In vivo blood T1 mapping using inversion recovery TrueFISP

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Introduction

In vivo estimation of blood T_1 is desirable for flow quantification using arterial spin labeling (1) and clinical diagnosis of tumor (2,3). The movement of blood causes particular challenges for achieving this goal, often leading to either lengthy or unreliable measurement of blood T_1. TrueFISP is a balanced steady state free precession (bSSFP) technique characterized by high imaging speed while preserving a high signal-to-noise ratio, especially for tissues with a larger T_2/T_1 ratio such as blood (Fig 1). It has been shown that an $\alpha/2$ RF pulse followed by a train of polarity-alternating α pulses provides a smooth signal evolution toward steady state and therefore is suitable for readout after magnetization preparation (4). Inversion recovery (IR) prepared TrueFISP has been applied for in vivo T_1 mapping of static tissue (5). However, the estimated apparent T_1 is a complicated function of the flip angle (α), and the relaxation time constants of the tissue, although correction schemes have been proposed for concurrent fitting of T_1, T_2 and spin density images (6). The IR TrueFISP signal of a pixel filled with blood, nevertheless, has relatively small sensitivity to α and imaging parameters other than T_1 due to the continuous inflow of fresh blood with longitudinal magnetization undisturbed by the TrueFISP RF pulse train. In the present study, we inspected how the accuracy of blood T1 measurement using IR TrueFISP is affected by variations in α and flow effects using both experimental and theoretical approaches.

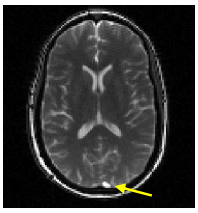


Fig 1. High signal in sagittal sinus in TrueFISP images.

Materials and Methods

With IR-TrueFISP, data were obtained at 41 consecutive TI's following a non-selective HS inversion pulse as depicted in Fig 2. Each image corresponding to one TI was acquired with 21 segments. Twenty dummy RF pulses were applied at the beginning of the IR-TrueFISP readout to stabilize the signal, while an $\alpha/2$ RF pulse was applied at the end of the image acquisition to place the magnetization back to the longitudinal direction. Imaging parameters included: TR = 5 msec, TE = TR/2, FOV = 22 cm, matrix size = 128x128. Each segmented acquisition was 4 sec and TI = 100 ms to 3995 ms with a step of 95ms. Scan time was 1min 30sec for a single 5-mm axial slice. Three different α's (30°, 50° and 70°) were used in separate scans. Magnitude IR-TrueFISP data were fitted to Eq. [1], using custom designed IDL program (6). IR TureFISP signals were extracted from regions-of-interest of grey/white matter and mid-sagittal venous sinus. Three healthy volunteers (25-36yrs, F = 1, M =2) were imaged after given written informed consent. All MR imaging was conducted on a 3.0 T whole body system (Siemens Trio, Erlangen, Germany) with a standard setup of body coil transmission and array head coil reception. Computer simulations based on Bloch equations were performed to evaluate the effects of α and blood flow entering the imaging slice during TrueFISP readout.

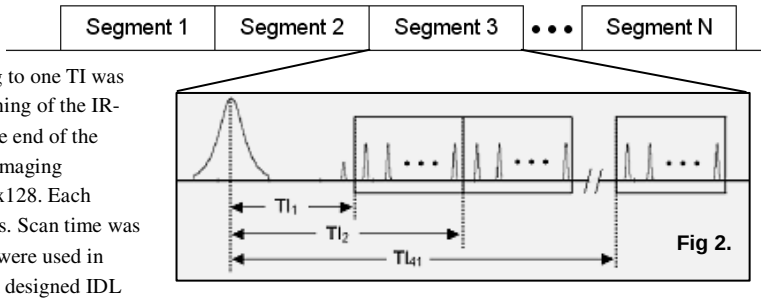


Fig 2.

$$S(t) = k_1\left(1 - k_2 \exp\left(-\frac{t}{k_3}\right)\right) \qquad [1]$$

Results and Conclusions

Fig 3 shows the dependency of signal evolution on T_2/T_1 and the α used. The recovery curve deviates from the standard T_1 relaxation as α increases in static tissues, resulting in T_1 underestimation if the conventional model is used for fitting. This effect is much reduced for blood (see Fig 4), since the 'fresh' blood that continuously inflows from outside of the imaging plane incidentally mitigates the saturation effect caused by the RF pulse train in TrueFISP. Fig 5 shows the experimental data from a representative subject. As expected, the fitted apparent T_1 values of gray (532-752ms) and white matter (295-459ms) were not only underestimated, but also varied considerably as a function of α (30~40%). In contrast, the fitted blood T_1 values (1579-1622ms) matched well with literature values (7) with minimal sensitivity to α changes (~3%). The average blood T_1 of 3 healthy subjects was 1660±93ms, with 1.4% coefficient of variation (CV) for repeated scans in one subject. We demonstrate the feasibility of fast in vivo blood T_1 mapping using IR TrueFISP with results in nice concordance with literature. The advantages of IR TrueFISP include high imaging speed (1-2min), high SNR for blood pool signal and image resolution. Further development and optimization are needed to further improve the accuracy and precision of this technique.

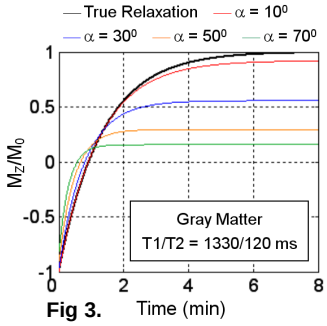


Fig 3.

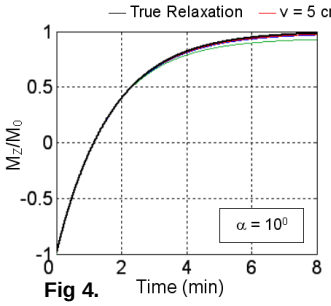
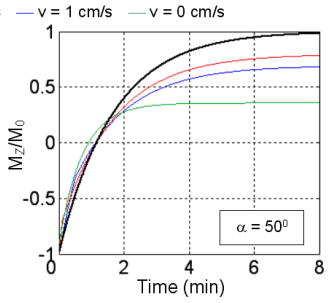


Fig 4.



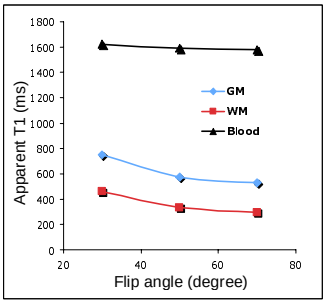


Fig 5.

References

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