Modified ZMART for supine breast MRI

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INTRODUCTION

Dynamic contrast enhanced (DCE) breast MRI shows a high sensitivity for breast cancer. However, in order to avoid respiratory motion artifacts, breast MR images are currently acquired with the patient in a prone position. This configuration is significantly different from the surgical setting, where the patient is supine. A supine positioning of the patient during DCE-MRI would simplify registration between the MRI images and the situation in the operating room (OR).

Supine breast MRI was previously implemented using custom-built coils and fixture [1], and the zonal motion-adapted acquisition and reordering technique (ZMART) [2] to compensate for respiratory motion. ZMART is a combination of gating and reordering based on a respiration pattern measured before the scan. Conventionally, if the respiration pattern during the scan changes the reordering is modified at the end of the acquisition in order to minimize scan-time, resulting in slightly corrupted reordering results.

Here a modification of ZMART is proposed, which keeps the reordering scheme constant even if changes in the breathing pattern occur during the scan by allowing a small increase in scan time.

MATERIALS AND METHODS

In order to perform breast MRI in supine position, a fast 3D spoiled gradient echo (fast 3D SPGR) sequence was used with the following two additions:

- Motion compensation using ZMART:
  Before the scan, the respiration pattern was tracked using a respiratory belt. A displacement threshold was selected above which to reject data (fig.1a). The remaining displacement range inside the gating window was segmented into zones in such a way that each zone was sampled an equal number of times during one respiratory cycle. In addition, the space-plane of the two phase-encoding directions (k_y-k_z) was segmented into circular zones around the center of *k*-space (fig.1b). Thereby, the central *k*-space-zones corresponded to the zones in the respiratory cycle closest to expiration. The choice of *k*-space zone was made in real-time during the scan based on the actual respiration state before acquiring the appropriate *k*-space line.
  Nearing the end of the scan, if a detected displacement corresponded to a zone that was already complete (i.e. in which all positions had already been acquired during prior repetitions), the next zone towards the periphery of *k*-space was considered. If no zones closer to the edge of *k*-space were available, the acquisition was forced into the next zone towards the center of *k*-space.
- Modification of ZMART:
  Before the scan the respiration pattern and the k_y-k_z-plane were segmented as in the original ZMART approach. However, instead of increasing the displacement range of neighboring zones, if the acquisition of one zone was finished during the scan, *k*-space positions of the next zone with larger displacement values were reacquired. If the zone next to the current gating limit was finished, the gating limit was set to the lower limit of the finished zone, i.e. the gating window was decreased.

Unilateral, slightly tipped coronal scans (T_E=4.2ms, T_R=6.4ms, FOV=190×190×88mm^3, matrix=256×256×44) of a free-breathing volunteer were acquired on a whole body 1.5T MR scanner (GE Signa Excite) using the two motion compensation techniques above. For both experiments the gating limit was set to 60% of the maximal displacement between expiration and inspiration. 32 zones were used for reordering.

RESULTS

Due to the changes of the displacement ranges at the end of the scan, the reordering of the original ZMART shows some peaks in the achieved displacement distribution (fig. 2a). In contrast, the modified ZMART approach results in a smooth displacement distribution (fig. 2b), but requires a little longer acquisition time (138s vs. 135s) due to reacquisition of *k*-space-positions and more rejected data. This difference leads to a slight improvement in image quality (fig.3).

DISCUSSION AND CONCLUSIONS

Modified ZMART guarantees the best possible reordering result even if the respiration pattern changes during the scan. For volunteers who are accustomed to MRI these respiration changes are less distinct. Therefore, the effects observed in this study were small. However, changes in the respiration pattern of a patient are likely to be bigger, especially for patients on the day of surgery. To aid breast conserving surgeries, only one high quality unilateral 3D MRI data set acquired at the time of maximal signal enhancement after contrast injection is required. Therefore the small increase in scan-time associated with modified ZMART is acceptable.

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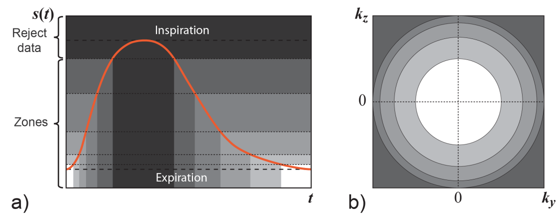

Figure 1: Principle of ZMART: (a) The displacement range in the gating window during one respiratory cycle is divided into zones. (b) Similarly, the *k*-space plane of the two phase-encoding directions (k_y-k_z) is segmented in corresponding circular zones around the *k*-space center.

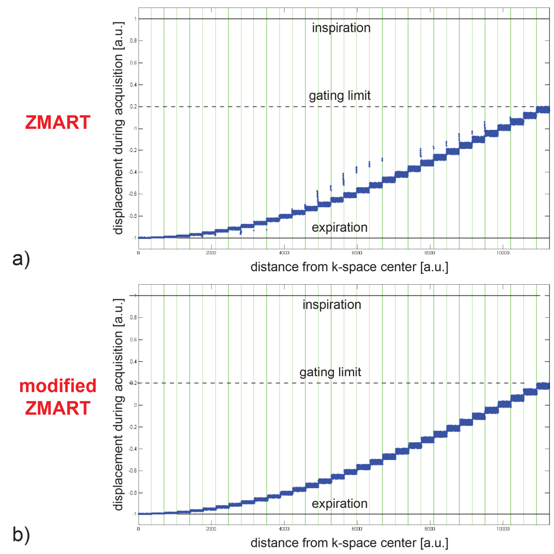

Figure 2: Achieved displacement distribution as a function of distance from the *k*-space center for the data acquisition using motion compensation according to (a) ZMART and (b) modified ZMART.

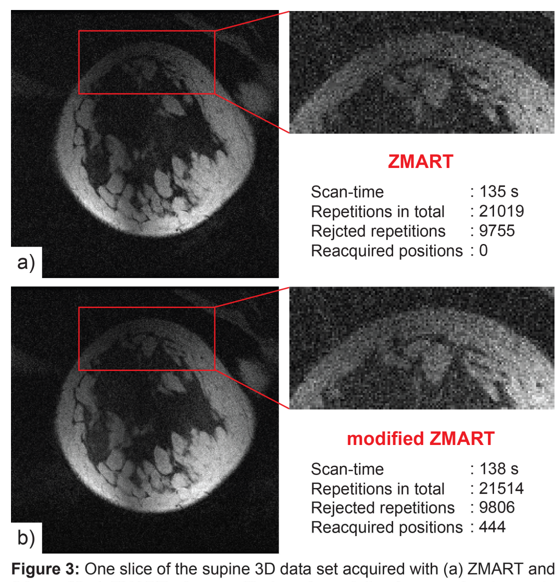

Figure 3: One slice of the supine 3D data set acquired with (a) ZMART and (b) modified ZMART. A magnified region of the images is shown to highlight the differences.

REFERENCES [1] Siegler P, et al. Proc. ISMRM-ESMRMB 2007: 2796 [2] Huber ME, et al. Magn Reson Med 2001;45:645-652