Efficient high resolution fMRI at 7T

A. Nordell[1], S. Holdsworth[2], R. Newbould[2], R. Bammer[2], and S. Skare[2]

[1]Hospital physics, Karolinska University Hospital, Stockholm, Sweden, [2]Radiology, Stanford University, Palo Alto, CA, United States

INTRODUCTION: At increasing static magnetic fields, the T2* decreases. At 7T the T2* in blood and GM is ~7ms and ~25ms respectively [1]. For fMRI studies at lower field strength, the bulk of the BOLD response comes from intravascular signal changes. At 7T, with an echo time larger than the T2* of blood, the signal from extravascular tissue dominates thus the intravascular BOLD response can be neglected [2]. It has been shown that this reduces the spatial extent of the hemodynamic point spread function (HWFM ~2mm) [3], potentially motivating the use of higher imaging resolution. In this work, we have investigated the use of a GRAPPA-accelerated gradient echo short axis readout propeller EPI (GE-SAP-EPI) sequence [4] for fMRI as a means to achieve high spatial resolution images, with reduced distortions and signal dropouts commonly to other fMRI acquisitions used at high field.

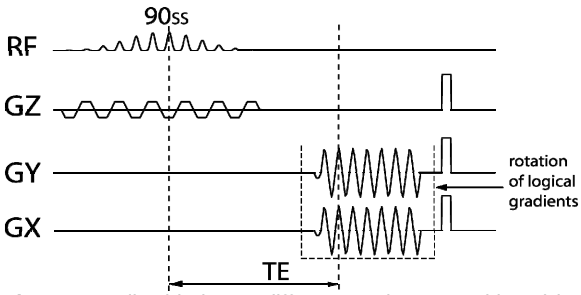

Fig. 1 Propeller blades at different angles are achieved by linear combinations of the phase encoding (GY) and readout gradient (GX) of the Cartesian EPI train.

METHODS: BOLD imaging using SAP-EPI was performed on a volunteer on a GE 7T system (Milwaukee, WI) equipped with a 16 channel transceive head coil (Nova Medical, MA). The stimulus consisted of simple left-handed finger tapping (20s work, 20s rest with a total scan time of 180s). Figure 1 shows the pulse sequence diagram for the GRE-SAP-EPI. The corresponding k-space trajectories are shown in Figure 2. Other parameters were; TR/TE/FA=1000ms/20ms/60deg, $N_x \times N_y$/FOV/sl.th./#slices = 48×192/26cm/3mm/20, a GRAPPA-acceleration factor of R=3, and half Fourier in the phase encoding direction. The target resolution was $N_x \times N_y$ = 202x202 using 5 propeller blades (0, 36, 72, 108, 144˚). Prior to gridding, referenceless image based ghost correction, GRAPPA estimation, and POCS reconstruction were performed on a per-blade basis. Since all blades cross the center of k-space, there is a degree of freedom in selecting the spatial and temporal resolution (e.g. a 64x64 image can be reconstructed at the highest possible frame rate). In this study, data was gridded to four different resolutions (64, 96, 128, 202), with each temporal frame constructed from the five most recent blades. Correlation analysis was performed according to [5].

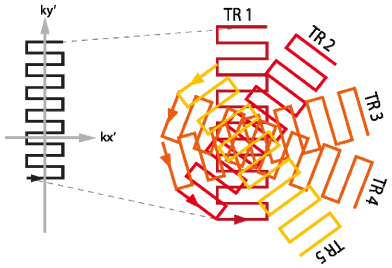

Fig. 2 The SAP-EPI trajectory is shown. A full k-space consists of 5 excitations at different angles, with all trajectories crossing the k-space centre. Full blades are achieved using half Fourier reconstruction. The extent of the half Fourier encoding is decided by the echo time.

RESULTS: Figure 3 shows a single slice of SAP-EPI reconstructed at different resolutions. These slices demonstrate different SNRs with no change in image distortions. Figure 4 shows the activation maps for 5 slices from the motor cortex, each row corresponding to a reconstructed resolution. The correlation coefficient threshold was set to 0.45. With increasing spatial resolution the spatial definition of the activation increases. On visual examination the sensitivity seems sufficient to resolve all activated areas up to the full target resolution of 202x202.

DISCUSSION: Using GRE-SAP-EPI, we have shown that it is possible to obtain plausible motor activation with a voxel size of 1.28×1.28×3mm^3 at 7T. With the TE chosen, low contribution from intravascular signal was achieved. While this work has used a fixed temporal resolution to investigate the SNR vs. resolution trade-off, an interesting benefit with this particular sequence lies in the flexibility to reconstruct the same data with variable spatial/temporal resolutions. It has been shown that the BOLD response from extravascular tissue is similar for gradient and spin echo at 7T. This suggests that Spin Echo BOLD imaging might further increase the spatial resolution at this field strength. Future work includes testing Spin Echo SAP-EPI with a similar resolution to that shown in this work.

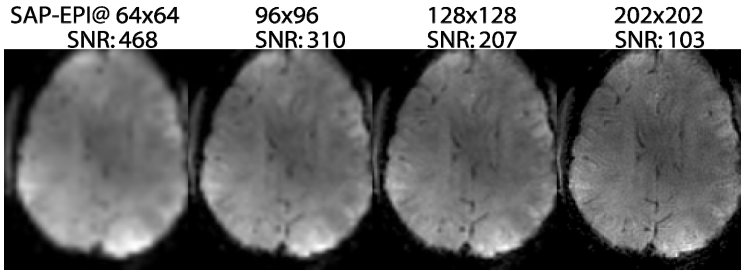

Fig. 3 One frame of the GRE SAP-EPI time course, reconstructed at different resolutions.

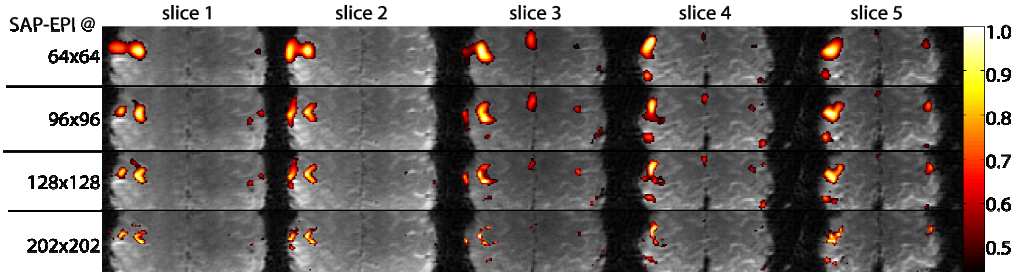

Fig. 4 Activation maps of the motor cortex. The correlation coefficient threshold was set to 0.45.

REFERENCES: [1] Yacoub E et al. MRM 2001;45:588–594. [2] Norris D. JMRI 23:794–807, 2006, [3] Olman CA et al. ISMRM, Kyoto, Japan, 2004, [4] Skare S. et al. MRM 2006;55:1298-1307, [5] Lai et al. MRM 1995 745-754