Absolute Regional Gray Matter Perfusion Measured with Arterial Spin Labeling Calibrated using Phase Contrast MRI

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Introduction

Arterial spin labeling (ASL) is an MRI technique which uses water in the blood as an endogenous contrast agent to assess the cerebral blood flow (CBF). The absolute value of CBF measurement obtained using ASL depends on the ASL method, the imaging parameters, and influenced by subject's hemodynamics. We have previously presented a method to calibrate CBF values derived by ASL using the total cerebral blood flow (tCBF) values obtained using phase contrast MRI (PCMRI) [1]. This study aims to quantify regional CBF in deep gray matter and cerebral cortex and compare values obtained with calibrated with non-calibrated 2D- whole brain ASL scans in healthy subjects and subjects with cognitive impairment.

Methods

MRI scans of 5 healthy subjects (2M:3F, age range 24-44) and 5 patients with neurological disorders with cognitive impairment (3M:2F, age range 56-82) were acquired with a 3T Siemens Trio scanner, which included whole brain 2D-ASL, cine phase contrast (PC) and T1-weighted (MPRAGE). The PCMRI imaging parameters were FOV of 14x14 cm, slice thickness of 6 mm, acquisition matrix of 256x192, flip angle of 20 degrees, minimum TR/TE of 10/4ms, and VENC of 70 cm/sec. The ASL imaging parameters were FOV of 20x22 cm, slice thickness of 4.1 mm, acquisition matrix of 64x58, flip angle of 90 degrees, TR/TE 3000/12ms, and TI1/TI2 1800/600 ms with a total scan time of 5min. The scan parameters for the T1-weighted MPRAGE images were FOV of 23x20 cm, slice thickness of 0.9 mm, acquisition matrix of 256x224, flip angle of 15 degrees, TR/TE 1900/2.97 ms, and inversion time of 1100 ms.

Regional processing of ASL data was implemented using FreeSurfer (version 4.5.0). In order the obtain the correspondence between the ASL image and the T1-weighted images, T1-weighted images were co-registered to the reference EPI-planar image through a rigid body (6 DOF) transformation using the FLIRT function [2] provided in FSL software package version 4.1.5. The T1-weighted image was parcellated using the subcortical segmentation routine in FreeSurfer [3]. The CBF values for seven gray matter regions produced by this parcellation (thalamus, putamen, hippocampus, caudate, ventral diencephalon, pallidum, and cerebral cortex) were obtained by integrating the perfusion values provided by ASL over all the voxels that fall within each region. Total cerebral blood flow from PCMRI was obtained by summation of the arterial inflow through the two internal carotids and vertebral arteries [4]. A calibration factor was calculated using the PCMRI based tCBF and ASL based CBF (integrated over the whole brain volume) [1], which was used to normalize the ASL based relative CBF values for the deep gray matter structures and the cerebral cortex.

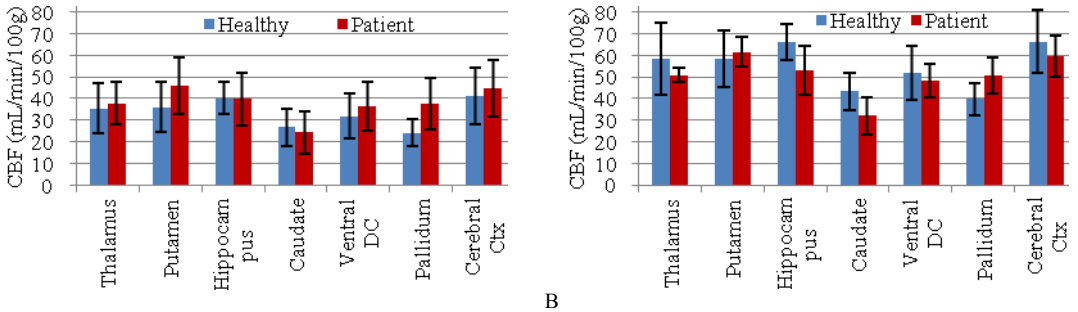

Figure 1: Mean CBF values (error bars ±1 SD) for healthy subjects and patients in deep gray matter regions and cerebral cortex before (A) and after calibration (B).

Results

The mean CBF values obtained for each deep gray matter structure and cerebral cortex is provided for healthy and patient groups, along with the calibrated mean CBF values with PCMRI in Fig. 1. Calibrated CBF values were significantly higher than uncalibrated CBF values for all investigated structures for both groups ($p<0.05$). It was also observed that the mean CBF in most regions including the cerebral cortex is lower in the elderly patients than the younger healthy subjects, consistent with previous findings [5]. The mean (SD) CBF value in hippocampus for healthy subjects before and after calibration was 40.3 (7.5) and 66.2 (8.2) mL/min/100g, respectively. The calibrated value is in agreement with recently reported value of 61.2 (9.0) mL/min/100g measured with the true fast imaging in steady precession arterial spin labeling method [6]. Similarly, the mean (SD) CBF value averaged over the thalamus, putamen, and caudate for healthy controls before and after calibration was 33.8 (10.5) and 55.1 (13.3) mL/min/100g respectively where the calibrated value is closer to the reported value of 68.0 (7.0) mL/min/100g for healthy controls obtained using dynamic susceptibility contrast-enhanced MRI [7]. An axial slice of T1-weighted image overlaid with subcortical segmentation map and the corresponding regions in the uncalibrated and calibrated ASL images for a healthy subject are shown in Fig. 2.

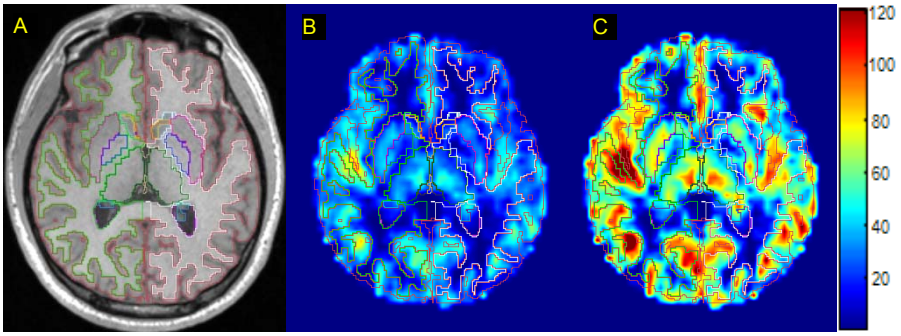

Figure 2: An axial slice of T1-weighted image overlaid with subcortical segmentation map (A) and the corresponding regions in the uncalibrated (B) and calibrated (C) ASL image.

Conclusion

The CBF values obtained by 2D EPI-based PASL are underestimated compared with CBF values calibrated with tCBF obtained by PCMRI. The PCMRI calibrated regional CBF values are more consistent with previously reported values compared with CBF values derived by ASL alone. CBF measurements using ASL in combination with PCMRI may help overcome the limitations of ASL in providing reliable absolute CBF values.

References

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