Association of Hemodynamic Factors With Intracranial Aneurysm Formation and Rupture

Anil Can; Rose Du MD, PhD
Department of Neurosurgery, Brigham and Women's Hospital, Harvard Medical School, Boston, USA

Introduction

Recent evidence suggests a link between the magnitude and distribution of hemodynamic factors and formation and rupture of intracranial aneurysms (1-5). However, there are many conflicting results. Our goal is to quantify the effect of hemodynamic factors on aneurysm formation and their association with ruptured aneurysms.

Methods

We performed a systematic review and meta-analysis through October 2014. Analysis of the effects of hemodynamic factors on aneurysm formation was performed by pooling the results of studies that compared geometrical models of intracranial aneurysms and "preaneurysm" models where the aneurysm was artificially removed. Furthermore, we calculated pooled standardized mean differences between ruptured and unruptured aneurysms to quantify the association of hemodynamic factors with ruptured aneurysms. Standard PRISMA guidelines were followed.

Results

The hemodynamic factors that showed high positive correlations with location of aneurysm formation were high wall shear stress (WSS) and high gradient oscillatory number, with pooled proportions of 78.8% and 85.7%, respectively. Positive correlations were largely seen in bifurcation aneurysms, whereas negative correlations were seen in sidewall aneurysms. Mean and normalized WSS were significantly lower and low shear area significantly higher in ruptured aneurysms.

Conclusions

Intracranial aneurysm formation and rupture are likely to have a multifactorial etiology with hemodynamics acting as an important component in the process. Increases in local WSS and GON may be important underlying mechanisms responsible for aneurysm formation, whereas low WSS parameters are significantly associated with ruptured intracranial aneurysms. The location of the aneurysm at the bifurcation or sidewall may influence these correlations. To determine if hemodynamic flow is useful to predict the individual risk of rupture, a large-scale prospective study of unruptured aneurysms should be performed to characterize the hemodynamics of unruptured aneurysms that eventually rupture and those that do not, while taking into account the location of aneurysms and clinically relevant factors such as genetics, age, sex, smoking, hypertension, and atherosclerosis.

Learning Objectives

By the conclusion of this session, participants should be able to describe the role of computational fluid dynamics (CFD) techniques to assess hemodynamic risk factors for intracranial aneurysm formation and rupture.

References

1. Cebral JR, Mut F, Weir J, Putman C. Quantitative characterization of the hemodynamic environment in ruptured and unruptured brain aneurysms. AJNR Am J Neuroradiol. 2011;32(1):145-151.
2. Xiang J, Natarajan SK, Tremmel M, et al. Hemodynamic-morphologic discriminants for intracranial aneurysm rupture. Stroke. 2011;42(1):144-152.
3. Shojima M, Oshima M, Takagi K, et al. Magnitude and role of wall shear stress on cerebral aneurysm: computational fluid dynamic study of 20 middle cerebral artery aneurysms. Stroke. 2004;35(11):2500-2505.
4. Jou LD, Lee DH, Morsi H, Mawad ME. Wall shear stress on ruptured and unruptured intracranial aneurysms at the internal carotid artery. AJNR Am J Neuroradiol. 2008;29(9):1761-1767.
5. Alnaes MS, Isaksen J, Mardal KA, Romner B, Morgan MK, Ingebrigtsen T. Computation of hemodynamics in the circle of Willis. Stroke. 2007;38(9): 2500-2505.