Sub-millimeter Single-shot 3D GRASE with Inner Volume Selection for T2 weighted fMRI applications at 7 Tesla

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T_2 weighted BOLD imaging has proven to be beneficial for sub-millimeter fMRI applications in humans at high magnetic fields because of its intrinsic minimization of large vessel BOLD effects, and its enhanced sensitivity to signals from smaller vessels near the tissue (1). Inner-volume (3) segmented 2D SE-EPI has been vital for obtaining sub-millimeter resolutions, however, due to IV orthogonal RF pulses cross-irraditing images, it has not been possible to achieve multi-slice imaging. To overcome this limitation for high resolution fMRI applications, a novel approach combining inner volume with single-shot 3D imaging is proposed.

Materials and Methods

A 7T MR scanner (Siemens) equipped with a head gradient coil, 80mT/m G-maximum, 200mT/m/ms was used with a half volume radio-frequency (RF) coil for transmission, and a small (6 cm) quadrature coil for reception to maximize sensitivity in the visual cortex while maintaining uniform spin refocusing for T_2 weighted acquisitions. Imaging of the occipital lobe in 2 normal volunteers was performed using IV selection with 2D SE EPI (single slice) and 3D GRASE (4) with similar image parameters in order to compare SNR and fMRI performance. Fig 1a shows intersecting RF planes creating SE refocusing in the overlapping 3D 'inner volume' region. The RF plane oriented perpendicular to the Gp, limits the signal extent on the kp axis, thus minimizing the required FOV, in order to obtain high spatial resolutions without aliasing. Sequence parameters: echo train time; 220-250 ms, 41 - 64 echoes per RF period, 4-6 RF refocusings, Total ETL:164 - 384 echoes, $5/8^{th}$ partial Fourier and centric re-ordering on the slice axis, 0.8 ms echo spacing, 256 ADC points per signal. Image Parameters TE $_{effective}$: 45 ms, voxel size 0.5 mm x 0.5 mm x 3 mm (0.75 mm^3), FOV 128 x 32 x 12-18 mm^2, 4 or 6 images per 3D volume, bandwidth 2790 Hz/pixel, TR= 2 s

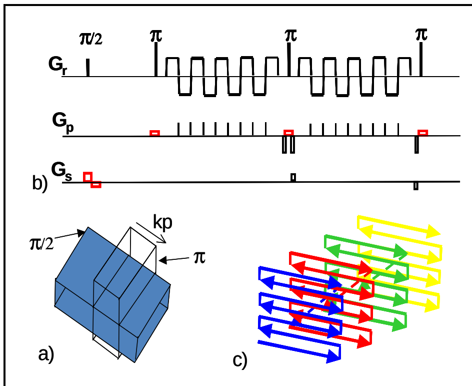
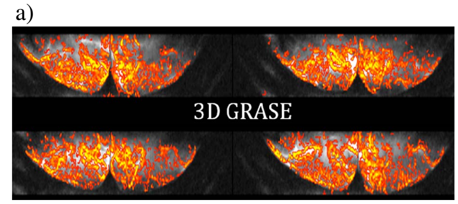


Fig.1 a) Inner volume defined by orthogonal RF volumes, **b**) single-shot IV 3D GRASE sequence, and **c**) 3D linear k-space trajectory.

Results

We were able to successfully obtain 3D T_2 weighted BOLD images at high spatial resolutions (0.5x0.5x3mm^3), in a single shot. The rapid T_2 decay at 7T (55 ms T_2 in grey matter) limited the GRASE acquisition to 4 - 6 RF pulses. Images were acquired during the presentation of a visual stimulus and corresponding fMRI activation maps were generated in 2 subjects. A representative example is shown in Fig. 2. The corresponding averaged time course is shown. In general, the 3D fMRI activation maps were very similar to the 2D single-shot maps as well as to our pervious 2D multi-shot fMRI maps (2).

a)



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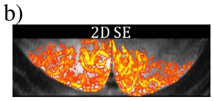

c)

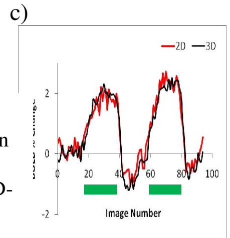

Fig. 2 a) 3D single shot GRASE fMRI activation maps from 4 slices and **b)** the corresponding 2D-SE slice from the same subject.

Discussion

The single shot 3D GRASE sequence demonstrated here is of significant value for high resolution fMRI applications at high fields for several reasons: First, as has been demonstrated previously (1-2) T_2 weighted fMRI contrast at high fields provides improved spatial specificity over lower fields and/or T_2* weighted contrast. Second, previous human high-resolution fMRI studies attempting to exploit the T_2 contrast have been limited to single slice acquisitions, thus, limiting the functional mapping to a two dimensional plane through a 3 dimensional structure. Third, by reducing the acquisition time (over previous segmented acquisitions (1-2)) via improved gradient performance, we were able to achieve these 3D sub-millimeter resolutions in a single shot. This is extremely beneficial for fMRI studies at high fields where physiological (or temporal) noise can be detrimental. In conclusion, our ability to image highly specific functional signals in a single shot over a 3D volume with sub-millimeter in plane resolutions, will facilitate probing the human brain at the level of details needed for a better understanding of the functional organization of cerebral cortex.

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