B_1 Insensitive T_2 Preparation Sequence for Coronary Imaging at 3T

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Abstract

We propose a B_1 insensitive T_2 preparation sequence employing the adiabatic plane rotation RF pulses for contrast generation in coronary MRA at 3T. The effective wavelength of RF field at 3T is comparable to the dimension of the human body, which causes a significant variation of the B_1 phase along the sample and B_1 standing wave effects which cause RF field inhomogeneity at higher field strengths. Non-endogenous contrast enhancement such as T_2 prep is used extensively in coronary imaging [1]. This preparation scheme is relatively insensitive to B_0 inhomogeneity, however it's not efficient in compensating for the B_1 inhomogeneity in high-field magnets. An adiabatic T_2 prep sequence in which the refocusing is achieved with two adiabatic inversion RF pulses to perform a plane rotation is proposed. Simulations and in-vivo results illustrate an excellent suppression of the artifacts originating from B_1 inhomogeneity while achieving similar T_2 contrast enhancement.

Materials and Method

Adiabatic plane rotation pulses [2] are used for refocusing the magnetization after excitation with a hard pulse in a T_2 magnetization preparation sequence to achieve a B_1 insensitive refocusing. This will compensate the effects of increased B_1 inhomogeneity which cause significant errors in 180° refocusing pulses. Numerical simulations were performed to study the effect of B_1 and B_0 variation on the magnetization response to the sequence. We calculated the M_z magnetization after T_2 preparatory pulses with A) hard excitation and tip-up pulses and either B) two MLEV composite refocusing pulses, or C) two sech/tanh modulated adiabatic pulses [2]. In vivo coronary experiments were performed on normal volunteers (N = 6) with no known cardiovascular disease. All experiments were performed on Philips 3T Intera system (Philips Medical Systems, Best, NL) using 6 element cardiac receive coil. A free-breathing ECG gated, fat suppressed, 3D segmented gradient-echo image was acquired using a 2D-selective navigator signal. Imaging parameters were as follows: FOV= 27cm, TR= 7.5ms, TE= 2.1ms, Matrix size = 384, slice thickness = 3mm. In order to study the effect of T_2 prep, we compared the results by doing the experiments without application of T_2 prep, using two composite MLEV pulse, and with T_2 prep using adiabatic plane-rotational pulses.

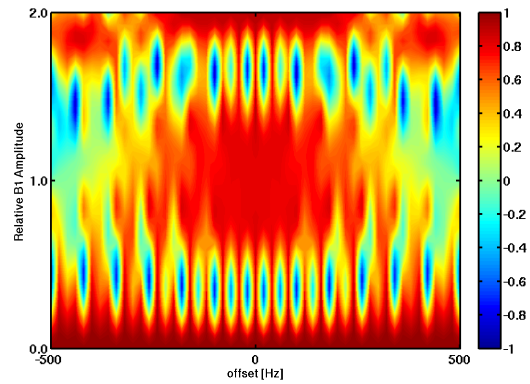

Figure1. M_z/M_{eq} after T_2 Prep with a two composite MLEV $90_x180_y90_x$ pulse for refocusing as a function of resonance-offset and B_1 variations. The hard pulse length was 0.43 ms, the reference $\gamma B1/2\pi$=575 Hz, TE 50 ms, T_2 / $T_1$200/1200 ms.

Results

Fig. 1 demonstrates the longitudinal magnetization, (M_z/M_{eq}) calculated from the numerical simulation of the Bloch equations. The simulation includes a T_2 prep sequence consisting of two MLEV composite pulses in the presence of B_1 and B_0 inhomogeneity. The results demonstrate that the magnetization does not consistently return to the longitudinal axis in the presence of strong B_1 inhomogeneity. Figure 2 shows the same simulation with the MLEV pulses replaced by an adiabatic plane rotation. Figure 3 shows the in-vivo right coronary MR images acquired with the proposed adiabatic T_2 preparation in comparison to two MLEV composite and no T_2 preparation sequence. Consistent with the simulated findings from Figure 2, an effective suppression of the B_1 inhomogeneity artifacts is obtained and an increase in visual sharpness of distal region of the RCA (arrow, Figure 3, C).

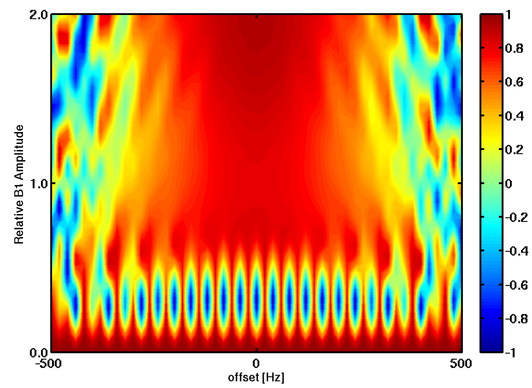

Figure2: M_z/M_{eq} for a two sech pulse plane-rotation adiabatic T_2 prep sequence as a function of resonance-offset and B_1 variations. Sequence parameters as in Figure 1. The sech pulse length was 11.8 ms for a design bandwidth of 1kHz.

Conclusions and Discussion

The proposed technique is less sensitive to B_1 inhomogeneity thereby providing improved T_2Prep endogenous contrast generation for coronary MRA at high magnetic field strength. Simulation and in-vivo results are in good agreement. The response variations far off-resonance in Fig 2, are related to the bandwidth of the sech/tanh pulse. Further improvements may be achieved by using adiabatic RF pulses for excitation and or tip-up, however at the expense of a further increase in SAR.

References: [1] Brittain JH ,Magn Reson Med. 1995 May;33(5):689-96. [2] Garwood M, et. al. J Magn Reson. 2001 Dec;153(2):155-77.

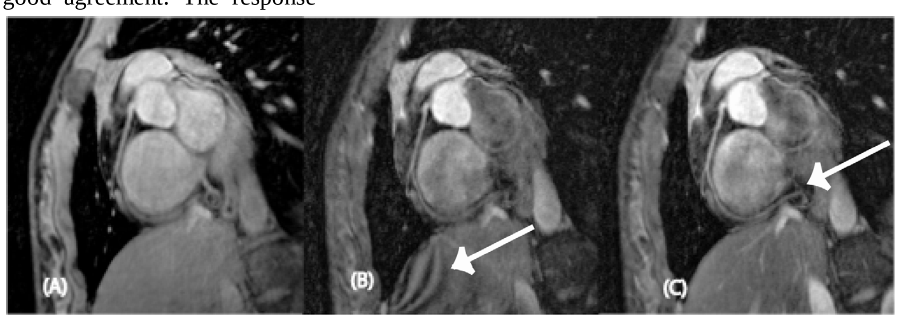

Figure 3: (A) No T_2 preparation (B) T_2 preparation with two MLEV composite pulses (C) Adiabatic T_2 preparation