

## Influence of orientation of the draining vein in fMRI

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### Introduction

Conventional fMRI involving gradient-echo EPI is mainly influenced by the magnetic distortion around the draining vein from the activation area. This distortion depends on the angle between the draining vein and the static magnetic field in MRI and is based on the electromagnetic theory [1]. Although the orientation of the draining vein influences the depiction of the activation area, this influence has not yet been studied. To investigate how the activation area is influenced by the angle between the draining vein and the static magnetic field, we performed the same fMRI study for different head positions in an RF coil by tilting the volunteer's head.

### Materials and Methods

Six volunteers underwent an fMRI study involving right or left finger opposition tapping, with a 1.5-T whole body scanner (Signa Horizon LX; GE Healthcare). The tapping and resting were repeated every 20 s. To alter the angle between the static magnetic field and the draining vein ( $\theta$ ) in the finger motor cortex, the head was positioned in an RF coil in 3 ways: normal orientation, rightward tilting, and leftward tilting. Each  $\theta$  of the draining vein was measured using the 3D data of the veins on the brain surface, obtained using 3D-PCA venography (voxel size,  $0.96 \times 0.95 \times 1.00 \text{ mm}^3$ ) and 3D head imaging with FLAIR. Gradient-echo EPI (TR, 4 s; TE, 40 ms) was used for the fMRI study. The activation area of each volunteer was depicted using SPM8, and we defined the activation center that had the largest t values. The percentile signal increase at the activation center was measured for quantitative model fitting. The fMRI data of all the volunteers were normalized to the MNI standard brain, and the activation area ( $P < 0.01$ ) was depicted for each experimental condition, i.e., right or left tapping and the 3 head positions.

### Results and Discussion

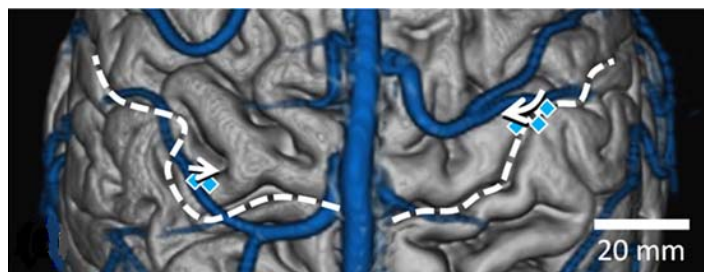
We successfully changed the  $\theta$  of the draining vein, with values ranging from  $40^\circ$  to  $90^\circ$ . The activation center shifted superiorly along the draining vein in each volunteer when  $\theta$  increased for both right and left tapping (Fig. 1). This shift was explained by the balance between the intravascular and extravascular signal contribution of the BOLD effect. The intravascular contribution, and hence the blood contribution, is large in the activation focus where the neurons are actually activated. In contrast, the extravascular contribution is large around the draining vein, in areas remote ( $>1 \text{ cm}$ ) from the activation focus and increases with an increase in the  $\theta$ . The activation foci are considered to be located in the inferior side of the head (origin of the arrow in Fig. 1), and the draining veins from the activation foci orient to the superior side. We modeled the percentile signal changes by using the theoretical intra- and extravascular signals and their phase difference [2]. Our model quantitatively explained the measured data pertaining to the percentile signal increase with the following fitting parameters: blood oxygenation, non-intravascular contribution, and non-extravascular contribution. For all the volunteers, the fMRI data normalized to the MNI standard brain clearly showed the shift of the activation area to the superior side with an increase in the  $\theta$  (Fig. 2). The distance between the most inferior and superior activation areas shown in Fig. 2 is larger than 2 cm. The  $\theta$  of the draining vein differs between brain areas and between subjects. When the  $\theta$  approaches  $90^\circ$ , the percentile signal change increases but the location of the largest signal changes tends to deviate from the true activation focus.

### Conclusion

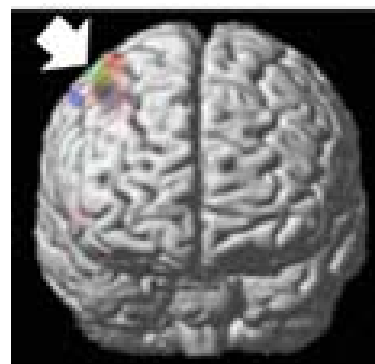
The activation area, especially the position of the largest signal increase, in fMRI is strongly influenced by the orientation of the draining vein from the activation focus where the neurons are activated.

### References

- [1] Anderson DJ, et al., Proc Intl Soc Mag Reson Med 2005;782.
- [2] Ogawa S, et al., Biophys J 1993;64:803-812.



**Figure 1** Displacement of the activation center (diamond) in a volunteer. The dashed lines represent the central sulci. The direction of the arrows indicates the increase in the  $\theta$ .



**Figure 2** Displacement of the activation area for left finger tapping. The arrow indicates the activation area (green) determined from the normal head position experiment. The activation area shifted when the head was tilted right (blue) and left (red).