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Multivariate Analysis for Rupture Prediction of Unruptured Cerebral Aneurysms Combining Computational Fluid Dynamics, Morphology and Clinical Information

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Introduction: Cerebral aneurysms can cause subarachnoid hemorrhages with its rupture, however, the rupture factor has not been cleared. It has been reported that aneurysm rupture is related to hemodynamic parameters, geometric parameters, or clinical information. In this study, we performed blood flow simulations using computational fluid dynamics (CFD) to get hemodynamic parameters. Additionally, geometric parameters of cerebral aneurysms and clinical information were also obtained from our database. Combining these parameters, we developed a new equation by multivariate analysis to estimate the rupture risk.

Materials and Methods: We identified 66 aneurysms at the internal carotid artery (ICA), including 6 rupture cases and 60 unruptured cases, and 50 aneurysms at the middle cerebral artery (MCA), including 7 rupture cases and 43 unruptured cases. CFD simulations were performed under pulsatile flow conditions using ANSYS CFX 18.1 to get the hemodynamic parameters. Morphologic parameters were calculated from stereolithography data (STL data). Clinical information was obtained from our patient database. Then, we executed multivariate analysis with the parameters and obtained the regression equation to estimate the rupture risk. A receiver operating characteristic analysis was performed to quantify the threshold for the obtained rupture risk in our model.

Results: By multivariate analysis, the regression equation to estimate rupture risk at the ICA included wall shear stress (*WSS*) and oscillatory shear index (*OSI*). Obtained rupture risk had significant difference between ruptured and unruptured aneurysms ($P<0.01$), and the threshold for rupture risk was estimated as 0.091 (sensitivitiy:1.00, specificity:0.900). On the other hand, the regression equation at the MCA included *WSS* and aspect ratio (*AR*) of aneurysm. It contained both hemodynamic and morphologic parameter. The rupture risk indicated statistical significant difference between ruptured and unruptured aneurysms ($P<0.01$), and the threshold value for the risk was estimated as 0.144 (sensitivitiy:0.714, specificity:0.767). Clinical information was not included in any regression equations.

Conclusions: We reveal that rupture risk of cerebral aneurysms can be assessed with *WSS* and *OSI* at the ICA, and *WSS* and *AR* at the MCA, respectively. This risk assessment method might classify the sample of this analysis object, but it needs improvement of reliability with a larger sample.