A Brain Phantom Composition for MR Applications Evaluation

C. C. Guclu[1], T. W. Skloss[1], R. M. Vavrek[1], R. Becerra[1]
[1]MR System Engineering, GE Medical Systems, Waukesha, Wisconsin, United States

Introduction

The phantoms used for everyday quality control may not be sufficient for MR application evaluation. For example, most brain phantoms reported in literature mimicked the T1 and T2 behavior of the white and gray matters. However, the importance of proton density is rarely emphasized [1]. In this work, we demonstrated the possibility of designing a more realistic human brain gel phantom, and compared the results with human scans using T1-weighted images. It is further shown that using the phantom solutions described, it is possible to observe and optimize the flip-angle for maximum T1 contrast in T1-weighted sequences [2].

Theory

The T1and T2 relaxation times, and hydrogen proton density for human brain white matter and gray matter vary across the patient population [3]. However, average values for white matter have been empirically determined to have a T1 of 600 ms and a T2 of a 90ms at 1.5T. Average human brain gray matter has been determined to have a T1 of 1000ms and a T2 of 100ms. The amount of nickel chloride and agarose gel powder determines the T1 and T2 relaxation times, respectively [4,5]. Potassium sorbate operates as a preservative to sustain the life span of the gels and as such, has equal concentrations in both the white matter and the gray matter. Deuterium oxide (D_2O,) water with two deuterium atoms instead of hydrogen, displaces the hydrogen proton density and used to adjust the proton densities of the phantoms to match the white matter and gray matter.

Methods

The experiments were run on a 1.5T GE Excite Lx scanner (GE Med. Syst. Milwaukee, WI). The test phantom was constructed of a gridded structure that supported two sets of tubes (Fig.1). The tubes contained a mixture of nickel chloride, agarose gel powder, potassium sorbate, deuterium oxide, and water such that the T1, T2, and proton density values of the first and second group of tubes mimiced white matter and gray matter of the human brain, respectively. The tubes of the white matter contained 1.532 mM nickel chloride ($NiCl_2$), 1.09% by weight agarose gel powder, 0.1% by weight potassium sorbate, 35% by volume deuterium oxide (D_2O), and 65% by volume water. The tubes of gray matter contained 0.904 mM nickel chloride ($NiCl_2$), 0.95% by weight agarose gel powder, 0.1% by weight potassium sorbate, and 20% by volume deuterium oxide (D_2O), and 80% by volume water. Two sets of phantoms (with and without D_2O doping) were scanned using a T1-weighted SE sequence (TR=500, TE=20, 256x192 matrix, 16kHz BW, 5mm slice, 15 slices-interleaved, 2 NEX.) The flip angle was varied from 50º to 100º. The SDNR (also referred as CNR) was measured as, $SDNR = (S_{WM} - S_{GM})/\sigma_{BG}$, where σ_{BG} is the noise in the background [6]. Small circular ROIs were used to measure the average signal within the ROI (S_{WM} and S_{GM}.) Similarly, volunteer scans on axial plane were acquired by varying the flip angle.

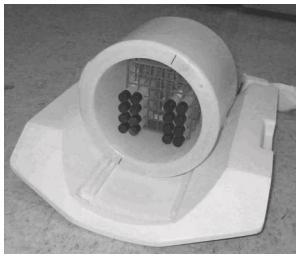

Figure 1: The preliminary structure of the phantom: array of culture tubes.

Results

Fig.2 compares two phantoms: (i) generic H_2O phantom simulating T1-T2 only, and (ii) the D_2O-doped phantom simulating T1-T2 and PD as reported in this study. A sample human brain data is also included in the plot. It is clear that SDNR as a function of flip-angle of the D_2O-doped phantom is closer to that of human brain than the H_2O phantom in which the PD difference is not accounted for. The discrepancy in the magnitude of the SDNRs is due to the T1-T2 variations across the patient populations, and can easily be compensated by modifying the phantom composition.

Conclusion

A new phantom composition was developed and used to mimic the white matter and gray matter T1, T2 and proton density. It is also shown that this phantom can be used to determine the optimum flip angle to maximize T1 contrast in T1-weighted sequences. The exact values for the white and gray matter compositions depend on the human brain characteristics to be mimicked. Although in this study we mostly concentrated on the properties of the brain, similar phantom compositions can be used for other tissue types.

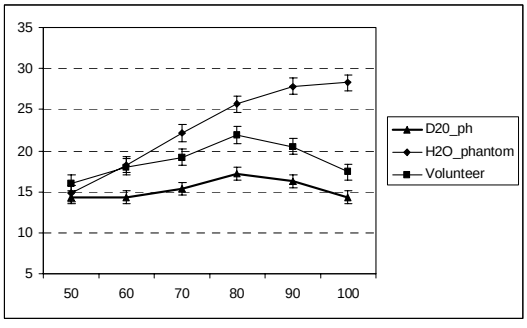

Figure 2: Comparison of CNR for D_2O-doped phantom, H_2O+Gel phantom, and human brain. (vertical axis is unitless , horizontal axis is flip-angle in degrees).

References:

1. S. Gutteridge et al. MRM 47 :871-879, 2002.
2. CC Guclu et al. Proc ISMRM 2002, abs# 1296.
3. PE Cowell et al, Proc ISMRM 2002, abs# 1311.
4. MD Mitchell et al. Mag Res Im. Vol 4:263-266, 1986.
5. PA Bottomly et al. Med Phys 11:425-448, 1984.
6. SD Wolff and RS Balaban, Radiology 1997 ;202 :25-29.