WAVELET-BASED FILTERING OF ARTERIAL SPIN LABELING (ASL) FMRI DATA USING A WIENER-LIKE FILTER

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Purpose

To reduce the noise in pulsed arterial spin labeling (ASL) applied to functional imaging.

Introduction

Functional MRI (fMRI) is used for investigation of cortical activation during neuronal stimulation. The most commonly used contrast mechanism is blood oxygenation level dependent (BOLD) contrast. It is, however, generally agreed that a substantial part of the BOLD contrast might originate from macroscopic draining veins (1), whilst the venous contribution to the ASL signal is almost negligible. In addition, perfusion changes constitute a more direct indicator of neuronal activation and ASL fMRI is thus an attractive alternative for functional imaging (2). The main drawback of ASL imaging is the very low SNR in the perfusion maps. To increase SNR and the detectability of activated regions, we implemented a Wiener-like filter in the wavelet domain. This filter is constructed using the wavelet coefficients of the average image calculated from all images in the ASL-fMRI time series. The filter is then applied to each difference image in the series.

Methods

A simulated synthetic image data set was designed with two regions showing different CBF values, 65 and 25 ml/100g/min, representing grey matter (GM) and white matter (WM), respectively. A dynamic signal change according to a typical block paradigm with five periods of activation and five periods of rest (10 images during each period) was added to five regions in GM in the series of 100 images. The CBF was assumed to increase by 50% in activated areas (3) following the haemodynamic response function found by Friston et al. (4). Gaussian noise was added to k-space data in order to obtain SNR values of approximately 2 in GM and 0.8 in WM in the CBF maps (5). The noisy data were filtered by a Wiener-like filter in the wavelet domain (**W**) (see Eq. 1), where σ^2 is the variance estimated from the square of the median absolute value of the finest scale wavelet coefficients (corrected by a factor according to Alexander et al. (6)), ρ is an empiric threshold factor, θ_{avg} is the average image in **W** (calculated from all images in the series), y is the image to be filtered in **W** and $\tilde{\theta}$ is the filtered image in **W**.

$$\tilde{\theta}(i,j) = \frac{\left|\theta_{avg}(i,j)\right|^2}{\left|\theta_{avg}(i,j)\right|^2 + \rho\sigma^2} \cdot y(i,j) \qquad (1)$$

Results

In the filtering procedure the Daubechies wavelet bases of order 3 and a threshold factor of $\rho=0.5$ were employed. Both unfiltered and filtered data were analyzed without any preprocessing in the fMRI analysis software package (SPM2, www.fil.ion.ucl.ac.uk/spm) using a threshold p-value of 0.001 and an extent threshold of 1 voxel. Figure 1a shows the true location of the simulated activation signal and the corresponding results from unfiltered and filtered images are shown in Figs. 1b and 1c respectively. No true activation was observed when unfiltered images were analyzed.

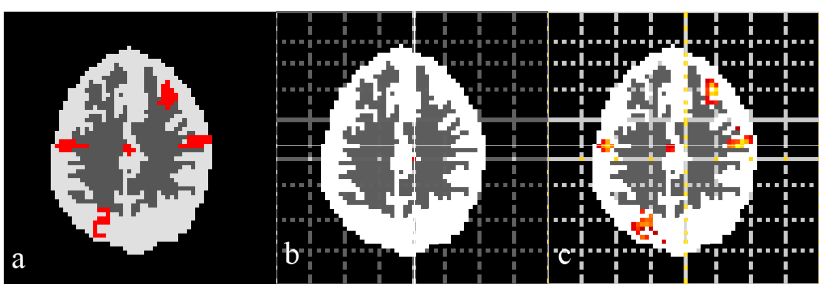

Figure 1. (a) True location of simulated activation signal, (b) activation recognized by SPM2 using unfiltered images, (c) activation recognized by SPM2 using filtered images.

Discussion

The results indicate that the proposed filtering scheme permits analysis of ASL fMRI data without any preprocessing such as smoothing or averaging. Additionally, the image quality increased and the noise decreased within the object as well as in the background. The choice of wavelet bases is not of immense importance although the Haar wavelet should be avoided due to the risk of square artefacts. The empirical threshold factor ρ should be between 0.5 and 1.5, since extensive thresholding leads to smoothing of the images.

References

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