

Rapid Fieldmap Estimation for Cardiac Shimming

S. Shah¹, P. Kellman², A. Greiser³, P. J. Weale¹, S. Zuehlsdorff¹, and R. Jerecic¹

¹Siemens Medical Solutions USA, Inc., Chicago, IL, United States, ²National Institutes of Health, Bethesda, MD, United States, ³Siemens AG Healthcare Sector, Erlangen, Germany

Introduction

Cardiac MR imaging techniques such as TrueFISP imaging and cardiac spectroscopic applications require a high degree of homogeneity in the static magnetic field (B_0). Present shimming methods rely on a B_0 -map estimation and apply compensatory shim currents to reduce the local field perturbations^[1,2]. Field map estimation in the heart is challenging due to the presence of cardiac and respiratory motion, and blood flow effects. Typically, a gradient echo (GRE) sequence with two in-phase echoes is used to obtain B_0 -map. During field map data acquisition, respiratory motion can be compensated with breathholding. If ECG-triggering is added, the time of acquisition may get prolonged beyond reasonable breathhold duration and also may not be feasible to apply in patients with arrhythmia. In this study, we investigate the effects of cardiac and respiratory motion for field map acquisition using a flow-compensated 2-echo GRE acquisition. The data acquisition time was minimized using parallel imaging (GRAPPA)^[3] to reduce the effects of cardiac motion in a non-ECG triggered acquisition. The described approach provides volumetric coverage of the heart in 5-6 seconds and can be used with or without breathholding.

Material and Methods

Fieldmap Variation Over Cardiac Cycle: To investigate the spatial and temporal variation over cardiac cycle, a 2-echo GRE cine sequence was implemented on a clinical 1.5T MR scanner (MAGNETOM Espree, Siemens AG Healthcare Sector, Erlangen, Germany). The acquisition parameters for a breathhold scan were: FOV=400x300 mm², matrix=128x96, spatial resolution=3.12x3.12mm², slice thickness=8 mm, echo-train length=2, TE=4.8/9.6 ms, TR=11.7 ms, flip angle (FA)=12°, bandwidth (BW)=797 Hz/pixel, phases=13, temporal resolution=58.5 ms, T_{Acq}=9.97 sec. The field maps were calculated using complex conjugate multiplication of two in-phase echoes and corresponding frequency maps were derived using MATLAB (Mathworks, Natick, MA, USA). Thereafter, an elliptical ROI and linear profiles were plotted to derive spatial and temporal variation of frequency maps within the heart across different cardiac phases.

Comparison of Acquisition Schemes: To compare different acquisition schemes, field maps were acquired on a 3T clinical scanner (MAGNETOM Trio, Siemens AG Healthcare Sector, Erlangen, Germany) using a flow-compensated 2-echo GRE acquisition with and without GRAPPA. The sequence parameters were: FOV=400x300 mm², matrix=72x96, spatial resolution=4.16x4.16 mm², TE = 2.4/4.8 ms, TR=6.6 ms, FA=12°, BW=800 Hz/pixel. 18 axial slices / partitions (8 mm thickness) were acquired covering entire heart. For 3D and non-ECG triggered 2D acquisitions total duration was 8.7 sec, whereas for 2D triggered acquisitions it took 18 heartbeats (~14 sec) to acquire a complete dataset. With the use of GRAPPA (acceleration = 2), the acquisition time for 1 slice was reduced from 480 ms to 320 ms, resulting in a total duration of 5.76 sec. The resulting field maps were compared by plotting horizontal and vertical frequency profiles across the heart.

Results

Fig. 1 shows magnitude and frequency map images for 14 cardiac phases of a 2-echo cine acquisition in a 4-chamber view. A region of interest (ROI) (Fig 2A - ellipsoid) and two linear profiles across long-axis (Fig 2A - red line) and short-axis (Fig 2A - blue line) were drawn over all cardiac phases. The ROI covered 1228 pixels and had a peak-to-peak variation of 207 Hz with std deviation of 23 Hz and avg temporal variation of 7.61 Hz over 14 cardiac phases. Similarly, Fig. 2C & 2D show close agreement for long-axis and short-axis frequency profiles in all phases.

All field maps acquired in breathholds matched closely; with or without the use of ECG-triggering (Fig 3); however, a visible difference was observed compared to the field maps of free-breathing acquisitions. The use of parallel imaging reduced scan-time but did not alter the field map.

Discussion

Field map estimation is the first step towards an optimized cardiac shimming. Sometimes, ECG-triggering is enabled during field map acquisition to compensate the cardiac motion, which in turn increases the total acquisition time. However, for a breathhold cine acquisition in a 4-chamber view of the heart, field maps showed a negligible (3.6%) avg. temporal variation over different phases of cardiac cycle. Therefore, without ECG triggering, accurate low-resolution field maps can be acquired within 8-10 seconds. This was verified by comparing field maps acquired in breathholds using 3D, 2D triggered and 2D non-triggered protocols. The difference in field maps of breathhold and free-breathing acquisitions can be attributed to the change in the heart position and/or change in the lung-geometry. To closely match the scan geometry during imaging scans, field maps could be acquired with breathholding. Moreover, the use of parallel imaging (GRAPPA) was shown not to alter the field maps and could be used to further reduce total imaging time to 5-6 seconds for an even shorter breathhold duration.

References

[1] Schneider *et al.*, MRM 1991 Apr;18(2):335-47 [2] Wen *et al.*, MRM 1995 Dec;34(6):898-904 [3] Griswold *et al.*, MRM 2002 Jun;47(6):1202-10

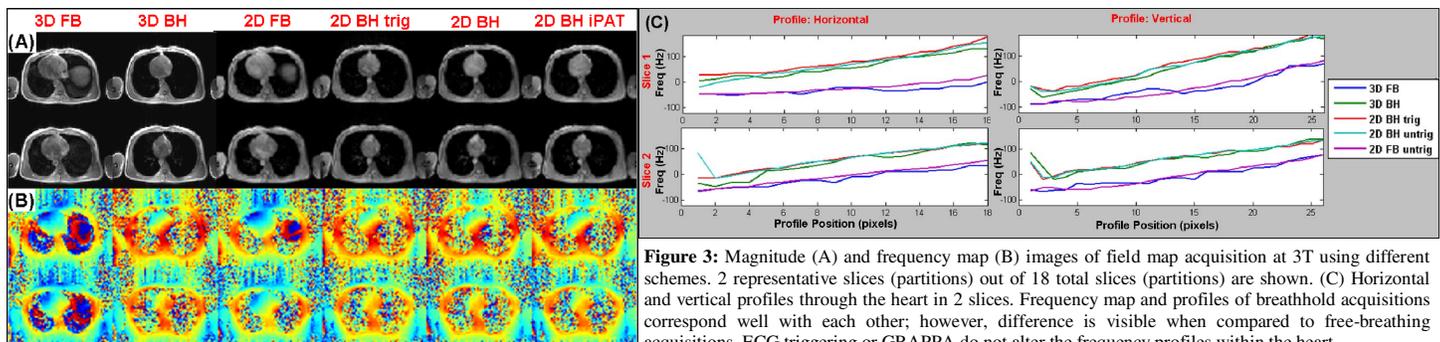


Figure 3: Magnitude (A) and frequency map (B) images of field map acquisition at 3T using different schemes. 2 representative slices (partitions) out of 18 total slices (partitions) are shown. (C) Horizontal and vertical profiles through the heart in 2 slices. Frequency map and profiles of breathhold acquisitions correspond well with each other; however, difference is visible when compared to free-breathing acquisitions. ECG triggering or GRAPPA do not alter the frequency profiles within the heart.

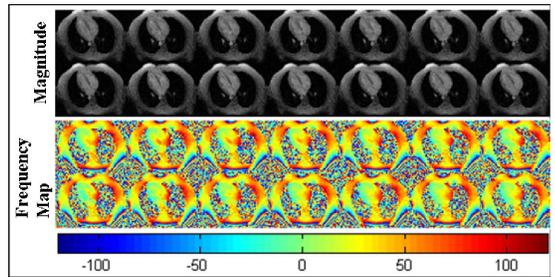


Figure 1: Magnitude and Frequency Map images for 14 cardiac phases. The frequency map images show minor variations in the heart over the entire cardiac cycle.

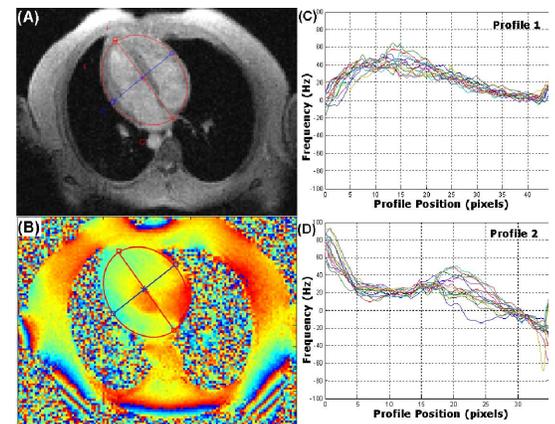


Figure 2: Magnitude (A) and frequency map (B) showing ROI (red ellipsoid) and linear profiles across long-axis (1 - red line) and short-axis (2 - blue line) of the heart. The frequency profiles (C & D) show little variation over different phases of the cardiac cycle.