Improvement of Magnetic Field Homogeneity for Cardiac MRI at 3 Tesla

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Objective

The objective of this work is the assessment of the possible reduction of patient induced main magnetic field inhomogeneities over the entire cardiac cycle, by applying cardiac phase dependent shim settings at 3T.

Introduction

Cardiac imaging at 3 Tesla demands dedicated shimming techniques to avoid image degradation by off-resonance induced artifacts. To ensure diagnostic image quality at 3T MR, excellent local magnetic field homogeneity is required in the region of interest (ROI). Furthermore, cardiac and respiratory motion may effect the optimal shim settings depending on the current motion state. To achieve an improved homogeneity, a high order shim system including 1st and 2nd order shims was used. All shim constants were assessed dependent on the cardiac phase. The main objective was to prove that artefacts caused by cardiac motion can be efficiently suppressed by phase dependent shimming. Secondary objective was to assess whether an optimal cardiac phase can be found, providing shim coefficients, which ensure sufficient field homogeneity over the entire cardiac cycle in the respective ROI. The latter would avoid the necessity of rapid switching of the shim fields and thus reduce hardware demands.

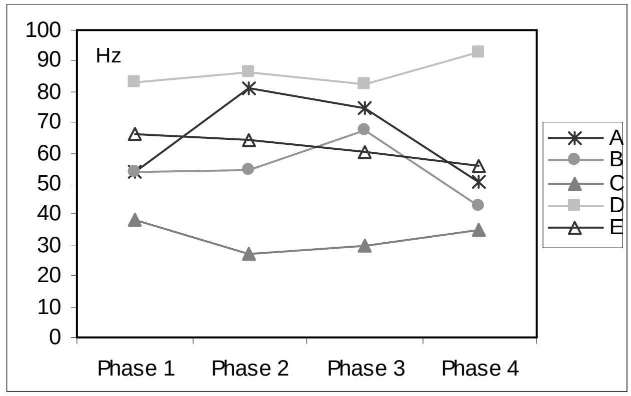

Fig. 1: Standard Deviation [Hz] over Cardiac Cycle, prior Shimming

Methods

In this work, a high order shim system comprising (x, y, z, z^2, xz, yz, x^2-y^2, 2xy) was used. A cardiac phase resolved B0 field map (TR = 4.1ms, TE = 1.56ms, ΔTE = 1ms, Resolution (ap/rl/fh) = (6/6/6) mm) was acquired over 4 cardiac phases in a single breathhold. A region of interest (ROI) was chosen encompassing the epicardial border of the heart or the left ventricle in each cardiac phase. Five volunteers were included. For each cardiac phase individual shim constants (linear for A and B, linear and second order for C, D and E) were calculated with a least squares fit inside the ROI. The resulting improvement in B0 field homogeneity and image quality was determined separately for each cardiac phase in subsequent scans. Each set of shim coefficients for one particular cardiac phase was applied over the whole cardiac cycle and the resulting homogeneity of the magnetic field was determined inside the ROI for all cardiac phases. The resulting quality was assessed by the standard deviation of the off-resonances in the ROI. Hence four shimmed B0 maps, each over the whole cardiac cycle, were available. The ROIs in volunteer A and C covered the left ventricle over 8 slices, the ROIs in volunteer B, D and E included the epicardial border heart over 3 slices. The average heart rate was 66.6 ± 9.

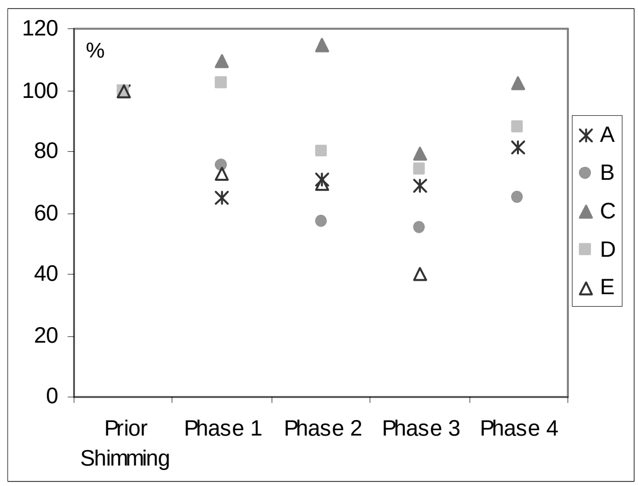

Fig. 2: Relative Change [%] of Standard Deviation over Cardiac Cycle, post Shimming

Results and Discussion

All scans could be completed successfully. The off-resonance patterns changed over the cardiac cycle in all volunteers. The magnitude of the variations increased with the volume of the ROI. Fig. 1 summarizes the variation of the standard deviation of the off-resonances over the different cardiac phases.

Assessment of the mean standard deviation averaged over all four cardiac phases indicates that the use of a single shim coefficient set can be applied for improving the field inhomogeneity over the entire cardiac cycle if the shim coefficients derived from phase three were applied to all cardiac phases (see Fig. 2). This could be observed for linear shims only as well as for linear and 2nd order shimming. The optimal cardiac phase corresponds to mid diastole. Therefore one is advised to use these shim values for high order shimming of the heart.

References

M. Schär, S. Kozerke, S. Fischer, P. Boesiger ; Cardiac SSFP Imaging at 3 Tesla ; MRM 2004 ;51 :799-806