Improving CBF Image Contrast with Frequency Extrapolation for DSC-MRI during Acute Stroke

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Introduction:

Dynamic susceptibility contrast (DSC) MR imaging can be used to determine the perfusion state of brain tissue during acute ischemic stroke. Perfusion-weighted imaging (PWI) when combined with diffusion-weighted imaging (DWI) has been proposed as a method for determining the volume of salvageable tissue during initial hours of onset (< 6 h) [1]. Use of the cerebral blood flow (CBF) estimates obtained from PWI is effective at identifying ischemic tissue, however, the accuracy of this parameter has been observed to vary in performance with the type of deconvolution technique used for its calculation [2]. Several deconvolution methods have been observed to have an MTT dependence due to regularization, resulting in an underestimation of CBF values in healthy tissues (*i.e.*, healthy tissues have shorter mean-transit times (MTT) and are more heavily filtered, while ischemic tissue has longer MTT and less signal removed) [3]. We hypothesize that by restoring high-frequency components during the deconvolution process, there will be an improvement observed in the CBF accuracy and in image contrast between healthy and ischemic regions, resulting in better detection of final infarct.

Methods

A 3 T MR scanner (Signa VH/*i*, General Electric Healthcare, Waukesha, WI) was used for imaging of acute stroke. As part of the standard stroke imaging protocol, patients receive whole-brain PWI (TR/TE/flip = 2000 ms/30 ms/45°) and DWI. From our studies, ten ischemic stroke patient data sets were assessed. Five deconvolution methods were compared with respect to CBF maps: 1) spectral division, 2) block-circulate singular value decomposition, 3) Tikhonov based singular value decomposition, 4) Tikhonov regularization, and 5) frequency-domain extrapolated spectral division. The extrapolated method restores the attenuated high-frequency components by linearly estimating the filtered coefficients during deconvolution. Each method was optimized by finding the parameter values that minimized the CBF error via simulations. Image contrast between healthy and ischemic tissue, in both grey matter (GM) and white matter (WM), were measured. A two-way (factors: tissue type and deconvolution method) repeated-measures ANOVA test was used to determine the significance of differences ($p < 0.05$). Receiver operator characteristic (ROC) analysis was performed on one untreated patient who had follow-up imaging 30 days later, allowing for MR assessment of the final infarct.

Results

Across the ten patient data sets there was a mean increase in healthy-ischemic tissue CBF image contrast with the simple extrapolation method when compared to the other methods (average image contrast increased between 125 % and 266 %, depending on method and tissue type, $p = 0.001$. The simple extrapolation method generated CBF maps with significant increase of image contrast for WM when compared with methods 1) ,2) and 4) (labeled above) and GM for methods 1) and 2). While each technique permitted the penumbra to be determined on visual inspection (Fig 1), ROC analysis clearly showed the proposed extrapolation approached outperformed the other techniques.

Conclusions

The simple extrapolation method resulted in improved contrast between healthy and ischemic tissue. By restoring the high frequency components during the deconvolution process, better tissue state prediction was achieved, improving the estimates of DSC.

References:

1. Easton *et al.*, *Stroke*, 2009; 40:2276-2293
2. Salluzzi, *et al.*, *Magn Reson Image* 2005; 3:481.
3. Carpenter, *et al.*, *Magn Reson Med* 2006; 55:1342.

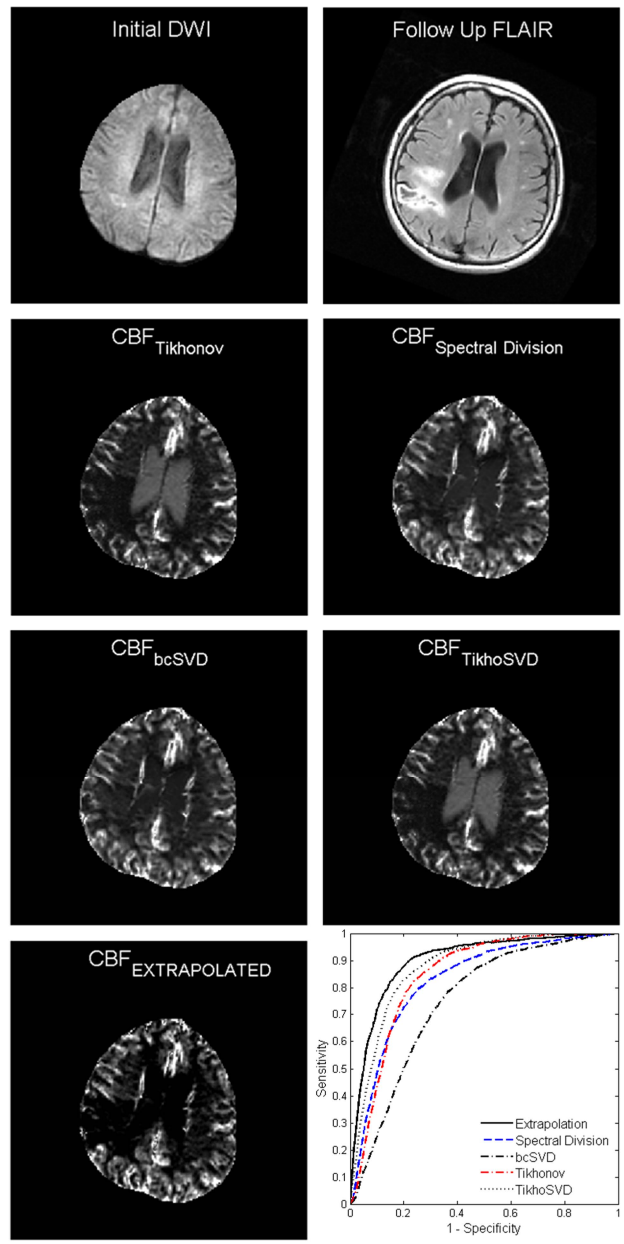

Fig 1: Initial DWI image and 30 day follow up FLAIR scans. Several CBF maps are processed from deconvolution techniques. These maps are compared with ROC analysis based on 30 day infarct.