Magnetization Prepared DREAM for Fast Flow-Robust B1+ Mapping

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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, accelerated RF pulses or appropriate post-processing to correct quantitative MR results for any B_1^+ imperfections. The recently introduced DREAM B_1^+ mapping approach (1) is therefore very promising, allowing single shot B_1^+ mapping within a fraction of a second. However, the stimulated echo mechanism used for B_1^+ encoding in DREAM might be sensitive to flow (2,3), potentially degrading the B_1^+ maps for the blood pool signal in large vessels and in the heart. Recently, DREAM, which is based on a magnetization prepared transient gradient echo sequence (1), has been combined with a preceding dual-inversion black-blood magnetization preparation for masking the flowing blood signal (3). This approach was successful but shows a couple of drawbacks. (I), the duration of this preparation is a factor 2-3 longer than the actual DREAM sampling, making the entire sequence rather inefficient. (II), a black-blood pre-pulse requires a good knowledge about the blood's T_1, tend to fail when the blood T_1 is unknown, esp. after contrast injection. And (III), due to a global inversion pulse involved interleaved locally restricted or multi-slice B_1^+ mapping becomes difficult.

In the present work these drawbacks have been overcome by using a more efficient and robust magnetization preparation approach instead, studied in detail here for high field applications.

Methods

The STE signal of flowing spins cannot be fully recovered because the action of the fields of G_c and G_m (see Fig.1b) do not compensate in case of flow resulting in an amplitude loss (2). Thus, a Motion-Sensitized Driven-Equilibrium magnetization preparation (4) was added before the DREAM sequence (Fig.1a), which employs small flow sensitizing gradients, here in all three directions, to suppress flowing signal components. Those are losing coherence during MSDE and are thus not tipped up anymore. To partly compensate for the expected and existing B_1^+ inhomogeneity an even number of refocusing 180° RF pulses (two) is used in the MSDE. See Fig.1b for more sequence details. To test the performance of this approach in-vivo experiments were performed on 9 healthy volunteers, written consent obtained, using two different dual-transmit platforms at 7T (Philips Achieva) and at 3T (Philips Ingenia). For the MSDE preparation the following parameters were used (TE: 30ms, venc: 5-10cm/s, total duration 40ms). DREAM (Fig.1b) was used to acquire 2D B_1^+ maps (voxel size brain: 3.3×3.3×7mm³, cardiac and abdomen: 5×5×10mm³, SENSE: 2, STEAM flip: 50-60°, imaging flip 5-10°, $TE_{FID}/TE_{STE}/TE_{FID}$:1.4/2.0/3.3ms @7T and 1.4/2.4/3.8ms @ 3T, respectively, resulting shot duration: 120-140ms). For comparison, DREAM mapping was performed with and without MSDE black-blood preparation. The B_1^+ maps were masked automatically using a simple magnitude threshold applied to the source images.

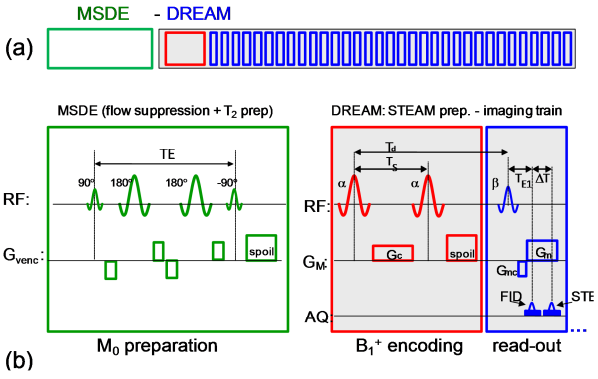

Fig.1. MSDE - DREAM. (a) Scheme of the Motion-Sensitized Driven-Equilibrium (MSDE) preparation (green) preceding a single-shot DREAM. (b) MSDE (green) suppresses flow in the prepared M_z before the DREAM detection block (red and blue). The spatial encoding train (blue) is repeated N times to read-out the FID and STE signals.

Results and Discussion

Figure 2 shows selected examples for DREAM in the brain (7T) and cardiac applications (3T). The flow-induced signal loss in the stimulated echo (STE) results in an underestimation (arrows) of B_1^+. Using MSDE flow-suppression, the signal from flowing fluids is suppressed for both, STE and FID (irrespective of arterial or venous blood or CSF). Thus, MSDE can avoid the potential contamination of the DREAM signals in those areas and consequently improves the quality of the B_1^+ maps. In the cardiac applications B_1^+ information is restricted to the myocardium, because the STE signal from the blood chamber is likely compromised by flow. The MSDE preparation slightly changes the contrast of the STE and FID images. This is not a problem for the accuracy of the B_1^+ maps because STE and FID are influenced in the same way and read-out in a low-high phase encoding fashion (1). Moreover, SNR is not a real issue due to the coarse spatial resolution of the B_1^+maps. However, the B_1^+ inhomogeneity will also compromise the initial 90° tip-down and tip-up RF pulse performance in the MSDE pre-pulse. Consequently, in areas of high B_1^+ inhomogeneity flow suppression will not be perfect, but the results at 7T and 3T (brain, abdomen, heart) confirmed a substantial and sufficient improvement.

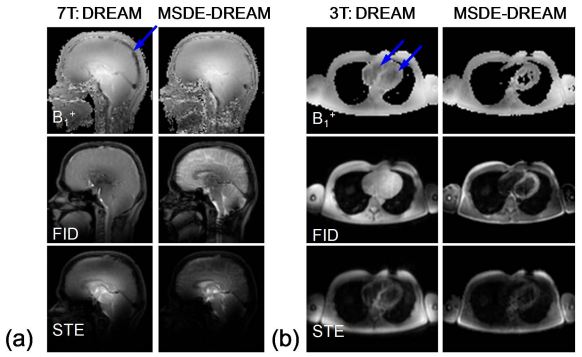

Fig.2. DREAM versus MSDE-DREAM. (a) Flow artifacts in brain B_1^+ maps at 7T (arrow) can be suppressed (great vein, ventricle). (b) The 3T cardiac B_1^+ map can be made more reliable suppressing the blood in the chambers. Below the maps the underlying images (FID, STE) are shown. Note the flow related signal loss in the plain STE vs. FID and the slightly changed T_2 contrast in case of MSDE preparation.

Conclusion

Using MSDE preparation for DREAM improved the B_1^+ mapping quality and accuracy significantly, overcoming potential flow sensitivities. The MSDE-DREAM is simpler, faster and more flexible than dual inversion DREAM approaches (2), because MSDE allows for shorter and also regional selective signal preparation and does not need any detailed knowledge about the T_1 of blood. The inherent signal loss due to T_2 weighting in MSDE and present B_1^+ inhomogeneities do not compromise MSDE-DREAM-mapping accuracy because the source image SNR is usually high, and potential signal uniformity will effects cancel out, when the ratio between the two acquisitions is calculated in DREAM.

References

[1] Nehrke MRM 2012;68:1517. [2] Fischer, MRM 1995; 34:80-91. [3] Nehrke ISMRM 2013, 4271. [4] Wang JMRI 2010; 31:1256.