



Neurosurgical Forum
LETTERS TO THE EDITOR

Middle cerebral artery tortuosity associated with aneurysm development

TO THE EDITOR: We read with great interest the article by Kliś et al.² (Kliś KM, Krzyżewski RM, Kwinta BM, et al: Computer-aided analysis of middle cerebral artery tortuosity: association with aneurysm development. *J Neurosurg* [epub ahead of print May 18, 2018; DOI: 10.3171/2017.12.JNS172114]). The authors conclude that “an increased deviation of the middle cerebral artery (MCA) from a straight axis (described by relative length [RL]), a decreased sum of all MCA angles (described by sum of angle metrics [SOAM]), a local increase of the MCA angle heterogeneity, and an increase in changes in an artery’s course (described by inflection count metric [ICM]) are associated with MCA aneurysm formation.” They revealed that MCA tortuosity may play an important role in aneurysm formation and provided important clues for exploring the pathological causes of aneurysm formation. However, we still have some confusion about the article.

First, according to the calculation method for the tortuosity descriptors proposed by the authors, the size of the SOAM, ICM, and triangular index (TI) is positively related to tortuosity; that is, the larger the value, the greater the degree of tortuosity. The RL is negatively associated to the degree of tortuosity; that is, the smaller the value, the greater the degree of tortuosity. The product of the angle distance (PAD) may have a positive or a negative correlation with tortuosity since that descriptor is calculated as the product of the SOAM and the RL.⁴ The results of their study showed that patients with aneurysms had higher TI and ICM values but lower RL and PAD values.¹ The above results clearly show that the degree of tortuosity is greater in the aneurysm group. However, in contradiction with this, the SOAM values are lower in the aneurysm group. Moreover, the authors mention in the *Discussion*, “In terms of a lower SOAM in arteries with an MCA aneurysm, the explanation is most probably connected with fluid dynamics. Artery tortuosity increases the resistance to blood flow. . . . Therefore, blood flow through an artery with larger local angles may cause a local decrease in blood pressure. This also leads to a decrease in local blood flow. Lower blood flow and blood pressure are pro-

TECTIVE factors against aneurysm formation.” Nevertheless, according to that explanation, it can be inferred that the incidence of aneurysms in patients with local tortuosity should be decreased rather than increased. Therefore, it would be better for the authors to provide an in-depth explanation about the above results and arguments.

Second, the authors stated, “There are a few rare genetic syndromes that are linked to the presence of vessel tortuosity, such as artery tortuosity syndrome or Loews-Dietz syndrome.” The genetic syndromes they mention are systemic lesions involving multiple parts of vessels of the body and therefore often involve multiple intracranial aneurysms.^{1,3,5} However, this article did not provide detailed information on the characteristics of intracranial aneurysms, for example, the incidence of multiple aneurysms, the specific sites of the MCA aneurysms (M₁, M₂, M₃, M₄), and the size of the aneurysms, etc. We believe this information has important implications for further exploration of the factors related to the formation of an aneurysm and its relationship with arterial tortuosity.

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Disclosures

The authors report no conflict of interest.

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Published online September 7, 2018; DOI: 10.3171/2018.7.JNS181688.

Response

Firstly, we would like to clarify the meaning of SOAM. The sum of angle metrics is a descriptor that shows us not the absolute value of the angle but the value additive to the angle of 180°. The hemodynamics of the tortuous blood vessel is complex and must be analyzed in three dimensions. A decrease in blood pressure on one side of the wall can mean an increase in blood pressure on the opposing side. The environment created by increased tortuosity facilitates the development of an aneurysm not only by creating decreased or increased blood pressure, but also by creating blood pressure gradients. In our current analysis, we are planning to study the relation between local wall shear stress and cerebral artery tortuosity, in a manner similar to the methodology proposed by Xie et al.² in the context of coronary arteries. It is still not clear whether aneurysm development is associated with increased or decreased wall shear stress.¹ We hypothesized that blood pressure gradient and wall shear stress gradient are more important factors in the development of an aneurysm than their absolute values. Increased SOAM may be associated with a decreased gradient in the MCA.

In response to the second query, we are adding the missing data. As a majority (75.47%) of our study group had single, one-sided MCA aneurysms, we focused mostly on the influence of tortuosity on changes in blood flow hemodynamics. Additionally, patients with connective tissue disorders were excluded from our study group. Although higher tortuosity of the MCA among patients with multiple intracranial aneurysms may naturally indicate systemic factors that promote arterial wall weakening, we found no statistically significant difference in terms of the tortuosity descriptors between these patients and those with a single aneurysm. For our next study, we plan to investigate whether increased tortuosity of the cerebral arteries is associated with the tortuosity of other arteries, e.g., coronary ones, which further addresses that issue. In terms of aneurysm characteristics, as mentioned, a total of 14 (24.53%) patients had multiple aneurysms, including 3 patients with mirror MCA aneurysms. The mean number of aneurysms was 1.33 ± 0.64 , and the most common location was the M₁ bifurcation (79.63%), then M₁ (14.81%), M₂ (3.70%), and M₃ (1.85%). We also found no statistically significant relationship between tortuosity descriptors and aneurysm location. The mean size of the aneurysm dome was 4.92 ± 2.43 mm, and the mean size of the aneurysm neck was 4.14 ± 1.43 mm. Given the length limits on submitted papers, we were not able to put all necessary data into one paper and are planning to extend our research in other studies.

We are grateful for the appreciation of our paper and the insightful comments. We will supplement our future

work with suggestions supplied by Dr. Yin et al. Moreover, we encourage other authors to cooperate with our team. We are planning in the next 5 years to analyze the entire intracranial arterial system in the context of arterial tortuosity.

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Published online September 7, 2018; DOI: 10.3171/2018.8.JNS182006.

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Imaging predictor for rebleeding after surgery in intracerebral hemorrhage

TO THE EDITOR: With great interest, we read the article by Miki et al.⁸ (Miki K, Yagi K, Nonaka M, et al: Spot sign as a predictor of rebleeding after endoscopic surgery for intracerebral hemorrhage. *J Neurosurg* [epub ahead of print May 25, 2018; DOI: 10.3171/2017.12.JNS172335]) regarding the role of spot sign on CT angiography in predicting rebleeding after endoscopic surgery in intracerebral hemorrhage (ICH). The results of this study suggest that the spot sign is an independent predictor for rebleeding in patients with ICH receiving endoscopic surgery.

Spot sign is a reliable indicator for predicting hematoma expansion.^{2,3,9} Moreover, it has been suggested to be related to intraoperative and postoperative bleeding in patients with ICH receiving surgery.¹ In Miki et al.'s study, spot sign is shown as a predictor for rebleeding after endoscopic surgery. Thus, patients with ICH who have positive spot sign may have a higher risk of rebleeding after receiving surgery. Appropriate surgical methods should be adopted to decrease this risk in these patients.

In addition, spot sign can be used to screen eligible patients with ICH for specific surgical strategies. Recently, Li et al. have reported that ultra-early stereotactic aspiration can be adopted in patients with ICH and without positive spot sign.⁷ Ge et al. showed that only craniotomy can benefit patients with positive spot sign, whereas both craniotomy and minimally invasive craniopuncture can be used in patients with negative spot sign.⁴ Negative spot