Regional Coherence-based Denoising (RECODE) for Arterial Spin Labeled Perfusion MRI

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Introduction.

Arterial spin labeled (ASL) perfusion MRI has an intrinsic low SNR [1], and can benefit from advanced data processing strategies. ASL and other fMRI data have abundant spatial-temporal correlation since brain regions consisting of multiple voxels are most likely to be activated in unison while engaged in the administered task or even during the resting state [2]. In ASL MRI, the regional data coherence should be particularly prominent as the systematic spin labeling and control labeling automatically introduces additional coherence. In this study, we assessed a novel regional data coherence-based denoising (RECODE) method for improving SNR in ASL MRI.

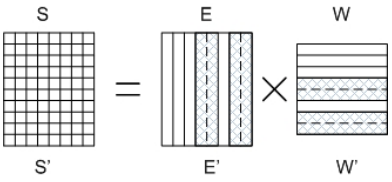

Fig. 1. Scheme for the PCA data reduction in RECODE. The columns in E and rows in W marked with grid are the components and the associated coefficient vectors to be excluded.

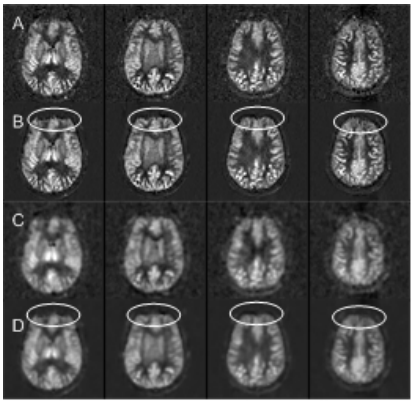

Fig. 3. A normal subject's perfusion difference signal maps calculated using different methods. No spatial smoothing was applied to the raw data in A and B. B and D are the results of RECODE.

Materials and Methods.

RECODE was applied to each voxel using a predefined neighborhood. Principal component analysis (PCA) was used to reduce both the spatial and temporal noise of the time series of the voxels within that neighborhood. Suppose that we have 8 ASL images (4 L/C pairs). With a neighborhood of 10 voxels (75 surrounding voxels used in this study), Fig. 1 illustrates the procedures for temporal noise reduction for the data S (each row contain one voxel's time series) within the neighborhood of one voxel. PCA decomposed S into the eigenvectors E and the associated representation coefficients W. Then reduction started from retaining the most principal eigenvectors that accounted for 90% of the total variance of the original data in order to keep the regional data coherence. To preserve the ASL signal, any of the remaining eigenvectors was retained if the representation coefficient vector (row vectors of W in Fig. 1) was correlated to the label/control paradigm with a significance level of $P<0.05$. This reduction yielded a reduced eigenvector matrix E' and the associated representation coefficient matrix W', which was used to generate the noise-reduced data S'. Similar procedures were used to reduce the spatial noise after replacing S with its transposed version S^T. The denoised data then replaced the original data in each voxel included in the current RECODE step. Since the neighborhood was moved throughout the whole brain, each voxel was cleaned multiple times as it was included in different neighborhoods. The mean of all cleaned values was set as the final RECODEd signal.

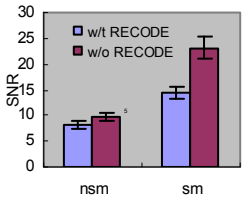

Fig. 2. SNR performance of different ASL data processing data reduction in RECODE.

ASL data from 6 normal subjects (100 CASL images) and a Frontal-temporal Dementia (FTD) patient (80 CASL images) were selected from previously published data and used for evaluating the proposed method. Each subject's ASL images were motion corrected and temporally filtered using ASLtbx [3]. Then RECODE and spatial smoothing (FWHM=6 mm) were applied to compare their performance for denoising ASL data. CBF maps were calculated from the RECODEd data or spatially smoothed data separately. SNR was calculated from the averaged perfusion map after subtraction by dividing the mean signal of an ROI in the brain tissue by the standard deviation of data in an ROI outside of the brain.

Results and Discussion

Fig. 2 shows that RECODE significantly improved SNR in the cases of without or with spatial smoothing ($P<0.0005$, SNR increased for all 6 subjects after using RECODE). Fig. 3 shows the mean perfusion difference (control-label) maps of a representative normal subject. As compared to regular processing (Fig. 3A, 3C), RECODE (Fig. 3B, 3D) markedly suppressed the background noise. Although the within brain signal looks similar with or without RECODE, RECODE improved the perfusion signal particularly in the edge of brain cortex as we can see in the prefrontal brain-air boundary (marked by the white ellipses in Fig. 3B and 3D). Spatial smoothing reduced background noise, but also reduced resolution. RECODE based on the smoothed data still improved signal in the edge brain. Fig. 4 shows the CBF maps of a FTD patient. RECODE (Fig. 4B) showed a better tissue contrast, and more clearly showed reduced CBF in the temporal and frontal lobes as marked by the white ellipses, which is very typical for patients with FTD [4]. Our data demonstrate the efficacy of RECODE for ASL data denoising. Parameters including the neighborhood size and criteria for cleaning components need to be optimized in future work. Although RECODE was proposed for ASL data denoising, the same approach can be applied to other types of neuroimaging data as well.

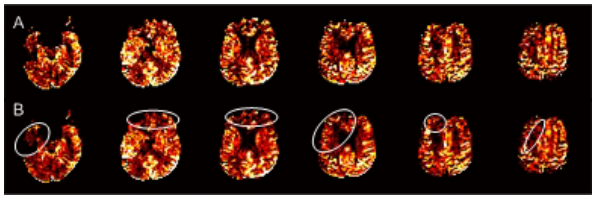

Fig. 4. CBF images of a FTD patient calculated without A) and with B) RECODE denoising. Display window is 0-90 ml/100g/min.data reduction in RECODE.

Reference [1] Wong, E.C. in *Functional MRI*, Bandettini, Editor. 1999: New York. p. 63-69. [2]. Biswal et al., MRM. 1995 Oct;34(4):537-41. [3] Wang et al, MRI, 2008. 26(2): p. 261-269. [4] Hu, W.T., et al., Neurology, 2010. **75**(10): p. 881-8.

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