NIST/ISMRM MRI System Phantom T1 Measurements on Multiple MRI Systems

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Introduction: Accurate T1 relaxation time measurement is critical for many quantitative MRI applications. An MRI system phantom has been developed through collaboration between the ISMRM Ad Hoc Committee on Standards for Quantitative MR and the National Institute of Standards and Technology (NIST). The system phantom has SI-traceable components and is being monitored by NIST for stability and accuracy. We used the system phantom to assess T1 relaxation time measurement variation across MRI systems at the same field strength. We asked: 1) how does measured T1 relaxation time compare to the known T1; 2) is there variation in the measured T1 relaxation time across multiple MRI systems; and 3) how do inversion recovery (IR) and variable flip angle (VFA) methods compare?

Methods: The system phantom, as shown in Fig. 1, is a 200 mm spherical phantom filled with undoped water which consists of the following elements: 1) fiducial, T1, T2 and proton density arrays; and 2) resolution, slice profile, and SNR inserts. Two prototype system phantoms were imaged at MD Anderson Cancer Center, Massachusetts General Hospital, and the Intermountain Neuroimaging Center using 1.5 T and 3.0 T scanners from multiple vendors. T1 arrays were created by doping deionized water with $NiCl_2$. The study included T1 estimation by inversion recovery (IR) using 2D FSE-IR and variable flip angle using 3D FSPGR. The T1 data was fit using custom software (Phantom Viewer, developed at NIST).

Each site was allowed to select their own parameters for IR and VFA acquisitions; thus, there is some variation in the parameters. For IR acquisitions: in-plane resolution was 1-2 mm^2; slice thickness was 6-8 mm; TR was 4000-4500 ms; TE was 6-13 ms; and inversion times ranged from 22 to 4500 ms with 6 to 11 inversion times. For VFA acquisitions: in-plane resolution was 1-2 mm^2; slice thickness was 3 mm; TR was 7-12 ms; TE was 1.3-2.4 ms; and flip angles ranged from 2 to 30 degrees with 6-8 flip angles.

Results: T1 relaxation times measured by IR (Fig. 2) have good agreement to the known T1 values, especially for T1 relaxation time greater than 400 ms. For the IR repeatability study (C and C2, blue lines), there is consistency in the result. T1 relaxation times measured by VFA (Fig. 3) do not agree well with the known T1 values, especially for T1 relaxation times greater than 400 ms. This is opposite the result with IR measurements. For the VFA repeatability study (F and F2, orange lines), there is consistency in the result, though significant errors.

Discussion & Conclusion: Systematic differences in T1 relaxation time measurement can be identified as a function of measurement method (IR or VFA), protocol and scanner type. For both the IR and VFA measurements, a more complex model could provide a better estimate of T1 relaxation time. B1 inhomogeneity could contribute to the systematic error in VFA measurements. Each site selected their own parameters for IR and VFA measurements; this could be a cause of the variation in measured T1 relaxation time. Finally, there is variation from scanner to scanner, which cannot be accounted for in the previously mentioned sources of error.

The NIST/ISMRM phantom allows comparison of measured T1 via multiple methods; at 1.5 T and 3.0 T; across multiple sites and systems; and a multiple time points. We are currently incorporating B1 mapping techniques into the suggested protocol for improved estimation of T1 relaxation time via the VFA method. For more information on the NIST/ISMRM phantom, please visit: http://collaborate.nist.gov/mriphantoms/bin/view/MriPhantoms/MRISystemPhantom.

Fig. 1: NIST/ISMRM System Phantom

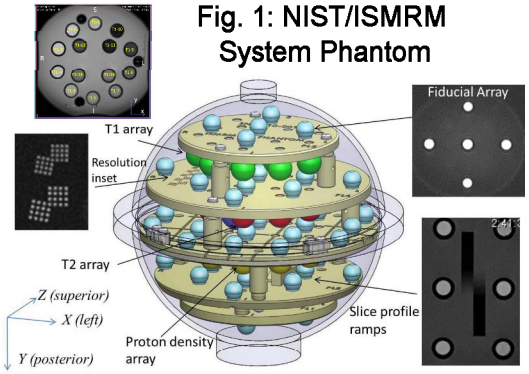

Fig. 2: Inversion Recovery

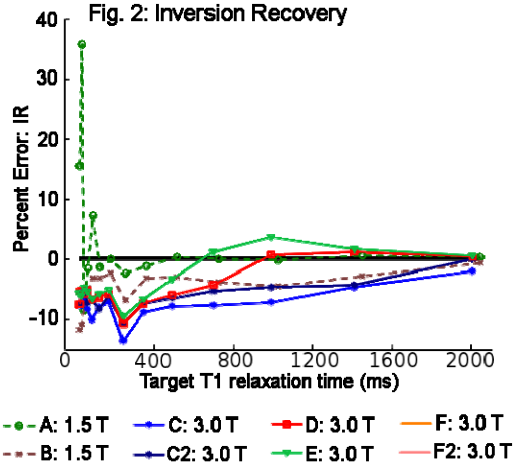

Fig. 3: Variable Flip Angle