Optimization of the MPRAGE sequence for fully automatic brain volumetry and a comparison of reproducibility between two different phased array receiver head coils at 3 T

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Introduction: Regional and global brain volumes are of great interest in many different research projects, not least in Alzheimer's research. The purpose of this study was to optimize the MPRAGE sequence for automatic and reproducible segmentation of human brain tissue. The volume has been calculated for the whole brain and for white matter (WM), grey matter (GM) and cerebrospinal fluid (CSF) respectively. The optimization was performed on a 3 T MRI unit using two different multi array head coils; one 12 channel and one 32 channel. The optimized sequence was then used to evaluate the reproducibility of the volumetric measurements, and compare the results between the two different head coils.

Materials and methods: MPRAGE is a T1 weighted 3D sequence with high resolution showing fine anatomical details of the brain. The high resolution and high T1 contrast makes it a good choice for tissue specific segmentation of the brain [1]. Parameters in the sequence that were changed to adjust the contrast relationships between WM-GM and GM-CSF were flip angle (FA) and inversion time (TI). The contrast relationship between different types of tissue is an important parameter to achieve a successful segmentation. The sequence optimization includes a volunteer study with 9 healthy subjects aged 22-41 (5 men and 4 women) and was carried out on a 3 T Magnetom Trio (Siemens, Medical Solution, Erlangen, Germany). FA of 8-11° were used with TI varying between 700-1000 ms. The study also includes a comparison between a 12 channel- and a 32 channel Matrix head coil and a test of the reproducibility in measurement with the optimized sequence. In the reproducibility study one volunteer was scanned 6 times with each head coil. The volumes were calculated using in house developed software, Brain Map Statistics (BMAP), written on the HERMES platform (Hermes Medical Solutions, Stockholm, Sweden). BMAP is a fully automatic tool for brain tissue segmentation. Image histograms were analyzed for quantification and classification of brain tissue. The images were also evaluated by an experienced neuro-radiologist in terms of tissue contrast for clinical diagnosis.

Results: Contrast differences between WM-GM up to 56% could be found when the contrast parameters of the sequence were changed. It is shown that small FA and short TI results in higher WM-GM contrast. The results from the optimization study shows that the best contrast parameters of the MPRAGE sequence for automatic brain tissue segmentation at 3 T are TI = 850 ms and FA = 8° with both head coils used. For inversion times below 800 ms the CSF signal was too weak for a successful segmentation of CSF. All images acquired with FA and TI in the range of 8-10° and 800-900 ms respectively was approved for clinical use by a neuro-radiologist. The images from the 32 channel head coil was perceived as less noisy than those from the 12 channel head coil but the anatomical information was the same between the two coils (figure 1). The reproducibility study resulted in a coefficient of variation (CoV) $\leq$ 0.3% with the 12 channel coil and CoV $\leq$ 0.5% with the 32 channel coil for the total brain volume and brain parenchymal fraction (BPF). The reproducibility of the specific tissue volume measurements (WM, GM and CSF) was lower; CoV was in the range of 1.5-4.6% with the 12 channel coil and 2.5-6.5% with the 32 channel coil. The largest variations could be found for CSF.

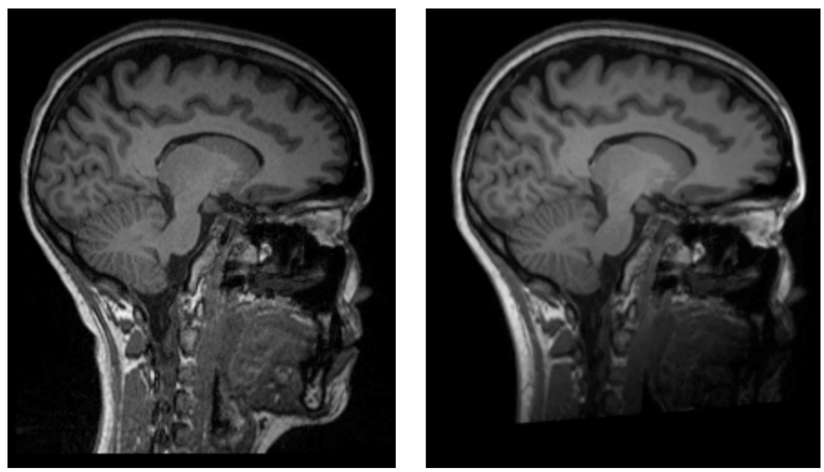

Figure 1. Images acquired with the MPRAGE sequence after optimization of tissue contrast at 3 T. The left image is acquired with a 12 channel head coil and the right image is acquired with a 32 channel head coil.

Discussion: There are two likely explanations for the problems with CSF segmentation. One explanation is the partial volume effect (PVE) occurring extensively because CSF surrounds many small structures of the cortex. Many voxels will contain a mixture of CSF and GM resulting in an averaged signal between these two tissue types. To avoid this problem a small voxel size should be used to minimize PVE. The second explanation is that the CSF signal is close to the signal of bone structures and noise. The intensity threshold parameters in BMAP can be adjusted to minimize the impact of noise and avoid bone structures from being included. The comparison between the 12- and the 32 channel head coils show a larger contrast variation as a function of FA and TI with the 32 channel coil. There was also a slightly deteriorated reproducibility with the 32 channel coil. The most probable explanation for this is signal intensity variations due to non-uniform B1 sensitivity profiles of the receiver coils [2]. These intensity variations have been corrected for in the image post processing using the same configuration for both head coils. It may be possible to improve the reproducibility for the 32 channel coil by adjusting the intensity correction settings to the B1 sensitivity profile of that receiver coil. No other studies about optimization of the MPRAGE sequence for volumetry measurements, also containing a comparison between two different multi array head coils, have been performed. The result from this study, showing differences between the two head coils, is an important finding when analyzing data from longitudinal multisite-studies where different MRI equipment is used. This study also shows that the MPRAGE sequence together with BMAP make automatic brain volumetry possible with good reproducibility for the total brain volume and BPF.

References: [1] Diechmann, R. et al. NeuroImage 12, 112-127 (2000) [2] Leow, A.D. et al. NeuroImage 31, 627-640 (2006)