Correction of B1 and Estimation of Oversampling Effect to Enable Accurate T1 Mapping Using 3D Variable Flip Angle Technique

Kosuke Morita[1,2], Tomoyuki Okuaki[3], Masanori Komi[1], Akiko Kuraoka[1], Daisuke Utsunomiya[2], Mika Kitajima[2], Masahiro Hashida[1], and Yasuyuki Yamashita[2]

[1]*Radiology, Kumamoto University Hospital, Kumamoto, Kumamoto, Japan,* [2]*Diagnostic Radiology, Faculty of Life Sciences, Kumamoto University Hospital, Kumamoto, Kumamoto, Japan,* [3]*Philips Electronics Japan, 13-37, Kohnan 2-chome, tokyo, Japan*

INTRODUCTION

T1 mapping has garnered increasing attention as a basic tool for MR imaging, in research and in the clinic. It holds the promise of a method for scanner-independent T1 contrast, and provides useful quantitative tissue information. The method of driven equilibrium single-pulse observation of T1 relaxation (DESPOT1) [1], also known as the variable-flip-angle method, is one such T1 mapping method, based on the acquisition of 3D fast field echo (FFE) sequences over a range of flip angles, which provides fast volumetric T1 mapping. This method is not expected to yield accurate results at high fields (≥3T) without a B1 correction to account for B1 inhomogeneities [2]. The purpose of our study was acquired precise 3D T1mapping by variable flip angle DESPOT1 method with B1 correction for a clinical abdominal MR imaging. Moreover, the inaccurate T1 values of outerslices for 3D acquisition occurred from that the slice selective RF pulse is not a perfect rectangular pulse. To resolve this problem, we evaluated slice oversampling factor to acquire accurate T1value for 3D acquisition.

$$\alpha = \cos^{-1}\left(\frac{f^2E_1 \pm (1-E_1^2)\sqrt{1+f^2}}{1-E_1^2(1-f^2)}\right) \quad (1)$$

$$T_1 = \frac{T_R}{\ln\left\{\frac{S_{\alpha 1opt}/\sin(b_1\alpha_{1opt}) - S_{\alpha 2opt}/\sin(b_1\alpha_{2opt})}{S_{\alpha 1opt}/\tan(b_1\alpha_{1opt}) - S_{\alpha 2opt}/\tan(b_1\alpha_{2opt})}\right\}} \quad (2)$$

MATERIALS and METHODS

Experimental data was collected from six phantoms and five healthy volunteers. Written informed consent was obtained from each volunteer and the protocol was approved by the local ethics committee. Six cylindrical phantoms (T1 230 -1200 ms; T2 40 - 110 ms) were used. All phantom and clinical studies were performed with 3.0T clinical MR scanner (Philips, Achieva 3.0T X-series TX) and 32-channel torso cardiac coil. Reference T1 measurement was performed with single-slice Look-Locker method with both phantom and volunteer studies. Scan parameters of 3D FFE were as follows: TR/TE = 9.0 / 2.1 msec, slices thickness = 8.0 mm, number of slices = 10, field-of-view = 36 × 36 cm^2, acquisition matrix = 128 × 128 (reconstruction matrix = 160 × 160), NSA = 1, startup echo = 50, SENSE factor = 2.0. B1mappings were performed with 2D-turbo spin-echo (TSE) dual angle method (TR/TE = 800 / 40 ms, number of slice and slice gap = 10 / 0 mm, dual flip angle = 65 / 130 degree, field-of-view = 36 × 36 cm^2, acquisition matrix = 128 × 128 (reconstruction matrix = 160 × 160), NSA = 1, TSE factor = 19, startup echo = 4, SENSE factor = 1.5). T1 determination using the variable flip angle approach requires a minimum number of two consecutive measurements with two different FAs $\alpha 1_{opt}$ and $\alpha 2_{opt}$. We determined the optimal FAs as Eq.(1), where E1= exp(-TR/T1) and over the complete range of TR/T1 investigated the function is maximized at f =0.71. In our study, we decided optimal TR of 9 ms, estimate T1 of 800 ms, optimal FAs of $\alpha 1_{opt}$ = 4 degree and $\alpha 2_{opt}$ = 22 degree. Subsequently, we determined the T1mapping by calculating T1 values with B1 correction using Eq.(2), where $S_{\alpha 1opt}$ and $S_{\alpha 2opt}$ represent the acquired signal amplitude of the T1mapping measurement using the optimal FAs. In phantom study, mean T1 values were measured in the regions of interest (ROI) on T1 maps with or without B1 correction. A ROI of at least 80% of whole area was drawn on the center of the phantom. Subsequently, we evaluated the T1 value of slice direction various oversampling factor (1.28, 1.5, 2.0 and 3.0). In volunteer study for T1mapping using the optimal slice oversampling factor, Mean T1 values were measured in ROIs on T1 maps with or without B1 correction. Two ROIs were drawn on the right and left lobe of the liver. Statistical analyses (Steel-Dwass test) were performed after the quantitative evaluation.

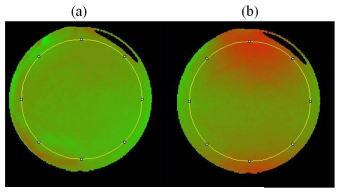

Figure 1 Phantom

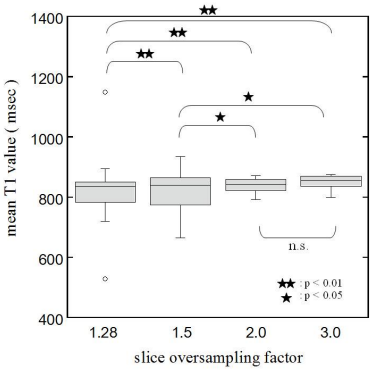

Figure 2 Box plots among slice oversampling

RESULTS

In phantom study, mean T1 values were (a) 224.0 ± 9.5 ms [mean ± SD] (-2.61%) with B1 correction, (b) 244.7 ± 24.1ms (+6.39%)without B1 correction, and reference 230 ms (Figure 1). Higher slice oversampling factor became mean T1 value stable, accordingly the acquisition time was increased (Figure 2). Figure 3 shows 3D T1mapping images of a volunteer. A mean T1 value of with B1 correction, without B1 correction and reference were 732.0 ± 41.2 ms (-0.14%), 806 ± 149.5 ms (+9.96%), 733 ± 7.8 ms, respectively. Compared to reference T1 value, mean T1 values with B1 correction was better than that of without B1correction.

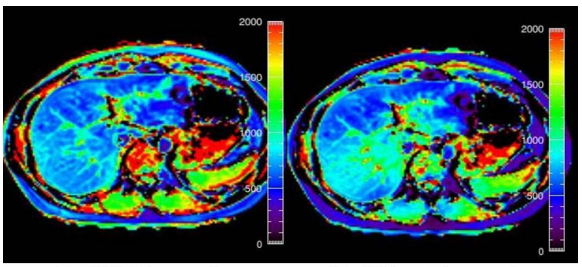

Figure 3 Volunteer images of liver.

CONCLUSION

A new 3D T1mapping with B1 correction using variable flip angle method was available to more accurate quantify T1 values for phantom and clinical study. Furthermore, T1 values for 3D T1mapping were improved by optimizing slice oversampling factor.

REFERENCE

[1] Sean C.L. Deoni et al., MRM 49:515-526; 2003. [2] Reto Treier et al., MRM 57:568-576; 2007. [3] Kyuung Ah Kim et al., JMRI 36:405-410; 2012.