Visualization of Hemodynamics at the Carotid Bifurcation with MR Imaging: Cine Vector Representation of blood flow using PC MRA

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Abstract

The feasibility of vector representation of blood flow at the carotid bifurcation based on PC MRA was examined. The visualization of hemodynamics was compared with two different PC techniques, the average blood flow method acquired without ECG gating and the cine method with ECG gating. Cine method enables observation of the changes in pressure flow against vessel wall, which provides detail information of the turbulent flow in carotid artery. The examination of various level of stenosis using this method is considered to be useful in the analysis of how vortex flow and blood stagnation participate in the formation of stenosis.

Introduction

Evaluation of carotid bifurcation hemodynamics plays an important role in the analysis for the process of arterial stenosis formation. In this study, the feasibility of vector representation of blood flow based on PC (phase contrast) MRA was examined. The accuracy of the vector representation was verified using a phantom with constant velocity flow. The visualization of hemodynamics was compared with two different PC MRA techniques, the average blood flow method acquired without ECG gating and the cine method with ECG gating, in which vector image was created at each cardiac phase and displayed in cine mode.

Methods

All the experiments were performed on a 1.5T MRI system (VISART^{TM}/EX Ver.5.30 Toshiba Medical Systems, Japan). The imaging parameters of phase contrast MRA sequence were TR/TE=30/16msec, flip angle=20 degree, VENC of 100-130cm/sec, FOV=12.8cm, 128x128 matrix, slice thickness =3mm and NAQ=2. Using the phase shift data, direction and velocity of flow in each voxel was represented as a colored vector. In the phantom experiments, gadolinium-doped water, which simulates the relaxation time of arterial blood (T1=786msec and T2=102msec), was run through a glass tube of 4.0mm inner diameter with constant velocity. First, the correlation between the velocity measured by means of PC MRA and the resultant vector length was validated. Secondly, the phantom was placed at the angle of 45 degree to the static magnetic field in order to examine whether the flow velocity of vessel that run at a certain angle could be represented with accurate vector orientation and length. Finally, the origins of internal carotid artery of two healthy volunteers were imaged in sagittal plane with the read-out axis of superior to inferior direction for the comparison of the two methods, without ECG gating which represents average flow velocity and the cine vector representation, from the viewpoint of hemodynamics visualization.

Results

The resultant vector length was confirmed to be proportional to the flow velocity measured by means of PC MRA. The orientation and the length of vector were verified to represent the actual flow of the phantom placed at 45 degree to the z-axis within a velocity range from 10.20cm/s to 32.35cm/s (Fig.1). In volunteer study, cine display of vector images was found to be superior in clear delineation of blood flow changes at each cardiac phase where vortex present, compared with average flow method without ECG gating. Vortex flow and blood stagnation were observed at the origin of internal carotid artery. This observation agreed with the previous report [1] and the vector representation was considered to be a correct reflection of hemodynamics at this region. In this study, the velocity variation of internal carotid artery caused by pulsation was observed to be smaller than that of external carotid artery (Fig.2).

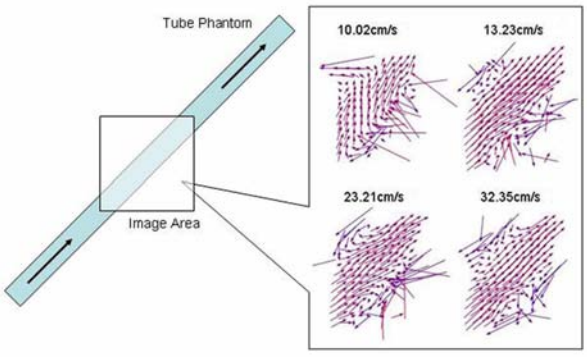

Fig.1 The evaluation for accuracy of the vector representation using flow phantom placed at a certain angle.

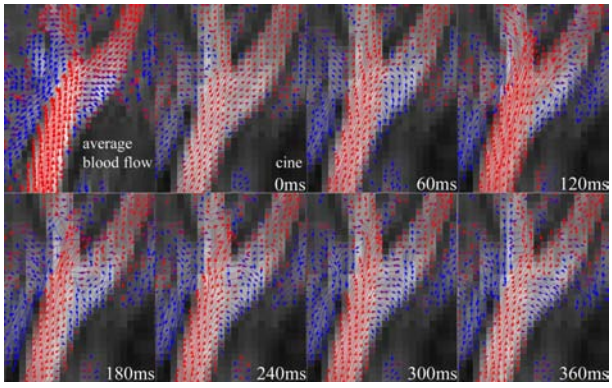

Fig.2 Vector representation of carotid bifurcation obtained from volunteer: Comparison between average blood flow method (top left) and cine method.

Conclusions

Cine vector representation of carotid bifurcation enables observation of the changes in pressure flow against vessel wall from moment to moment, which provides detail information of the turbulent flow in the inner carotid artery. The examination of various level of stenosis by means of this method is considered to be useful in the analysis of how vortex and blood stagnation participate in the formation of stenosis. In addition, 2D TOF method, which is commonly used in routine carotid MRA, often gives stenosis-like observation due to signal loss at the origin of carotid artery, and thus comparison of the vector representation and 2D-TOF images is thought to help estimate the cause of this signal loss in TOF images to be deteriorated in-flow effect due to vortex.

Reference

[1] Listerud J, et al. Magn Reson Q 1991; 7:136-170