HEMODYNAMIC ABNORMALITIES REFLECTED BY HIGH OSI AS A POTENTIAL TRIGGER TO ATHEROSCLEROSIS IN NON-DILATED LOWER ABDOMINAL AORTA.

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Background

Majorities of physiological evidences indicate that the decrease of wall shear stress (WSS) or increase of Oscillatory Shear Index (OSI) produces an expression of pro-atherogenic genes (1). Previously, measurement of blood flow velocity and OSI calculation were quite difficult and time-consuming in vivo. However, recently developed 3 Dimensional cine Phase Contrast MR imaging (4D-Flow) has enabled the coverage of full spatial and cardiac phase resolved data of the velocity vectors of the flowing blood within the whole abdominal aorta, thereby allow Wall Shear Stress (WSS) and OSI maps to be generated with an aid of flow analysis software. We have previously determined that diastolic WSS and OSI to be the determinant of generation of atherosclerosis. However, the study was limited due to small number of patients and lack of laboratory data such as serum total cholesterol and HbA1c.

Purpose

The purpose of our study was to determine, among hemodynamic parameters derived from 4D-Flow and laboratory data what was the determinant factor for the initiation of atherosclerosis in the non-dilated lower abdominal aorta.

Materials & Methods

Between March 2013 and September 2014, thirty seven consecutive patients (with age ranging from 30 to 84 years) who were examined with MRI including 4D-Flow, contrast enhanced or non-enhanced abdominal CT, and laboratory data within a period of one year were enrolled in the study. All the MR studies were conducted on a 3.0T MR imager (750 Discovery, GEHC, WI, USA) with 16 ch torso phased array coil. Two experienced radiologists evaluated the wall of lower abdominal aorta, and visually determined the presence or absence of atherosclerosis in the lower abdominal aorta on CT. The atherosclerosis was rated in three grades in terms of the presence or absence of the calcium deposits and low density lipid depositions (i.e., atheromas) in the abdominal wall. ECG gated, respiratory compensated gradient-echo-based coronal 4D-Flow covering the whole abdominal aorta was performed following the contrast enhanced 3D MR Angiography (MRA) performed for the determination of the aortic boundary. Acquired data were transferred to a workstation and were post-processed with flow analysis software (flova, R's-tech, Japan). The velocity data derived from 4D-Flow and the geometric data of the boundary of the aortic wall determined by Gd3DMRA were interpolated. The WSS of whole cardiac phase and the oscillatory shear index (OSI) of the aortic wall were calculated. The streamlines of the abdominal aorta were generated and with a view of each cine loops, flow patterns were visually determined by two observers in consensus.

Statistics

Multiple logistic regression analysis with explanatory variables of age, sex, systolic and diastolic blood pressure, diameters and tortuosity of the aorta, systolic and diastolic WSS, OSI, total cholesterol and HbA1c was performed. The response variable was CT determinations of atheroma in the lower abdominal aorta. $P<0.05$ was considered to be significant.

Results

Based on the CT findings, 9 patients with atheroma and 26 patients without atheroma in the lower abdominal aorta were subdivided. Among all flow dynamic parameters derived from 4D-Flow, only OSI ($p = 0.0349$) was the determinant factor for the presence of atheroma in the lower abdominal aorta. No laboratory data were significantly related to the presence of atheroma. In most cases, the streamline images based on 4D-Flow delineated mostly laminar flow during systole. In patients with atheroma, prominent back flow was observed at early diastole (figure 3).

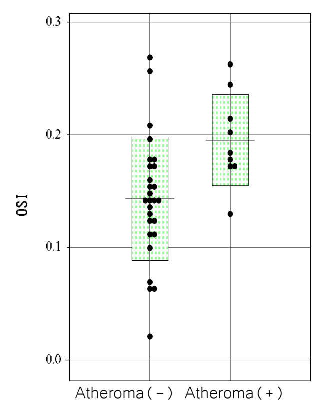

Figure 1
There is a trend in abdominal aortic wall in patients with atheroma to show higher OSI within abdominal aorta.

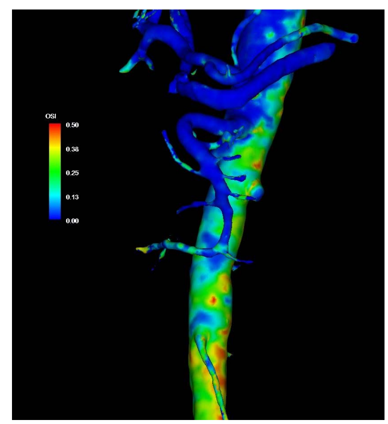

Figure 2
OSI mapping of lower abdominal artery in atherosclerotic patient.

Discussion

Prominent back flow was observed at early diastole within aortic wall in atherosclerotic patients. In our previous study turbulent blood flow during diastole was also observed in atherosclerotic patients. The back flow and turbulent flow during diastole were considered to have induced instable shear stress direction, which resulted in higher OSI. We deem this could be due to the reflection of flow from the iliac arteries, which may be due to the lack of compliance of the atherosclerotic aorta.

No laboratory findings were significantly related to the presence of atheroma. This might be because substantial number of hyperlipidemic and/or diabetic patients have already been given medical treatment for it.

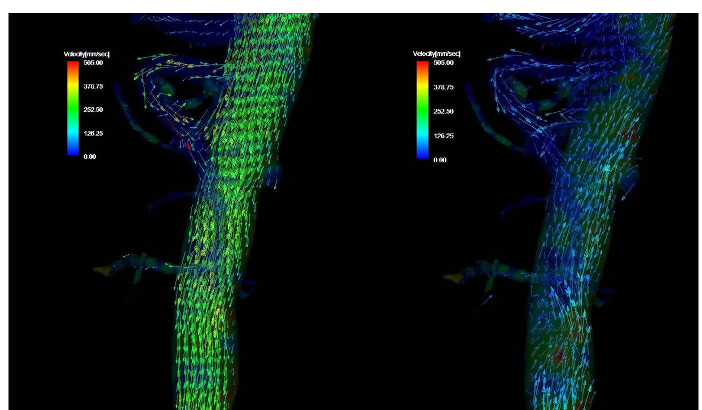

Figure 3
Flow vector of a patient with atherosclerotic lower abdominal aorta during systole (left) and early diastole (right).
Back flow was observed at early diastole within aortic wall with higher OSI.

Conclusions

Hemodynamic abnormalities such as prominent back flow and turbulence during diastole, reflected by high OSI, are considered to be the potential determinants of lower abdominal atherosclerosis. 4D-Flow with an aid of flow analysis software can provide information concerning the initiation of abdominal aortic atherosclerosis in vivo non-invasively.

References

1) Laughlin MH, J Appl Physiol. 2008 Mar;104(3):588-600.