Anatomical brain scans derived from quantitative T1maps: investigation of SNR, CNR and signal uniformity in comparison to conventional methods

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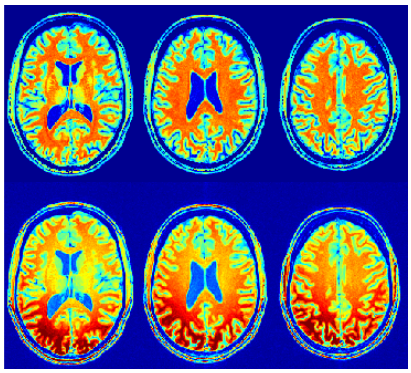
Introduction: Several techniques for studying the brain anatomy are based on T1-weighted magnetization prepared sequences such as MP-RAGE or MDEFT. However, non-uniform coil sensitivities yield an image intensity bias requiring suitable correction [1]. The fast acquisition of quantitative T1 maps with whole brain coverage and high spatial resolution allows for the calculation of synthetic MR images with arbitrary T1 contrast that are free from signal non-uniformities [2]. The goal of the study presented here was (1) to determine the noise level in a T1 mapping sequence presented recently [3], (2) to optimise the conversion of T1 maps into synthetic MDEFT and MP-RAGE images for maximum signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) between white matter (WM) and grey matter (GM), and (3) to test the method *in vivo*, comparing results to SNR and CNR values reported in the literature for standard anatomical sequences [4].

Materials and Methods: *In vivo* MRI measurements were performed on six healthy volunteers using a 3 Tesla whole body scanner (body coil transmission, 8 channel phased array head receive coil). T1 mapping with whole brain coverage and 1 mm isotropic resolution was based on the variable flip angle technique with a spoiled FLASH-EPI hybrid readout for increasing the SNR [3]. Parameters were: matrix size 256x224x160, 1 mm isotropic resolution, TR/TE/FA1/FA2 = 16.4ms/6.7ms/4°/24°, BW=222Hz/pixel, fat insensitive excitation pulses to avoid motion artefacts [5], scan duration 9min 48sec. B1 mapping was based on the technique proposed in [6] (duration 53sec). The total acquisition time for T1 and B1 mapping was 10min 41sec. T1 maps and T1 noise maps (σT1) were calculated as described in [3]. Synthetic MR images were subsequently calculated from $S_{MPRAGE}(T1) = abs(1-2\cdot\exp(-\tau/T1))$ and $S_{MDEFT}(T1) = (1-\exp(-\tau/T1))^2$. The parameter τ influences the contrast and was optimised in each case for maximum SNR and CNR, with $SNR = S/\sigma S = S/[(\partial S/\partial T1)\cdot\sigma T1]$ both for WM and for GM, and $CNR = sqrt(2)\cdot abs(S_{WM}-S_{GM})/sqrt(\sigma S_{WM}^2+\sigma S_{GM}^2)$. For each subject, the synthetic MDEFT data set was segmented using SPM5, and GM and WM masks were created from the respective tissue maps with a threshold of 0.98. Average SNR and CNR values were determined as described above. For comparison with literature values, SNR and CNR efficiencies were calculated (SNR and CNR divided by square root of acquisition time in seconds). Image intensities were investigated histographically, both for the synthetic anatomies and for a typical conventional anatomy which was based on the data set acquired at the larger flip angle for T1 mapping.

Results: The average T1±SD (N=6) in WM and GW was 908±55ms and 1474±49ms, respectively. The respective noise values (σT1) were 28±2ms and 51±3ms. The simulation yielded optimum τ values of 2200ms (MP-RAGE) and 1800ms (MDEFT). The Table shows the average SNR in WM and GM, the resulting average CNR, and the respective SNR and CNR efficiencies for the optimum synthetic MP-RAGE and MDEFT data sets. For reference, average SNR and CNR efficiencies for actual MDEFT and MP-RAGE sequences as reported in the literature [4] are given in brackets. Fig. 1 shows for a single subject three representative slices of the synthetic MDEFT data set (top row) and of the conventional anatomy (bottom row). The synthetic images have considerably better signal uniformity. This is also visible in Fig. 2, showing intensity histograms for GM (dashed line) and WM (solid line) for synthetic MDEFT (red) and the conventional anatomy (black).

	MP-RAGE	MDEFT
WM-SNR	**63**±8	**51**±4
eff. WM-SNR *(lit.val.)*	**2.49**±0.31 *(1.07)*	**2.02**±0.16 *(1.82)*
GM-SNR	**24**±2	**28**±2
eff. GM-SNR *(lit.val.)*	**0.95**±0.08 *(0.71)*	**1.11**±0.08 *(1.20)*
CNR	**14.4**±1.5	**15.3**±1.7
eff. CNR *(lit.val.)*	**0.57**±0.06 *(0.35)*	**0.60**±0.07 *(0.62)*



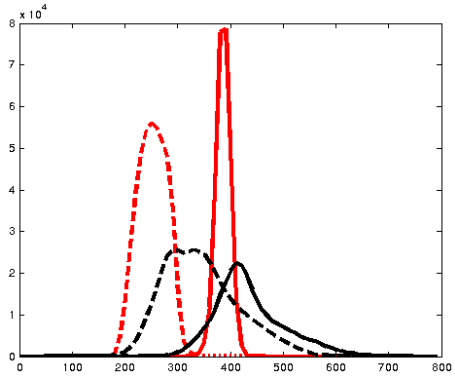


Fig. 1 (left): Synthetic MDEFT anatomy (top row) and conventional anatomy (bottom row).

Fig. 2 (right): Histogram of WM (solid) and GM (dashed) intensities for the synthetic MDEFT anatomy (red) and the conventional anatomy (black).

Discussion and Conclusion: The results confirm that synthetic T1-weighted anatomical data sets based on a fast T1 mapping technique presented recently [3] yield similar or better SNR and CNR values as compared to standard anatomical data [4], providing the advantage of a considerably higher signal uniformity. Another frequent problem in standard magnetization prepared data sets is image blurring due to relaxation effects during the acquisition process. In contrast, the T1 mapping method used here acquires all data under steady state conditions, so it can be expected that the synthetic anatomies do not suffer from spatial blurring.

References: **[1]** Ashburner J et al. 1997, NeuroImage **6**: 209–217. **[2]** Marques et al. 2010, NeuroImage **49**: 1271–1281. **[3]** Preibisch C et al. 2009, MRM **62**: 240–246. **[4]** Tardif C et al. 2009, NeuroImage **44**: 827-838. **[5]** Howarth C et al. 2005, NeuroImage **29**: 930-937. **[6]** Volz S et al. 2010, NeuroImage **49**: 3015–3026.