

Phase Contrast MRI Absolute Cerebral Blood Flow Estimation: A Method To Obtain Absolute Cerebral Blood Flow Maps From Dynamic Susceptibility Contrast Imaging.

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Introduction

Phase-contrast MRA (PC-MRA) is a reproducible way to measure the total cerebral blood flow (tCBF) (1). In contrast, measurement of absolute cerebral blood flow using dynamic susceptibility contrast MRI (DSC-MRI) is hampered by systematic errors, such as lack of knowledge of the individual microvascular hematocrit, non-linear ΔR_2^* response between large and small vessels, partial volume effects, arterial signal saturation at peak concentration, local geometric distortion during bolus passage, different bolus arrival times in gray and white matter and bolus recirculation (2). The most common approach to scale the relative CBF (rCBF) maps obtained with DSC-MRI, is the use of population means of microvascular hematocrit (3) and normal white matter CBF (4). After correction based on PET average CBF values, both over- and underestimation of CBF may occur. Assumption of a "normal" white matter flow value will most likely lead to systematic errors, since CBF varies from individual to individual, and may change as a function of age, as well as in pathologies such as stroke (e.g. due to both possible cardio- and cerebro-vascular disease) and brain tumors (e.g. due to mass effect/increased intracranial pressure).

In this abstract, a method to calibrate DSC-MRI rCBF maps using a single slice PC-MRA technique to determine tCBF is developed. This technique requires only a minimal extension of the clinical protocol by a 50 sec sequence. Initial results demonstrate that the white matter CBF estimate in the hemisphere contralateral to the pathology demonstrates significantly less variability and better agreement with literature values (4) than uncorrected data.

Material and Methods

6 patients underwent MR imaging at 3 Tesla (Magnetom Trio, Siemens Medical, Erlangen, Germany) during their clinical work up. Imaging included DSC-MRI and single slice PC-MRA in addition to routine brain MRI.

DSC-MRI (GRE-EPI 2d, 18 slices, 50 phases, 0.1 mmol/kg gadolinium based contrast agent (Multihance) IV, TR 1614 ms, TE 45 ms, 1 average, 5.6 mm slice thickness, 128x128 matrix, 230 mm FOV) data were processed using deconvolution by standard singular value decomposition (sSVD) (5) (PENGUIN software, Aarhus University, <http://www.cfin.au.dk/software/penguin/>) to generate relative cerebral blood flow (rCBF) maps. Automated arterial input function detection was used from a single slice at the level of the circle of Willis.

PC-MRA (fast low angle shot (FLASH) 2D sequence, flip angle 15 degrees, TR 49 ms, TE 7.7 ms, 1 slice above the carotid bifurcation, with cross-sections of right and left vertebral and internal carotid arteries, velocity encoding (VENC) 70 cm/sec, 32 phases, cardiac gated, 256x256 matrix, 5 mm slice thickness, 138 cm FOV) data were analyzed using in-house software to determine the total cerebral blood flow as the sum of the blood volumetric flow rate of the 4 neck vessels (tCBF-PC).

Statistical parametric mapping (SPM, Wellcome Trust Centre for Neuroimaging, <http://www.fil.ion.ucl.ac.uk/spm/>) software was used generate gray and white matter masks using tissue segmentation. A total brain mask was generated as the sum of gray and white matter masks and this mask applied to the rCBF map. The integral of all voxel values in the masked rCBF map was divided by the integral of the total brain mask (the cerebral volume) to generate the estimated rCBF (tCBF-DSC) in units of ml blood/100 ml brain tissue/minute. A correction factor was derived as the quotient of tCBF-PC and tCBF-DSC. A hemispheric mask was used in combination with gray and white matter masks to determine the average CBF of gray and white matter in the hemisphere contralateral to the pathology (tumor/stroke). The correction factor was applied to these data and results of corrected and uncorrected gray and white matter CBF values compared with the literature (4).

Results

Figure 1 shows that the uncorrected tCBF estimated by DSC-MRI is not strongly correlated with the tCBF estimated using PC-MRA, as expected. After correction of DSC-MRI maps (with the tCBF-PC derived correction factor), the average white matter flow measurements of the contralateral hemisphere have decreased variance (pre-correction 27.3 ± 18.1 ml/100ml/min; post-correction 27.7 ± 6.0 ml/100ml/min; mean \pm standard deviation). This is shown in Figure 2 in the form of box plots of uncorrected DSC-MRI measurements (left) and of the data after correction (right). Of note, one single case of a patient with unilateral meningioma yielded very high flow estimates for the DSC method (62.1 ml/100 ml/min) (outlier in the left boxplot in Figure 2), which after correction to 36.1 ml/100 ml/min lay within the observed variation of the data. An F-test on the data of the 6 cases revealed that the variance about the mean was significantly lower ($t=0.019$) after correction.

Discussion

These data suggest that PC-MRA derived correction significantly reduces the variance in white matter CBF values as determined by DSC-MRI. The method was able to correct for the clear overestimation of tCBF by DSC in one case, and resulted in mean white matter CBF values in good agreement with the literature. The protocol may be implemented on clinical scanners with only minimal increase of scan time compared to conventional DSC. Further studies are required to improve statistical power, and to understand the factors which lead to CBF under- or over-estimation by DSC-MRI.

References

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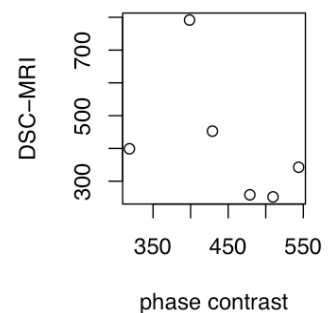


Figure 1: tCBF in ml/min as determined by PC-MRA plotted against DSC-MRI.

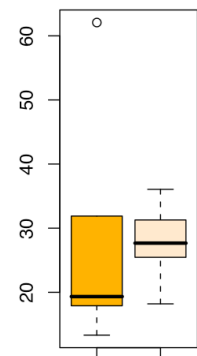


Figure 2: Boxplot of contralateral hemispheric white matter perfusion in ml/100 ml/min by DCE-MRI alone (left) and after correction of DCE data by PC-MRA correction factor.