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Rupture prediction for internal carotid (IC) and middle cerebral (MC) artery aneurysms by hemodynamic parameters

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Introduction: Computational fluid dynamics analysis has been performed to find a rupture prediction indicator (RPI) for cerebral aneurysms. Several hemodynamic parameters have been proposed for the RPI in some journals. However, the most of those studies were performed using geometries after rupture for ruptured cases, though morphological change of the aneurysm after rupture has been reported. Therefore, the RPI should be investigated with the images before rupture. The objective of this study is to find a RPI based on hemodynamic parameters focusing on IC and MC aneurysms. The images taken before rupture are used for ruptured cases.

Materials & methods: Total 137 aneurysms (69 for IC and 68 for MC aneurysms) observed at Jikei University hospital were analyzed. 13 cases (7 for IC and 6 for MC aneurysms) were ruptured. Vessel geometries were reconstructed from 3D-CT angiography images. Computational fluid dynamics simulations were performed using CFD research prototype (Siemens Healthcare GmbH, not for diagnostic use) under two cardiac cycles. For the inlet boundary condition, the pulsatile waveform measured from 17 healthy adult volunteers by Ford et al. (2005) was scaled to get average wall shear stress (WSS) of 1.5 Pa in a circular tube of equivalent area to the inlet section. Proposed significant hemodynamic parameters such as Normalized WSS (NWSS) and Pressure Loss coefficient (PLc) were calculated.
Multivariate logistic regression analysis was performed to estimate the RPI model as a function of hemodynamic parameters. The performance of the estimated RPI was examined by receiver operating characteristics analysis. A cutoff point was determined as the closest point to the upper left corner, at which sensitivity and specificity equal "1".

Results: Statistically significant difference was identified in Time-Maximum PLc (TMAXPLc) between ruptured and unruptured cases ($P < 0.00169$; Sensitivity, 0.769; Specificity, 0.750; AUC, 0.766). By multivariate analysis, TMAXPLc and Time-averaged and Spatial-Maximum aneurysmal Normalized WSS (TASMAXNWSS) were contained in multivariate RPI (Sensitivity, 0.769; Specificity, 0.758; AUC, 0.789), showing similar sensitivity and specificity to those with only TMAXPLc.
Conclusion: TMAXPLc may be a useful parameter for the rupture prediction of IC and MC artery aneurysms.