

Quantitative BOLD using a Diffusive Model

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Introduction The ability to map blood oxygenation and venous blood volume fraction using MRI has considerable implications, both in diagnostic imaging and fMRI signal calibration. A promising approach is to fit a model of BOLD signal decay to data from the Gradient Echo Sampling of a Spin Echo (GESSE) sequence. Using this method, He and Yablonskiy were able to produce Oxygen Extraction Fraction (OEF) maps that were in good agreement with those from PET studies, both in healthy and diseased states [1,2]. However, there were some unexpected results that were attributed to the absence of spin diffusion in their model [3]. This study demonstrates the advantages of accounting for diffusion by fitting a diffusive BOLD model to GESSE data from 8 healthy volunteers.

Methods The diffusive BOLD model was developed using phenomenological approach similar to that of Stables et al [2] and finding the dependence on OEF from a series of simulations. This model was then incorporated into the quantitative BOLD (qBOLD) method of He and Yablonskiy [4], which was then used to analyse GESSE data from 8 healthy volunteers. All experiments were performed on a 3T Siemens scanner. The parameters of the GESSE sequence were: FOV 192x256mm, slice thickness 5mm, sampling matrix 96x128, TR=3500ms, NEX=4. The spin echo was at 60ms which was between the 11th and 12th gradient echo out of a total of 41. A 32 channel head coil was used with a GRAPPA acceleration factor of 4. Acquisition time was 9.8 minutes for 9 slices.

Results The phenomenological model was found to accurately describe the results of diffusive BOLD simulations with a physiological distribution of vessel radii, across the full range of OEF (fig. 1). By incorporating this into the qBOLD method we were able to closely fit the T₂ corrected timecourses from single voxel GESSE data (fig. 2). PET studies have shown that OEF is approximately constant at a value of ~40% across the healthy brain, while the blood volume fraction is far higher in grey matter than in

Fig 1. The phenomenological fit to simulated SE data

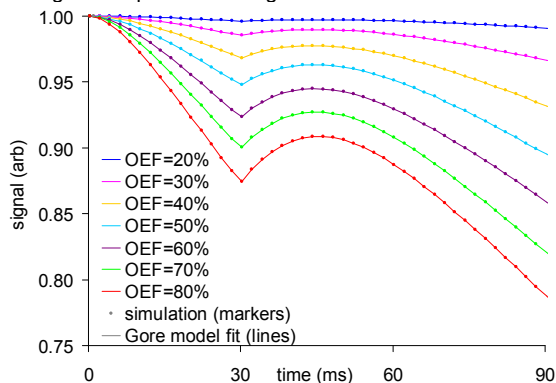


Fig 2. The diffusive qBOLD fit to real GESSE data

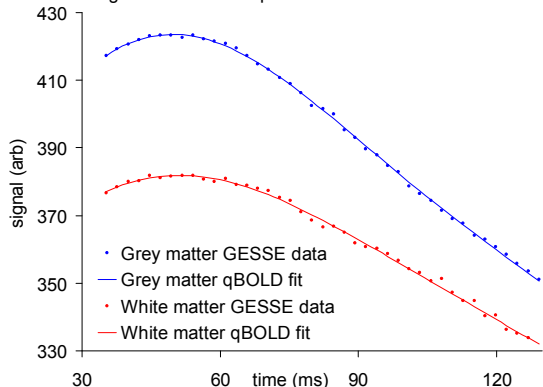
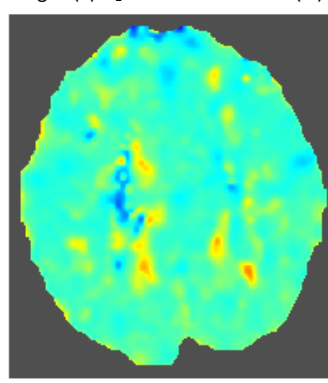


Fig 3. (a) O₂ Extraction Fraction (%)



(b) Deoxygenated Blood Volume (%)

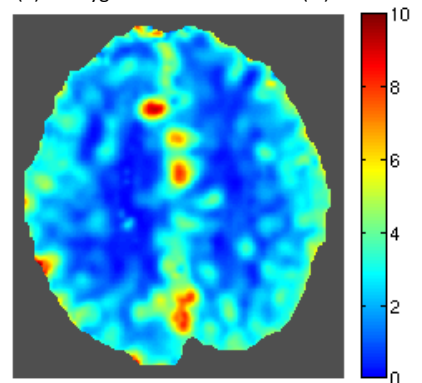


Table 1. Average values from 8 healthy volunteers.

Model	O ₂ Extraction Fraction (%)		Venous Blood Volume (%)	
	Diffusive	Static	Diffusive	Static
Mean	37.6	33.6	2.5	2.6
Mean grey matter	37.3	34.7	3.0	3.0
Mean white matter	38.2	32.4	1.7	2.1

white matter. The parameter maps in fig. 3 agree with these well established findings. Table 1 shows that the average values from the diffusive model are closer to the expected levels than those from the static model. This was also the case for T₂ measurements which are a by-product of the qBOLD method (not shown).

Conclusion Using a diffusive model it is possible to obtain measurements of blood oxygenation and volume that agree more closely with literature values than those obtained when using a static model.

References [1] Yablonskiy and Haacke, *MRM*, 1994; 32(6):749-763. [2] He, Zhu and Yablonskiy, *MRM*, 2008; 60(4):882-888. [3] Gore, et al., *MRM*, 1998; 40:432-442. [4] He and Yablonskiy, *MRM*, 2007. 57(11): p.115-126.