Fast B_1^+ Mapping for Cardiac MR using a Black Blood DREAM Sequence

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Introduction

Fast and robust in vivo B_1^+ mapping is an essential prerequisite for multi-element transmit applications like RF-shimming or accelerated multi-dimensional RF pulses (1-3). However, most B_1^+ mapping techniques are relatively slow, making an integration into the clinical workflow difficult. This is in particular the case for cardiac B_1^+ mapping, where cardiac triggering and breath-holding used to suppress physiological motion further reduces scan efficiency. The recently introduced DREAM B_1^+ mapping approach (4) allows the acquisition of a B_1^+ map in a small fraction of a second, thus fitting in the diastolic phase of a single heart-beat. However, the stimulated echoes used for B_1^+ encoding are sensitive to flow, potentially degrading the B_1^+ maps for the blood pool signal in the heart chambers. For the present work, the DREAM sequence has been combined with a black-blood prepulse for masking the blood signal and has been studied for in vivo RF shimming of the heart at 3T.

Methods

In vivo experiments were performed with healthy volunteers on a dual-transmit 3T MRI system (Ingenia, Philips Healthcare, Best, The Netherlands). Written consent was obtained according to the rules of the institution. The DREAM sequence (Fig.1) was used to acquire transversal 2D B_1^+ maps of the heart in a single diastolic heart phase (FOV= 450×270 mm^2, scan matrix= 128×38, SENSE factor = 2, imaging slice thickness = 10 mm, STEAM flip angle α= 60°, imaging flip angle β= 10°, water fat shift = 0.35 pixels, TE_{FID} = 2.4 ms, TE_{STE} = 1.4 ms, T_S = 3.8 ms, TR= 3.8 ms, shot duration = 145 ms). The chosen echo timing scheme resulted in an approximately in-phase water/fat signal for both echoes. For comparison, experiments were performed without and with a black-blood preparation pulse (non-selective/selective inversion pulses, 400 ms inversion delay). The B_1^+ maps were masked automatically using a simple threshold applied to the source images. RF homogeneity was quantified in terms of the coefficient of variation (cv). The sequence was employed for RF shimming of the two transmit channels in two heart beats. For verification, additional DREAM B_1^+ maps were acquired for quadrature and shimmed excitation in a single heart beat, respectively.

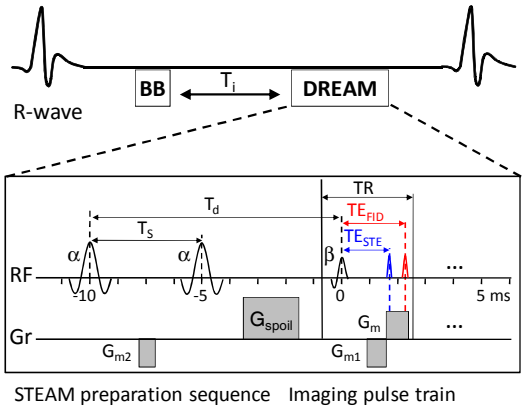

FIG. 1. **DREAM pulse sequence scheme.** The basic sequence consists of a STEAM magnetization preparation sequence (left), and a low-angle single shot imaging sequence (right, only one TR is shown). The imaging RF pulse β creates a stimulated echo (STE) and an FID, which are measured as separate gradient-recalled echoes during a single readout (only measurement gradients are shown). Due to the short TR, a 2D B_1^+ map can be acquired in a single shot in the diastolic heart phase. Additional preparation sequences such as a black-blood saturation pulse may be applied to suppress potential artifacts.

Results

Figure 2 shows the impact of cardiac flow on the DREAM B_1^+ maps. The flow-induced decay of the stimulated echo (STE) results in an underestimation of the B_1^+ in the blood pool. Using blood-suppression, the low signal in these areas can be used easily for masking, restricting the maps to the myocardium. Figure 3 shows the results on RF shimming. For quadrature excitation, a relatively strong B_1^+ inhomogeneity (cv = 27%) was observed, which was reduced by about 50% (cv = 14%) for RF shimmed excitation.

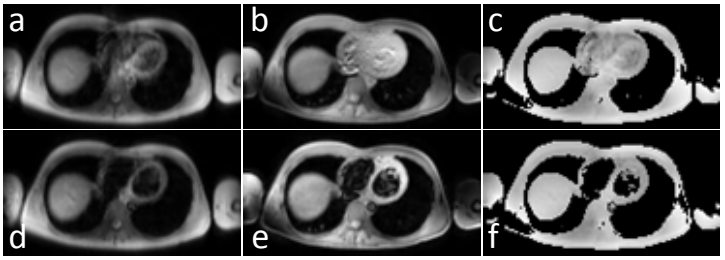

FIG. 2. **Impact of cardiac flow on DREAM B_1^+ map:** Underlying images (left : STE, centre FID) and resulting B_1^+ map (right) are shown. For a conventional DREAM sequence (top row), flow artifacts in the STE and FID images lead to a degraded B_1^+ map in the area of the heart chambers. The application of a black-blood preparation pulse facilitates automatic threshold-based masking of the B_1^+ map (bottom row), improving the reliability of the map significantly.

Discussion

The DREAM approach allows a 2D B_1^+ map to be acquired in a single heart beat, which makes it easy to integrate the sequence into the clinical workflow of a parallel transmit MRI system. Thus, B_1^+ maps could be acquired for several slices, orientations, and/or transmit channels in clinically acceptable breathhold durations. The proposed magnetization preparation based blood suppression scheme facilitates masking of the blood pool signal, thus improving the accuracy of the maps, and hence, the quality of RF shimming, considering only reliable B_1^+ estimates. More advanced black-blood preparation pulses suitable for multi-slice excitation (5) could be employed in a straight forward manner, further increasing the flexibility of the approach.

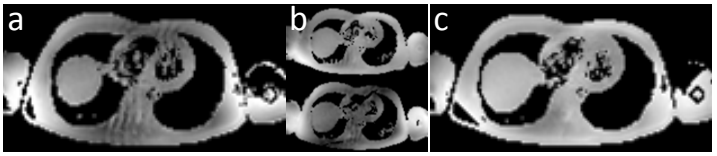

FIG. 3. **DREAM B_1^+ mapping and RF Shimming of the heart:** B_1^+ maps are compared for quadrature excitation (a) and RF shimmed excitation (c). RF shimming was based on a 2-channel calibration scan (b) and resulted in significant improvement of homogeneity (50% reduction of cv).

References

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