The discrimination between hemodynamically stable and unstable intracranial aneurysms remains challenging. Recent studies reveal the potential existence of intraneurysmal velocity fluctuations, which appear at high frequency. Since these flow disturbances might promote the vessel wall remodeling process, indications regarding the occurrence of such phenomena are desired.

Materials and Methods To quantify unstable hemodynamics, image-based blood flow simulations were carried out in a ruptured aneurysm at the posterior inferior cerebellar artery. Since the exact rupture site could be identified during the angiographic imaging, local flow analysis was feasible. Besides the evaluation of time-varying velocity fluctuations, shear stress distributions and vortex generations were analyzed. Furthermore, the existing spectral flow entropy was assessed using proper orthogonal decomposition. Finally, all simulations were repeated in an unruptured aneurysm at the middle cerebral artery, which was similar with respect to size and shape.

Results The high-resolution blood flow simulations reveal the existence of complex flow patterns in combination with high-frequency fluctuations. These predominantly occur after the peak-systolic inflow and maintain in the diastolic phase. Furthermore, the wall shear stress distribution demonstrates a strong oscillatory behavior emphasizing the unstable character of the flow. The calculation of the spectral entropy resulted in a value of 0.76, which was associated with highly disturbed flow in advance. In contrast, these observations are absent in the reference simulation of the unruptured aneurysm. Specifically, stable flow patterns are visible and a low spectral entropy of 0.12 was calculated (a value of 0 represents steady flow conditions).

Conclusion The presence of high-frequency fluctuations and increased spectral entropy could be a potential biomarker for the discrimination between hemodynamically stable and unstable intracranial aneurysms. Since strong deviations were detectable in aneurysms with similar shape and location, stronger focus on the surrounding vasculature (e.g., with respect to the angle of proximal and distal branches) is suggested.


1Neuroradiology, University Clinic Magdeburg, Magdeburg, Germany; 2Research Campus Stimulate, Department of Fluid Mechanics and Technical Flows, University Magdeburg, Magdeburg, Germany; 3Research Campus Stimulate, Department of Simulation and Graphics, University Magdeburg, Magdeburg, Germany; 4Research Campus Stimulate, Department of Fluid Dynamics and Technical Flows, University Magdeburg, Magdeburg, Germany; 5Department of Fluid Mechanics and Technical Flows, University Magdeburg, Magdeburg, Germany