A NON-INVASIVE METHOD FOR MEASURING PERFUSION IN MOYAMOYA DISEASE WITH FUNCTIONAL MAGNETIC RESONANCE IMAGING

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Target audience: Those interested in brain-vascular disease and radiologists, neurologists, scientists and MRI researchers.

Introduction: Moyamoya disease (MMD) is defined in angiography as a chronic progressive steno-occlusion of internal carotid arteries with characteristically abnormal vascular networks at the base of the brain. Digital subtraction angiography (DSA) is a standard method for evaluating blood vessels that provide useful information for diagnosis and treatment. However, both DSA and DSC-MR are invasive and require the use of contrast agents that require careful management, and are not suitable for frequent follow-up examinations. As a non-invasive method, arterial spin-labeling (ASL) could acquire both relCBF and ATT with multi-TI protocol. However, the labeled signal will attenuate and the temporal information can't be measured when the blood arrival time is longer than 3.5s, which might be the case for many patients. In this study, we extracted the pattern of low-frequency fluctuation with an iteration algorithm and obtained the time-shift between this template and each voxel to measure the temporal information of blood perfusion non-invasively.

Materials and methods: 31 MMD patients participated in this study. MRI exam included TOF-MRA, resting-state fMRI (rs-fMRI) and DSC-MR. All data were collected on a MAGNETOM Skyra 3T MR scanner (Siemens AG, Erlangen, Germany). The parameters are as follows: Resting-state fMRI: TR=2500 ms, TE=30 ms, flip angle=90°, 43 slices, slice thickness=3 mm, distance factor=20%, FOV=210 ×210 mm^2, matrix= 70×70, measurements=300. DSC: TR=1500 ms, TE=30 ms, flip angle=90°, 24 slices, slice thickness=5 mm, distance factor=20%, FOV=210×210mm^2, matrix=128×128, measurements=80. The data of DSC-MR was analyzed using Perfusion Evaluation tools on a syngo.via workstation (Siemens AG, Erlangen, Germany). The fMRI data was pre-processed with a standard pipeline for resting-state data analysis (without regressing out the global signal). After pre-processing, the time-shift map could be obtained using the following steps: 1) Averaging the time series of the whole brain to create the first time series template. 2) For each voxel, the time course was shifted from -6TR to +6TR and correlated wit h the template at each TR. Each voxel was then labeled as the number of TR which had the maximal correlation coefficient value. 3) Realigning the time series of all voxels based on their time-shift value determined by step 2. 4) Averaging the re-aligned time series of the whole brain to create a new global template. 5) Repeating step 2 to 4 until the number of voxel, who had changed their time-shift value between two iterations, is less than 100.

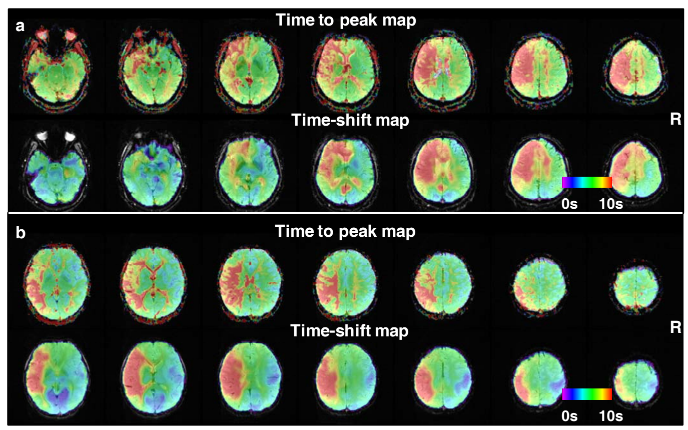

Figure 1. The results of TTP and time-shift-map (obtained from Resting-state fMRI) of two MDD with internal carotid arteries of left middle cerebral artery before surgery.

Results: Fig.1 shows the TTP map calculated from DSC-MR and time-shift map calculated from rs-fMRI of two patients with internal carotid arteries of left middle cerebral artery before surgery. The perfusion deficit areas with long TTP in the left frontal and parietal lobe matched with the areas as identified by time-shift map (TSM). Using the TTP map from DSC acquisition as reference, the overall specificity is 82% and the sensitivity is 80%. One patient underwent a follow-up exam 3 months after the surgery. From the time-shift map in Fig.2a, it can be observed that the deficit of blood perfusion presents a significant improvement after surgery. The histogram of the time-shift value of the whole brain (Fig.2b) demonstrates, after the encephaloduro-arteriosynangiosis operation, that the areas with large time-shift were reduced and most of the time-shift values were in the normal range.

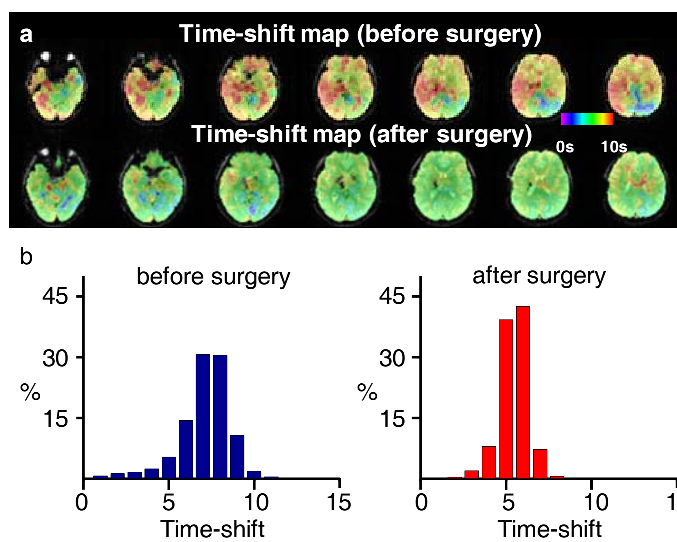

Figure 2. The results of time-shift-map (a) and the histograms of time-shift value of the whole brain (b) before and after vascular anastomosis

Conclusions: By analyzing the rs-fMRI data with the iteration algorithm described in this paper, the perfusion deficit areas that had long TTP value could be detected non-invasively. The results of our technique match well with TTP maps from DSC-MR and could be a good alternative for monitoring long-term changes of cerebral blood flow pattern in MMD frequently.