Post mortem quantitative MRI of the human brain in situ using high-resolution multi-echo FLASH

G. Helms[1], W. J. Schulz-Schaeffer[2], A. Wrede[2], N. K. Focke[3], and P. Dechent[1]
[1]MR-Research in Neurology and Psychiatry, Universitymedicine Göttingen, Göttingen, Germany, [2]Neuropathology, Universitymedicine Göttingen, Göttingen, Germany, [3]Clinical Neurophysiology, Universitymedicine Göttingen, Göttingen, Germany

Introduction

Post mortem (pm) MRI may provide the link to establish correlations between in vivo neuroimaging and neuropathology or microanatomy (1). A higher resolution can be achieved without motion artefacts. When performed in situ the intact skull warrants an unaltered topology while avoiding spatial deformations, air interfaces, and severe contrast alterations of fixated specimens. A quantitative multi-parameter in vivo protocol yielding T1, R2* and MT (2) was adapted for pm brain studies. We present initial results on the influence of environmental parameters and physiological pm changes on structural gradient echo MRI.

Methods

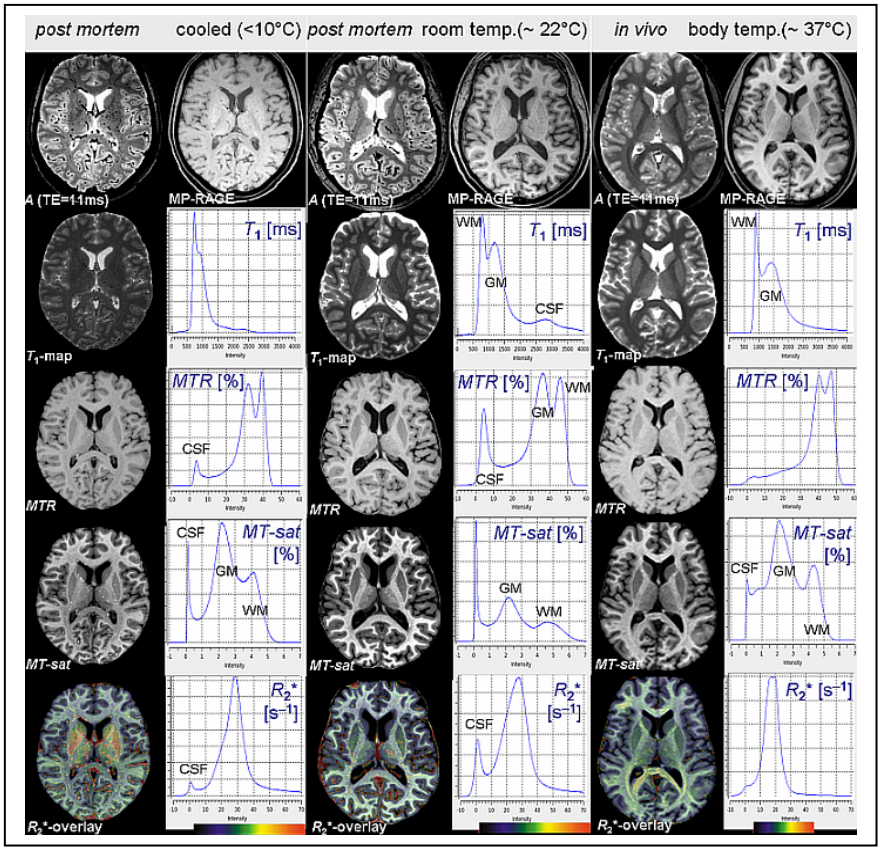
Five deceased individuals (51 to 85 years, 2 male) were scanned in situ on a 3T Siemens TIM TRIO using standard sequences and 8-(or 32-) channel head receive arrays. Two subjects had been previously cooled, the others were at room temperature. Four brains were macroscopically unsuspicious; one case showed multiple infarctions due to septic-embolic encephalitis.
First, a T1-w anatomical dataset at 0.9 mm³ was acquired (3D MP-RAGE) followed by quantitative 3D FLASH (256 sagittal partitions of 320x320 pixels). Eight gradient echoes at TE = 2.46, 4.92, …19.68 ms (480 Hz/pixel, water and fat in phase) yielded the R2* relaxation rate by regression of log signals. Echo-averaging reduced the noise (3) of T1-w (α/TR=20°/23ms), PD-w (proton density, 7°/23ms), and MT-w (10°/38ms with MT-pulse) volumes, taking 10+10+16 mins. Maps of T1, MT-sat(uration) (4), MTR(atio), and the signal amplitude were calculated using FSL 4.1 as in (2). All data was tilted to the commissural plane and interpolated to 0.5 mm. Histograms of parameter maps were plotted after brain extraction. Individual head size determined the resolution (0.7mm or 343µl, 2 averages, 72 mins; 0.65mm or 275µl, 4 averages, 144 mins). Seven healthy adults (25-55 years) were scanned in vivo at 1mm resolution (19 mins).

Results

A massive increase of R2* of blood (130±17 s^{-1} pm vs. venous 49±11 s^{-1} in vivo) over-emphasized vascular details on the amplitude maps (effective TE=11 ms) and shone through even on MP-RAGE images at TE=3.5 ms. The T1-w contrast between gray and white matter (GM/WM) almost vanished in the cooled brains as reflected by progressive merging of the corresponding modes in the T1 histograms. The MT-sat did not change in GM and the high contrast of cortical and deep GM was maintained at room temperature. At low temperature, the MT-sat maps showed a reduced contrast in deep brain. Pixels around major vessels showed high MT-sat. The pm contrast of the R2*-overlay was dominated by high values in vessels, whereas WM bundles dominate in vivo (5) at an adapted color-scale (bottom row).

Discussion

Mapping of the semi-quantitative MT-saturation based on an SNR-efficient multi-echo approach achieved sub-millimeter isotropic resolution (2,3) and helped to overcome the loss of contrast associated with conventional gradient-echo T1-w structural MRI at low temperatures. In particular, maps of MT-saturation are largely independent of changes in R2* and T1 (4,6) and showed unchanged contrast at room temperature. Whether MT-sat in individuals is consistent in vivo and post-mortem remains to be tested. The loss of MT-sat in WM at low temperature is tentatively explained by slower exchange across multiple myelin layers; the vascular "spots" by direct saturation in local field distortions. The reduced MTR in pm brain is likely due to faster T1 relaxation (7) and not to structural changes. T1 alterations can be overcome by spin-echo MRI at long TR, at the cost of limited slice resolution. Since the influence of temperature and structural alterations cannot be separated, control of temperature in pm MRI is strongly recommended.



References

1. Grinberg LT et al. *J Neurol Sci*, 283 2-8, 2009.
2. Gringel T et al. *JMRI* 29(6) 1285-92, 2009.
3. Helms G Dechent P *JMRI* 29(1) 198-204, 2009.
4. Helms G et al. *MRM* 60(6) 1396-407, 2008.
5. Li TQ et al. *MRM* 62(6) 1652-7, 2009.
6. Helms G et al. *NeuroImage* 47(1) 194-8, 2009.
7. Helms G et al. *MRM* 64(1) 177-85, 2010.

Figure

Parameter maps and histograms and MP-RAGE images in deceased subjects (cooled and at room temperature) and a living subject.