Hemodynamic assessment of the splanchnic arteries with aneurismal dilations using time-resolved three dimensional phase contrast MRA (4Dflow)

Y. Takehara[1], H. Isoda[2], S. Yamashita[2], M. Kamiya[2], N. Unno[3], H. Takeda[1], M. Hirano[4], M. T. Alley[5], R. Bammer[5], T. Kosugi[6], Y. Ohkura[6], and H. Sakahara[7]

[1]Radiology, Hamamatsu Univ. Hospital, Hamamatsu, Shizuoka, Japan, [2]Radiology, Hamamatsu Univ. School of Medicine, Hamamatsu, Shizuoka, Japan, [3]Vascular Surgery, Hamamatsu Univ. School of Medicine, [4]GE Healthcare, Hino, Tokyo, Japan, [5]Radiology, Stanford Univ., [6]R's Tech Co. Ltd., [7]Radiology, Hamamatsu Univ. School of Medicine

Background: Hemodynamic analysis of the splanchnic arteries prior to surgical or catheter interventions for the corresponding arteries is important in order to determine catheter approaches and surgical plannings with considerations of estimated risk of rupture.

Purpose: The purpose of the study is two folds; 1) to test the usefulness of time-resolved three dimensional phase contrast MRA (4Dflow) in preoperative assessment for the splanchnic arteries with aneurismal dilatation and 2) to test the ability of 4Dflow in characterizing hemodynamic abnormalities of the pathologies.

Patients and Method: Written informed consent was provided in all cases for this IRB approved study. Eleven patients who are planned to be treated with surgical or catheter interventions (eight males and three females; 40-80 years) for aneurismal dilatation of the splanchnic arteries (i.e.; splenic artery in three, celiac artery in two, common hepatic artery in two, pancreatic arcade in six; All numbers are lesion basis.) were included in the study. In all cases, contrast enhanced CT study and X-ray angiography were performed preoperatively. The study included one ruptured aneurysm and one impending rupture. Multiple aneurysms were seen in four and single aneurym in seven patients.

MR imaging: All examinations were performed on 1.5T MR scanner (Signa TwinSpeed with Excite or Signa HD, GE Healthcare, WI, USA).

2D PC cine study: Prior to 4Dflow, 2D PC cine was performed on the transverse section. The maximum flow velocity was calculated within the abdominal aorta, and the velocity encoding value (VENC) was determined.

Gd 3D MRA: Prior to flow measurements, time resolved contrast enhanced 3 dimensional MR angiography (Gd3DMRA) was performed with a bolus injection of gadolinium chelate (0.1 mmol/kg). A 3D data set of arterial dominant phase was picked out and was used to determine the boundary of the inner wall of the arteries. Then, 4Dflow was performed

4Dflow data acquisitions: The 4Dflow is based on a SPGR sequence encoding flow velocities in three orthogonal directions. The parameters used were TR/TE/FA/NEX of 4.5-5.0/1.6-2.0/15/1, FOV of 30-34 cm, Matrix of 224-256x160-224, 2-3 mm thickness, 38-40 partitions, 12-20 phases during one cardiac cycle and imaging time of 10-20 min (10 min for parallel imaging with reduction factor of 2). ECG gating and respiratory compensation were also combined. VENC was optimized based on the values measured with 2D PC cine study performed prior to the 4Dflow. Acquired data were transferred to a workstation and were post-processed with flow analysis software (flova). The velocity data derived from 4Dflow and the geometric data of the boundary of the aortic wall determined by Gd3DMRA were interpolated, and we could delineate streamlines or calculate the wall shear stress (WSS) of the arbitrary arteries within the field of view, and can overview the change of WSS related to cardiac cycle as color maps.

Results: The abnormal hemodynamics was mainly due to celiac artery stenosis or occlusion in eight out of eleven cases (73 %) including median arcuate ligament compression in five and celiac artery dissection in two. According to the information, median arcuate ligament was dissected in one case, and the segments of coil embolization were determined so that the hepatic blood flow was maintained. In two cases of celiac artery dissection, stream line within the true lumen was readily delineated in contrast to turbulent flow in the pseudolumen, which was helpful in catheter passage into the narrow channel before coil embolization and the isolation of the aneurysms. In the cases with multiple aneurysms in the pancreatic arcade measuring over 10 mm in diameter, wall shear stress calculated from the flow was significantly lower (<1.5Pa) than non-aneurysmal portion of the arteries (>1.5Pa).

Discussion: Hemodynamic WSS is defined as blood viscosity times velocity gradient near the vascular wall. It is an important determinant of endothelial function and phenotype. Arterial wall shear stress over 15 dyne/cm2 (1.5 Pa) is said to induce endothelial quiescence and an atheroprotective effect, while low shear stress less than 4 dyne/cm2 stimulates an atherogenic phenotype and apoptosis of vascular smooth muscle cells, which promote atherosclerosis. Atherosclerosis ultimately leads arterial wall to various sorts of vascular diseases including aortic aneurysm or arteriosclerosis obliterans. It is intriguing that in 73 % of our cases there was an aneurysm in the segment of collateral circulations with altered flow dynamics caused by celiac artery stenosis.

Conclusions: Combined use of 4Dflow and flow analysis software was useful in planning the catheter and surgical intervention. The method identified the significant alteration in the flow dynamics in splanchnic arteries mostly due to celiac artery stenosis. WSS of the segment of aneurismal dilatation was significantly lower than that of unaffected segment, which may reflect that the aneurismal wall is continuously affected by the growing risk of aneurismal growth and rupture.