A novel design 20-channel head coil for cortical imaging with ultra-high resolution.

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Introduction

Innovations in hardware, such as the progression to ultra-high magnetic fields, and sequence development, i.e. accelerated image acquisition have allowed large increases in the resolution available for fMRI. As smaller and smaller (sub-millimeter) voxel sizes become the norm, specialized receiver hardware may be necessary to allow sufficient SNR for functional imaging of the cerebral cortex. We have recently implemented a dedicated half-shell multi-channel head coil with a 20-channel high-density receiver array for 7 Tesla ultra-high resolution imaging in visual cortex. With the goal of performing sub-millimeter resolution EPI we intentionally used a coil for focusing only superficial depths in brain in order to mitigate traditional constraints that drive coil performance by allowing smaller loop sizes in high-density arrays. We compare SNR and tSNR values for our novel coil compared with a whole-brain 32-channel Rx coil and demonstrate fMRI data acquisition.

Methods

TSNR data were collected using zoomed (OVS) simultaneous multi-slice EPI (MB Factor 2, iPAT 2, Matrix Size 256x128, 50 slices, 50% distance factor, flip angle 70, partial Fourier 6/8, TR=3120ms) were collected at two different resolutions, 0.75mm isotropic (TE=27ms, B/W=1085, Echo Spacing=1.05ms, FOV 220x110, ETL 50.4ms) and 0.55 mm isotropic (TE=34ms, B/W=781, Echo Spacing=1.4ms, FOV 160x80, ETL 67.2ms). Data were collected on a 20-channel half shell coil (Virtumed, LLC) and a whole-head 32-channel coil (Nova Coil, Inc) on UCSF-VA 7T Scanner. FMRI data were collected using the same 20-channel coil used for the tSNR comparisons on the CMRR 7T Scanner. Zoomed simultaneous multi-slice EPI data were collected with a resolution of 0.75mm isotropic (MB Factor 2, iPAT 3, Matrix Size 272x208, 60 slices, flip angle 75, partial Fourier 6/8, TR=1500ms, TE=22ms, B/W=1414). Data were collected as subjects viewed a flashing-checkerboard, leading to diffuse activation across visual cortical areas.

Results

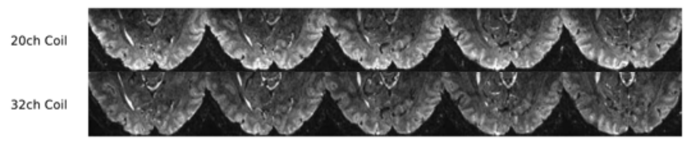

Fig 1: 5 slices collected at 0.75 mm isotropic resolution

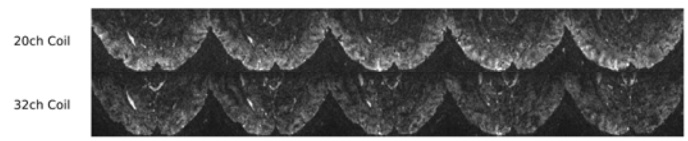

Fig 2: 5 slices collected at 0.55 mm isotropic resolution

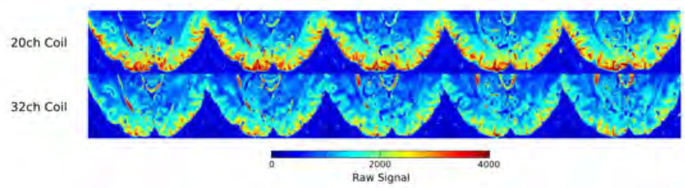

Figure 3: Mean signal at 0.75 mm isotropic resolution

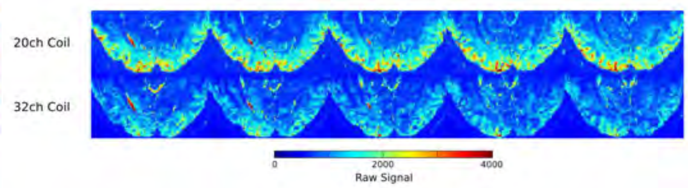

Figure 4: Mean signal at 0.55 mm isotropic resolution

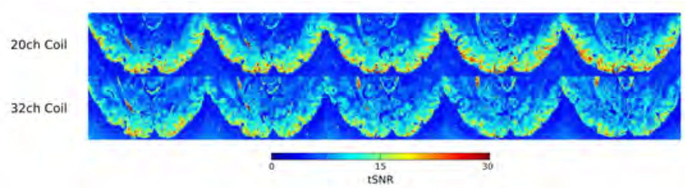

Figure 5: tSNR at 0.75 mm isotropic resolution (scale 0 to 30)

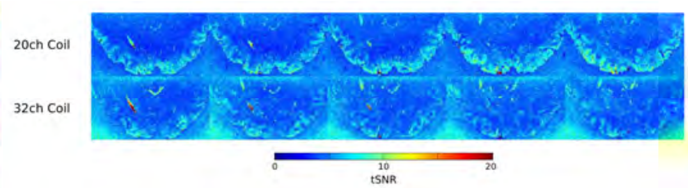

Figure 6: tSNR at 0.55 mm isotropic resolution (scale 0 to 20)

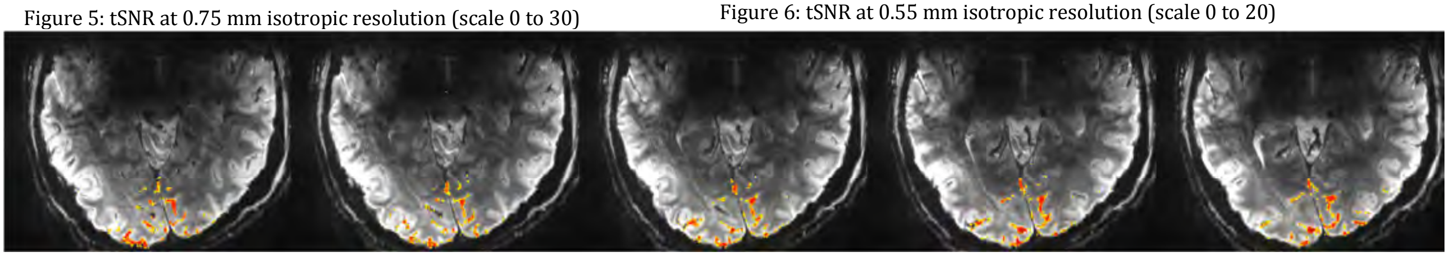

Figure 7: Coherence maps (>0.6) for BOLD activity measured during flashing checkerboard stimulation, with 0.75 mm isotropic resolution.

Discussion

Raw images collected at two different resolutions on the two coils (Fig 1 & 2) shows the greater amount of signal available in cortical areas on the 20-channel coil (upper rows) compared to the 32-channel (lower rows). This increased signal is even more readily apparent in maps of mean signal over time (Fig 3 & 4). This increase in signal increases the tSNR in these areas, with the largest gains found in areas where the available signal is highest, at both 0.75 mm (Figure 5) and to a lesser extent at 0.5 mm (Figure 6). Signal dropped off for deeper brain areas using the 20-channel coil, and tSNR gains were not seen in these regions. Activation maps collected at 0.75 mm for a visual stimulation task show good activation in visual regions, with activated voxels confined primarily to gray matter (Figure 7). It should be noted that the fMRI data were collected using a larger field of view and higher iPAT factor compared to the tSNR data. This was due to faster switching gradient coil (Siemens, AC84) installed on that scanner, allowing a longer echo train without increased TE. Further development of cortex specific coils should allow general benefits in signal and tSNR and for reduced g-factor in simultaneous multi-slice and parallel imaging.

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