Free-Breathing Abdominal B_1 Mapping at 3T Using the DREAM Approach

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Introduction

At higher field strengths, the dielectric shortening of the wavelength in the body typically results in inhomogeneous RF fields (1). In case of the thorax and abdomen, also temporal changes of the RF fields may be expected due to cardiac, respiratory and peristaltic motion, because motion-induced displacements of anatomical structures potentially affect the spatial conductivity and permittivity. However, current B_1 mapping approaches are by far too slow for real-time B_1 mapping, making appropriate gating or synchronization techniques necessary (2).

In the present work, a new B_1 mapping approach dubbed DREAM (Dual Refocusing Echo Acquisition Mode) is proposed for free-breathing abdominal B_1 mapping to study potential effects on RF homogeneity. The DREAM technique acquires a 2D B_1 map in a fraction of a second, making it possible to freeze respiratory motion efficiently. The approach is used to study dynamic changes of B_1 in the liver during free breathing at 3T.

Theory

The DREAM method employs a STEAM preparation sequence (3) followed by a tailored single-shot low-angle gradient echo train. In contrast to existing rapid STEAM B_1 mapping techniques (4), both, the free induction decay (FID) and the stimulated echo (STE), are refocused quasi-simultaneously as gradient-recalled echoes I_1 and I_2, which are used to derive the actual flip angle α of the STEAM preparation pulse sequence (Eq.[1]).

$$\alpha = \arctan\sqrt{2\,I_2/I_1} \quad [1]$$

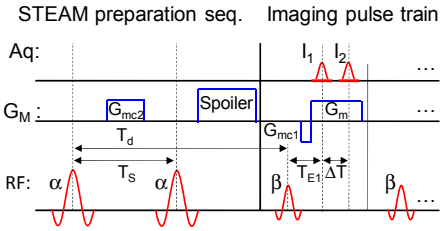

FIG. 1. **DREAM B_1 mapping sequence.** For clarity, the employed slice-selection and phase-encoding gradients have been omitted in this diagram.

Methods

In vivo experiments were performed on a 3T MRI system (Philips Healthcare, Best, The Netherlands) equipped with an eight-channel parallel transmit extension (5). The DREAM approach was used for B_1 mapping of the abdomen in five healthy volunteers. Written consent was obtained according to the rules of the institution. 2D sagittal B_1 maps of the liver were acquired in a dynamic loop during free breathing (FOV= 450×270 mm^2, scan matrix= 128×76, imaging slice thickness = 10 mm, nominal STEAM flip angle α= 60°, nominal imaging flip angle β= 15°, TE_1=2.3 ms, ΔT =-0.6 ms, T_S = 4 ms, T_d =9 ms, TR= 3.2 ms, profiles per shot = 76, shot duration = 270 ms, shot delay = 2s, total number of shots = 30). The chosen echo timing scheme resulted in fat-water in-phase signals for both echoes, with the stimulated echo acquired first. To minimize T_1 effects, no startup echoes were acquired, and a low-high profile order was used. The eight-channel body coil (6) of the system was driven in quadrature mode for both, signal transmission and reception. The magnitude of B_1 was derived according to Eq.[1]. The FID signal was used for masking the B_1 maps by applying a simple signal threshold. No filtering or smoothing of the B_1 maps was performed.

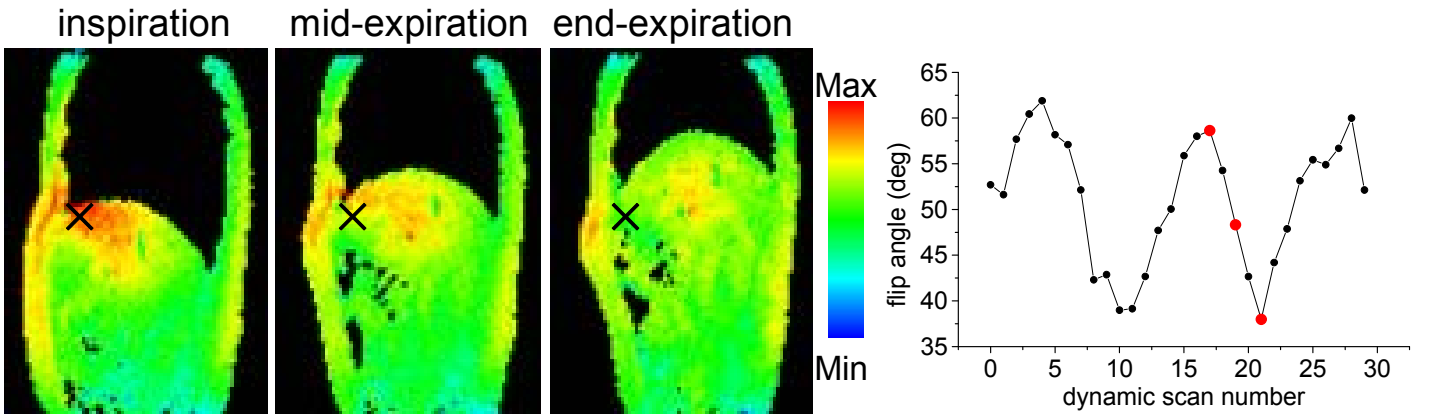

FIG. 2. **Free-breathing DREAM B_1 mapping:** Three B_1 maps selected from a time series are shown, representing inspiration, mid-expiration and end-expiration (left). The black crosses indicate the position of the voxel selected for the plot on the right, which shows the actual flip angle over time. The three selected B_1 map time frames shown on the left are indicated by red symbols in the plot.

Results and Discussion

Figure 2 shows three selected B_1 maps representing three different respiratory states along with a flip angle breathing curve for a selected voxel. In the anterior-superior region of the liver, a considerable increase of the flip angle by approx. 50% is observed during inspiration. These initial results indicate that significant dynamic changes of the RF-field may occur in free-breathing MRI at high field strengths, potentially influencing MR image contrast and SAR of the employed pulse sequence. Nevertheless, parallel transmit MRI systems have the potential to adapt the RF shim settings dynamically to the respiratory state, thus controlling RF homogeneity and SAR over the whole respiratory cycle. The DREAM approach as a fast single-shot sequence can easily be combined with respiratory navigators, and hence, would ideally serve as a navigator-based RF calibration sequence. The 2D DREAM sequence used in this study could be extended easily to a multi-slice sequence without trading spatial or temporal resolution. Appropriate respiratory phase-dependent RF shim settings could be derived and stored along with navigator measurements e.g. in a lookup-table for subsequent navigator-based real-time RF shimming. However, extended studies in real patients are required.

References

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