High spatial resolution functional imaging of perfusion and BOLD contrast in humans at 7 Tesla

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Introduction

The spatial resolution of functional magnetic resonance brain imaging has generally been limited by the loss of signal-to-noise ratio as voxel dimensions diminish. This is particularly true for perfusion imaging based on arterial spin-labeling, in which the absolute magnitude of functional signal changes is even smaller than those seen due to blood oxygenation level-dependent (BOLD) contrast. The increasing availability of high-field imagers in the seven to eight Tesla range has created new opportunities for pushing the boundaries of spatial resolution in these methods, due to increased tissue magnetization and (for BOLD) susceptibility contrast through intra-voxel de-phasing of spins. High-field platforms are particularly interesting for pulsed arterial spin-labeling, due to the longer blood T1 values observed, since signal decay during the post-label delay results in a considerable loss of sensitivity.

Arterial spin-labeling at high-field also poses a number of challenges. Construction of volume RF coils with homogeneous B1 fields is a complicated undertaking in which many decisions must be made based on empirical observations. Fortuitously, our initial experiences have suggested that dielectric resonances create B1 'hot-spots' near the center of the head in regions including some of the major supply arteries for the brain. This may actually aid in production of adiabatic conditions necessary for high-efficiency inversion in pulsed ASL.

Another potential issue is that of energy deposition, which is increased with the application of high-amplitude RF pulses at high field. This could potentially limit transmitter voltages below the threshold required for adiabatic inversion and diminish the sensitivity available in ASL measurements on high-field systems.

Our group has constructed a transmit/receive coil for the head using an end-cap TEM design that has provided reasonable homogeneity over the head and neck, and which we have used in initial trials of arterial spin-labeling. By using the PICORE labeling geometry for our measurements, we have also been able to acquire simultaneous BOLD signals during a hand movement task in a small group of normal volunteers.

Methods

Experiments were conducted on a 7T imager that has been assembled in collaboration with Siemens Medical Systems. The system uses a Magnex magnet fitted with a Siemens gradient-set and driven by a Siemens console running the Numaris 4 software environment. Excitation and detection were performed with the RF coil described above, using real-time monitoring of reflected RF power to ensure that energy deposition was within allowable limits. The pulse sequence used the PICORE labeling geometry with QUIPSS2 saturation [1] to control duration of the inflowing label. The sequence TR value was 3 seconds, with an echo-time of 25ms and nominal flip angle of 90deg. The interval between inversion and excitation was set to 1.4s, with Q2TIPS saturation pulses terminating the label 700ms after inversion. Five slices of 4mm thickness were acquired on a 128x128 matrix with 1.6mm voxels. Perfusion signals were isolated through pairwise subtraction of control images alternated between the label images, and BOLD signals were derived from the series of control scans.

Subjects (n=3) performed a self-paced finger apposition task during one minute intervals separated by a minute of rest over a total of three periods within a six minute scan. Voxel time-courses for both perfusion and BOLD scans were analyzed by fitting a linear signal model and computing a t-statistic and windowing the displayed data so that values passing a p=0.05 significance were colored yellow to red (Fig 1).

Results

Good functional contrast was observed in both BOLD and perfusion signals, resulting in sensitive and specific maps of hand representation at high spatial resolution, as shown in Figure 1 for one subject. BOLD changes within grey matter were typically higher than 10%. The resting flow map, derived from the DC term of the linear model fit, also showed good contrast-to-noise and excellent depiction of increased flow in the cortical gray matter.

Conclusions

In spite of the potential difficulties described above, our initial experiences with functional ASL with simultaneous BOLD acquisition at 7T have been encouraging. We anticipate that with the addition of a higher performance phased-array receive coil and dedicated neck transmit coil for labeling, further gains in sensitivity and spatial resolution will be possible.

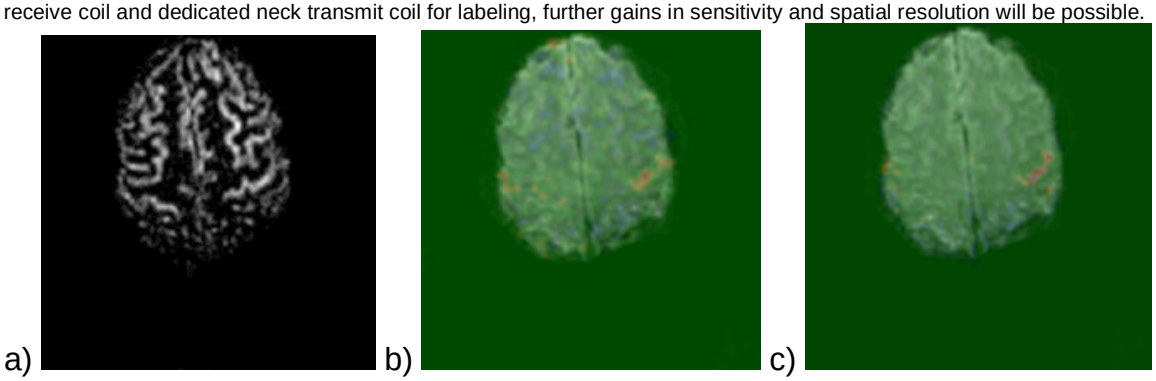

Fig. 1a) Axial perfusion image b) t-statistic map from flow data overlaid on EPI scan c) t-statistic map from BOLD data overlaid on EPI scan. Yellow to red regions in statistical map correspond to $p<0.05$ significance. Image left is subject left.

References

1) E Wong, R Buxton, L Frank. Magn Reson Med. 1998 39(5):702-8