ACCURATELY MEASURED COLLATERAL PERFUSION IN STROKE PATIENTS USING MULTI-TI ARTERIAL SPIN-LABELING

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Target audience: Those interested in Stroke and radiologists, neurologists, scientists and MRI researchers.

Introduction: As a non-invasive MR technique, Arterial Spin Labeling (ASL) has become a popular tool for investigating cerebral blood flow in many diseases, such as stroke, moyamoya and brain tumor. Especially in acute stroke, the presence of collateral circulation is highly correlated with outcomes after thrombolytic. Methodologies including digital subtraction angiography (DSA), CT perfusion and dynamic susceptibility contrast (DSC)-MR all require the use of exogenous contrast agent and they are costly for evaluating the collateral blood flow. However, ASL with a single inversion time can only measure the relCBF and has a bias in the areas with different arterial transit times (ATT), especially in the areas with prolonged ATT compared to normal tissue. Although ATT can be estimated by measuring ASL data with different delays (4-6), one cannot determine the curve of hemodynamic response in areas with perfusion deficits and collateral circulation. In this study, a 3D multi-TI ASL (mTI-ASL) protocol had been applied to measure the blood perfusion of stroke patients. The bolus arrival time (BAT) and relCBF obtained from fitting the hemodynamic response curve were compared with the results of CT perfusion and 3D single-TI ASL (sTI-ASL) to test the performance of this new ASL method.

Materials and method: 11 stroke patients participated in this study. MRI exam included TOF-MRA, sTI-ASL and mTI-ASL. All data were collected on a MAGNETOM Skyra 3T MR scanner (Siemens AG, Erlangen, Germany). The data of CT perfusion were analyzed by using Perfusion Evaluation tools on an ADW4.4 workstation (GE, USA). Both the sTI-ASL and mTI-ASL images were acquired using a prototype 3D ASL sequence with the following parameters. sTI-ASL: FAIR Q2TIPS, TR/TE 4600/16 ms, 40 slices, slice thk 3 mm, FOV 192×192 mm^2, matrix 64×64, TI1/2 700/2000 ms, repetitions 6, total acq. time 6 min. mTI-ASL with: TR/TE 4600/22 ms, 20 slices, slice thickness 4 mm, 16 inversion time from 500-4000 ms, total acq. time 5 min including an M0 scan. The Buxton model with a non-linear fit to CBF and BAT was used for quantification.

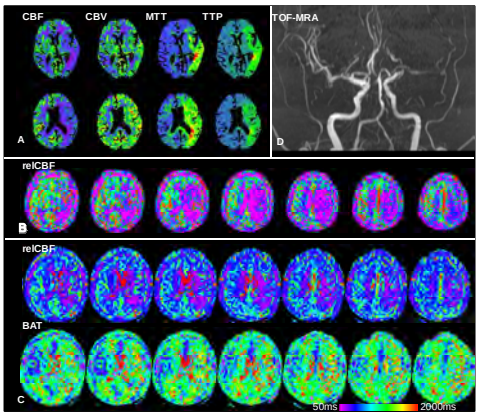

Figure 1. The results of patient1

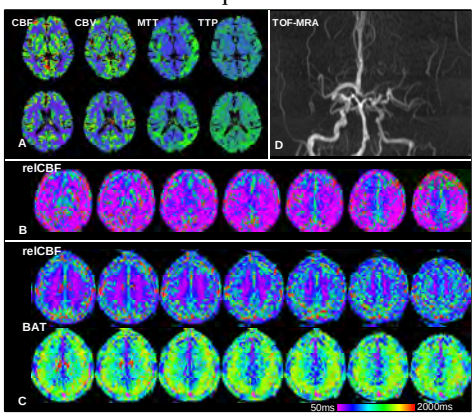

Figure 2. The results of patient2

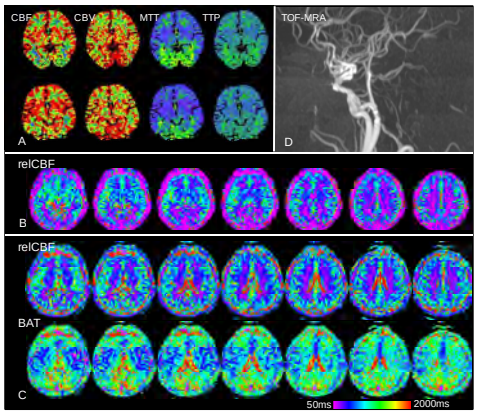

Figure 3. The results of patient3

(A) CT perfusion. (B) relCBF of ST-ASL. (C) relCBF (first row) and BAT (second row) of MT-ASL. (D) TOF-MRA

Results: Three sample cases are shown in Fig.1-3 with different types of ischemia conditions. From the results of CT perfusion, we found that patient1 with left middle cerebral artery blockage (Fig.1) had low CBF combined with long TTP mainly in left parietal lobe. The relCBF of patient1 obtained by both sTI-ASL and mTI-ASL showed significantly low values in the same area, while the BAT obtained by mTI-ASL presented a long delay in the bolus arrival. Patient2 (Fig.2), with bilateral middle cerebral artery blockages, had slightly reduced CBF and prolonged TTP in bilateral frontal and parietal lobe. mTI-ASL showed slightly reduced CBF in the same area, while the BAT obtained by mTI-ASL presented a long delay in the bolus arrival. However, the sTI-ASL results showed excessively low relCBF bilaterally compared with CT perfusion and mTI-ASL. The vertebral artery blockage of patient3 (Fig.3) leaded to a delayed perfusion in the occipital lobe that was found on the TTP and MTT maps of CT perfusion. The BAT map of mTI-ASL matched with CT perfusion very well and the relCBF after correction with BAT did **not** show any deficits in the occipital lobe. This provided a clear evidence of a collateral circulation. After treatment, the patient did not have any long-term behavioral deficits after. However, the relCBF obtained by sTI-ASL showed significantly reduced CBF values in that area. Among which, 5/11 of the patients had overestimated low relCBF with sTI-ASL compared to CT perfusion and no cases with mTI-ASL.

Conclusions: The preliminary results demonstrated that the 3D multi-TI ASL sequence introduced in this study could measure both the relCBF and BAT and by specifically characterizing the hemodynamic response. By incorporating BAT in the calculation of CBF, mTI-ASL is able to improve CBF quantification especially in areas with prolonged ATT and revealed the same performance as CT perfusion in stroke patients. The accurate BAT and relCBF measured by mTI-ASL could be a useful tool for evaluating collateral circulation in stroke patients.