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MODELING THE LOCATION-DEPENDENCY OF ANEURYSM SHAPE – A MORPHOMETRIC COMPARATIVE STUDY

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SUMMARY

The typical characteristics of intracranial aneurysms vary for different anatomic locations. Here, we study the location-dependent variability of aneurysm shape, and propose means to model and visualize this variability. We further elaborate to which extent the configuration of the cerebral vasculature could affect the outcome of an aneurysmal lesion.

Key words: *Intracranial aneurysms, morphology, location-dependency, Circle of Willis*

1 INTRODUCTION

Intracranial aneurysms (IAs) are common, focal dilations of larger cerebral arteries. Although IAs remain quiescent most of the time, they may rupture at a rate of about 1% per year. Most IAs are located in the proximity of vessel bifurcations and the Circle of Willis (CoW), an anastomotic arterial network located at the skull base connecting the anterior and the posterior circulation as well as both cerebral hemispheres. [1]

It is well established that aneurysm characteristics vary with the anatomic location of the aneurysms. For instance, the rupture rates differ widely for IAs located at different vessel segments [2], or they share common shape characteristics, as illustrated in Figure 1. While the anatomic embedding and the local hemodynamic environment are thought to account for this location dependency, the implications of location dependency on IAs are not well understood.

The purpose of this study is to investigate the location dependency of aneurysm morphology. We propose means to compare and visually summarize the characteristics of aneurysm morphology for different anatomical locations. Finally, we discuss the extent to which the arterial architecture (e.g., configuration of the CoW) might in itself be a risk factor for aneurysm formation or rupture.

2 METHODOLOGY

The data used for this study are part of the AneuX morphology database, a collection of 3D geometric models of totally 750 IAs (261 ruptured, 474 unruptured). The main portion of the data ($n = 357$ IAs) was collected prospectively and consecutively between September 2006 and July 2015 at the Geneva University Hospital (HUG). The database is supplemented by publicly available data from the @neurIST ($n = 151$) and Aneurisk ($n = 97$) projects [5, 6]. All geometric models of the aneurysms (represented as 3D surface meshes) were extracted from 3D rotational angiography (3DRA) and processed following a very similar semi-automated procedure. In addition, the rupture status, the anatomic location (a categorical variable covering 12 common locations), as well as the age and sex of the affected patient were available for each aneurysm.

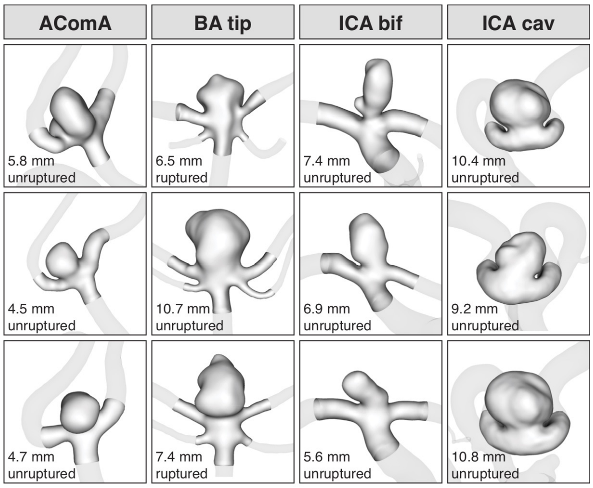

Figure 1: 3D models of intracranial aneurysms stratified by four different anatomic locations: anterior communicating artery (AComA), tip of basilar artery (BA tip), terminal bifurcation of the internal carotid artery (ICA bif), cavernous segment of the internal carotid artery (ICA cav).

To quantify the aneurysm shape, a set of established morphometric indices (such as aneurysm size, non-sphericity, total Gaussian curvature, and more) were computed for each aneurysm [7, 8]. This morphometric data was supplemented by qualitative shape characteristics (e.g., the presence of blebs, lobules or asymmetry) as judged by human raters. Spider charts ("location profiles") were used to visualize the average characteristics per anatomic location.

3 RESULTS AND CONCLUSIONS

Preliminary results suggest that the morphology varies substantially with different anatomic locations. Figure 2 shows location profiles for four different anatomic locations. Further stratification of this location dependency by aneurysm disease status revealed that the morphological discrepancy between ruptured and unruptured aneurysms varies for different anatomic locations. Finally, although aneurysms at the same anatomic location often share similar morphological attributes, a statistical analysis revealed that shape and location carry independent information about the aneurysm disease status (here: rupture status).

It is well known that the cerebral angioarchitecture varies markedly from person to person, with anomalies (e.g., missing or underdeveloped vessel segments) present in more than half of the population. [4, 3] It is conceivable that different variants of the CoW succumb to different risks related to aneurysms. Our study reveals the need for a method to characterize and compare different CoWs observed in medical imaging data in terms of morphology and topology. This would permit to examine the CoW configuration as independent risk factor for pathologies such as IAs.

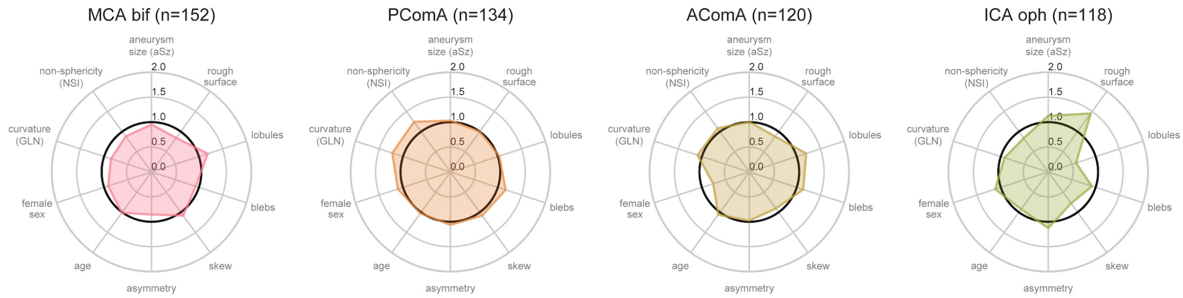

Figure 2: Location profiles for four different anatomic locations: middle cerebral artery (MCA), posterior communicating artery (PComA), anterior communicating artery (AComA), and the ophthalmic segment of the internal carotid artery (ICA oph). The axes indicate different quantitative and qualitative morphological characteristics, as described in [9].

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