HEMODYNAMIC ABNORMALITIES REFLECTED BY LOW DIASTOLIC WALL SHEAR STRESS AND HIGH OSI AS POTENTIAL DETERMINANTS OF LOWER ABDOMINAL AORTIC ATHEROSCLEROSIS

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Background

Majorities of physiological evidences indicate that the locally decreased wall shear stress (WSS) alter arterial endothelial phenotype to atherogenic state (1). Likewise, the increase of Oscillatory Shear Index (OSI) produces an expression of pro-atherogenic genes (2). Previously, these two parameters were quite difficult and time-consuming to be measured in-vivo; however, recently developed 3 Dimensional cine Phase Contrast (4D-Flow) MR imaging has enabled the coverage of full spatial and temporal data of the velocity vectors of the flowing blood within the whole abdominal aorta, thereby allow WSS and OSI maps to be generated with an aid of flow analysis software.

Purpose

The purpose of our study was to determine, among hemodynamic parameters derived by 4D-Flow, which one was related to atherosclerosis in the lower abdominal aorta.

Materials & Methods

Between January 2013 and June 2013, twenty-six consecutive patients (with age ranging from 30 to 82 years) who were examined both with MRI including 4D-Flow and contrast enhanced or non-enhanced abdominal CT within a period of one month 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 the CT. The atherosclerosis was determined by the presence or absence of the calcium 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 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-`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 blood pressure, diastolic pressure, diameters and tortuosity of the aorta, systolic WSS, diastolic WSS and OSI was performed. The response variable was CT determinations of atherosclerosis in the lower abdominal aorta. $P<0.05$ was considered to be significant.

Results

Based on the CT findings, 10 atherosclerosis and 16 non-atherosclerosis in the lower abdominal aorta were subdivided. Among all flow dynamic parameters derived from 4D-Flow, diastolic WSS ($p = 0.0224$) and OSI ($p = 0.0172$) were determinant factors for the presence of atherosclerosis in the lower abdominal aorta. In most cases, the streamline images based on 4D-Flow delineated mostly laminar during systole. In cases with atherosclerotic patients, the streamline delineated backward flow and/or vortex flow particularly during diastole within the abdominal aorta (Fig. 2). To the contrary, only brief turbulences were delineated within non-atherosclerotic cases.

Discussion

Lower WSS was related to atherosclerotic change of the lower abdominal aorta, which was consistent with previous physiological evidences. Turbulent blood flow during diastole was considered to have induced instable shear stress direction, which lead to higher OSI.

Conclusions

Hemodynamic abnormalities reflected by low diastolic WSS and high OSI are considered to be potential determinants of lower abdominal atherosclerosis. 4D-Flow with an aid of flow analysis software can provide these hemodynamic parameters objectively.

References

1) Malek AM, Alper SL, Izumo S. JAMA. 1999 Dec 1;282(21):2035-42. 2) Laughlin MH, J Appl Physiol. 2008 Mar;104(3):588-600.

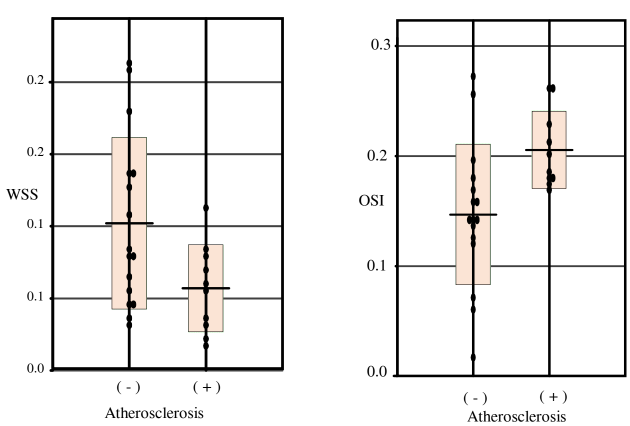

Figure 1
WSS is lower and OSI is higher in lower abdominal atherosclerotic patients.

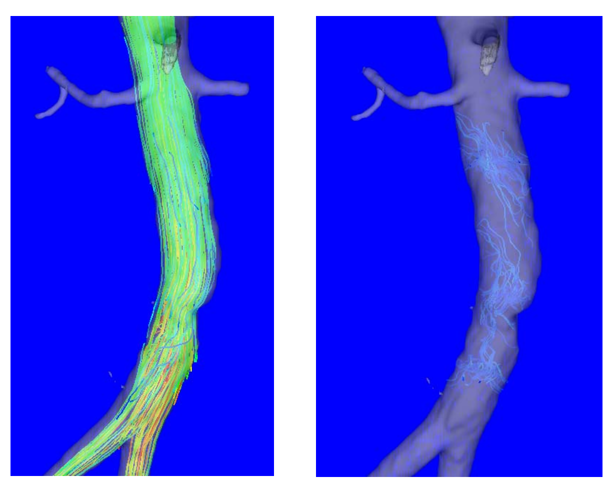

Figure 2
Streamline of a patient with atherosclerotic lower abdominal aorta during systole (left) and diastole (right).