Image inhomogeneity correction in human brain at high field by B_1^+ and B_1^- maps

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Introduction

Images obtained at higher field are advantageous in high sensitivity and good spatial resolution, but suffer from inhomogeneous intensity due to B_1 inhomogeneity derived from RF interference effects and from RF coil design. Recently, it has been reported that transmission and reception fields represented as B_1^+ and B_1^-, respectively differ in spatial distribution even with RF coils for transmission and reception at higher filed (1, 2). A B_1^+ map is obtainable in short measurement time using a phase method (3). However, measurement of B_1^- has not been well pursued.

In this work, we hypothesize that a ratio map of B_1^- to B_1^+ has a similar spatial pattern in various brains from experimental findings and that B_1^- map is expressed as a function of B_1^+ map. We propose a correction method of image inhomogeneity using this relationship. First, we investigated relationship of B_1^+ and B_1^- in human brain through B_1^+ maps and images obtained with adiabatic pulses at 4.7 T. Second, we corrected images by using measured B_1^+ and calculated B_1^-. Third, fractions of water content (f_w) in several regions were measured on corrected M_0 maps using B_1^+ and B_1^-.

Methods

All experiments were performed using a 4.7 T whole-body NMR spectrometer (*INOVA*, Varian). A volume TEM coil with 300 mm diameter was used both for transmission and reception.

Relationship between B_1^+ and B_1^- in human brain: Two dimensional images were obtained using a multi-echo adiabatic spin echo sequence (MASE, 4) through the basal ganglia with varied TE's. The image intensity pixel by pixel was fitted using a formula, $SI = M_{obs}\exp(-TE/T_2)$ where M_{obs} is the product of $M_0(1-\exp(-TR/T_1))$ and B_1^-. The term of $M_0(1-\exp(-TR/T_1))$ in M_{obs} stayed within a range of ±5% in gray and white matters (GM, WM), when we assumed reported values of f_w (5, 6) were applicable as M_0 to our measurements. Thus, M_{obs} map is close to B_1^- map, and a ratio map of M_{obs} to B_1^+ is close to a ratio map of B_1^- to B_1^+. To obtain a ratio of B_1^-/B_1^+, we divided M_{obs} maps with B_1^+ maps in 24 subjects. B_1^+ maps were measured using a phase method (3).

B_1^- calculation and Image correction: The ratio maps of M_{obs} to B_1^+ had similar profiles throughout 24 brains (Fig. 1), thus we hypothesized that ratio maps of B_1^- to B_1^+ have a similar spatial pattern, ρ and that a B_1^- map can be calculated by $B_1^- = \rho \times B_1^+$ in each brain. For obtaining that ratio map of ρ, we calculated a map of $\langle M_{obs}/B_1^+\rangle_{ave}$ averaged among 24 subjects (Fig. 2a). This averaged map is slightly affected by deviations in $M_0(1-\exp(-TR/T_1))$ in GM and WM as mentioned above. Then, this map was fitted with a spatial polynomial function to achieve a more flattened spatial pattern. This fitted spatial pattern was regarded as a ratio map ρ (Fig. 2b). Each M_{obs} map calculated from MASE images was corrected using measured B_1^+ and B_1^- calculated using $\rho \times B_1^+$. Regional fractions of water obtained on M_0 maps after T_1 correction were compared to reported values (5, 6). Spin echo (SE) images (TE/TR = 30ms/500ms) were also corrected by both B_1 maps and relaxation times of T_1 and T_2 using a formula $SI = M_0 B_1^- \sin^3\beta \exp(-TE/T_2)(1-\exp(-TR/T_1))$ where β was a flip angle in excitation pulse.

Results & Discussion

Central region of brain has higher intensity due to RF interference effects at high field in original M_{obs} from MASE (Fig. 3a) and an original image from SE (Fig. 3d). This higher intensity disappeared after a correction using measured B_1^+ and calculated B_1^-, and homogeneous images can be obtained (Figs. 3b, e). A M_0 map calculated from MASE images has a similar pattern as that from a SE image (Figs. 3c, f). Calculated values of f_w in GM and WM were in good agreement with reported values (Fig. 4). Corrected maps from SE have a little higher intensity in right peripheral regions (Figs. 3e, f). This may be caused by a cubic term of sinβ when even a small amount of error in B_1^+ leads to overcorrection.

Conclusions

From experimental findings, B_1^- was related to B_1^+ in spatial distribution. B_1^- can be calculated using B_1^+ map and an experimentally defined ratio map, ρ. Image inhomogeneity in human brain was corrected even at high filed using this relationship.

References

1. Hoult D. I., *Concepts Magn. Reson.* 12, 173-183, 2000., **2.** Van de Morrtele P. F., Akgun C., Adriany G., Moeller S., Ritter J., Collins C. M., Smith M. B., Vaughan J. T., Uğurbil K., *Magn. Reson. Med.*, 54, 1503-1518, 2005., **3.** Park, J-Y, Garwood M., *Proc. Intl. Soc. Mag. Reson. Med.*, 16, 361, 2008., **4.** Mitsumori F., Watanabe H., Takaya N., Garwood M., *Magn. Reson. Med.*, 58, 1054-1060, 2007., **5.** Randall L. O., J. Biol. Chem., 124, 481-488, 1938., **6.** Gelman N., Ewing J. R., Gorell J. M., Spickler E. M., Solomon E. G., *Magn. Reson. Med.*, 45, 71-79, 2001.

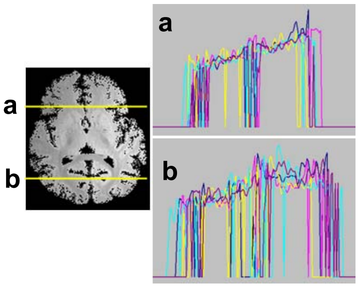

Fig. 1. Profiles (a, b) in ratio maps of M_{obs}/B_1^+ obtained from 5 volunteer's images.

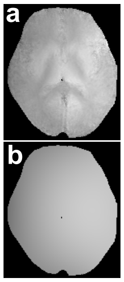

Fig. 2. A map of $\langle M_{obs}/B_1^+\rangle_{ave}$ (a) and a ratio map of B_1^-/B_1^+ (ρ) calculated by fitting of $\langle M_{obs}/B_1^+\rangle_{ave}$ (b).

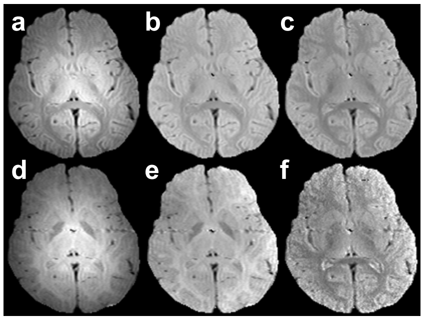

Fig. 3. Images from MASE (a, b, c) and from SE (d, e, f). a,d: original, b,e: B_1 corrected, c,f: M_0 corrected by B_1^+, B_1^-, T_1 and T_2.

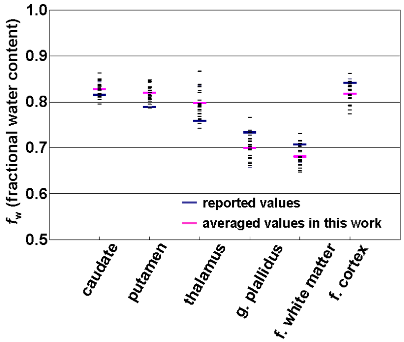

Fig. 4. Individual and averaged values of fw on M_0 maps (n = 22) and reported values were plotted.