Visualization of Hemodynamics in Intracranial Arteries using Time-Resolved Three-Dimensional Phase-Contrast MRI

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Purpose: Hemodynamic factors such as flow velocity or shear stress of the arterial wall affect the development of various vascular lesions, such as aneurysms and atherosclerosis. If we could analyze the hemodynamics of intracranial arteries precisely, we could predict the occurrence of aneurysms or atherosclerotic lesions. The purpose of our study was to visualize hemodynamics of intracranial arteries using Time-Resolved Three-Dimensional Phase-Contrast MRI (4D-Flow) (1).

Materials and Methods: MR examinations for five healthy volunteers (age, 23-47 years old; 32.4 years old on average) were performed with a 1.5T MR unit. The 4D-Flow was based on radio frequency-spoiled gradient-echo sequence and velocity encoding was performed along all three spatial directions. Four-dimensional data including time dimension were obtained. Measurements were retrospectively gated to the electrocardiogram cycle and CINE series of three-dimensional data sets were generated. Utilized imaging parameters were as follows; TR/TE/NEX = 5.2-5.4/2.3-2.7/1, FA = 15, RBW = 62.5 kHz, FOV = 16 cm, Matrix = 160 x 160, slice thickness = 1-2 mm, number of slices = 12-40, VENC = 60 cm/sec, acquisition time = 20-40 minutes, Slew Rate = 120 T/m/ms. Time-resolved images of three-dimensional stream lines, three-dimensional particle traces and two-dimensional velocity vector fields on arbitrary planes were calculated from four-dimensional data sets by flow visualization software (EnSight).

Results: When we generated three-dimensional stream lines originating from the bilateral C1-2 segment of internal carotid arteries and the basilar artery we were able to see the three-dimensional stream lines from the Willis' circle to the bilateral M2 segment of middle cerebral arteries (Fig. 1). Time-resolved images of three-dimensional particle traces also clearly demonstrated intracranial arterial flow dynamics. Two-dimensional velocity vector fields on the planes traversing carotid siphon or basilar tip were clearly visualized (Fig. 2). These images could be observed as CINE images. These results were obtained for all five volunteers.

Conclusion: The 4D-Flow technique helped us understand three-dimensional in-vivo hemodynamics in the human intracranial arteries. This method might be a useful and promising non-invasive method for analyzing in-vivo hemodynamics of intracranial arteries. The hemodynamic information provided by this technique will hopefully enable us to predict the risk of aneurysmal rupture or occurrence of atherosclerotic plaques. We could then provide tailor-made therapies and managements for each patient.

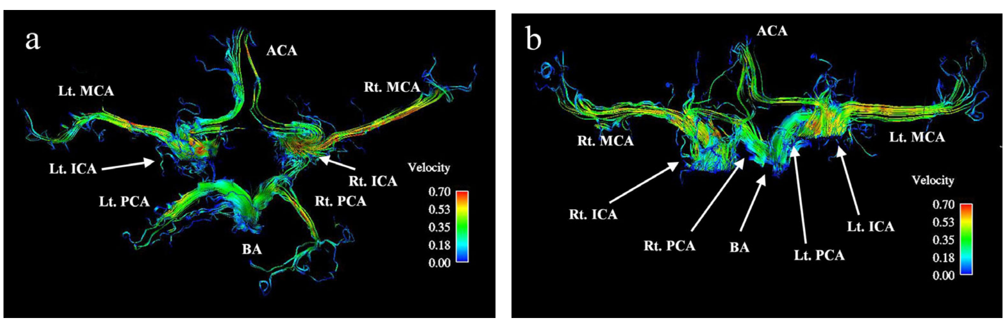

Fig. 1 Three-dimensional stream lines originating from bilateral C1-2 segment of internal carotid arteries and basilar artery clearly demonstrated Willis' circle and bilateral middle cerebral artery. **a:** Superior-inferior view **b:** Anterior-posterior view

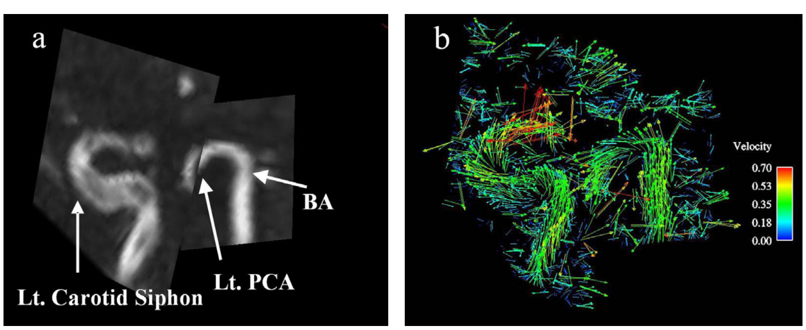

Fig. 2 Two-dimensional velocity vector fields on the planes traversing carotid siphon and basilar tip. **a:** Magnitude image of the planes **b:** Two-dimensional velocity vector fields

Reference

1) Michael Markl, Frandics P. Chan, Marcus T. Alley, et al. Time-Resolved Three-Dimensional Phase-Contrast MRI. J Magn Reson Imaging 2003;17:499-506