Human T_2* and Phase Imaging at 9.4 T

J. S. Budde[1], G. Shajan[1], J. Hoffmann[1], F. Muehlbauer[1], K. Ugurbil[2], and R. Pohmann[1]
[1]Max Planck Institute for Biological Cybernetics, Tuebingen, Germany, [2]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, United States

Introduction

Effects due to susceptibility differences of different tissue types scale with the static magnetic field B_0. They cause local magnetic field variations ΔB_0 which lead to shorter T_2* values as well as larger variations of the image phase [1]. Both effects can be used to obtain a contrast in magnetic resonance images, which profits from a higher static magnetic field. This is especially useful since regular gradient echo (GRE) sequences yield a decreased grey matter - white matter contrast for ultra-high field strength. Therefore phase images [2] and T_2* maps could supplement magnitude images for differentiating different tissue types in the brain. In this work, detailed T_2* maps and phase images in the human brain were acquired at 9.4 T, which show excellent tissue contrast, and demonstrate internal structures in white and grey matter.

Subjects / Methods

Images were acquired on a 9.4 T scanner (Magnetom, Siemens, Germany), using an elliptical 16 channel transmit/receive array head coil. The study was approved by the local ethics committee. For the T_2* maps, high resolution 3D GRE images with 5 different TE values (6.0ms, 11.7ms, 14.0ms, 20.0ms, and 27.7ms) were acquired in 4 subjects. Further imaging parameters: TR = 35ms, resolution 0.35mm x 0.35mm x 2mm, BW = 130Hz/pixel, FA 10°, 2 averages, GRAPPA reduction factor r = 2 with 100 additionally acquired lines. The magnitude images were fitted to an exponential curve to determine T_2* values. Phase images were acquired with a 3D GRE sequence. Imaging parameters were: TE/TR = 23ms/29ms, FOV = 180mm x 141.43 mm, resolution 200µm x 200µm x 1mm, BW = 235Hz/pixel, 3 averages, GRAPPA parameters r = 2 with 100 additional lines, FA 10°. Phase data of each channel was filtered with a 2D Gaussian kernel [3]; only voxels with sufficient signal in the magnitude image were used and combined by complex addition. In regions with severe phase wraps, phase images were unwrapped and fitted to a polynomial. Final phase images were combined from filtered and fitted phase images. Ultra-high resolution phase images were acquired with a 2D GRE sequence with reduced FOV of 130mm and a resolution of 130µm x 130µm x 1.5mm. Further imaging parameters were: TE/TR = 20.2ms/500ms, 15 slices, BW = 60Hz/pixel, FA = 40°, 2 averages, and GRAPPA (r = 2, 100 additional lines). Phase images were created by filtering with a 2D Gaussian kernel.

Results

In the T_2* map (Fig. 1, scale ms) GM and WM regions such as the optic radiation, putamen, head of caudate nucleus, and globus pallidus are clearly discernible. The T_2* contrast is not completely homogeneous over the entire image, since changes in the B_0 field due to non-perfect shim cause local variations of T_2*. To obtain mean T_2* values, GM and WM regions in one slice were segmented, and mean values of 27.6ms ± 11.7ms for T_2* in GM tissue and 21.6ms ± 6.2ms for WM tissue were found. In the same subject, regions with high GM – WM contrast were chosen from all slices, from which the average T_2* value was quantified as 27.8ms ± 4.6ms in GM and 19.6ms ± 2.9ms in WM. In the other 3 subjects, GM values of 29.3ms ± 8.6ms, 26.6ms ± 6.2ms, and 29.5ms ± 5.0ms were found. Adjacent WM was determined to have a T_2* of 20.2ms ± 4.4ms, 20.1ms ± 3.5ms, and 21.8ms ± 4.5ms. This gives a rough estimate of about 6 to 9ms difference in T_2* values, and we chose TE = 23ms for optimal contrast in the phase images. A reconstructed phase image in Hz can be seen in Figure 2. Contrast between grey and white matter is excellent, especially in the posterior parts of the brain. There, we segmented grey matter and adjacent white matter and calculated the average phase shift in Hertz of these regions of interest. We found a value of -9.1Hz ± 11.3Hz for grey matter and 6.7Hz ± 8.0Hz for the adjacent white matter, though with quite high standard deviations. Figure 3 shows a zoomed region of the high resolution phase images where lines within the inferior frontal and precentral gyrus can be distinguished. These lines vary in thickness and sharpness. In addition, grey matter generally gets darker towards the inner layers of the cortex. In these images, SNR was only sufficient in the outer parts of the brain.

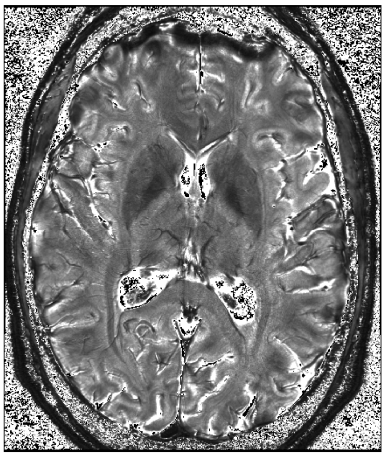

Figure 1: Details from the computed T_2* maps.

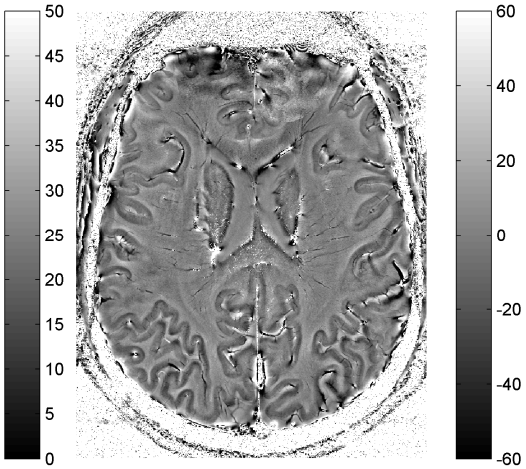

Figure 2: Post-processed phase image.

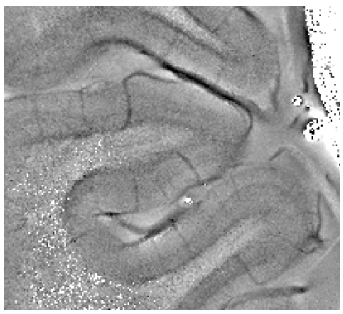

Figure 3: Zoomed region from a high resolution phase image.

Conclusion

In this work, we showed that T_2* maps with high details are feasible at ultra high field and allow the visualization of internal structures. Phase images can be post-processed to yield images with high tissue contrast between grey and white matter. In the high resolution phase images with 130µm x 130µm in-plane resolution, internal structures within the grey matter can be visualized.

References [1] Haacke EM et al, Wiley & Sons, 1999 [2] Duyn JH et al, PNAS 2007;28:11796-11801 [3] Schaefer A et al, NeuroImage 2009;48:126:137