Imaging T_1, T_2 and proton density with minimum possible acquisitions

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TARGET AUDIENCE. MRI clinicians and scientists interested in efficient, complete T_1, T_2, proton density (PD) characterization.

PURPOSE. The T_1 and T_2 relaxation times, and proton density (PD) contain almost all of the ^{1}H MRI information routinely used in clinical diagnosis and research, but are seldom imaged directly. In addition, their accuracy depends critically on B_1-field homogeneity, making field mapping essential, especially at higher field strengths. Here we propose a novel 'Tri-FA' method to measure and image T_1, T_2, PD and B_1 with only 4 acquisitions–the minimum possible. This 'Tri-FA' method encodes T_1 with 3 varied flip-angles (FA), and T_2 via long 0° BIR-4 pre-pulses instead of spin-echoes. 2D and 3D 'Tri-FA' MRI is demonstrated *in vitro* and *in vivo* at 3 Tesla.

METHODS. It was recently noted (1) that self-refocusing B_1-independent rotation (BIR-4) adiabatic pulses are prone to intra-pulse T_2 decay that depends on the BIR-4 pulse duration (τ), B_1 amplitude, sweep frequency, but is independent of BIR-4 FA. Using four spoiled gradient-echo sequence (SPGR) acquisitions, the 'Tri-FA' measures signals $S_{1\text{-}3}$ acquired with the same TR (eg, 600ms) but varied excitation FAs ($\theta_{1\text{-}3}$=30°, 80°, 140°), and a 4th signal, S_4 acquired with a τ=20ms 0° BIR-4 prepulse (excitation FA=θ_1, TR'=1036ms). It can be shown that: $S_{1\text{-}3}=M_0(1-E_1)\sin(q.\theta_{1\text{-}3})/(1-E_1.\cos(q.\theta_{1\text{-}3}))$, and $S_4=M_0(1-E_1').\sin(q.\theta_1)E_p./(1-E_1'.\cos(q.\theta_1).E_p)$, where q reflects the B_1 field inhomogeneity. T_1, T_2, M_0, and q are solved from $S_{1\text{-}4}$.

Tri-FA was validated in 2D and 3D MRI studies on a clinical *Philips* 3T scanner. *In vitro* validation was performed on 11 $CuSO_4$ doped agarose phantoms with 186 $\leq T_1 \leq$1332ms, 13.2 $\leq T_2 \leq$227ms. *In vivo* brain studies were performed on healthy consenting adult volunteers (3D matrix =224x224x5, FOV= 200x200x25mm^3; 2D matrix=224x224, FOV=200x200x5mm^3). Tri-FA measurements were compared with the central slices of standard 3D spin-echo (SE) T_2, partial saturation (PS) T_1, PD maps and B_1 maps acquired by actual flip-angle imaging (AFI)(2). 2D Tri-FA measurements were corrected for slice profile distortions.

RESULTS. The measured T_1, T_2, PD and B_1 of the phantoms are plotted vs. the standard values in Fig.1(a-d). The T_1, T_2, B_1, and PD errors(%) vs the standard values is 2.5%±14%, 3.6%±9%, 0.9%±8%, and 3.6%±4%, respectively. *In vivo* 3D results from a volunteer are shown in Fig.1(e-h). Mean (±SD) errors are-4.8(±10.4)% for T_1, and 1.1(±12.5)% for T_2, measured in the boxes annotated in Fig.1(e). For 2D Tri-FA brain MRI, errors are -3.6(±6)% for T_1, and -8.5(±3.6)% for T_2 after slice profile correction. Analysis shows Tri-FA provides considerably higher accuracy/unit time vs other parameter mapping methods (DESPOT1/2, etc; not shown).

Conclusion. The novel Tri-FA method offers a minimum-acquisition option for imaging single-component T_1, T_2, and PD, with B_1-inhomogeneity self-correction. Tri-FA was validated in 3D applications at 3T, as well as 2D MRI where standard methods can fail.

References. 1. Wang G et al. J Magn Reson 214(2012): 273 – 280. 2. Yarnykh VL. Magn Reson Med 57(1):192 – 200 (2007)
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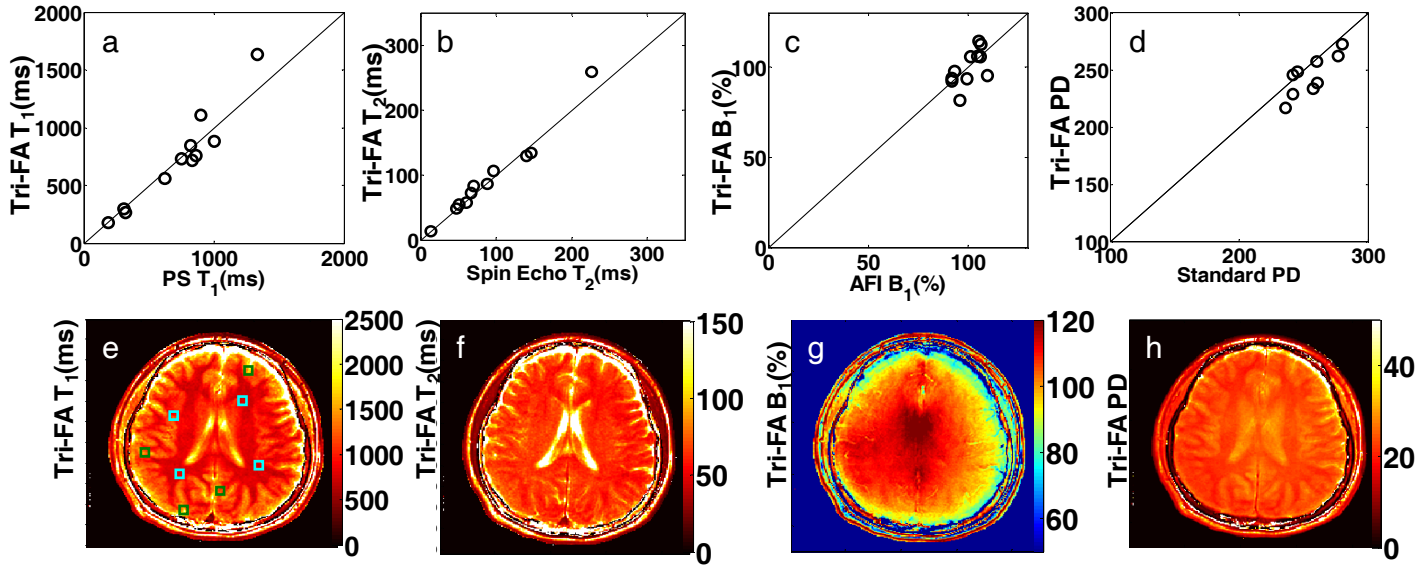

Fig 1. (a-d) *In vitro* Tri-FA results vs. standard values in 11 phantoms. (e-h) Color coded *in vivo* 3D Tri-FA maps for a volunteer.