Determination of the Brain Tissue-Specific Temporal Signal to Noise Limit of 3T BOLD-weighted Time Course Data.

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Introduction: Krueger et al. introduced the model describing the physiological noise present in the resting state brain that depends on the MRI signal strength and it is significantly greater in cortical gray matter (GM) than in white matter (WM) (1). This model also predicts that as image SNR increases it causes temporal SNR (TSNR) in oxygenation-sensitive MRI BOLD signal to saturate (2). Therefore at higher field strength due to increase in image SNR the TSNR gains in BOLD imaging will saturate (3). It is expected that CSF and Vasculature compartments show higher physiological noise level than brain parenchyma, but this has not been quantitatively demonstrated. Here we will test these predictions at 3 Tesla and higher image SNR limit and finer spatial resolution due to recent advance in parallel imaging (4,5). Our resting state data further confirmed Krueger model (1,2). Based on high-resolution EPI and pixel-wise T1-based image segmentation we have found a TSNR limits for physiological noise contribution for GM, WM which followed the model predictions. Additionally we were able to separate CSF and Vasculature compartments and studied their effects onto the physiological noise.

Material and Methods: Imaging hardware: 3T General Electric VH/3 MRI scanner (3T/90cm, a whole body gradient inset 40mT/m, slew rate 150 T/m/s, a whole body T/R RF coil) equipped with home-built 16 channel MRI digital receiver (1); standard T/R head coil and 16-channel receive-only array (5); single shot full k-space gradient echo EPI with matrix sizes 128x96 (72.3ms readout) single shot gradient-echo SENSE (rate=2) EPI with matrix size 192x144 and 71.4ms readout. "Resting fMRI" experiments were performed on human subjects (n=4). Parameters: Axial plane, 8 slices, FOV/slice 22cm/4mm, TR=3sec, TE=45ms, flip angles (90,70,45,20,1 degrees), number of volumes 70. For segmentation purpose the apparent T1 maps were computed from ratio of the first EPI time course image (infinite TR,flip angle=90) over an average steady state image. For vessels mapping a very high resolution SENSE EPI with cubic 1.0 mm^3 voxel and longer TE=55ms was used. To match imaging volume 50-60, 1 mm slices were acquired (TR=6s). To enhance vessels visualization Minimum Intensity Projection (MIP)(6) was calculated through slice direction to match fMRI slice thickness (4mm). Resulting MIP EPI images – MR-Venographs were processed to extract Vasculature masks.

Figure 1. EPI (a); MR-Venograph (b); Vasculature mask (c); CSF mask (d); GM mask (e); WM mask (f).

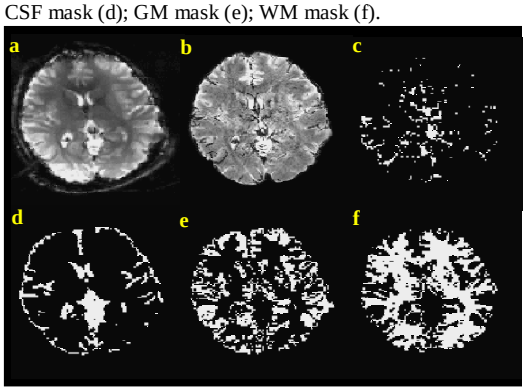
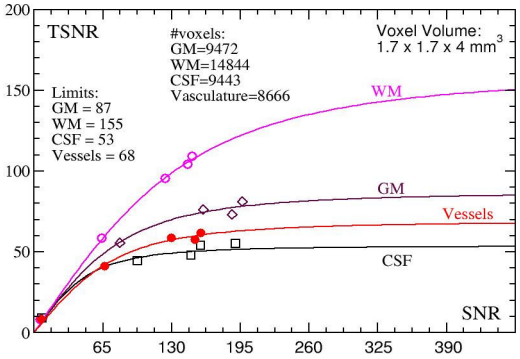


Figure 2. TSNR versus SNR plot for different brain tissues (GM,WM,CSF, Vessels).



Result and discussion: Representative single subject data are show on Figures 1 and 2. Figure 1 shows: (a) high res EPI, (b) corresponding SENSE EPI MR-Venograph, (c) Vasculature mask obtained from (b), (d) CSF mask, (e) GM mask and (f) WM mask. Figure 2 shows TSNR versus SNR plot at echo time 45ms for different tissue compartments (data symbols: mean values from large number of voxels within the mask). From group data (N=4, TE=45ms) for different brain tissue compartments we have found the following TSNR limits: GM: $TSNR_{GM}$=78+/-14, $TSNR_{WM}$=117+/-27, $TSNR_{Vessels}$=52+/-12 and $TSNR_{CSF}$=47+/-5.

Conclusion: We have verified the physiological model introduced by Krueger et al. at 3 Tesla and high SNR limit. At echo time 45ms and based on high-resolution EPI image segmentation and very large number of voxels within different brain tissues mask, we have found TSNR limits for different brain compartments. Group data provides the mean TSNR limits for GM and WM as 78 and 117 respectively and a new TSNR limits for CSF and Vasculature compartments as 47 and 52 respectively. Our data indicated that TSNR value for a given voxel is determined by a mixture of multiple compartments. Lastly, we have showed that contamination from CSF and/or Vasculature to the given voxel lowers the voxel TSNR limit.

References: (1)Krueger et al., Magn Reson ed 2001:45:595;(2)Krueger et al., Magn Reson Med 2001:46:631;(3)Triantafyllou et al., Proc. Intl. Soc. Mag. Reson. Med. 2004:11:1071;(4)Bodurka et al, Magn Reson Med 2004:51:165; (5)de Zwart et al., Magn Reson Med 2004:51:22; (6)Reichenbach JR. et al. NMR Biomed 2001:14;453.