

Comparison of an FT Based MMSE Method with oSVD Method for CBF Estimation in Patients with VCI

U. Sakoglu¹, B. H. Garate¹, G. Rosenberg¹, and R. Sood¹

¹University of New Mexico, Albuquerque, NM, United States

Introduction

PW- MRI based on dynamic susceptibility contrast (DSC) MRI provides a powerful non-invasive way for assessing brain function. The PW-MRI technique allows estimation of three important parameters; cerebral blood flow (CBF), cerebral blood volume (CBV) and mean transit time (MTT) [1]. Due to the widespread availability of MR imaging modality as a diagnostic tool, PW-MRI method is routinely used for investigating neurological disorders such as stroke and guiding acute stroke therapy. The bolus tracking (BT) technique is the most popular PW DSC-MRI method used for estimating CBF, CBV and MTT. The BT technique uses a convolution model that establishes the input-output relationship between blood flow and the vascular tracer concentration. This relationship is expressed mathematically as a matrix equation and requires the use of deconvolution methods to extract blood flow. Two deconvolution methods that are popular and widely used for estimating PW-MRI parameters are the SVD (Singular Value Decomposition) and FT (Fourier Transform) based methods. However, from the published literature it appears that SVD is more widely accepted than other method. SVD method is a model-independent approach that applies a cutoff threshold to the singular values of the matrix. This strategy makes the method less sensitive to noise. However, SVD method has some drawbacks; it is only an approximation of deconvolution, the CBF estimates are influenced by the choice of cutoff threshold for matrix diagonal, and as a result, induce distortion of high frequency components. The method is therefore sensitive to both delay and dispersion effects. The FT based deconvolution methods involve application of a shaping filter in the frequency domain and are very sensitive to noise and therefore requires filtering and/or fitting of the experimental data. On a positive note, these methods are insensitive to AIF delay. Additionally, this method is sensitive to AIF dispersion effects. One of the drawbacks of existing FT deconvolution method is that data filtering (for suppressing noise) is performed using empirically derived low pass filters. This may cause the filter to be unreliable and sub-optimal resulting in under or over estimation of CBF values. Some of these drawbacks may be reduced using the MMSE method. Thus, in this study, an FT based MMSE method has been used to estimate CBF in 9 VCI patients and results are compared with the widely used circular SVD (oSVD) [2] method.

Materials and Methods

The study was approved by the University Human Research Review Committee and Institutional Review Board. In this study, 9 patients (age range 19-84, mean 44, 6 males, 3 females) with VCI were imaged on a 1.5T Siemens whole body scanner retrofitted with Sonata gradients (Malvern, PA, USA). After acquiring the localizer and structural scans consisting of FLAIR, T1 and T2w images, perfusion study was implemented as part of the MRI protocol using the following parameters, Spin-echo EPI sequence, axial plane, TR/TE of 1600ms/78ms, flip angle 90°, matrix 128x128, FOV of 220mmx220mm, # slices 6, slice thickness/slice gap of 5/0mm. For the perfusion protocol, all the slices were prescribed superior to the ventricles. 0.025 mM/kg of Gd-DTPA was injected intravenously at the rate of 5ml/second using a power injector about 10 seconds after the start of the perfusion protocol (to allow acquisition of the baseline dataset). A total of 50 phases were acquired as part of the perfusion protocol with the total scan time of 85s. Due to technical reasons and MR protocol restrictions, a non-conventional lower dose of Gd-DTPA was elected for this study. Data were reviewed on the scanner prior to transferring it to an offline workstation for further processing. A MATLAB (7.2.0 R2006a, Mathworks, Natick, MA) based perfusion GUI software [3] was used to calculate CBF maps; the original software used oSVD deconvolution method, and, it was modified to apply the recently developed FT based MMSE method. AIF was automatically estimated for each slice by the software and an optimal AIF was selected for each patient by the operator by examining the arrival, sharpness, and proximity of the estimated AIF curves to the anterior cerebral artery and the same optimal AIF was used by both of the methods. Raw MRI data was post-processed to generate color coded CBF maps. ROIs were drawn manually on the CBF maps in regions of NWM, WML and NGM under the guidance of the FLAIR structural images by using ImageJ software (NIH ImageJ) and the results were read into a spreadsheet for further analysis. For each patient and for each method two values were calculated: 1) relative CBF for NWM, obtained by dividing the average ROI CBF value in NWM with average CBF in GM and 2) relative ROI CBF for WML, obtained by dividing the average flow value in WML with average flow in GM.

Results and Discussion

The relative CBF values in NWM obtained using both the deconvolution methods are in good agreement with the published values in the literature. A significant ($p < 0.05$) decrease in estimated CBF was observed in the WML in all the patients using MMSE method ($p = 0.0013$), while for the oSVD method ($p = 0.020$), the decrease was observed in all but one VCI patient. In one patient, using the oSVD method, the relative CBF value in WML was estimated to be higher than NMW. In this study, it was assumed that the GM was normal and that the pathology was restricted to WM only. Initial results suggest that MMSE method is comparable to oSVD method for estimating CBF in NMW while it may be better than oSVD for estimating flow in WML. It is possible that MMSE method is more sensitive to low flow than oSVD method. Studies in a larger patient population may be required to further validate this finding.

References [1] Østergaard et al, MRM 36(5):715-725 (1996) [2] Wu et al, MRM 50(1):164-74 (2003) [3] <http://www.cfin.au.dk/software/penguin>

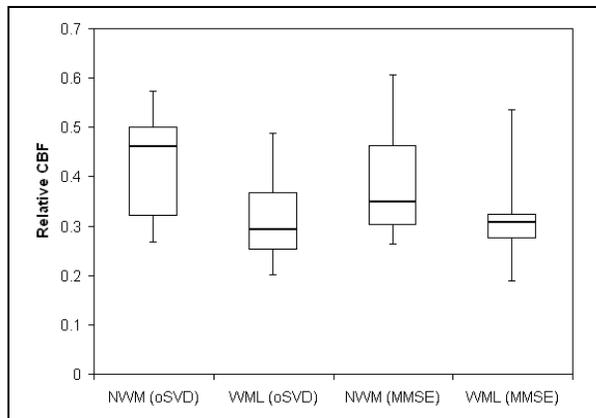


Figure shows a series of box plots with Y-error bars for relative CBF estimates in normal white matter and white matter lesions in 9 VCI patients obtained using oSVD and FT based MMSE method. Both the methods showed a significant decrease in CBF in WML. The Inter Quartile Range (IQR) for the relative CBF was 0.17 and 0.16 for NWM; 0.11 and 0.05 for WML obtained using oSVD and MMSE based method, respectively. This suggests that most of the data spread for relative CBF values for NMW was similar for both methods. However, the data spread for flow values in WML was different. Additionally, relative CBF values for WML estimated using MMSE method were centered around the median. The median relative CBF values for oSVD and MMSE method for WML was similar (0.29 and 0.31, respectively). The average relative CBF values obtained using oSVD and MMSE method for NWM, WML were 0.42 ± 0.11 , 0.31 ± 0.10 and 0.39 ± 0.12 , 0.33 ± 0.11 (mean \pm SD), respectively. Y-error bars represent the upper and lower extreme of the data.