Fast Three-Point Approach for Volumetric T1 Mapping

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Introduction: Volumetric mapping of the longitudinal relaxation time may be accomplished using multiple spoiled gradient-echo measures at different flip angles and / or TRs. While rapid and accurate T1 mapping has been demonstrated with two-point approaches using a single pair of flip angles, the use of such methods is limited at higher field strengths due to increased B1 inhomogeneity [1]. A three-point approach using data acquired at two different TRs and flip angles can compensate for inaccuracies in the transmitted flip angle, and has been shown to produce accurate whole-brain T1 maps at 1.5 T with an acquisition time of 29 minutes [2]. This relatively long acquisition time is a result of long TRs used to produce high SNR images needed for accurate T1 mapping. In this work, we explore the application of such a three-point approach towards rapid T1 mapping at 3 T. In addition to shorter TRs made possible by increased SNR at 3T, we aim to further reduce TR while maintaining strong T1 accuracy over a range of interest. While short TRs affect the ability to accurately measure long T1s, many biological tissues have reported T1 values between 1000ms-1200ms at 3T, with post-contrast T1 shortening on the order of hundreds of milliseconds [3, 4]. Here we investigate T1 mapping at 3T using this fast three-point (FTP) approach focused on a range of 300ms-1200ms and present first results in a phantom as well as whole-brain pre- and post-contrast T1 maps from a volunteer.

Methods: Experimental measurements were acquired on a 3T Philips Achieva System (Philips Medical Systems) using the transmit-receive birdcage head coil. A phantom was prepared using 19 samples of distilled water with varying concentrations of $MnCl_2$ (Sigma-Aldrich). Reference T1 values for the samples were obtained using a single-slice IR sequence (TE = 15ms, TR = 4000ms, TI = 50, 100-1000 every 100ms, 1250-3000 every 250ms). T1 was estimated by using a linear least squares fit to the data. Three 3D gradient echo volume measures were captured (TE = 1.9ms, Voxel size = 1x1x2mm, FOV = 180x180x50mm; point 1: TR = 10, flip angle = 10; point 2: TR = 20, flip angle = 10; point 3: TR = 20, flip angle = 20). Voxel-wise TR ratio and flip angle ratio images were obtained and T1 was calculated from a two-parameter fit using the Gauss-Newton method (as described in [2]). Linear regression was performed between measured FTP data and reference T1 values. To validate the technique in vivo, we obtained informed consent from a volunteer to perform whole-brain T1 mapping in order to measure T1 in white matter (1084ms+/- 45 reported [3]) before and 10 minutes after administration of 10mL of Gadovist (Bayer Healthcare). Volunteer data was acquired using 3D gradient echo measures with TR and flip angle points as above (TE = 1.92, FOV = 240x240x100mm Voxel size = 1x1x2mm, total acquisition time of 5 minutes per volumetric T1 map).

Results: Linear regression of the phantom data returned an R-squared value of 0.9967, with a best fit line of 123.9ms +/- 0.12 offset and a slope of 0.723 +/- 0.002 (Figure 1). Corrected T1 values had error less than 6% across all samples in the 300ms-1200ms range, with a mean error of 1.89%. The volunteer data returned white matter T1 values of 1089.3ms +/- 37.77 pre-contrast and 792.04ms +/- 14.36 post-contrast, showing strong agreement with reported pre-contrast values (1084ms +/- 45) and consistent with reported post-contrast T1 shortening observed in tissue at 3T [4] (Figure 2).

Discussion and Conclusions: We present here a method of measuring T1 values at 3T with moderate spatial resolution (1x1x2mm) whole brain coverage in less than 5 minutes. The work, validated in phantom studies, is a promising and easily implemented method of rapidly acquiring accurate quantitative T1 maps at 3T. While its accuracy is limited to a prescribed T1 range, this range can be extended as necessary by increasing TRs to provide the higher SNR needed for fitting of longer T1s. Furthermore, as the T1 fit is dominated by the lower SNR short TR acquisition, parallel imaging may be used in the high SNR long TR acquisitions to reduce the time without a concomitant reduction in accuracy.

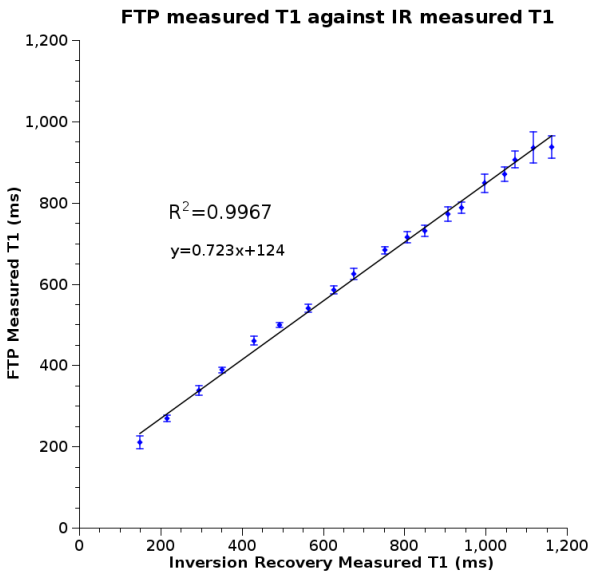

Figure 1: Linear Regression between FTP method and least squares fit inversion recovery data. The values are highly correlated with the gold standard data, however, with a slope of 0.723 and an offset of 124ms.

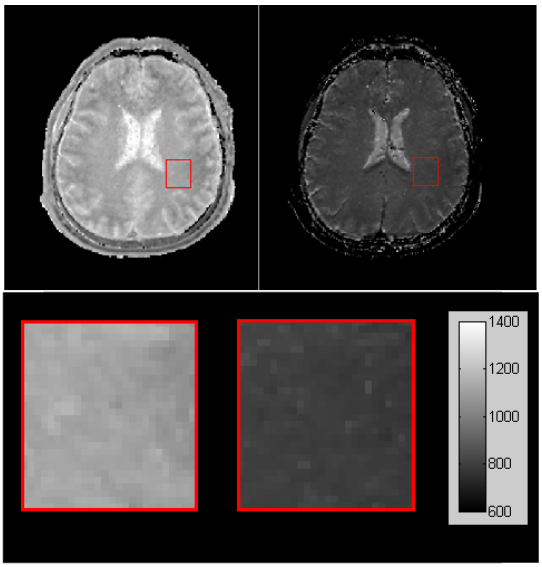

Figure 2: Representative slice of a T1 map on a volunteer at 3T pre-contrast (top left), and post-contrast (top right). Corresponding regions of interest are shown for the pre-contrast (bottom left) and post-contrast (bottom right), showing visible T1 shortening in white matter. Data was acquired in 5 minutes for full brain coverage, with pre-contrast values of white matter in strong agreement with previously reported values (1089ms +/- 37.7 vs. 1084ms +/- 45[3]).

References 1.Deoni SCL et al. MRM 49:515-526 (2003) 2.Mihara H et al. J. App. Physics 97:10E107 (2005) 3.Stanisz GJ et al. MRM 54:507-512 (2005) 4.Sharma P et al. JMRI 23:323-330 (2006)