IMPLICATIONS OF 2D SLICE PROFILE DEFORMATIONS FOR RAPID MYOCARDIAL T1/T2 QUANTIFICATION USING DESPOT

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INTRODUCTION

Quantitative cardiac MR (CMR) is in the research spotlight for non-invasive tissue characterization using parametric mapping of T1 and T2. DESPOT1/2 have been proposed for rapid and accurate T1 and T2 quantification [1] of the brain which exhibits rather long T1/T2 relaxation times. DESPOT1/2 comprises (i) 3D RF-spoiled fast low angle shot (FLASH) acquisitions for T1 quantification and (ii) 3D balanced steady state free precession (b-SSFP) acquisitions for T2 quantification, each including at least two acquisitions using different flip angles [1]. Besides B_1 non-uniformities, which already present a threat to accuracy at (ultra)high fields, short repetition times (TR) evoke T1 and flip angle dependent saturation phenomena that deform the slice profile [2,3] and hence bear the potential to render T1/T2 quantification inaccurate. Although these phenomena are known for several years its impact on T1 and T2 quantification using DESPOT has not been examined yet. Slice profile deformation is mitigated in case of relatively small T1 reported for late gadolinium contrast enhancement of myocardium used for the detection of myocardial infarction. However, the need for optimizing of the dynamic range and the signal-to-noise ratio (SNR) shifts the the optimum flip angles to larger values. For all these reasons this study examines the impact of slice profile deformation on the signal of 2D FLASH and 2D b-SSFP and demonstrates its implications for rapid T1 and T2 quantification using DESPOT1/2.

METHODS

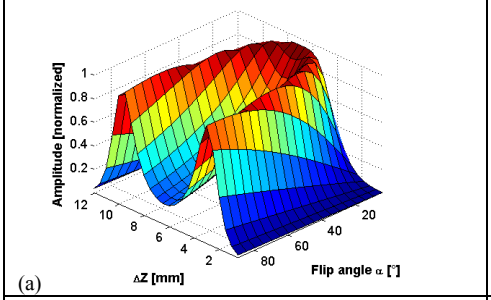
Predictive flip angle dependent signal intensities were calculated in the steady state using Bloch simulations with the same RF pulse shapes used for FLASH and b-SSFP imaging on a 3.0 T MR scanner (Siemens Verio, Siemens Healthcare, Erlangen, Germany). The readout gradient of an RF spoiled FLASH sequence (TR=4.7ms) and of a SSFP sequence (TR=6.5ms) were set to the slice selection direction to obtain slice profiles from an oil phantom (T1=200ms, T2=125ms). The oil phantom was used to mimic short T1 values, which occur in late gadolinium contrast enhancement imaging of myocardium, and to avoid B1 inhomogeneities that may influence the results. B1-homogeneity was verified by B1-mapping using the PhiFA CUP approach [4]. Reference measurements were performed using a single shot inversion recovery (IR) technique (TR=2300ms) for T1 mapping and a multi-echo spin echo technique (TR=2300ms) for T2 mapping. The integrated body coil was used for excitation. The impact of the signal change on the quantification of T1 and T2 using DESPOT1 and DESPOT2 approach were calculated.

RESULTS

Slice profile deformations derived from simulations and oil phantom measurements are presented in Fig.1 for FLASH and Fig.2 for b-SSFP. Severe slice deformation was observed for alpha larger than 20 degrees for FLASH and alpha larger than 60 degrees for b-SSFP. The application of large flip angles induces a flip over of the slice center. This leads to signal contributions predominantly from the peripheral slice locations. Figure 3 illustrates the discrepancy between the theoretical vs. the measured signal intensity that is prone to slice deformation. For T1 mapping the optimum angle set was calculated to be 5°/29°. Mean T1 deviation between the uncorrected DESPOT1 FLASH data and the IR data was found to be -61±5%. For the T2 measurements T1 was set to 200 ms and the optimum flip angles were found to be 36°/125°. In comparison to the ME-SE data, the uncorrected DESPOT2 b-SSFP data revealed a mean T2 deviation of +43±11%.

CONCLUSION

Our results demonstrate severe slice profile deformations for flip angles, which would be ideal for rapid myocardial T1/T2 mapping using the DESPOT1/2 approach. Consequently, it is essential to correct for slice deformation - especially in scenarios with relatively low T1 values and short TR - before T1 and T2 values derived from DESPOT acquisitions can be considered accurate.



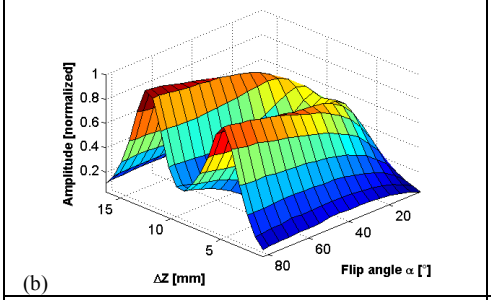
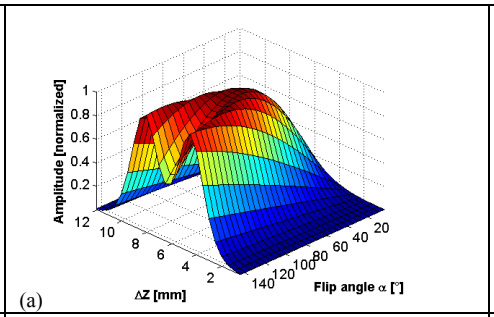


Figure 1: Simulation (a) and measurement (b) of the slice profile on a phantom with different flip angles using the RF spoiled FLASH formula/sequence. Severe slice deformation occurred for alpha larger than 20 degrees.



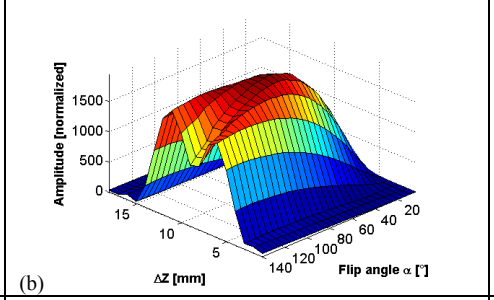
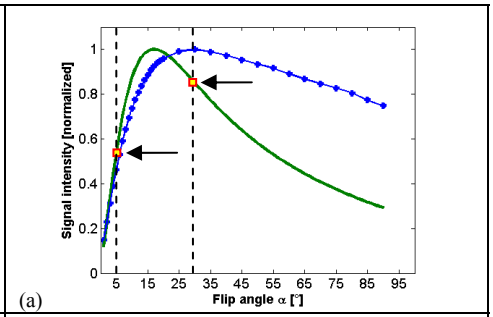


Figure 2: Simulation (a) and measurement (b) of the slice profile on a phantom with different flip angles using the balanced SSFP signal formula/sequence. Severe slice deformation occurred for alpha larger than 60 degrees.



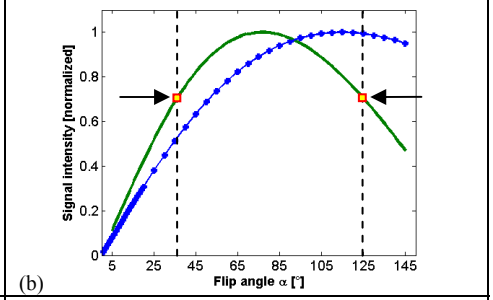


Figure 3: Theoretical (green) v. measured (blue) signal intensity for FLASH (a) and b-SSFP (b) over different flip angles. The dashed lines highlight the signal differences for a pair of flip angles suitable for T1/T2 mapping of short myocardial T1 values.

1) Deoni SC et. al., Magn Reson Med 2003;49:515-526., 2) Parker G.J.M et. al., Magn Reson Med 2001;45:838–845, 3) Deimling M. et al. SMRM 1986;p.926, 4) Santoro et. al., ISMRM 2010;p.4943