Superposition of activations of SWI and fMRI acquisitions of the motor cortex

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Abstract — **Functional Magnetic Resonance Imaging (fMRI) has been an important tool for the understanding of the neural basis of cognition and behavior in the past years. Most studies rely on changes in the blood oxygenation level dependent (BOLD) contrast, to get an insight of the metabolic activity of specific areas in the brain, yet the particular physiological phenomena being measured is not fully understood.**

The present work aims to identify the correlation between fMRI signals and the venous structures being activated during the same tasks. By co-registering fMRI, Susceptibility Weighted Imaging (SWI) and T1 weighted images we can highlight the specific areas being activated during a behavioral task and correlate the fMRI signal to the spatial location of the active vein closest to the activated cluster.

The SWI sequence activation is derived from the subtraction of images, obtained during rest and behavioral tasks, being able to provide images of the venous structures activated during a task.

Although most of the used SWI subtraction data was too noisy, the results were quite promising. For a particular case, we managed to apply registration techniques to the fMRI, SWI and T1 weighted image sets, showing coherence between fMRI activation of the motor cortex and the vein identified in the SWI. Further development of the technique under better controlled conditions is required, in order to reduce the noise and deal with the difficulties we encountered. We hope to add extra information to the problem of the physiology mechanisms that underlie behavioral brain activation.

Keywords— **fMRI, BOLD, SWI, brain activation, image registration**

I Introduction

Over the past years, functional Magnetic Resonance Imaging (fMRI) has been used as a tool in the study of the neural basis of cognition and behavior [1], with most studies relying on qualitative changes in the blood oxygenation level dependent (BOLD) contrast, in which hemoglobin is used as an endogenous contrast agent. fMRI measures the correlation of neural activity to the hemodynamic response, that is characterized by a chain of physiologic events [2-5]. The interpretation of BOLD fMRI signals relies on the complex interplay of changes in cerebral blood flow, cerebral blood volume and blood oxygenation [6-7], making the particular physiological phenomenon being measured unclear [8].

Susceptibility Weighted Imaging (SWI) [9] allows us to see unique magnetic susceptibility differences between a certain structure and its background or the surrounding tissue.

The deoxygenated venous blood, with its paramagnetic deoxyhemoglobin in red blood cells [10], is of particular interest to this study. The difference between oxygenated and deoxygenated hemoglobin [11], allows us to image the susceptibility of blood in small venous vessels in the brain. This technique opens the possibility of observing the changes in small vessels that occur during the activation of particular brain area. By acquiring a set of images at rest and another as the paradigm task is being performed, it should be possible to see changes in oxygenation at the vessel level, by performing the subtraction of the two image sets.

The present work aims to identifying the correlation between fMRI signals and the venous structures active during a particular behavioral task (Fig.1). By co-registering fMRI, SWI and T1 weighted images it is possible to highlight specific areas being activated during a behavioural task and correlate the fMRI signal to the spatial location of the active vein closest to the activated cluster. Ultimately, we intend to add new information to the mechanisms underlying fMRI.

II Materials and Results

All MRI images were obtained on a 3.0T Signa GE Healthcare system. For the fMRI we acquired a 28 slice BOLD EPI sequence with an 8 channel phased array head coil using a Flip Angle = 90°, TE=35ms, TR=3s, Sl.Th.=5.0 mm, FOV=24 ×24 cm2 and a 64x64 matrix, with a total acquisition time of 282s. During this, a motor activation paradigm, consisting of a simple closing and opening of the hand in 30 second blocks of activation and rest, was performed.

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The fMRI post-processing was performed with FSL, FMRIB's Software Library (Oxford, UK). Analysis was carried out using FEAT (fMRI expert analysis tool) V. The following pre-statistic processing was applied: motion correction using McFLIRT[12]; non-brain removal using BET[13]; spatial smoothing using a Gaussian Kernel of FWHM 5mm; mean-based intensity normalization of all volumes by the same factor; high pass temporal filtering (Gaussian-weight LSF straight line fitting, with sigma=50.0s). Time series statistical analysis was carried out using FILM with local autocorrelation correction[14]. Z (Gaussianised T/F) statistic images were thresholded using clusters determined by Z>3,5 with a cluster significance threshold of p=0,05[15]. Registration to high resolution was carried out using FLIRT[12, 16]. For visualize 3D functional MRI and display the regions of activation on a 3D cortex surface we used BrainVoyager QX software Version 2.0.7 (Maastricht, Netherlands). To better differentiate between sulcus and gyrus and to see the specific localization of BOLD activation, we applied flattening techniques.

Two high resolution 3D SWI sets were acquired with full velocity compensation gradient echo sequences. The SWI post-processing (phase filtering) was performed on a GE Advantage Windows workstation. The first set was obtained with the subjects at rest and the other while performing the previously defined motor task. The movement was performed for the whole length of the acquisition sequence. In order to see SWI activation of the veins, a series of processing steps were performed on the FSL software to obtain the subtracted sets of the two SWI images. The subtraction was performed with basic commands, already in high resolution space. In order to reduce noise from the subtraction, we applied the tool SUSAN[17].

With this, we managed to highlight the changes in the blood vessel signal and in the oxyhemoglobin content between rest and activation tasks[11].

III Results

Although most SWI subtraction data was too noisy to give a proper subtraction, for one particular case, the SWI subtraction was very evident and a 3D representation of the activated vein was obtained (Fig.1). By applying registration techniques, we managed to superimpose both the fMRI activation and the SWI activated vein on the 3D FSPGR (Fig.2), exactly located on the area specific for the motor task performed[18].

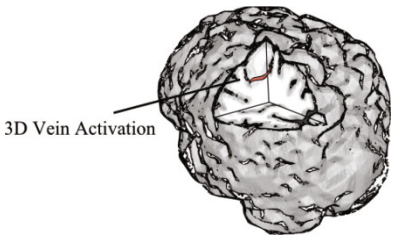

Fig. 2: 3D representation of the activated vein.

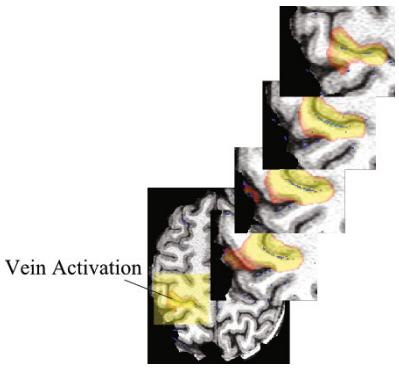

Fig. 3: Superposition of SWI and fMRI BOLD, on a 3D FSPGR anatomical sequence.

The activated vein actually lies in the sulcus, which can be located on the flattened brain, by increasing the threshold of the activation until a certain threshold (Fig.3).

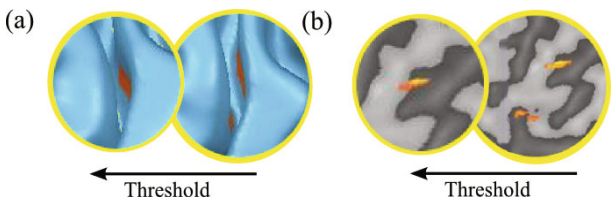

Fig. 4: BOLD activations on 3D cortex surface (a) and on flatted space (b).

This allows us to get a good spatial correlation of the various processes involved in brain activation.

V Conclusions

We were able to use post-processing to reveal coherence between fMRI activation of the motor cortex and the vein identified in the SWI in only one of our 5 study subjects due to the noise involved in the SWI subtraction images. However, in this case, the images were quite promising. We need to further develop the technique, under better controlled conditions, in order to reduce the noise and deal with the difficulties we encountered, and hope to add some extra information on the problem of the physiology of brain activation.

V References

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