Rapid High Resolution 3D Volume Imaging of the Human Brain Using Spin Echo EPI, Parallel Imaging, Reduced-FOV Methods, and Oversampling Reduction at 7T

Christopher Joseph Wargo[1] and John C Gore[1]
[1]*Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States*

Purpose

The aims of this research were to develop and evaluate very high-resolution inner volume imaging at high fields in dramatically reduced scan times by combining 3D EPI, parallel imaging, reduced-FOV methods, and oversampling reduction.

Introduction

Three-dimensional (3D) acquisitions are commonly used to image volumes in human MRI studies, and benefit from higher SNR compared to traditional 2D scans. For high-resolution imaging, 3D scan times can become prohibitive, placing constraints on the number of slices, spatial resolution, or volume coverage. 3D scan times are due in part to required over-sampling (OS) of extra slices at the end of volumes to address roll-off of slab selective RF pulses, increasing durations by as much as 40% to 80%. Rapid imaging techniques such as Echo Planar Imaging (EPI) are often used to reduce scan times, but EPI is highly sensitive to susceptibility variations, resulting in geometric distortions, signal dropout, and blurring artifacts that worsen as resolution increases. These effects can be notably reduced by applying parallel imaging methods such as SENSE to diminish the echo train length [1,2], with similar improvements possible by localizing signal using reduced-FOV methods [3]. Applying saturation slabs at the edges of the volume signal further enables reduction of scan times by lowering OS values [4]. In this abstract, we describe the combination of a 3D EPI sequence, SENSE parallel imaging, inner-volume imaging (IVI) for reduced-FOV, and outer-volume suppression (OVS) to diminish oversampling, to rapidly obtain 300 to 500 μm resolution within selected volumes in the human brain in three to seven minutes at 7T.

Methods

Sequence Design - Reduced FOV imaging was accomplished using an inner-volume (IVI) approach with an excitation pulse that is selective in the phase encoding direction and a refocusing pulse that is slice selective with balanced crushers. Suppression of signal at the end of the 3D volume was achieved with an OVS design using two repetitions of frequency modulated RF pulses with a linear FM profile, with 180° and 90° flip angles, respectively. OVS used a single selective gradient, with additional crushers positioned between each set of pulses (figure 1).

Human Imaging - 3D spin echo scan was performed using cartesian EPI readouts in human subjects on a 7T system, with a 32 channel head coil, quadrature volume transmission, and the following scan parameters: TR of 1500 ms, TE of 64 ms, 2 mm thickness, multi-shot EPI factor of 23, SENSE factor of 1.85, and SPAIR fat suppression. In preliminary studies on normal volunteers, the FOV was diminished 3.5 fold to 60x60 mm^2 using IVI. A total of 20 slices and 2 acquisitions were collected at 500 μm resolution with OVS slabs placed at the ends of the imaging volume (figure 1). Scans were repeated with an OS of both 1.0 and 1.4, with and without OVS slabs. 300 μm images were additionally collected using an OS = 1.0 and 1.4, a halfscan value of 0.87, with both multi-shot and single-shot EPI. Scan times were 3m4s for 500 μm, 7m34s for 300 μm multi-shot EPI, and 6m44s for 300 μm single shot EPI (8 acquisitions).

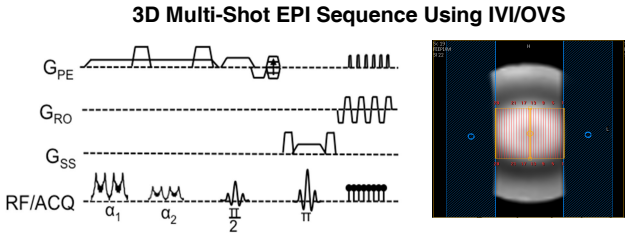

Figure 1 – Pulse sequence containing IVI and OVS prior to EPI, image demonstrating slab placement in a phantom.

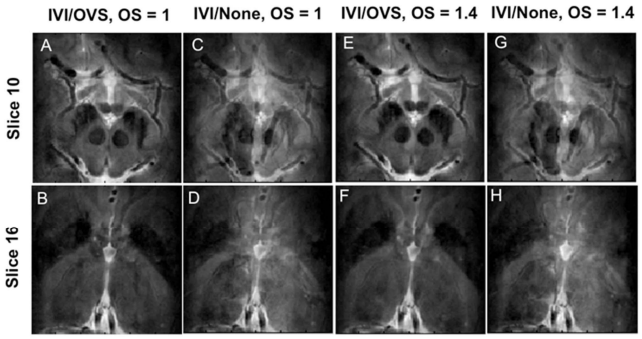

Figure 2 – 500 μm images: A,B) IVI/OVS, OS = 1, C,D) OS = 1.0, no OVS. E,F) IVI/OVS with OS = 1.4, G.H) OS =1.4 no OVS.

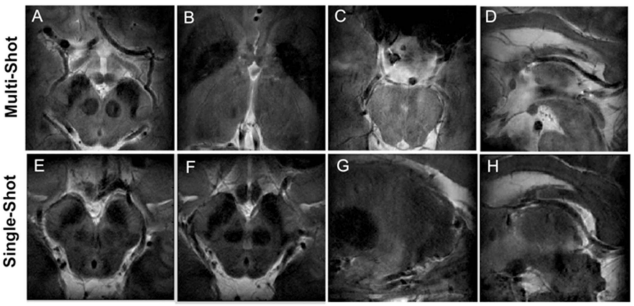

Figure 3 – 300 μm IVI/OVS 3D EPI images: A-D.) multi-shot, OS = 1.0, E-F) single shot, OS = 1.4.

Results

The applied IVI/OVS combination with parallel 3D multi-shot and single-shot EPI produced high SNR, high-resolution images of selected regions of the midbrain, with no visible fold-over or discernable artifactual signals (Fig. 2,3). This was consistent for both 0% and 40% slice OS, at 500 and 300 μm resolutions. Comparatively, scans with no OVS slabs at the volume ends produced notable image corruption at both 0% and 40% oversampling through all slices imaged. FOV reduction combined with SENSE and OS reduction accounted for a 16 fold total reduction in scan time, 372 fold with a multi-shot EPI factor of 23, 1428 fold for single-shot.

Conclusions

The results demonstrate high 3D imaging acceleration to achieve T2 weighting in the human brain at high SNR and spatial resolution using multi and single-shot EPI, parallel imaging, reduced-FOV, and OS reduction at 300μm and 500 μm at 7T. This approach supports rapid high-resolution volume imaging for various ultra-high field studies.

References 1. Pruessmann, *MRM* 42, 952,1999. 2. Speck, *Magma* 21, 73,2008. 3. Feinberg, *Radiology* 156, 743,1985. 4. Hu, Proc. *ISMRM* 18, 2010.