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The relationship between the arterial geometry and wall shear stress in the vertebrobasilar system

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Abstract

Atherosclerosis, which is related with systemic risk factors including hypertension, smoking and diabetes, is now nearly the leading cause of death worldwide. In that case, we want to find out the possibility of pre-diagnose and primary prevention of vertebrobasilar atherosclerosis to decrease the high mortality up to 80-95% without successful treatment. Researchers have shown that flow features such as shear stress is one of the contributions to atherosclerosis. The flow features in vertebrobasilar system are also influenced by morphology. Therefore, doing searches on the detailed relationship between basilar artery curvature and shear stress, in order to find a possible index for predicting shear stress according to MRA, which is a non-invasive medical method for checking intracranial arteries, is showing its potential. With the index, the diagnose of whether people are having risk factors or not, and access to primary prevention for vertebrobasilar atherosclerosis with regular health examination is becoming available.

Samples were selected from both genders, smoking and non-smoking. The database is collected from patients with primary addosteronism, a disease in which patients are easy to have hypertension. All data usage are agreed by patients and doctors. Patient-specific STL models of vertebrobasilar system were created according to MRA imaging sequences. Then combined with CFD method for further details of flow features. The simulations were done by STAR-CCM+13.04.010(SIEMENS,German). The boundary conditions were settled as: rigid wall; constant density; viscosity as blood (1056kg/m2 0.0035Pa*s); steady Newtonian laminar flow; 0.1mm meshing base size on independent test. The flow rate of basilar artery for all models was 165mL/min based on references and derived to vertebral arteries by cubic law. The curvature of basilar artery is calculated by the least square method and defined as'1/R' where R represents the radius of the ball which fits the centerline of the basilar artery best. The BA was divided into four based on the length of the centerline. The area of the BA was calculated as the mean value of five cross-section planes per case.

The average wall shear stress (WSS) of basilar artery is varying a lot, from 2 Pa to 31 Pa with the curvature changing from 0.01 mm-1 to 0.11 mm-1. According to the statistical results, both the area and curvature of BAs are associated with WSS. In nearly all cases, WSS in the anterior side is larger than in posterior side, which is the side of the wall attaching to the pons.

Previous researches have shown that shear stress is a contributor to vascular remodeling. When it comes to vertebrobasilar system, it is presented as different morphology in basilar artery. According to the patient-specific models, the basilar arteries are not only deforming to anterior side, many of them are also deforming towards both lateral directions. Flow features in the conjunction of basilar arteries have been analyzed by researchers and demonstrated to be correlated with the geometry in vertebrobasilar system. It is observed that even in this two-inlet-curved model, the area and the WSS are still negatively related. Meanwhile, the curvature of the basilar artery is positively correlated with the magnitude of WSS. Additional the whole range of WSS is varying a lot when it compared to those calculated from healthy young people, which demonstrates that when corresponding WSS to morphology, other issues such as age and smoking should also be taken under consideration. In conclusion, with much more detailed relationship between the morphology and the WSS, the prediction of the risk factors will become possible in the future.