# Nulling the CSF Signal in Quantitative fMRI

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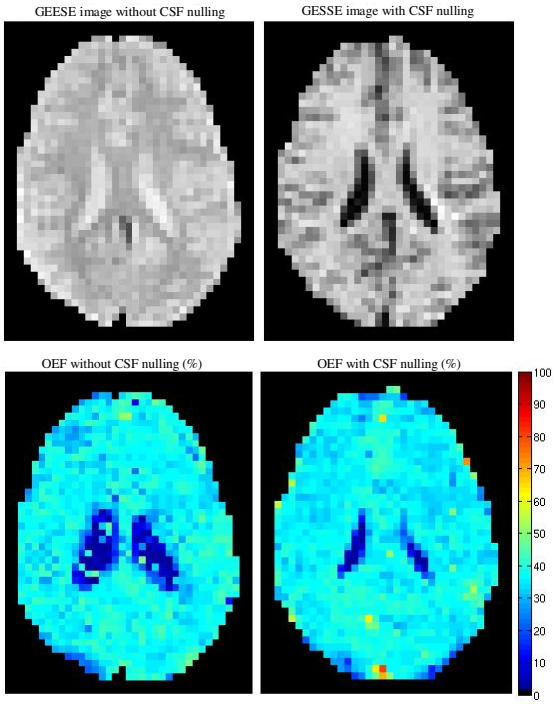
**Introduction:** By quantifying the BOLD signal it is theoretically possible to measure the venous Cerebral Blood Volume (vCBV) and Oxygen Extraction Fraction (OEF). If this were to be achieved within clinically realistic scan times it would provide a powerful tool for the analysis of cerebral vascular disorder such as stroke. One of the confounds which make accurate measurements of these parameters using the GESSE (Gradient Echo Sampling of a Spin Echo) sequence difficult to achieve is the component of signal from extracellular fluid [4]. There are two main contributions to extracellular fluid in the brain, cerebral spinal fluid (CSF) and Interstitial Fluid (ISF). Since these have different $T_2$ relaxation times their contributions to the signal will differ. This could be dealt with by including it in the model, although increasing the number of estimated parameters results in greater uncertainty in their values. This study shows that realistic readings of OEF can be made in voxels that have a partial volume of CSF by nulling the CSF signal and only fitting for the ISF component. As scan time needs to be kept to a minimum, it is not possible to achieve a high resolution for this sequence whilst maintaining high SNR. This makes the partial volume problem of particular relevance.

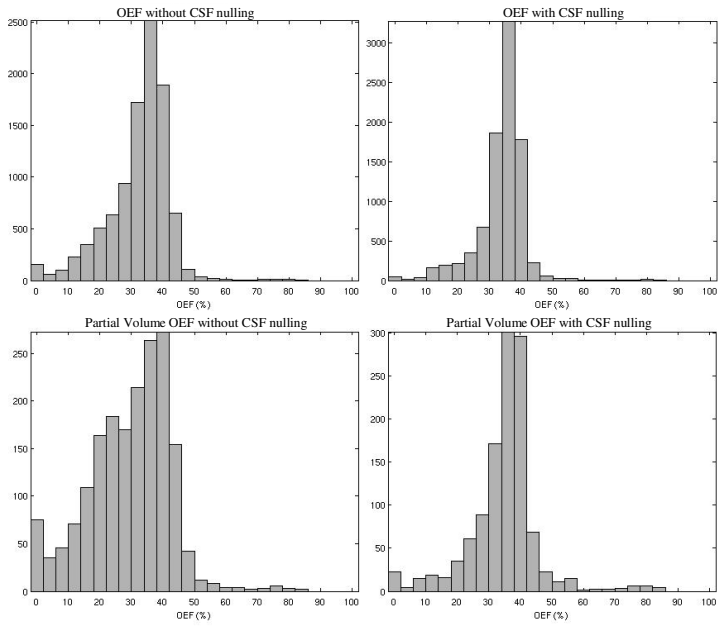
**Method:** All experiments were performed on a 3T Siemens scanner. The GESSE sequence had the following parameters: FOV 192x256x56mm, sampling matrix 48x64, TR=3500ms, NEX=4. A 32 channel head coil was used, with a GRAPPA acceleration factor of 4. Acquisition Time was 7 minutes for 9 slices. The spin echo was at 40ms and coincided with the 7$^{th}$ gradient echo (GE) out of a total of 41. To null the CSF signal an inversion pulse was added to the beginning of the sequence followed by an inversion time TI=1100ms. The GESSE data were smoothed by a Gaussian window to increase SNR and then corrected for macroscopic variations in magnetic field before fitting the model in [1]. In order to assess the effect of the nulling on regions affected by partial volume problems, voxels containing CSF were identified by SPM. This map was then used to produce histograms of calculated OEF in partial volume regions and in the brain as a whole for each GESSE sequence.

Fig 1. Effect of CSF nulling on images and OEF maps




**Results:** Fig. 1 shows that The CSF nulled GESSE images gave more uniform readings of OEF, especially in regions of CSF partial volume. The SNR of the CSF nulled images was lower by a factor of 2.1, consistent with incomplete recovery of GM/WM after the inversion pulse. The histograms in Fig. 2 show that when the CSF is nulled (right column), partial volume voxels (bottom row) produce similar results to pure WM/GM voxels (top row). This can be seen adjacent to the ventricles in Fig.1, where the region of low OEF is significantly smaller when CSF signal is reduced. Without CSF nulling, voxels with a partial CSF volume are likely to give artificially low OEF measurements.

Fig 2. Effect of nulling on CSF partial volumes




**Discussion:** By nulling the signal from CSF it is possible to get more reliable measurements of OEF in partial volume voxels. The drawback (for a fixed scan time) is the associated drop in SNR. However, since the partial volume effects occur at a resolution lower than we are currently able to achieve, this may be an appropriate compromise to increase the utility of this technique.

**References:** [1]. He and Yablonskiy, *MRM*, 2007. 57(11): p.115-126. [2] An and Lin, *MRM*, 2003. 50: p.708-716. [3] Yablonskiy and Haacke, *MRM*, 1994. 32(6): p.749-763. [4] Fujita et al, Neuroimage, 2003. 20: p.2071-2083.