Comparison of Analysis Methods for T1 Measurement by trueFISP Readout of Inversion Recovery

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Introduction

T1 is commonly used as a contrast mechanism in MRI. Although quantitative measurement of T1 can aid in determining tissue type and function, prohibitively long scan times prevent use in normal clinical settings. Recent studies have shown trueFISP readout of inversion recovery (IRFISP) allows rapid simultaneous measurement of T1 and T2 [1,2,3]. However, quantitative values of T1 and T2 are sensitive to the form of analysis used. We present a comparison of different analysis strategies and their accuracy as determined by comparison with standard T1 measurement by gradient echo readout of inversion-recovery (IRGRE) and T2 measurement by spin echo (SE).

Material and Methods

Images were acquired in a 1.5T scanner (Sonata, Siemens Medical Solutions, Erlangen, Germany) in volunteer brain and in a gelatin phantom designed to mimic white matter (T1=700msec, T2=110msec by baseline measurements described below).

Baseline measurements of T1 and T2 were performed with IRGRE (TI=30,200,360,480,600,1500,3000msec, TR/TE/flip angle = 7000msec/3.47msec/90°) and SE (TE=12,39,45,60,75,90,100msec, TR=1200msec, flip angle=90°), respectively. T1 and T2 parameters were extracted by fits to standard exponential recovery and decay.

IRFISP measurements (TR/TE/flip angle=3msec/1.5msec/50°, matrix=128x128, slice thickness=5mm, 512 time points) used a nonselective adiabatic inversion pulse followed by a single half-angle preparation pulse. A single phase-encoding value was acquired after each inversion. Acquisition time was 1536 msec followed by a half-angle pulse and 3000 msec delay to allow recovery to equilibrium. Manual shimming was performed to ensure that frequency offsets did not affect the signal.

Analysis

Figure 1 shows a typical signal intensity-time curve taken from an ROI in a gelatin phantom. Data in ROI's and voxels in brain are similar. T1 was determined by four methods:

1) Null point method: $T1 = T_{null} / \mathrm{Ln}(2)$
2) Fit of time points preceding null point to $S_0|1 - 2\exp(-t/T1)|$
3) Fit of all time points to $Si|(Sss/Si) - (1+Sss/Si)\exp(-t/\tau)|$ followed by inversion of the following equations [2] to extract T1 and T2:

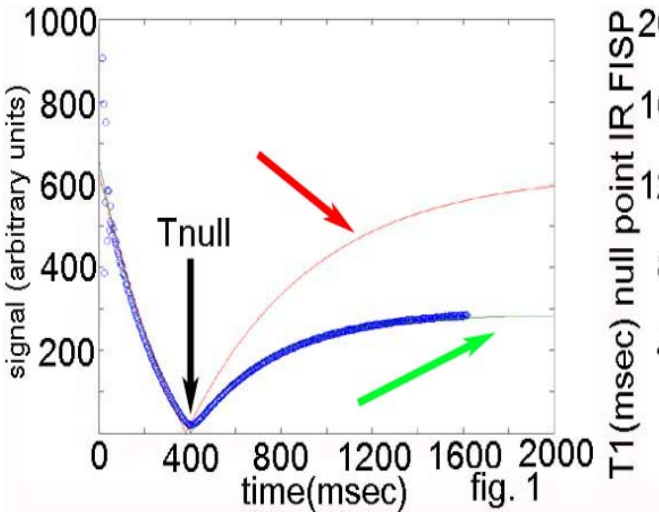
a) $\exp(-TR/\tau) = (1/2)\left(\cos(\alpha)(E1-E2) + \sqrt{\cos^2(\alpha)(E1-E2)^2 + 4E1E2}\right)$

b) $Sss = Si\ 2\sqrt{E2}(1-E1)\cos(\alpha/2)/\left(1-(E1-E2)\cos(\alpha)-E1E2\right)$

where E1=exp(-TR/T1), E2=exp(-TR/T2), Si corresponds to the initial signal amplitude, Ss corresponds signal amplitude in the steady state, and α is the flip angle. Effects of non-delta function pulses with rectangular or sinc function profiles were accounted for by numerical simulation.

Results

Analysis of data from voxel maps of T1 and from ROI's show that method 2 consistently underestimates T1 by approximately 10% while method 3 overestimates T1 by over 10%. T2 values tend to be overestimated by at least 10%. Overestimation of T1 and T2 is exaggerated after accounting for effects of non-delta function pulses. The simple null point method, however, finds T1 values that are the same as those found by baseline measurements (figure 2). Outliers correspond to voxels in fat and CSF, where extremely short and long T1 values render the baseline and trueFISP measurements inaccurate.



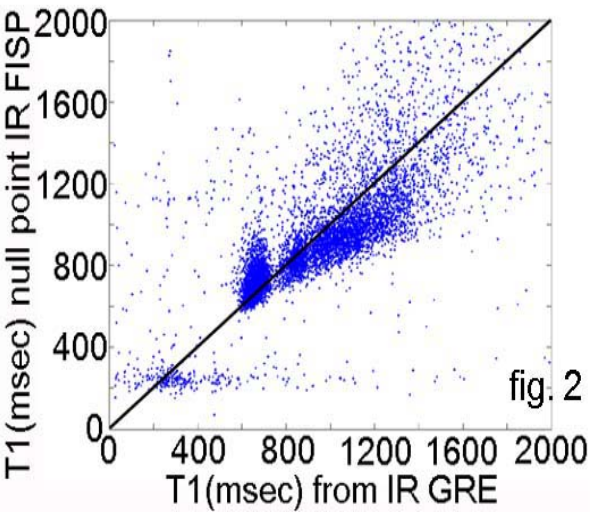


Figure 1: Plot of signal read by trueFISP after inversion (blue dots) with fits to formula b (red arrow) and formula c (green arrow). The time of the signal null, Tnull, is indicated. Figure 2: Voxel-by-voxel comparison of T1 measured by IRGRE and null point method with IRtrueFISP

Conclusion

In theory, IRtrueFISP should yield accurate simultaneous measurement of T1 and T2. In practice, however, the simple null point analysis method yields more accurate values of T1 than more involved analysis approaches.

References

[1] Scheffler K and Hennig J MRM 45:720-23(2001),[2] Scheffler K MRM 49: 781-783 (2003),[3] Schmitt P et al Procedings ISMRM, 135 (2003)