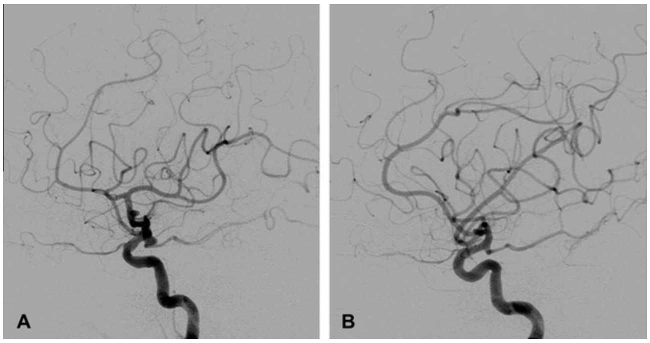

Fig. 1. Angiograms of one patient showing: (A) on one side an internal carotid–posterior communicating artery aneurysm; and (B) the normal other side.

acquired and transferred to the workstation. A 3D angiogram showing all vessels included in the field of view was automatically displayed at the workstation. The $128 \times 128 \times 128$ angiograms were generated for regions of interest. The 3D images were displayed using the gradient rendered technique. The vessels were transparent and the bifurcation points of the arteries were shown clearly. The threshold for the gradient-rendered image was fixed as the default value provided by the software.

2.3. Definition of parameters

Four parameters were estimated in this study: (i) the diameter of the ICA (Dica); (ii) the diameter of the PcomA (Dpcom); (iii) the angle between the ophthalmic and communicating segment of the ICA (Aica); and (iv) the angle between the ICA and PcomA (Apcom). The parameters were obtained from the 3D workstation. A description of the four parameters, according to Dhar et al.,[2] follows:

(i) Dica – the vessel diameter obtained by measuring two representative cross-sections of the ICA (D1 at proximal ICA–PcomA bifurcation; D2 at $1.5 \times$ D1 upstream), and averaging their values (Fig. 2A, C);
(ii) Dpcom – the average of D1 at the origin of PcomA and D2 at $1.5 \times$ D1 downstream (Fig. 2B, D);
(iii) Aica – the angle formed by the centerlines of the ophthalmic and communicating ICA segments drawn in a plane selected to avoid them appearing as overlapping (Fig. 3A, C);
(iv) Apcom – the angle formed by centerlines of the ICA and the origin of the PcomA close to the ICA–PcomA bifurcation in a plane selected to avoid them appearing as overlapping (Fig. 3B, D).

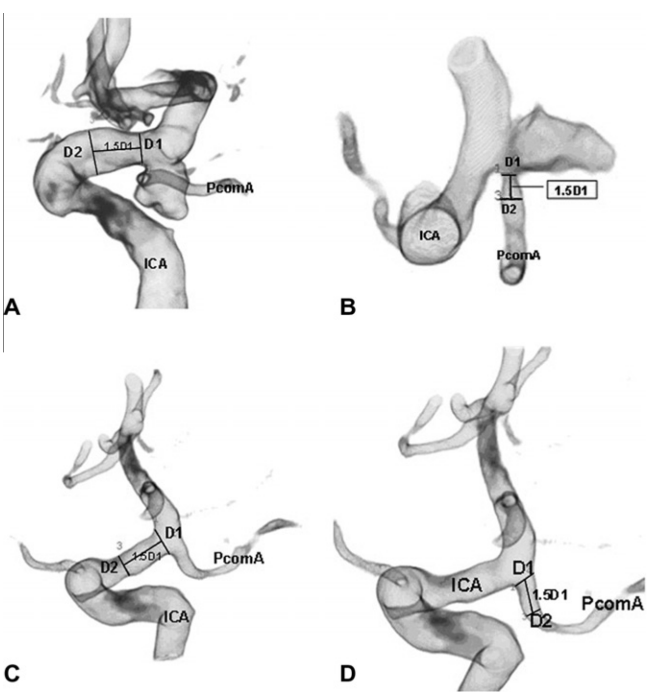

Fig. 2. The internal carotid artery (ICA) diameter (Dica) and posterior communicating artery (PComA) diameter (Dpcom) in the viewing plane, showing: (A, B) the aneurysmal side; and (C, D) the normal side. Dica = (D1 + D2)/2 of the ICA and Dpcom = (D1 + D2)/2 of the PComA.

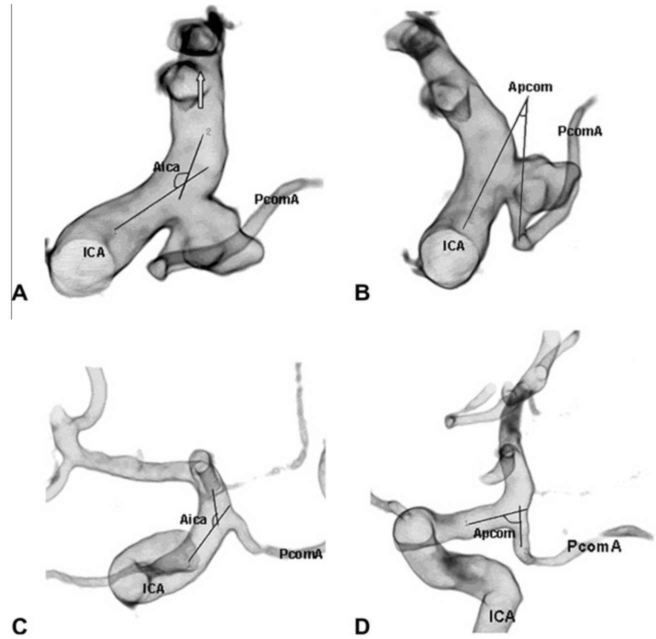

Fig. 3. The angle between the ophthalmic and communicating segments of the internal carotid artery ICA (Aica) and the angle between the ICA and the origin of the posterior communicating artery (PcomA) (Apcom) in the viewing plane, showing (A, B) the aneurysmal side; and (C, D) the normal side.

2.4. Statistical analysis

The aneurysmal and normal side of each patient made up a pair. A paired-samples *t*-test was performed for each pair of parameters to assess the statistical significance of the observed difference between the means of aneurysmal and normal groups. The *p* values from the *t*-test were calculated and reported. A $p < 0.05$ was considered as statistically significant. The receiver operating characteristic (ROC) analysis was also performed for the significant parameter. The ROC curve and the area under the curve (AUC) indicate the limits of a parameter's ability to predict aneurysm formation. Thresholds for optimal sensitivity and specificity were also calculated for significantly different parameters. The cut-off point was set by the maximum Youden Index:

$$\text{Youden Index} = \text{sensitivity} + \text{specificity} - 1.$$

All statistical analyses were performed using the Statistical Package for the Social Sciences for Windows 13.0 (SPSS; Chicago, IL, USA).

3. Results

In all patients, the angiographic procedures were successfully performed without any complications. The PcomAs were shown