Evaluation of a template-based B1 field correction approach for 3T MRI brain images

M. A. Castro[1], J. Yao[1], C. Lee[1], Y. Pang[1,2], E. Baker[1], J. Butman[1], and D. Thomasson[1]

[1]Radiology and Imaging Sciences, National Institutes of Health, Bethesda, Maryland, United States, [2]Philips Healthcare, Cleveland, Ohio, United States

Purpose: To evaluate a template-based approach to correct B_1 field inhomogeneity in brain MRI using B_1 maps from other subjects to reduce the acquisition time.

Introduction: Accurate estimation of T_1 maps is increasingly important for some clinical applications. Low noise, high resolution, fast and accurate T_1 maps from MRI images of the brain can be performed using a dual flip angle method [1]. However, B_1 inhomogeneity limits the ability of the scanner to deliver the prescribed flip angle and hence introduces errors into the T_1 map [2]. Obtaining a B_1 map at the time of imaging can correct for this error at the expense of increasing imaging time. In this work, a template-based approach using previously acquired B_1 maps is used to obviate the need for acquiring B_1 maps in each subject.

Methods: T_1 maps were generated using a dual flip angle method (5° and 15°) after rigid registration of two 3D T1W fast field echo (FFE) images, and B_1 maps were acquired using a dual repetition time (50ms and 250ms) strategy with similar sequences [3] on a 3T Philips Scanner (Philips Healthcare, Best, NL) in five volunteers. T_1 maps were computed without B_1 correction and also with B_1 correction obtained at the same scan session to create a "reference" (R) T_1 map. Additionally, each B_1 map was transformed by means of an affine registration algorithm to match the geometry of the other subjects. Afterwards, each T_1 map was also corrected using the other non-subject-specific B_1 maps. The quality of each correction was characterized by the percentage of voxels having a relative difference less than 10% with respect to the reference T_1 map. Intensity histograms were generated for each map and white matter (WM) and gray matter (GM) peaks were computed from a 3-Gaussian fitting. The T_1 value of those peaks was compared in three series: reference T_1 map, best non-patient-specific T_1 map and the average values for the other corrections using a ANOVA single factor test to determine whether or not those series had different mean values.

Results: Histograms of T_1 values when B_1 correction was not used were unimodal, i.e. the two peaks corresponding to WM and GM tissues were not distinguishable. The T_1 histograms when B_1 correction was applied had two distinguishable peaks (Table 1) with relaxation times in agreement with previously reported data [4]: WM from 1000 to 1100 ms and various GM tissues between 1200 and 1700 ms. Fig.1 shows the T_1 histograms for Subject #5 without B_1 correction, corrected using the B_1 map from the same subject, and corrected using the B_1 map from Subject #1, which is the non-subject-specific correction that showed the best performance for that particular subject. In that case corrected maps exhibit similar distributions and 76% of their voxels have intensities that differ in less than 10% with respect to the other map (Table 2). That percentage drops to 28% when comparing the reference map to the non-corrected map. For all subjects, every non-subject-specific correction significantly improved the quality of the T_1 map (Table 2). Figures 2 and 3 show the intensity value of WM and GM peaks, respectively, for the reference (R), best corrected (B) and mean T_1 values of the other corrected T_1 maps (M). Table 3 shows that R and B series do not differ. Although p-values computed when comparing R and M series are not sufficiently small to prove that those series are different, that is due to the small size of the sample and significance could be achieved by considering as many as twice the number of subjects.

Subject	WM	GM	WM	GM
# 1	824	1271	1028	1430
# 2	899	1323	1156	1662
# 3	940	1404	1152	1573
# 4	909	1409	1082	1546
# 5	849	1267	1024	1481
mean ± σ	884±47	1335±69	1088±64	1538±89

Table 1: T_1 (in ms) of WM and GM peaks before (left) and after (right) correction using the B_1 map from the same subject.

Subj.	# 1	# 2	# 3	# 4	# 5
B_1 #1	**100**	50	72	69	76
B_1 #2	64	**100**	72	70	65
B_1 #3	59	50	**100**	70	67
B_1 #4	58	44	74	**100**	62
B_1 #5	65	45	70	66	**100**
No B_1	**22**	**27**	**25**	**28**	**28**

Table 2: Percentage of voxels in a given corrected T_1 map whose relative difference with respect to the reference T_1 map is less than 10%.

	R-B	R-M	B-M
WM	0.923	0.138	0.214
GM	0.608	0.172	0.261

Table 3: p-values of the ANOVA single factor test when comparing reference (R), best correction (B) and mean correction (M) series, for the mean T_1 of both WM and GM peaks.

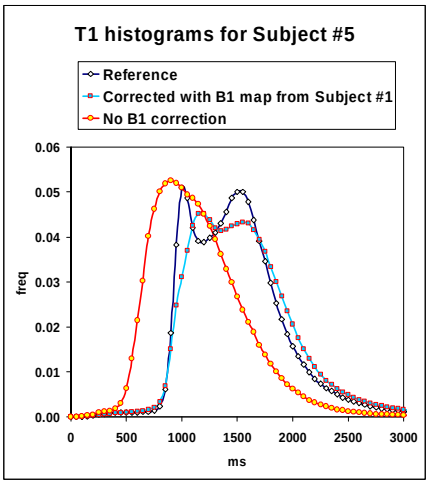

Fig. 1: T_1 histograms for Subject #5, without correction, corrected using the proper B_1 map, and corrected using the B_1 map from Subject #1, which is the best non-subject-specific correction.

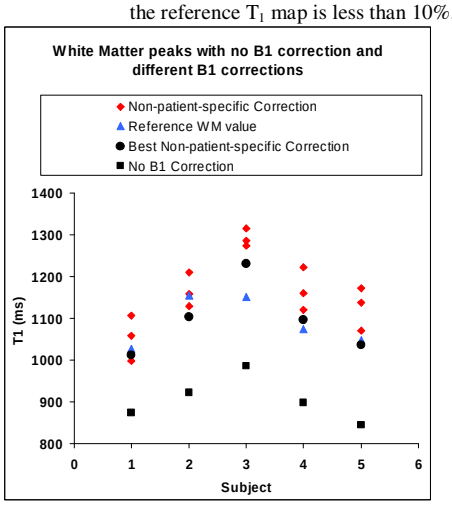

Fig. 2: WM peaks computed from the reference maps, non-corrected map, best corrected map and the other T_1 maps corrected with non-subject-specific B_1 maps.

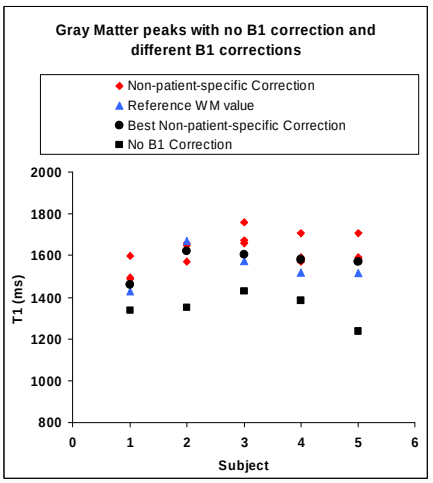

Fig. 3: GM peaks computed from the reference maps, non-corrected map, best corrected map and the other T_1 maps corrected with non-subject-specific B_1 maps.

Conclusion: B_1 correction is essential for any quantitative clinical application based on accurate T_1 measurements, especially at higher magnetic fields. We proposed a method to correct B_1 field inhomogeneity using a template instead of measuring individual B_1 maps for each subject, which has the potential advantage of saving time during clinical acquisitions. Our results show that the best corrections significantly improve the quality of the T_1 maps, which has the potential for clinical applications.

References: 1) Wang, H., S. Riederer, and J. Lee, *Optimizing the precision in T1 relaxation estimation using limited flip angles.* Magnetic Resonance in Medicine, 1987. **5**(5): p. 399-416. 2) Yarnykh, V., *Actual flip-angle imaging in the pulsed steady state: A method for rapid 3D mapping of the transmitted radiofrequency field.* Magnetic Resonance in Medicine, 2007. **57**(1): p. 192-200. 3) Castro, M.A., et al. *T1 mapping with B1 field and motion correction in brain MRI images: Application to brain DCE-MRI.* MICCAI 2008 - Workshop on analysis of Functional Medical Images. 2008. New York, USA. 4) Deoni, S.C.L., *High-resolution T1 mapping of the brain at 3T with driven equilibrium single pulse observation with T1 high-speed incorporation of RF field inhomogeneities (DESPOT1-HIFI).* Journal of Magnetic Resonance Imaging, 2007. **26**(4): p. 1106-1111.