Constant Phase Statistical Method Better Localizes Activations than Phase Regressor Statistical Method

A. S. Nencka[1], and D. B. Rowe[1]

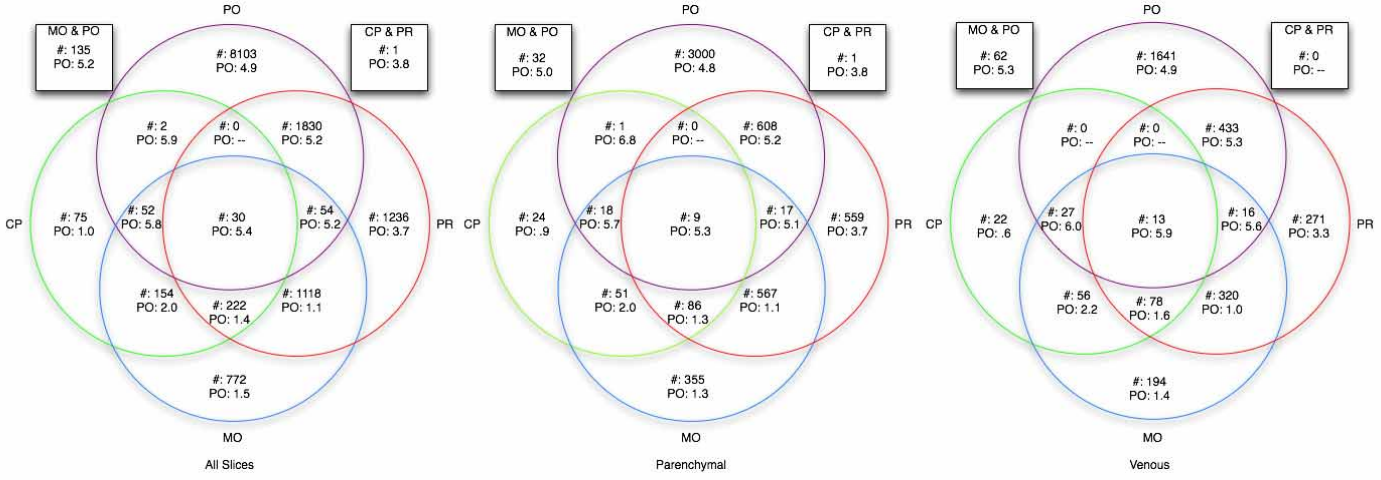
[1]Department of Biophysics, Medical College of Wisconsin, Milwaukee, WI, United States

Introduction: As GRE EPI BOLD fMRI depends upon capillary and venous blood oxygenation changes with cortical activity, it is sensitive to both capillary responses and resulting down-stream draining vein responses. Thus, although BOLD computed cortical activations are robust and find large areas of activation, they often may contain delocalized activations from down stream draining veins.[1] Because of this, methods have been developed to reduce contributions from voxels contaminated by draining veins. In 2002 Menon argued that voxels containing draining veins exhibit task related phase changes as the intra-vascular susceptibility changes with blood oxygenation. This led to the phase regressor model which regresses magnitude as function of phase, and reduces venous contributions to the magnitude observations by subtracting a phase-estimated magnitude from each time point.[2] In a different approach, Rowe and Logan developed a constant phase activation model utilizing complex data, in which activation statistics are reduced when voxels do not exhibit a constant phase time series[3] as expected in the capillary bed. This method has been shown to localize activations to active parenchyma in single subjects.[4,5] Fundamental theoretical differences have been shown between these methods in simulations with the phase regressor method over-correcting task related magnitude changes because of the improper estimation of phase contributions to magnitude observations.[6] In this abstract, results from applying the phase regressor and complex constant phase statistical methods to data from five subjects are presented.

Methods: Five subjects were scanned using a GE Signa LX 3.0 T scanner while performing a block designed bilateral finger tapping task. In each subject ten 96×96 slices of $(2mm)^3$ isotropic voxels were acquired with a TE of 50ms and TR of 2000ms. Collected slices included the hand region of the motor cortex, as well as superior slices identified to contain draining veins from the region in a separately acquired angiogram. Activations included voxels with signed z-statistics above an α=0.05 slice wise Bonferroni adjusted threshold. Slices with no apparent vasculature in the angiogram in the regions of activation were defined to be parenchymal. Slices at least 1cm superior to the slice with maximal traditional magnitude-only activations and which contained active voxels co-localized with identified vasculature in the angiogram were defined to be venous. The localization and inter-method similarities of the activations in the parenchymal and venous slices were compared.

Results: Figure 1 shows Venn diagrams for the results from the cumulative data set. The constant phase activations (CP) are generally a subset of the magnitude-only activations (MO), while the phase regressor activations (PR) include many activations which are co-localized with phase-only (PO) activations or which are found to only be active by the phase regressor statistical method. Constant phase activations include significantly lower phase-only activation statistics than phase regressor activations. Figure 2 shows representative parenchymal and venous slices from one subject. While the constant phase and phase regressor models find similar activations in the parenchymal slices, their similarities to each other and the traditional magnitude-only model diverge in the venous slices. Several confounding physical factors corrupt the phase data alone[7] leading to large regions of activation, although strong de-activation is seen bilaterally in the venous slice where magnitude-only activations are located from draining veins. The constant phase model reduces these venous activations, while the phase regressor model is quite sensitive to the noise in the phase time series and does not markedly reduce these activations.

Discussion: This experimental data supports the results from previous simulations. The complex constant phase statistical model generally finds a subset of the traditional magnitude-only activations, reducing delocalized activations associated with draining veins. The phase regressor model is quite sensitive to an imperfect fit of the magnitude as a function of phase, thus leading to the over-correction of magnitude observations and unexpectedly located, scattered activations.



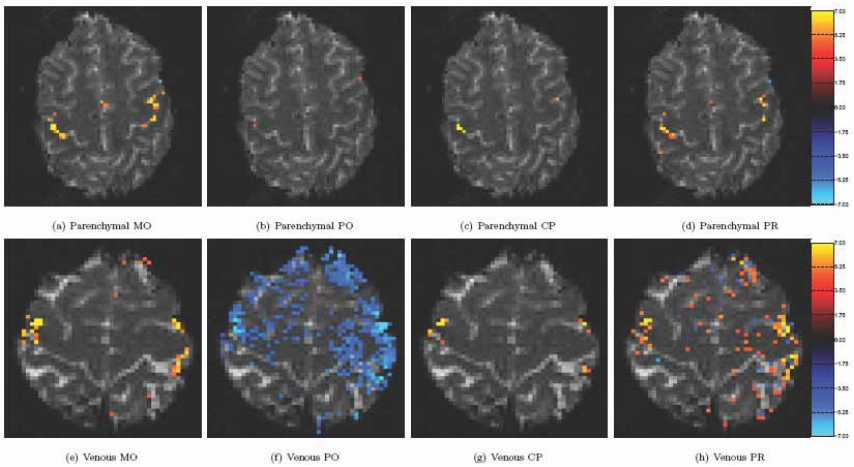


Figure 1 (Above): Venn diagrams showing the correspondence of the CP, PR, MO and PO activation methods in all five subjects. The number of active voxels (#) and the median phase-only statistic for the group (PO) are included. All slices are compared in the left diagram while parenchymal and venous slices are compared in the center and right diagrams.

Figure 2 (Left): Parenchymal (first row) and venous (second row) activations from one subject. Traditional MO (first column), analogous PO (second column), complex CP (third column) and PR (fourth column) are shown.

References: (1) Turner, R. NIMG 16: 1062-1067. (2) Menon, R. MRM 47:1-9. (3) Rowe, D.B. and Logan, B.R. NIMG 23: 1078-1092. (4) Nencka, A.S. and Rowe, D.B. Proc. ISMRM 13: 495. (5) Rowe, D.B. and Nencka, A.S. Proc. ISMRM 14: 2834. (6) Nencka, A.S. and Rowe, D.B. Proc. ISMRM 14: 3269. (7) Pfeuffer, J., et al. MRM 47: 344-353.

Acknowledgments: Supported in part by NIH EB000215, AG020279, MH019992.