3D Balanced-EPI Magnetic Resonance Fingerprinting at 6.5 mT

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Purpose

In recent work [1], we demonstrated high speed MRI in the very low magnetic field regime (6.5 mT) using a balanced steady state based (b-SSFP [2]) acquisition scheme. b-SSFP provides the highest SNR per unit time [2] and image contrast depends on the ratio T_2/T_1. At very low field, most species have T_2 relaxation times approaching T_1, so b-SSFP images are essentially proton density (PD) weighted. In previous work [3] we have shown that 2D MR Fingerprinting [4] can be implemented at low magnetic field and provide simultaneous quantification of T_1 and T_2 as well as proton density and B_0 field maps. MRF at low magnetic field creates a rapid dynamic series of low signal to noise ratio (SNR) images where the magnitude of each voxel of each image changes at every time step. Generally, the TR and flip angle of each image in the time series is varied pseudo-randomly [5]. Here, we demonstrate MRF in 3D at 6.5 mT, using an optimized set of 15 flip angles and repetition times (FA/TR), in a Cartesian acquisition of *k*-space with a new hybrid b-SSFP-EPI sequence.

Methods

The low field MRI scanner was previously described [5]. The imaging sequence is a hybrid multishot b-SSFP-EPI with an echo-train of 4 echoes (Fig. 1). The sequence was set with matrix size = 64×64×5, corresponding voxel size = (2.5×3.5×10) mm^3, FOV = (125×175×50) mm^3, number of average NA = 2. The minimum TR was 62 ms with 9091 Hz bandwidth. The total acquisition time was 25 min. A flip (FA/TR) trajectory of length N=15 was generated using an optimization method previously described [6]. Lack of SNR at low magnetic field required redesigning our optimization scheme with a narrow range of larger flip angles [60-120°] and shorter TRs [62-400 ms]. The optmized FA/TR trajectory is compared to a non-optimized trajectory in Fig. 2. The imaged phantom consists in a stack of three 10 mm thick compartments of similar volume with different T_1 and T_2 properties.

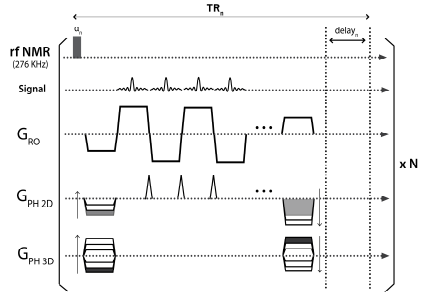

Figure 1: Pulse sequence diagram of the hybrid b-SSFP-EPI sequence used for 3D MR Fingerprinting. The FAs and TRs were set according to the optimized trajectory.

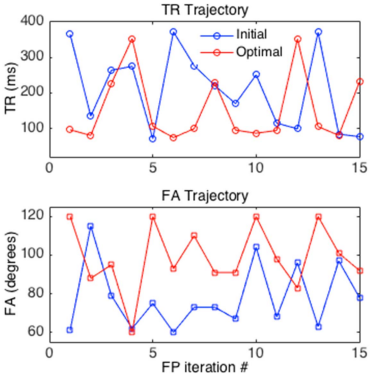

Figure 2: Comparison of our optimized trajectory with a random non-optimized trajectories for N=15.

Results

Each image generated in the reconstructed fingerprinting set (Figure 3) reveals different information. In regions with no signal (Slice 1, Slice 5), no matched value can be found. The spin density (M_0) map of Figure 3.a is equivalent to traditional b-SSFP, and only subtle differences are seen between compartments. Figure 3. b–c reveals that the compartment in slice 3 has the lowest T_1 and T_2 values, and that the compartment in slice 4 has the highest T_1 and T_2 values. Mean T_1 values are 200ms, 168ms, and 320 ms in slices 2, 3, and 4 respectively. Mean T_2 values are 180, 157, and 260 ms in slices 2, 3, and 4 respectively.

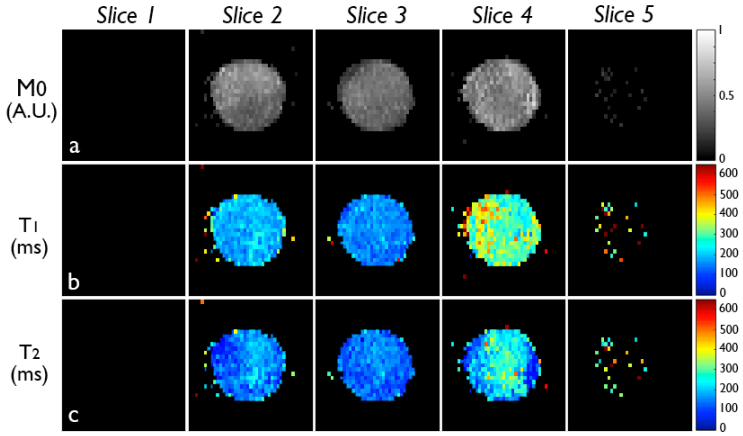

Figure 3 : MR Fingerprinting results at 6.5 mT : a. M_0, b. T_1, and c. T_2 in 3D, in a 3 compartment phantom. Each slice in the figure matches one of the phantom compartments.

Conclusion

We have demonstrated 3D MR Fingerprinting at very low magnetic field with a hybrid b-SSFP-EPI sequence enabling fast and robust acquisition of k-space. The optimized FA/TR strategy provides good dispersion while drastically reducing the total acquisition time. We measure quantitative parameters in 3D, and generate several image contrasts in a single acquisition (proton density, T_1, T_2) in less than 30 minutes. This technique is of particular relevance at low magnetic field where SNR and contrast are tied to long acquisition times. The combination of 3D MRF with low field MRI scanners has great potential to provide clinically relevant contrast with portable low cost MR scanners.

References: [1] Sarracanie M *et al.* Proc. ISMRM 2013 #5322; [2] Scheffler K *et al.* Eur Radiol 2003 13:2409-18; [3] Sarracanie M *et al.* Proc. ISMRM 2014 #6370; [4] Ma D *et al.* Nature 2013 495:187-193; [5] Tsai LL *et al.* JMR 2008; 193:174-85; [6] Cohen *et al*, Proc ISMRM 2014 #7153

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