T1-mapping using two flip angle spoiled FLASH-EPI hybrid sequences

C. Preibisch[1,2], S. Volz[2], and R. Deichmann[2]

[1]Abteilung für Neuroradiologie, Klinkum rechts der Isar der TU München, München, Germany, [2]Brain Imaging Center, Universitätsklinikum Frankfurt, Frankfurt, Germany

Introduction: The acquisition of spoiled FLASH data sets with two excitation angles (α_1 and α_2) allows for fast T1 mapping with a high isotropic spatial resolution (1). However, for low signal-to-noise ratios (SNR), a noise bias may cause systematic errors in T1 estimation (2,3). A potential means of improving SNR is the use of FLASH-EPI hybrid sequences (4,5), acquiring several echoes with different phase encoding after each excitation. The SNR is increased because the method yields longer repetition times (TR), so the same T1 contrast is obtained with larger α. Since the same formula for the steady state signal as in the FLASH case applies, this method can be expected to allow for T1 mapping with improved SNR at similar or even reduced acquisition times. The aim of this study was, therefore, to investigate the improvements in SNR and accuracy of T1 maps achieved with double-echo FLASH-EPI hybrid sequences.

Subjects and Methods: T1 mapping was performed in vitro (gel phantom) and in vivo (five healthy volunteers, brain scans) with an isotropic resolution of 1mm (FOV 256x224x160mm^3) and an acquisition time of 9min:05sec, using two different readouts: 3D spoiled FLASH (6) with α_1/α_2=4°/18°, TR/TE=7.6ms/2.4ms, bandwidth (BW) 206Hz/Px, and a 3D double gradient echo FLASH-EPI hybrid (4) with α_1/α_2=4°/24°, TR/TE1=15.2ms/6.7ms, BW=222Hz/Px. The tip angles α_1 and α_2 of the non-selective excitation pulses were individually optimized for maximum SNR. An RF increment of $\Delta\Phi$=50° was used for RF spoiling. B1 mapping was performed according to (7) with parameters and evaluation as described in (6). T1 calculation included corrections for insufficient RF spoiling at $\Delta\Phi$=50° (6).

Results: In the phantom, T1 mapping with all corrections applied (6) yielded homogeneous T1 maps for both investigated sequences. The results of the ROI analysis are summarized in Table 1. Images acquired with the hybrid sequence showed a clear SNR increase when compared to images acquired with FLASH. The SNR increase amounted to 18 % for the low flip angle data set and 49 % for the high flip angle data set. This resulted in a theoretical SNR gain in the T1 maps of 1.58. This value corresponded closely to the experimental gain of 1.60 which was determined directly from the standard deviation of T1 across the ROI. These results could be confirmed in healthy volunteers. Figure 1 shows orthogonal slices of T1 maps acquired on a single volunteer with both methods. The data sets show overall good image quality with only minor signal dropouts in the hybrid sequence. However, the SNR in the T1 maps acquired with the hybrid sequence is clearly increased compared to the map acquired with FLASH, where the experimental gain exceeded the theoretical expectations, ranging from 1.41 in WM to 1.64 in GM.

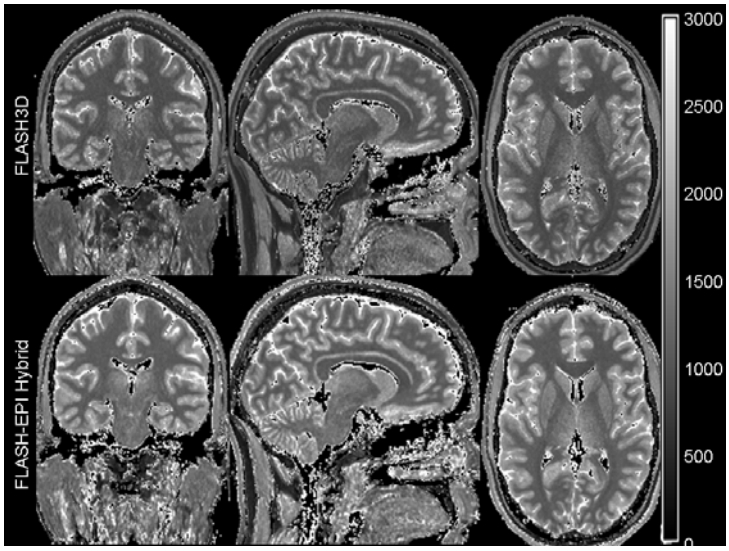

Table 1: Phantom measurement: SNR in the underlying images acquired with different flip angles (SNR(α_i)), theoretical SNR gain in the T1 map (G_{theo}), average T1 value, standard deviation of T1 across ROI, experimental SNR gain in the T1 map (G_{exp}).

METHOD	FLASH3D	HYBRID3D
SNR(α_1)	60 ± 15	71 ± 15
SNR(α_2)	41 ± 13	61 ± 20
G_{theo}		**1.58 ± 0.09**
T1 [ms]	1170 ± 8	1193 ± 11
σ(T1) [ms]	56 ± 14	36 ± 9
G_{exp}		**1.60 ± 0.16**

Fig 1: Orthogonal sections of T1 maps acquired on a single subject with a 3D spoiled FLASH sequence and a 3D spoiled FLASH-EPI hybrid sequence.

Conclusion: These results clearly demonstrate that FLASH-EPI hybrid sequences with two echoes per excitation can be used to improve the SNR in T1 maps based on the variable excitation angle approach. The T1 values are comparable to those obtained with a standard 3D FLASH readout. At constant total acquisition time, SNR gains of 41 % (WM) to 64 % (GM) can be achieved in vivo, exceeding SNR gains due to the performance of two averages.

References: (1) Deoni SC, et al. MRM 2003;49(3):515-526. (2) Cheng HL & Wright GA. MRM 2006;55(3):566-574. (3) Chang LC, et al. MRM 2008;60(2):496-501. (4) Deichmann R. NeuroImage 2006;33(4):1066-1071. (5) Deichmann R, et al. MRM 1995;34(3):481-489. (6) Preibisch C & Deichmann R. MAGMA 2008;21(Suppl 1):724. (7) Yarnykh VL. MRM 2007;57(1):192-200.