High resolution R_2* maps reveal laminar structure of human visual cortex *in vivo*.

M. Fukunaga[1], M. Bianciardi[1], P. van Gelderen[1], J. A. de Zwart[1], and J. H. Duyn[1]

[1]Advanced MRI/LFMI/NINDS, National Institutes of Health, Bethesda, MD, United States

Introduction

Recently phase images derived from high resolution T_2* weighted MRI at high field strength (ex. 7 T) have been shown to reveal laminar contrast in cortical gray matter (GM) [1]. This contrast is particularly strong in the primary visual cortex of the occipital lobe and allows identification of the line of Gennari (LG), a prominent layer with high myelin content. This contrast and has been attributed to variations in magnetic susceptibility, possibly due to myelin and iron. Since susceptibility variations generally lead to changes in R_2*, we investigated whether the LG has altered R_2* compared to surrounding GM.

Materials and Methods

This study was conducted on a Signa 7.0 T whole-body MRI scanner (GE Healthcare, UK) with head transmit coil and a 32 channel receive only head detector array insert (NOVA medical, Wilmington, MA). Due to a limited number of available receivers, only 10 occipital and 6 frontal coils of head array were used. Four normal volunteers (1 male and 3 female, age: 22-37 years) participated in this study after providing informed consent. High resolution 2D multi gradient echo (GRE) acquisitions were performed with the following parameters: TR=1600 ms, TE=11.4/23.9/36.4/48.9 ms, flip angle: 70 degrees, slice thickness/gap: 1.2/1.0 mm, 20 slices, field of view: 256x96 mm, matrix size: 768x288, SENSE rate: 2 (333 μm in-plane resolution) bandwidth: 125 kHz, total scan time: 7m44s. Twenty axial slices were located throughout the occipital lobe. During the scan, real-time higher order shimming was performed to compensate for B_0 fluctuations related to the respiratory cycle [2]. For the SENSE reconstruction, low resolution 2D GRE acquisitions were performed with the same slice location as the high resolution GRE and with following parameters: TR=800 ms, TE=6.2 ms, flip angle: 45 degrees, slice thickness/gap: 1.2/1.0 mm, 20 slices, field of view: 256x192 mm, matrix size: 128x96, bandwidth: 125 kHz, total scan time: 1m19s. Data processing, including image reconstruction, and calculation of phase and R_2* maps were performed with IDL 6.4 (ITT Visual Information Solutions, Boulder, CO) software. Images were reconstructed using phase-sensitive noise-weighted channel combining. For removing low frequency variation of background phase changes (macroscopic field inhomogeneity), a fifth-order 2-dimensional polynomial fit to the phase data was subtracted from original phase images.

Results and Discussion

The high resolution GRE images at four different echo times showed excellent cortical laminar structure in the visual cortex on all subjects (see example in figure 1). In the phase image, contrast-to-noise-ratio between LG and surrounding gray matter was superior to that in the magnitude image. The R_2* value of GM and LG ranged from 27-32 s^{-1} and 35-40 s^{-1} respectively (figure 2). The frequency difference between GM and LG reached up to 3 Hz (figure 3). The R_2* values and phase shifts were similar for all subjects. The accuracy of these values is expected to be somewhat affected by partial volume effects. While possible sources of local susceptibility difference (leading to R_2* increase and phase shift) in cortical gray matter include iron and myelin concentration differences between laminae, a recent iron extraction study on post mortem brain implicates non-heme iron as the primary source [3]. Therefore, *in vivo* quantitative analysis of local susceptibility variations based on combined analysis of R_2* and phase shifts in cortical gray matter may enhance the study of human fine-scale variations in tissue iron concentration.

References

[1] Duyn et al., PNAS 104:11796 (2007), [2] van Gelderen et al., MRM 57:362 (2007), [3] Li et al., submitted to ISMRM 2008

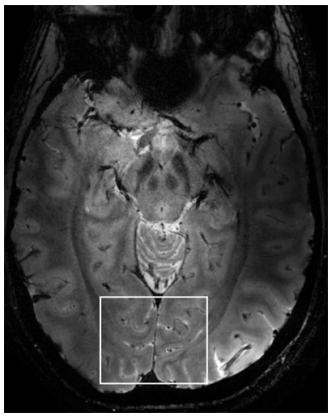

***Figure 1**: Magnitude image of GRE at 36.4 ms echo time. White box indicates zoomed area for figure 2 and 3.*

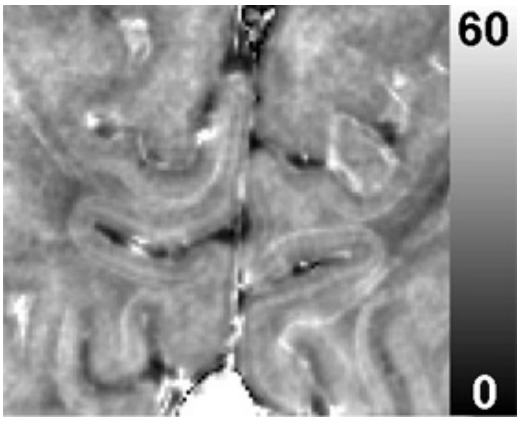

***Figure 2**: Calculated R_2* image (unit: s^{-1}).*

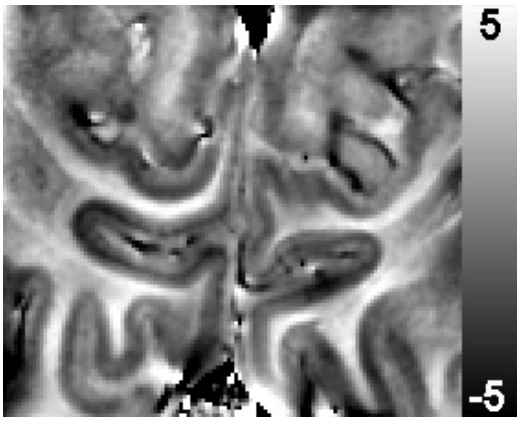

***Figure 3**: Phase image (unit: Hz).*