PHANTOM VERIFICATION OF B1 INHOMOGENEITY CORRECTION FOR 3D-VARIABLE FLIP ANGLE T1 MEASUREMENTS

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Introduction

3D Variable Flip Angle (3D-VFA) is a promising method for performing fast 3D T1 quantifications in vivo, for which there are several clinically relevant applications (e.g. dGEMRIC) [1]. However, the 3D-VFA method is sensitive to variations in the transmitted B1 field and not until recently methods have been introduced to correct for such B1 inhomogeneities [2]. The aim of this work was to verify the functionality and to investigate the performance of 3D-VFA with B1 correction (MapIt, Siemens Medical Systems) at 3T in an environment with known B1 variation.

Methods

With 3D-VFA T1 is calculated from two successive 3D gradient echo sequences (3D-GRE) with different excitation pulse flip angles (α_1 and α_2). T1 is solved using eq. 1, where Q(x, y) is the quotient of the signal intensities for the 3D-GRE sequences ($Q(x, y) = S_1(x, y)/S_2(x, y)$). Variable c(x,y) is the relative transmitted B1 field strength which is mapped using an additional sequence, in which a spin echo (S_{SE}) and a stimulated echo (S_{STE}) is generated using a 90°-90°-90° RF pulsing scheme (Eq. 2 and Eq. 3) [3].

Eq. 1

$$T_1(x,y) = \frac{T_R}{\ln\left(\frac{\sin(c(x,y)\cdot\alpha_1)*\cos(c(x,y)\cdot\alpha_2) - Q(x,y)\cdot\sin(c(x,y)\cdot\alpha_2)\cdot\cos(c(x,y)\cdot\alpha_1)}{\sin(c(x,y)\cdot\alpha_1) - Q(x,y)\cdot\sin(c(x,y)\cdot\alpha_2)}\right)}$$

Eq. 2

$$\cos(\alpha(x,y)) = \frac{S_{STE}(x,y)\cdot e^{T_E/T_1(x,y)}}{S_{SE}(x,y)} - 1$$

Eq. 3

$$c(x,y) = \frac{\alpha(x,y)}{\alpha_{Nom}}$$

Four long gel phantoms (diameter 40 mm, length 500 mm) with different T1 and approximately equal T2 were used. The phantoms were arranged along the length direction, extending out through both ends, of a T/R extremity coil in a Siemens Tim Trio 3T scanner. Since the B1 transmit field in such coil will decrease as the distance from the coil center is increased, an experimental setup with known B1 transmit field variation was achieved.

For 3D-VFA matrix size was 192x192x100, FoV 40 cm, TR 15 ms, TE 5 ms. Flip angles (FA) were 4° and 25°. The B1 map was acquired with same FoV 40 cm, matrix size 64x64x10 and TR 1000ms. Readout gradients were aligned parallel to the length direction of the phantoms. Both T1 and B1 were evaluated along this same direction through the phantoms. T1 values were calculated both with and without taking the B1 map into account, the latter was achieved by setting c(x,y) = 1. Reference T1 values were also measured using standard 2D Inversion Recovery (2D-IR) sequences.

Results

The B1 quality is close to its nominal value (i.e. 100%) only in the centermost 50 mm of the coil (fig. 1). As expected, the B1 value is constantly decreasing outside of this region. T1 values calculated without B1 correction are strongly deviating (dotted lines, fig. 2) from reference values (arrows, fig. 2), in all regions with low B1 field strength. By including the B1 information in the T1 calculation, accurate T1 values are acquired throughout all positions inside the coil (solid lines, fig. 2).

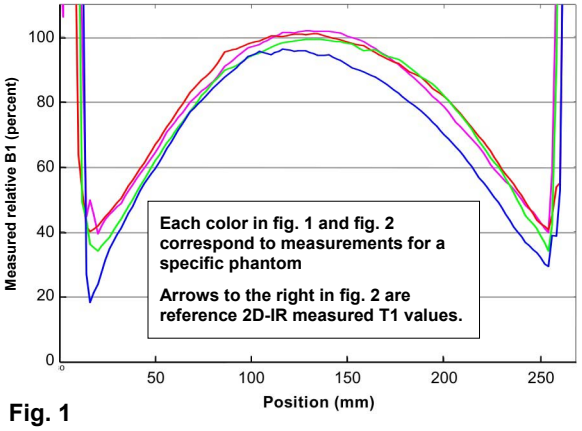

Fig. 1

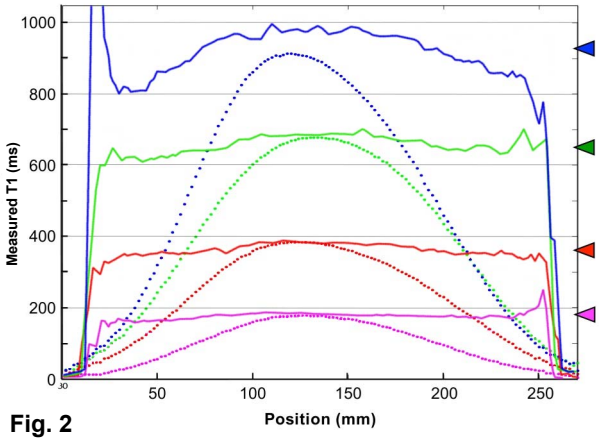

Fig. 2

Discussion and conclusions

The method evaluated here is shown to generate reliable T1 values also in areas with severe B1 deviation. In general, B1 inhomogeneities in vivo are considered to increase as the magnetic field strength is increased, which is primarily related to the dielectrical and the conductive properties of the investigated object. Thus, as field strength is increased this type of correction will be of even more importance. However, changes in the B1 field are usually expected to be slowly varying, which is why a fast low resolution B1 scan should be adequate. For the phantom with the highest T1 value there is a general discrepancy between the B1 corrected T1 values and the reference T1 value. This is likely an effect of unwanted stimulated echoes, resulting from the T1 value of the measured object being in the same regime as the repetition time of the B1 mapping sequence [3]. Care must be taken to avoid such effects.

References

1. Mamisch et al, MRM 60:768-773 (2008)
2. Wang et al, JMR 182:283-292 (2006)
3. Perman et al, MRM 9:16-24 (1989)