T1 and relative PD maps in 3D FLASH

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Abstract

This study aims to implement high resolution T1 maps based on 3D fast low angle shot (FLASH) imaging and measure the values between different tissue types in a whole brain. A series of 3D FLASH images were acquired with three different tip angles and the variation was evaluated on the brain tissue types. The T1 maps and relative Proton Density (PD) images with these tip angles were calculated and shown in all directions. Also the values between similar tissues at different regions at which located the white matter in corpus callosum and gray matter in the putamen were compared with the approximate general values known as the literature.

Introduction

3D FLASH (Haase et al., 2011) is a gradient echo sequence which combines a low tip angle (less than 90@) radio-frequency excitation with a rapid repetition time (TR). It is the most commonly used for the purpose of the frequency encoding along the length direction of the body to avoid aliasing. And it is called by different names depending on MRI manufacturers such as the name FLASH at Siemens, the name SPGR (Spoiled Gradient Echo) at General Electrics and the name T1-FFE (Fast Field Echo) at Philips. Its main three parameters (TR, TE, and tip angle a) are depended on the signal from a spoiled GRE sequence. Also the generated signal relies on three intrinsic tissue parameters (ex. T1, T2* and spin density [H]).

Theory and methods

Simulation and Scan Parameters

All of the experiments through a healthy volunteer were performed on a Philips Achieva 3T scanner (Best, Netherlands) using body coil for RF transmit and an 8 channel phased array head coil for receive. Acquisition parameters in the human brain include: a TE of 3.47 [msec], voxel size 1 x 1 x 1 [mm^3]; flip angle 3, 8, and 20 [degree]; FOV (AP, RL, FH) 240 x 240 x170 [mm]; TR 10

[msec]; water fat shift 2.27 [pixels]; scan duration 318 [sec]. All simulations, data analysis and visualization were done with developed least-squares fitting procedures using MATLAB R2014a (The MathWorks, Inc., Natick, MA). The Brain Extraction Tool (BET) was used to the common skull stripping method in an FSL routine using MATLAB scripts.

T_1 Quantification of Tip Angle

After many repetitions, the longitudinal magnetization is given by

$$M_z(t_{n+1}) = M_z(t_n)\, cos(a) e^{-\frac{TR}{T_1}} + M_0(1 - e^{-\frac{TR}{T_1}}), \tag{1}$$

where $M_Z(t_n)$ denotes the longitudinal magnetization after the nth pulse. The definition of steady state is $M_Z(tn) = M_Z(t_n{+}1) = M_{ss}$. When assuming that a longitudinal steady state has been reached and perfect spoiled, the steady state signal (S) (Haase, 1990) from an ideally spoiled gradient echo acquisition is given by

$$S = K[H]\, sin(a)\, \frac{1 - E_1}{1 - cos(a)\, E_1}\, e^{-\frac{TE}{T_2^*}} \tag{2}$$

with $E_1 := \exp(-TR/T_1)$ and a proportionality factor K that includes the proton density, the coil sensitivity, and T2* relaxation. However in this study because the echo time (TE) is much shorter than T_2*, the last term of the equation is ignored. From at least two measurements at three different tip angles, K and T_1 can be determined by this equation using nonlinear least squares fitting procedures (Deichmann et al., 1999).

The choice of tip angle is important for determining not only signal intensity but also image contrast. Ernst angle (a_{Ernst}) (Ernst and Anderson, 1966) can be calculated from the equation that MR signal is maximized.

$$Ernstangle(a) = arccos(e^{\frac{TR}{T_1}}) \tag{3}$$

Let us calculate the optimal tip angle for FLASH sequence in the brain. Acquisitions were performed at least three tip angles, e.g. 3, 10, and 20 degrees. The middle tip angle is close to the Ernst angle for the brain tissue at 3T from the equation, so that measurements give little saturation, medium saturation and fairly strong saturation of the brain tissue.

Results and discussion

Figure 2 shows PD maps and T1 maps from all direction of a whole brain. And the values were compared between the acquired 3D images and signal model fitting in figure 3.

Conclusion

This study is aimed to implement high resolution T1 maps based on 3D FLASH imaging and measure the values between different tissue types from all direction in a whole brain. Also the

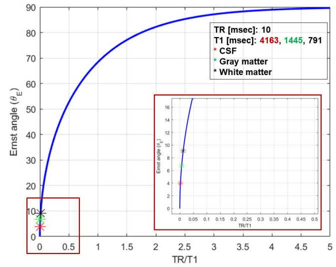

Figure 1: The Ernst angle was calculated from the equation and shown by the proportional of TR over T_1 including the different brain types.

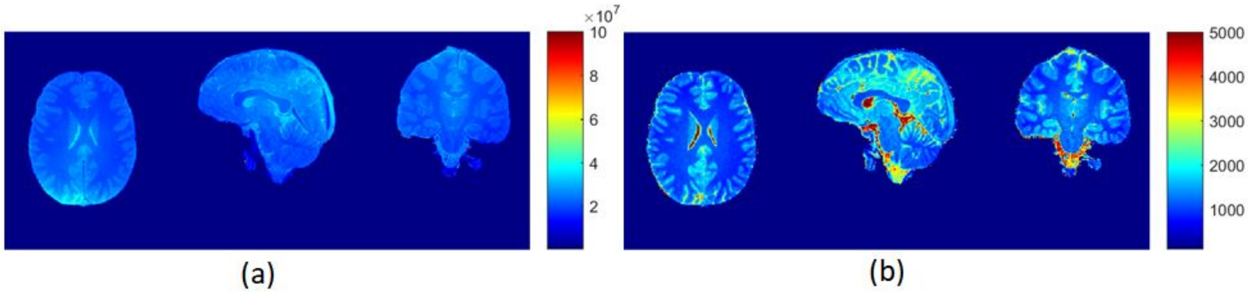

Figure 2: PD maps (a) and T1 maps (b) are shown by using nonlinear least square fitting algorithm in MATLAB.

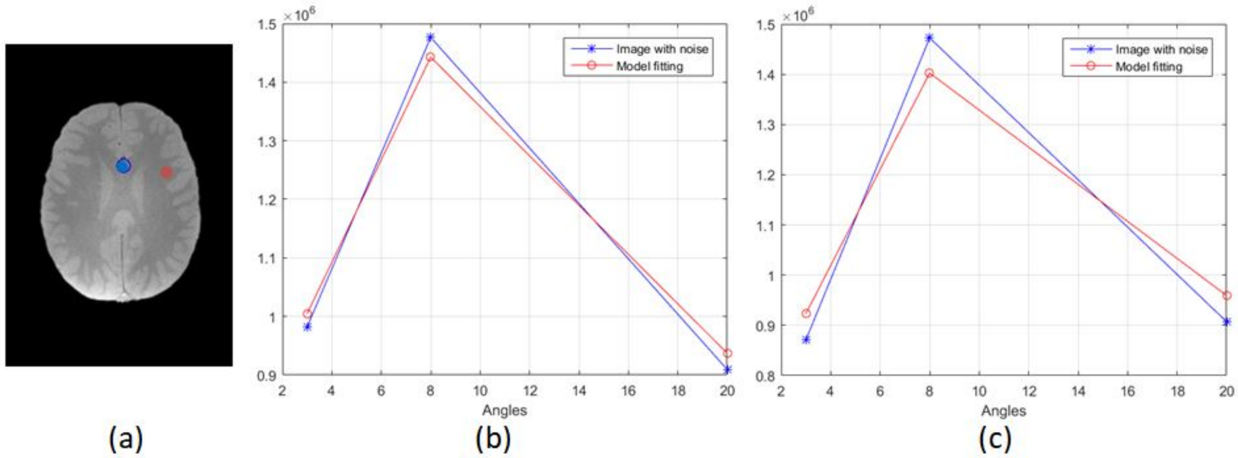

Figure 3: (a) The image is shown by the white matter in corpus callosum (blue circle, b) and gray matter in the putamen (red circle, c) and its value was compared the FLASH image with noise with the model fitting.

values between similar tissues at different regions compared with the approximate general values known as the literature.

References

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