Fast Isotropic Volumetric B_1^+ Calibration Improves RF Shimming in Abdominal MRI at 3T

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Introduction

The use of dual-source parallel radiofrequency (RF) excitation has been shown to significantly improve image quality in abdominal MRI at 3T[1,2]. Currently, patient adaptive optimization of RF-settings is based on a transversal single-slice $\mathbf{B_1^+}$ calibration scan, positioned in the center of the volume to be imaged, which requires one long breath-hold acquisition. The shimset (amplitudes A1 and A2 of the two channels and relative phase ΔΦ) obtained by optimization of the $\mathbf{B_1^+}$ field in this single slice is applied to all subsequent image acquisitions irrespective of slice off-center and orientation. This single-slice approach already reduces $\mathbf{B_1^+}$ imperfections substantially. However, the recently proposed ultra-fast $\mathbf{B_1^+}$ mapping approach DREAM[3] allows the acquisition of a volumetric calibration dataset with isotropic voxel size in the same acquisition time as the conventional dual TR[4] single-slice calibration. Therefore, DREAM may be utilized to compute individually optimized shimsets for each slice, adaptive to position and angulations without prolongation of examination time. In this study, potential improvements in flip angle accuracy and $\mathbf{B_1^+}$ homogeneity by utilizing volumetric $\mathbf{B_1^+}$ information were analyzed.

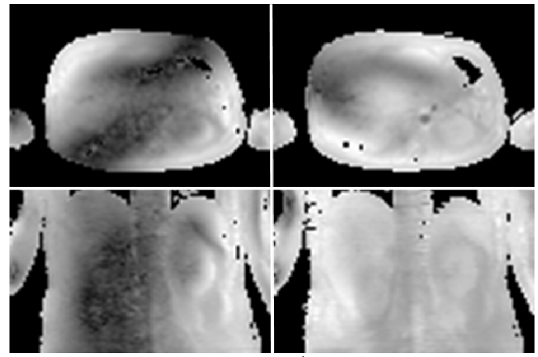

Fig. 1. **Volumetric DREAM $\mathbf{B_1^+}$ calibration scan** in a 64 year old female patient. Isotropic voxel size of 4.7mm. Left/right column: B_1^+ amplitude of transmit channel 1/ channel 2, bottom row: coronal reformats were used for RF shim optimization of coronal slices, acquisition time 15.3 s.

Methods

12 patients referred for MRI of the upper abdomen and two healthy volunteers all with written informed consent were included in this prospective study. DREAM $\mathbf{B_1^+}$ calibration scans (60 axial slices, FOV= 450×280 mm^2, voxel size = 4.7mm isotropic, SENSE factor = 2, STEAM flip angle α= 60°, imaging flip angle β= 15°, water fat shift = 0.35 pixels, TR= 3.8 ms, TE_{FID}= 2.4 ms, TE_{STE}= 1.4 ms, T_S= 3.8ms , shot duration = 127 ms, total scan time 15.3 s) were acquired in a single breath-hold at a dual-transmit 3T MRI system (Ingenia, Philips Healthcare, Best, The Netherlands). The chosen echo timing scheme resulted in an approximately in-phase water/fat signal for both echoes used in DREAM.

Based on this volumetric data, RF-settings were optimized separately for each of the 60 transversal, as well as for each of 40 coronal reformatted slices applying an iterative magnitude-least-squares algorithm[5]. Target area for $\mathbf{B_1^+}$ optimization was restricted to the torso. RF settings obtained by optimization of the central transversal slice (cs-tra) corresponding to the conventional shimming strategy as well as multi-slice adaptive settings for transversal (ms-tra) and coronal slices (ms-cor) were subsequently applied to the calibration data. Deviation from nominal flip angle and coefficient of variation in $\mathbf{B_1^+}$ (cv = standard deviation/mean) were computed for comparison of shim results, respectively.

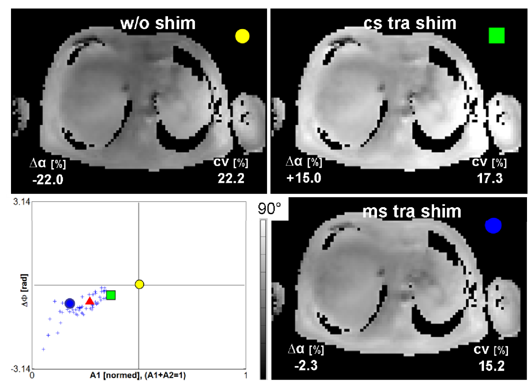

Fig. 2. **Comparison of shim results in an off-centered transversal slice** in a 70 year old male patient with extensive ascites. Green square: shimset obtained in central slice, small blue crosses: slice adaptive shim sets, blue dot: shimset for displayed slice, red triangle: shimset obtained by optimization of the whole volume.

Results

Figure 1 shows an example of a DREAM $\mathbf{B_1^+}$ calibration scan. Quantitative comparison of RF shim results obtained with multi-slice adaptive shimming versus conventional single-slice optimized shimming (Figure 2 and 3) revealed a significant ($p = 0.001$) improvement in flip angle accuracy in the slices with maximum mean deviation from nominal flip angle |Δα| from 12,9% (cs-tra) to 4.4% (ms-tra) for transversal slices, and from 15.6% (cs-tra) to 2.56% (ms-cor) for coronal slices. Evaluations of the slice with maximum improved homogeneity in each case showed a relative reduction in cv of 8.5±5.4% for transversal (ms-tra vs. cs-tra) and 27.8±9.8% (ms-cor vs. cs-tra) for coronal slices, respectively.

Discussion

Acquisition of isotropic volumetric $\mathbf{B_1^+}$ calibration data allows the determination and application of optimal shimsets for each slice, adaptive to position and angulations. The benefit of this approach is a higher flip angle accuracy and an improvement in $\mathbf{B_1^+}$ uniformity. While this was demonstrated exemplarily for standard transversal and coronal slices in the upper abdomen at 3T, isotropic $\mathbf{B_1^+}$ calibration data may also be utilized for optimal shimming of double-oblique slices, regional shim optimization, and sophisticated shimming strategies in which different $\mathbf{B_1^+}$ shimsets are applied to different RF pulses, e.g. pre-pulses for magnetization preparation which is essential at 7T[6,7]. The use of the ultra-fast $\mathbf{B_1^+}$ mapping approach DREAM allows the application of advanced shimming strategies without prolongation of the examination time, which is essential for clinical application.

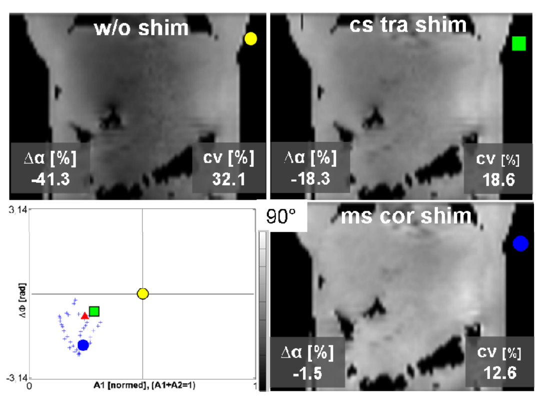

Fig. 3. **Shim results in coronal orientation** in a 47 year old female patient. Green square: shimset obtained in central transversal slice, small blue crosses: slice adaptive coronal shim sets, blue dot: shimset for displayed slice.

References

1. Willinek WA et al., Radiology 2010;256:966-975. **2**. Kukuk GM et al., Radiology 2011;259:421-428. **3**. Nehrke K et al. MRM 2012;68:1517-1526. **4**. Yarnykh VL, MRM 2007;57:192-200. **5**. Setsompop K et al. MRM 2008;59:908-915. **6**. Li X et al. Proc ISMRM, 2011:593. **7**. Metzger GJ et al. MRM 2012; doi: 10.1002/mrm.24237