Preliminary study of wall shear stress of an intracranial aneurysmal model based on the data of Time-Resolved Three-Dimensional Phase-Contrast MRI

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PURPOSE

Hemodynamics plays a very important role in the development, growth and rupture of intracranial aneurysms. We are now developing a postprocessing software called "Flow visualization and analysis (Flova)" for 4D data sets obtained by Time-Resolved Three-Dimensional Phase-Contrast MRI (4D-Flow) (1), which provides us with 4 dimensional information of flow including space and time. Flova can calculate wall shear stress (WSS), streamlines, pathlines and particle traces in a few minutes based on the data of both 4D-Flow and MR angiography. The purpose of our study was to evaluate the accuracy of hemodynamic analysis and WSS obtained by Flova using flow data of a straight tube and to demonstrate the WWS distribution of a silicon aneurysmal model.

MATERIALS AND METHODS

4D-Flow was performed for a straight tube with a 16mm diameter and constant flow of glycerin solution with an average velocity of 40cm/s by a 1.5T GE MR scanner with a head coil. Imaging parameters were as follows; TR/TE/NEX=15.4/4/1, FA=15, FOV=160x160x32mm, Matrix=160x160x32, voxel size=1x1x1mm , VENC=20, 40, 120cm/s, each imaging time=14min, transaxial direction. Based on these 4D-Flow data, Flova calculated maximum flow rate, average flow rate and WSS of the straight flow. Flova was able to interpolate sampled data near the vascular wall and the WSS based on the shearing velocity at 0.4-1 mm from the wall. We compared flow rate and WSS obtained by Flova with actual measured flow rate, 2D cine phase contrast MR measurement and theoretically predicted WSS. 4D-Flow acquisition and hemodynamic analysis by Flova was performed for a realistic hollow silicon IC-PC intracranial aneurysm model (based on clinical imaging data; aspect ratio 1.9; three times actual size) (Fig1) with a constant flow of glycerin solution. Imaging parameters were as follows; TR/TE/NEX=7/2.8/1, FA=15, FOV=160x160x72mm, Matrix=160x160x36, voxel size=1x1x1mm, VENC=40, 60, 80cm/s, each imaging time=12min 15sec, transaxial direction. Flova calculated the WSS based on the shearing velocity at 0.5 mm from the wall using the data set obtained by 4D-Flow with the VENC of 40 and 60cm/s. Streamlines of the silicon model were also obtained.

RESULTS

The WSS of straight tube based on the shearing velocity at 0.4-1 mm from the wall was estimated to be 2.64-2.04Pa and was similar to the theoretically predicted value (2.0Pa). The aneurysm model had relatively weaker WSS in the bleb than in the surrounding aneurysmal wall (Fig 2). The spiral flow toward the bleb in the silicon aneurysm model could be shown more clearly by the streamlines obtained by 4D-Flow with VENC of 80cm/s than 40cm/s (Fig 3).

CONCLUSION

WSS calculated by Flova based on the shearing velocity at the proper distance from the wall seemed to be accurate. Hemodynamic analysis of the data of 4D-Flow by Flova provided us with streamlines and WSS of the silicon aneurysmal model three times actual size with constant flow.

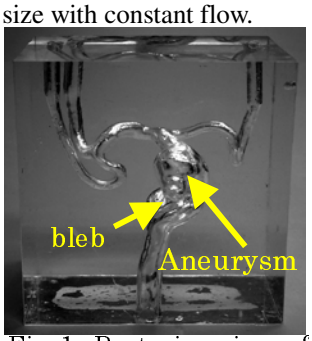

Fig 1. Posterior view of a realistic silicon IC-PC aneurysm model

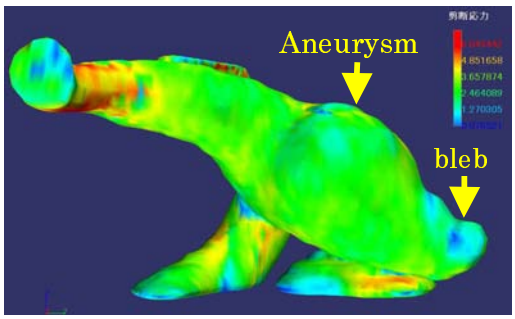

Fig 2. Left lateral view of WSS distribution based on the 4D-Flow data with VENC of 60cm/s

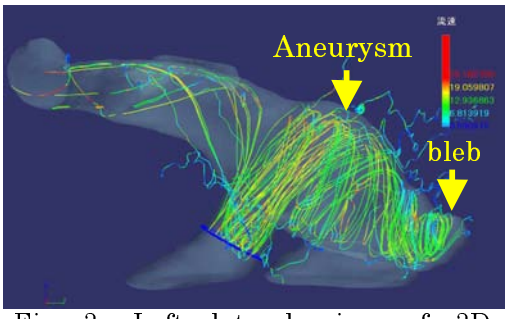

Fig 3. Left lateral view of 3D streamlines based on the 4D-Flow data with VENC of 80cm/s

REFERENCE

1. Markl M, Chan FP, Alley MT, et al. Time-resolved three-dimensional phase-contrast MRI. *J Magn Reson Imaging* 2003;17:499-506