Implementation of MR Breast Imaging in Supine Position

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INTRODUCTION

The extent of breast cancer seen by dynamic contrast enhanced (DCE) MRI correlates well with histological findings. As such, DCE-MRI is well suited for surgical planning and pre-surgical tumor localization. However, breast MRI is typically performed in a prone position and the breast configuration is significantly different to the surgical setting where the patient is supine. In consequence, MRI is currently not used to guide surgery.

The goal of this project is the implementation of MR breast imaging with supine positioning of the patient. The resulting images are expected to agree better with the later surgical situation allowing a surgical guidance after image registration in the operating room. Since the tumour location will be already known from previous diagnostic scans, a unilateral scan with high spatial resolution and moderate temporal resolution will be sufficient.

In supine imaging motion of the breast caused by respiration (in order of 2mm for shallow breathing according to [1]) is not negligible. Therefore motion compensation techniques are necessary to ensure.

MATERIALS AND METHODS

To provide a superior SNR, a receive phased array coil (2 elements, size of each element: 10.2×20.3cm^2) was designed and build (see fig. 1a). In addition a fixture was developed to permit the coil to be positioned above the patient's breast on the standard bed of a whole body 1.5T MR scanner (GE Signa Excite) in a patient specific manner.

All images were acquired using a fast 3D spoiled gradient echo (fast 3D SPGR) sequence with the following parameters: T_R=6.432ms, T_E=4.2ms, α=30°, matrix size: 256×256×32, FOV: 200×200×96mm^3 and 1 excitation per data-point. The imaging sequence was modified to allow compensation for respiratory motion according to the zonal motion-adapted acquisition and reordering technique (ZMART) [2]. The actual position in the respiratory cycle was tracked using a respiratory belt. ZMART is a combination of k-space reordering and gating. As the detected displacement from the expiration state increases, a line from a zone with a greater distance of the center of the k_y/k_z-plane is chosen for the corresponding acquisition (see fig. 1b). No data were acquired if the detected motion was above a given limit. The gating limit was set to 75% of the maximal displacement between expiration and inspiration. For the reordering the k_y/k_z-plane was divided in 32 zones of the same size.

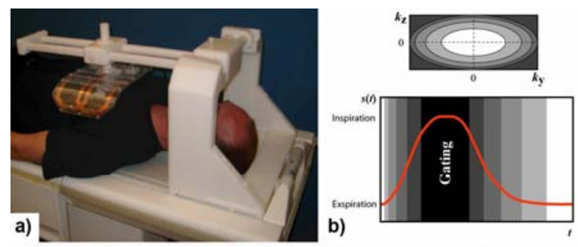

Figure 1: a) Setup for supine breast imaging: Two coil array and fixture, which permits an easy and comfortable positioning of the patient on the standard MR bed in supine position. b) Principle of ZMART: The two phase-encoding directions are divided in zones, which are acquired at different times according to the detected respiratory state (reordering). In addition, no data are acquired during very high displacements (gating).

- Phantom experiment:
  To test the motion compensation, a periodic motion was manually applied perpendicular to chosen imaging plane (amplitude: 3mm, time period: ≈6s) during the scan. Additional images were acquired with no motion and with motion but without motion compensation.
- Volunteer experiment:
  The right breast (unilateral) of a volunteer was scanned with and without motion compensation during the acquisition. A slightly tipped coronal plane position was chosen with a left-right phase-encoding direction ensuring a full coverage of the entire breast.

RESULTS

The designed coil array provided a reasonable image quality. According to the MR technologists, the entire setup design allows an easy placement of the patient in supine position on the standard MR bed. In addition a supine position is very comfortable for patients.

The results of the phantom experiment demonstrated that a good compensation for periodic motion could be achieved using ZMART (see fig. 2). Without motion compensation, typical streak artifacts occur in the direction of phase encoding.

In the volunteer experiment, ZMART led to a visible reduction of the motion artifacts caused by the respiration due to supine positioning of the patient (see fig. 3). The gating part of this technique increased the scan time per data set from 54s to 67s.

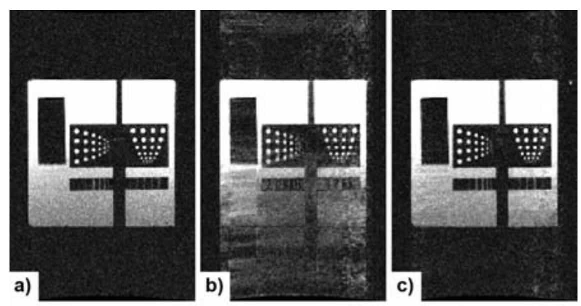

Figure 2: One slice of the acquired 3D volume through the phantom: a) No motion during acquisition. b) Periodic motion perpendicular during to the slices during acquisition causes streak artifacts in the direction of phase encoding (top to bottom) c) Using ZMART, the motion artifacts could be reduced significantly.

DISCUSSION AND CONCLUSIONS

Combining the standard MR breast imaging sequence with ZMART allows a good compensation for artifacts caused by respiratory motion, which can be not avoided when the patient is scanned in supine position. The increase in scan time due to the gating part will still permit the follow up of the contrast agent uptake in a clinical breast scan, which typically requires the acquisition of a time series over 10min after injection.

The next step of this project will be the acquisition of supine breast images with MR markers are attached on defined positions on the breast surface. This additional positional information will be used with an optical tracking system to register the MR images to the later situation in the operating room. Because the patient will be in supine position both for MRI and the surgery, a good match of the two situations is expected.

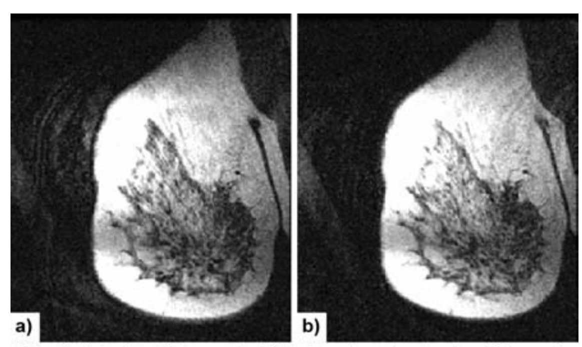

Figure 3: One slice of the acquired 3D volume through a breast: a) If no motion compensation is applied during the scan, streak artifacts are clearly visible in direction of the phase encoding (left to right). b) These motion artifacts could be reduced using ZMART.

REFERENCES

[1] Sato Y, et al. IEEE Trans Med Imaging 1998;17:681-693
[2] Huber ME, et al. Magn Reson Med 2001;45:645-652