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The Oxygen Artifact in Echo-Planar Imaging

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Introduction

Changes in signal intensity in the cerebrum due to changes in the concentration of exogenous or endogenous paramagnetic substances in the cerebral circulation have been used to produce functional magnetic resonance images. The paramagnetic effects of molecular oxygen in solution or bound to substrates have been documented (1). To the best of our knowledge, the effect of gaseous oxygen on magnetic susceptibility imaging has not been reported.

Methods

A 1.5 T imager (GE Medical Systems, Waukesha, WI) was used with a quadrature head coil and a three axis gradient head coil (2). From localizer images in the axial plane, 3 to 7 contiguous sagittal sections were prescribed. Susceptibility images were obtained in the selected planes at 2 sec intervals. Six experiments were performed on three volunteers. In five experiments a plastic anesthesia mask from which all metal had been removed was applied to the face of a volunteer positioned in the scanner. Room air and 100% oxygen (6L/min) were alternately supplied to the mask for 20 sec. In the sixth experiment, the mask was applied to the back of the subjects head while the air and oxygen were alternately supplied to the mask. Susceptibility images were also obtained with the mask applied to the inferior, superior, anterior and posterior aspects of a phantom containing 0.05 M NaCl and 0.005 M CuS04. Oxygen and room air were delivered alternatively during imaging of the phantom in 3 planes. During prescan, the magnitude of the echo was measured as the gradient changed and oxygen was delivered. Susceptibility images were analyzed using a correlation coefficient technique (3).

Results

In the 6 experiments on the human subjects, changes in signal intensity coincident with the delivery of oxygen were observed predominantly in cerebellar, frontal, temporal and occipital regions. A susceptibility image (Fig. 1a) illustrates regions with signal increases co-incident with oxygen administration through a face mask placed over the nose and mouth. Image processing of Fig. 1a with thresholding can result in apparent functional response, Fig. 1b. In another experiment, the mask was applied to the back of the subject's head. The time course of signal intensity in one pixel related to the temporal lobe is shown in Fig. 2. Thus, the signal changes cannot be functional in origin.

In phantom experiments, similar changes in signal intensity correlated to oxygen administration were observed. The susceptibility image and time-course plots for one phantom experiment are shown in Figs. 3a and 3b.

Changes in the magnitude of the gradient echo were evident on inspection of the prescan echoes. With no gradient on, the signal dropped by 5% when oxygen was administered. This change in signal was eliminated by applying the gradient in the direction of maximum change of oxygen concentration. After oxygen was removed, the signal diminished 5%. Removing the gradient restored the signal to baseline.

Conclusion

The homogeneity of the magnetic field and T2* relaxation can be altered by the introduction of pure gaseous oxygen into the imaging volume. By monitoring changes in the gradient prescan echo, we have seen changes in the uniformity of the static magnetic field attributable to the inhomogeneity of oxygen distribution inside the bore. Signal changes were well correlated with oxygen delivery. Furthermore, phantom experiments have proven that oxygen is solely responsible for the effect described. The significance of this experiment is twofold; first, that intermittent administration of oxygen may mimic and obscure functional changes and secondly, by administering gaseous oxygen in the imaging volume the effect of its paramagnetic susceptibility can be detected.

References

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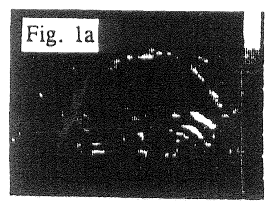
Fig. 1a

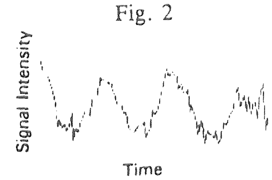

Fig. 2

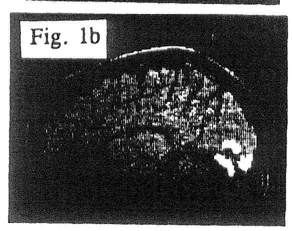
Fig. 1b

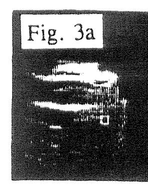
Fig. 3a

Fig. 3b