

Optimized, T1 weighted MPRAGE images at 3T identify several primary areas in individual brains

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Introduction: Cortical organization can be studied on the basis of anatomical features including myeloarchitecture which is the density of myelinated fibers in gray matter. With recent advances in MRI, it is now possible to visualize myeloarchitecture *in vivo*¹. There is much less myelin in the cortex than in the fiber tracts in the brain meaning intracortical contrast is difficult to obtain. Thus, studies of complete myeloarchitecture in humans have focused on group averaged data² or data acquired at higher fields³ than are typically used in clinical imaging. Here, we optimize a sequence specifically to generate strong intracortical contrast to visualize myeloarchitecture in individuals using clinically relevant protocols.

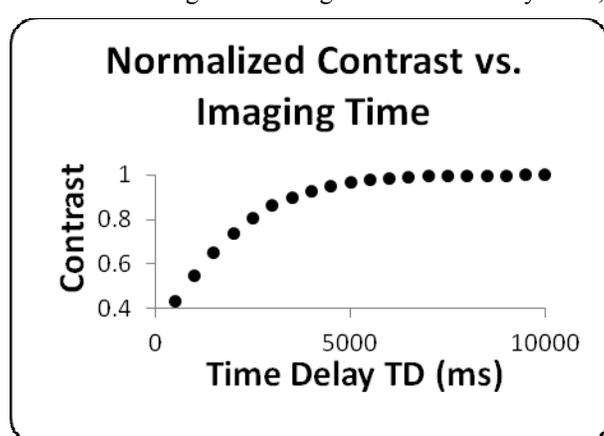
Theory: We are investigating intracortical contrast arising from T₁ shortening in highly myelinated areas of the cortex⁴. We consider a T₁-weighted MPRAGE that consists of an inversion pulse, followed by inversion time TI for partial recovery of longitudinal magnetization, a low angle gradient echo acquisition block, then a time delay TD before the sequence is repeated. The parameters which can be varied in this sequence to alter contrast are TI and TD; it is standard to optimize TI for imaging, but keep the TD short. Here, we are investigating the effect of lengthening TD on contrast. Ideally, we would like to use T₁ and ρ values measured in highly myelinated and unmyelinated cortex in humans to model intracortical contrast. No such data however, is available from our lab or in the literature yet; hence, we are modeling the gray-white (G-W) matter contrast assuming that intracortical contrast will follow the same trend. We have simulated G-W matter signal and contrast; based on published signal equations⁵ using T₁ and ρ values for these brain tissues at 3T from the literature⁶. We have calculated the dependence of contrast on TD using the TI for each value that produces maximum G-W matter contrast. We have assumed the following parameters: flip angle= 12°, matrix= 240x200x160, FOV= 24cm x 24cm x 16cm, resolution= 1 mm isotropic, segments = four, TE = 6.3 ms, TR = 8.3 ms, NEX = 1, imaging time = 25 min. We have found that in the range 0-5000 ms, contrast increases with TD. Once TD is beyond 6000 ms, the contrast curve shows saturation (See Figure (1)). Optimum values of TI were in the range 700-1000 ms.

Methods: We have scanned four individuals using the optimized MPRAGE on a 3T Phillips scanner (TI=1000 ms, TD = 700 ms and all other parameters as considered in the simulation). In one case, we imaged the occipital cortex alone to capture the primary visual cortex (V1) characterized by the very thin but highly myelinated Stripe of Gennari. This scan had all the same parameters as given before, but with a smaller FOV = 10 cm x 20 cm x 16cm, matrix = 200 x 400x320, NEX = 4, isotropic resolution of 0.5 mm and imaging time = 60 min. For comparison, we also made MPRAGE anatomical images, typical of the type used for image segmentation, with the following parameters suggested for use with the FreeSurfer package⁷(flip angle= 7°, matrix = 240x200x140, 1 mm isotropic resolution, segments = 1, TE = 3.48 ms, TR = 2530 ms, NEX = 1, TI= 1100 ms, imaging time=7.5 min,).

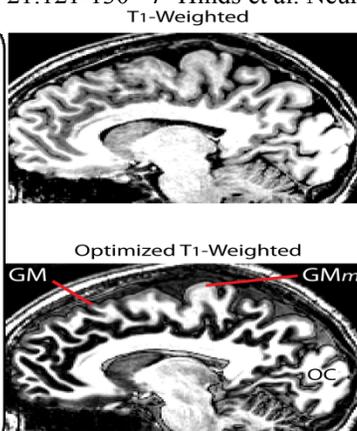
Results: Figure (2) shows that use of optimized sequence not only produces better G-W matter contrast, it also brings out highly myelinated cortex (labeled as GMm in the figure). Figure (3) shows the result of surface extraction on one subject's optimized MPRAGE image. It shows that many primary areas such as the motor cortex (M1)², the somatosensory cortex (S1)² and auditory cortex (A1) can be delineated on anatomical scans, based on intensity variation caused by myelin. Furthermore, as shown in the lower part of this figure, V1 can also be demarcated on the high resolution scan.

Conclusions: TD can be varied to obtain more contrast in T₁-weighted MPRAGE images. Anatomical scans obtained with optimized T₁-weighted MPRAGE can reveal cortical organization based on myeloarchitecture of the cortex.

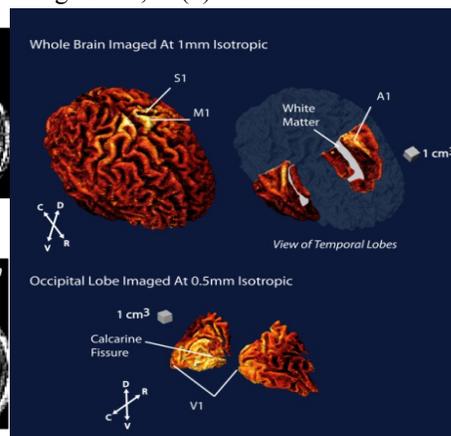
References: 1- Barbier et al. *MagResMeth*, 2002; 4:735-738. 2- Van Essen et al. *Jour Neuroscience* 2011; 31(32):11597-11616. 3- Geyer et al. *ISMRM-2011* p-2360. 4- Bock NA et al. *Jour Neuroscience*, 2009; 185(1):15-22. 5- Deichmann et al. *Neuroimage* 2000; 1:112:27. 6- Wright et al. *Magn Reson Mater Phy* 2008; 21:121-130 7- Hinds et al. *Neuroimage* 2009; 46(4): 915-922.



Figure(1)



Figure(2)



Figure(3)