Non-rigid Motion Correction in 3D Using Autofocusing with Localized Linear Translations

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INTRODUCTION: Motion degrades the quality of MR studies due to the duration of the scans. Recently, multi-coil arrays have been used to correct for these artifacts [1-3]. However, the additional spatial encoding from coil sensitivities still provides a rich source of unused motion information. Localized autofocusing is proposed to make use of that information for non-rigid motion correction.

METHOD: Correction Algorithm: Non-rigid motion can be locally characterized as localized translations. For this approximation to hold, images must be examined at a small enough spatial scale. To accomplish this, localized autofocusing is applied to determine the linear translations that best corrects for motion (Fig. 1). Motion is suppressed when the gradient-entropy is minimized. Usually, this metric is globally calculated [4-5], but in this work, only a small region around the pixel of interest is used to localize the metric. The vast search space is limited to motion measured using a coil array. The coil sensitivities provide a good means to observe linear motion at different spatial locations. For a multi-element coil array, these measurements are a good basis of possible motion trajectories for each image voxel.

Data Acquisition: Motion is measured using a strategy based on Butterfly navigators. These navigators are modifications to the spin-warp sequence that provide intrinsic motion information with negligible overhead [6]. The strategy is incorporated into a 3D spoiled gradient recalled (SPGR) sequence. For accurate navigation reference and motion-free coil-compression calibration [7], a small portion of data around the center of k-space is acquired using respiratory triggering and gating.

Experiments: Free-breathing abdominal studies were performed on pediatric subjects in a 3T GE MR750 scanner. Data was acquired using a 32-channel pediatric torso coil, flip angle = 15°, and bandwidth = 62.5 kHz. Additional Scan Parameters: Study 1: TE/TR = 2.1/5.5 ms, resolution = 0.94×0.94×3.0 mm³, FOV = 30×24×15.6 cm², navigation per TR = 0.14 ms, and 10% of k-space respiratory triggered and gated. Study 2: TE/TR = 1.7/4.8 ms, resolution = 0.94×1.2×3.0 mm³, FOV = 30×24×16.2 cm², navigation per TR = 0.11 ms, and 5% of k-space respiratory triggered and gated.

RESULTS/DISCUSSION: The autofocusing method was implemented in MATLAB and C++/CUDA. For a data size of 320×256×52 where 32-channels were compressed to 6-virtual coils, the total processing time was ~2 min – practical for online correction. Here, the localized linear model allowed for a simple correction without losing effectiveness. Motion artifacts from non-rigid motion were reduced (Fig. 3). Image sharpness was improved for many small structures that were poorly visualized prior to correction (Fig 3b). In a few areas, small residual motion-artifacts remain, which can be reduced by using more channels to expand the motion model space.

CONCLUSION: Using the localized gradient-entropy metric, we developed a practical autofocusing scheme for data acquired with a 32-channel coil array. A reduction of non-rigid motion artifacts was demonstrated.