Optimization of 3-D MP-RAGE for Neonatal Brain Imaging at 3.0 Tesla

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Synopsis

Using the known T1 values for neonatal brain tissue at 3.0T, contrast between white matter and gray matter has been simulated for the 3-D magnetization-prepared rapid gradient-echo (MP-RAGE) sequence. Phantom studies show that theoretical contrast is in close agreement with experimental contrast. *In vivo* studies show that high quality 3-D images can be obtained in 6.5 minutes. This is the first report of contrast optimization for the MP-RAGE sequence in neonatal brain imaging as well as the first report of *in vivo* 3-D MRI brain imaging in neonates at 3.0T.

Introduction

MRI measurements of regional brain volumes in neonates correlate well with long-term cognitive outcome.[1] Accurate volume measurements require 3-D images with good contrast between tissues such as gray matter (GM) and white matter (WM). Previous studies have shown that contrast in neonatal brain is very different from adults at 3.0T. Not only is the contrast between GM and WM reversed, but also relative T1 differences between these two tissues is much less in neonates. For example, $T1_{FGM}/T1_{FWM}$ ~ 2 for adults[2] whereas $T1_{FGM}/T1_{FWM}$ ~ 0.8 for neonates[3], where $T1_{FGM}$ and $T1_{FWM}$ are T1 values for frontal gray matter and frontal white matter, respectively. Therefore, contrast optimization is particularly important for neonatal studies of regional brain volumes. Presented here are numerical simulations that allow optimization of contrast (defined as the difference in signal intensity between GM and WM) for a given imaging time using the 3-D magnetization-prepared rapid gradient-echo (MP-RAGE)[4] sequence. In addition, phantom work exploring the accuracy of the simulations and sample optimized *in vivo* images are presented.

Methods

Phantom Studies: Contrast was simulated, using equations similar to those previously reported for 3-D MP-RAGE[5], for a distilled water solution phantom with two components having T1 values of 2700ms ([$MnCl_2$ = 0mg/L]) and 1700ms ([$MnCl_2$ ~ 5mg/L]). These T1 values are close to the values for neonatal WM and GM, respectively. 3-D images of the phantom were acquired using T1-weighted MP-RAGE with an inter-segment repeat time (TRseg) of 5200ms and TI = 250, 500, 750, 1000, 1250, 1500, 2000, and 3000 ms. Experimental contrast results were compared to the theoretical curve.

Neonatal Studies: In order to determine appropriate values for TI and TRseg, simulations for neonatal brain were performed using typical T1 values ($T1_{WM}$ ~ 2600ms, $T1_{GM}$ ~ 1900ms) and proton density (PD) values (PD_{WM} ~ 0.94, PD_{GM} ~ 0.89) of neonatal WM and GM found from our previous work[3]. Following this optimization, 3-D images were acquired from several neonates who had been referred by a neonatologist because of suspected neurological injury. In order to obtain maximum contrast in a clinically acceptable time (approximately 6.5 minutes), a centre-out acquisition of the MP-RAGE sequence was used with TRseg = 5200 ms and optimal TI as determined from simulations. Other sequence parameters included TR = 10 ms, TE = 5 ms, BW = 33.3 kHz, flip angle = 10 degrees, matrix size = $120 \times 120 \times 75$, and FOV = $160 \times 160 \times 100$ mm giving an isotropic resolution of 1.3 mm.

Results

From phantom studies, it was determined that there is a reasonable agreement between the experimental and theoretically expected contrast (Figure 1). Numerical simulations of the T1-weighted MP-RAGE signal for neonatal brain (Figure 2) allowed us to predict optimal inversion times for given total imaging times. Simulations of the MP-RAGE signal, using typical values of T1 for neonatal WM and GM, showed that TI = 2250 ms would be optimal when using TRseg = 5200 ms (Figure 2). Sample 3-D images are shown from premature infants (35 weeks (Figure 3a) and 36 weeks (Figures 3b and 3c) post-conceptual age at scan). These images clearly illustrate cortical GM and deep GM structures.

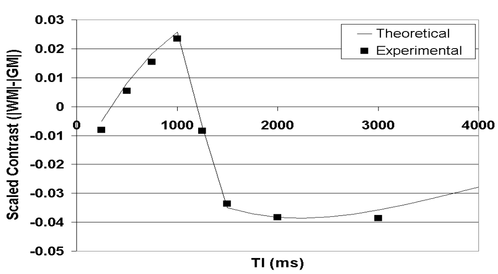

Figure 1: Comparison between theoretical and experimental contrast for phantom (TRseg=5200ms)

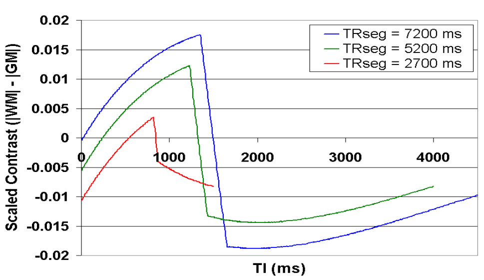

Figure 2: Calculated contrast between WM and GM assuming typical T1 values for these tissues

References

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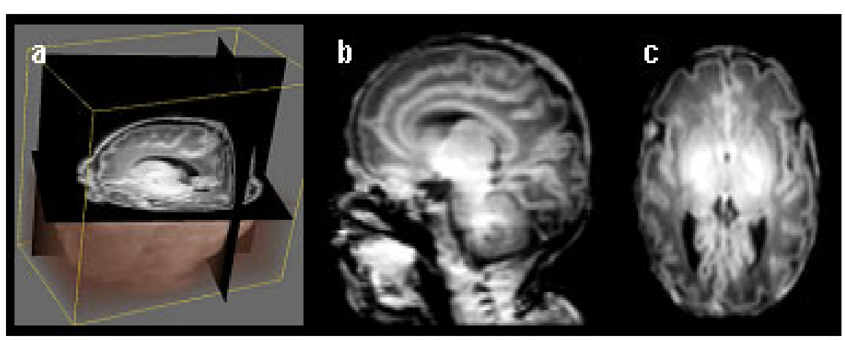

Figure 3: Sample 3-D images of premature infant brain