Comparison of SEEP and BOLD fMRI Contrast Mechanisms in Children Using a Motor Task

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Introduction

Functional magnetic resonance imaging based on a proton-density signal change, termed "Signal Enhancement by Extravascular water Protons" or SEEP, has previously been demonstrated (1-3). This change in proton-density is theorized to arise from the flux of water from the capillary beds to form extracellular fluid in the CNS. Here we investigate the signal changes in both Blood Oxygenation-Level Dependent (BOLD) and SEEP contrast mechanisms during a simple motor task in children aged 9-14.

Methods

Twelve healthy volunteers between the ages of 9 and 14 were studied in a 1.5 T GE Signa Horizon LX clinical MR system. Functional image data was acquired from eight, 4 mm thick slices, using echo-planar imaging with a 256 x 128 matrix and 20 cm field of view. Data were acquired with SEEP contrast (spin-echo EPI, TE = 26.4 msec, TR = 3 sec) and BOLD contrast (gradient-echo EPI, TE = 50 msec, TR = 3 sec). Activity in the motor and sensory areas was elicited by having the subject squeeze a ball with their dominant hand during the "task" periods. A block design was used with 8 alternating periods of rest and "task", each of 24 seconds duration. Experiments were repeated three times for each contrast mechanism (SEEP and BOLD). Data were analyzed by means of correlation to a model paradigm using SPM99 (4). Regions of signal change corresponding to the paradigm were overlaid on the subject's own mean reference image.

Results and Discussion

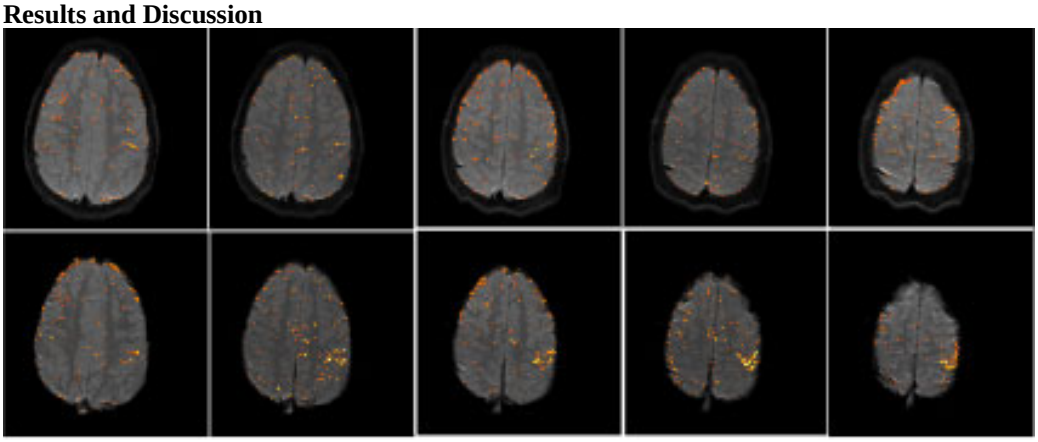

Figure 1: Example of functional activity observed in a single trial in one subject with SEEP contrast (top) and BOLD contrast (bottom). Areas of activity shown on both maps correspond to a level of $p \leq 0.01$.

Areas of activity in the somatosensory cortex were consistently observed in all studies with both BOLD and SEEP contrast. Greater functional activity, however, was observed using BOLD contrast in all cases (Figure 1). The reproducibility of both contrast mechanisms was also observed in all subjects with repeated experiments. Areas of SEEP contrast activity coincided with areas of activity identified with BOLD contrast. While the SEEP contrast mechanism showed significantly reduced area of activity, the signal changes observed tended to follow the gray matter. These results are consistent with signal changes observed with SEEP contrast upon neuronal activation in adults in experiments with the same resolution (5). The results obtained demonstrate that functional activity in children, elicited using a motor task, can be detected with SEEP contrast. While there is a high degree of localization to gray matter regions in the brain, the extent of activity is significantly diminished in comparison to BOLD. This is the first fMRI study utilizing the SEEP contrast mechanism involving children. The reduced extent of activation with SEEP compared to BOLD may present a problem when examining functional activity in children. While this study demonstrates that it is possible to identify regions of activity with SEEP contrast, more studies involving children are required to evaluate the two different contrast mechanisms. A greater understanding of the developing brain physiology and hemodynamic response function in children are required.

References

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