Heterogeneity of TE Response Curves Using Cubic mm Voxels

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PURPOSE: The contrast-to-noise ratio (CNR) in fMRI as a function of echo time is given by exp(-TE/T2*') - exp(-TE/T2*), where the prime indicates the T2* value in the presence of task activation (1). This equation is plotted in Fig. 1 for reference. It exhibits a maximum at T2*=TE. We define the "TE response curve" as the experimental plot of CNR at each TE value, as determined by the magnitude of the correlation coefficient of the data with respect to a model for task response, versus TE. The curve plotted in Fig. 1 is the "ideal TE response curve." It is based on the assumption of homogeneity of the T2* value across the voxel both at rest and in the presence of task. Experimental evidence has recently been presented in fMRI data acquired at high spatial resolution that T2* values are likely to be heterogeneous both within and across voxels (2). The purpose of this study was to acquire TE response curves at high spatial resolution in order to gain insight into T2* heterogeneity.

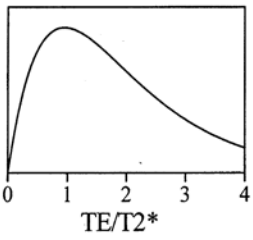

Fig.1. Ideal TE Response Curve.

METHODS: Data were obtained using gradient-recalled EPI at 3 T with a custom made three-axis, balanced torque, head gradient coil fitted with a shielded endcapped quadrature transmit/receive birdcage rf coil.Using partial k-space (3), several series of 144 sequential high-resolution EPI images of a six axial slices (1mm) were obtained using TR = 2000 msec, FOV = 19.2 cm, and matrix size = 192 × 192. The echo-time was increased in eight steps, starting from 10 msec, in increments of 15 msec and embedded in the pulse sequence. Acquisition of a complete data set required about 40 minutes. Four healthy volunteers (3M, 1F) 24-34 years of age, were studied. Image time-courses were obtained with identical imaging parameters for each subject. Volunteers were asked to tap fingers of both hands sequentially in a self-paced manner for 20 sec, followed by 20 sec of rest. In one subject, one additional bilateral finger tapping scan was obtained containing only one slice to minimize the effects from the adjacent slice. Changes in correlation-coefficient of the activated voxels were then studied as a function of echo-time.

RESULTS: Figure 2 shows a 9 x 9 array of TE Response Curves obtained from cubic millimeter voxels. It is immediately apparent that curves generally rise and fall in a manner consistent with BOLD contrast and the ideal response curve. However, the experimental curves have widely varying shapes, and the correspondence between the shapes of the experimental curves and the ideal curve is not close. Several categories of shapes of the experimental TE response curves can be identified. Curves a9, b9, c9 exhibit dips that go to zero value at intermediate TE values. Examination of the raw data shows that the sign of the response passes from positive to negative at these TE values. This observation is consistent with Ref. 4, which attributes negative fMRI responses at high TE values to voxels that are close to large intravoxel susceptibility gradients. Curve g5 is exceptional – peaking at TE = 85 ms with a correlation coefficient of 0.8. Some curves seem not to decrease in the experimental TE range, viz. c4, i5, h4. This suggests the presence of a few water proton pools with exceptionally long T2* values. Other curves are well above zero at the shortest TE value (10 ms), h2, c5. This suggests an inflow effect.

DISCUSSION:

The relative weightings of the acquisition of the various lines of k-space can be expected to affect the shape of the TE response curve, and partial k-space GR EPI is no exception. However, this will not affect the central conclusion of this study: at 1 mm resolution the heterogeneity of T2* is substantial and includes contributions from both intravoxel and intervoxel susceptibility gradients. The long range goal of our research is to identify voxels that arise from parenchyma. The present study seems to give insight that can help to achieve that goal, even though the time for acquisition of the data is too long to be practical on a routine basis.

REFERENCES:

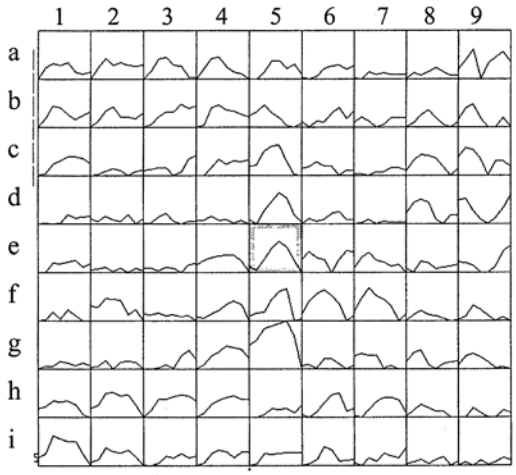

Figure 2 9 × 9 array of TE Response Curves for motor cortex cubical voxels. Magnitude of the correlation-coefficient is plotted, 0 to 0.8.

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