Combination of Motion Adapted Gating with Non-Rigid Motion Correction for Free-Breathing MRI

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Introduction

The navigator gating technique reduced respiratory motion artifacts and is suited to abdominal MRI with patients who have difficulty in breath-holding. The motion adapted gating (MAG) approach [1] employs varying gating threshold depending on phase encoding steps, which accelerates gating to reduce scan time. However, even the MAG approach results in considerably longer scan time compared to a single breath-hold scan (e.g. 1.7-fold) to get images with sufficiently suppressed motion artifacts. In this work, we combined the non-rigid motion correction technique with the MAG approach to reduce scan time to the level comparable to breath-hold, while preventing image degradation.

Methods

Navigator Gating Threshold Setting

Our navigator gating method used three acceptance thresholds depending on phase encoding steps (k_y values) to be scanned. To accelerate gating, each threshold was calculated larger than conventional MAG approach with the use of the navigator pre-scan histogram data. For example, we decided the lowest threshold to include 10 percent of the pre-scan navigator data set counted from the position of end-expiration, and the data with the k_y values of the central 5 percent were acquired when the diaphragm position fell under the threshold during the imaging period.

Non-Rigid Motion Correction

We applied non-rigid motion correction to sagittal abdominal imaging with linear expansion model in the SI direction. After inverse FFT of the k-space signals in the frequency encoding (SI) direction, each k_y line data $f_0(x,k_y)$ was corrected to $f(x,k_y)$ according to the displacement d from the end-expiration position as

$$f(x,k_y)=\begin{cases} f_0(x-dx/x_0,k_y) & if \quad x \le x_0 \\ f_0(x,k_y) & otherwise \end{cases}$$

where x_0 is the diaphragm position at end-expiration. Inverse FFT in the phase encoding direction followed the non-rigid correction to produce the final image.

Data Acquisition

We conducted 2D FSPGR with flip angle of 90 degrees (TR/TE=100ms/3.1ms, FOV=360mm^2, matrix=256x256) and navigator echo was incorporated every TR for respiratory gating. Cylindrical RF excitation across the right hemi-diaphragm was used for navigator echo sequence. We performed all scans on GE Signa 1.5T HDxt MR imaging systems (GE Healthcare, Waukesha, WI, USA) and informed consent was obtained from a volunteer.

Results

With the new MAG method with eased thresholds, navigator acceptance rate was improved above 90 percent (Fig.1), which resulted in less than 1.1-fold longer scan time than non-gating scan. The image with the MAG method (Fig. 2b) delineated the liver structure much more clearly than the non-gated image (Fig. 2a), though some ghosts remained near the liver edge (arrows) caused by large motion in this region. These ghosts were reduced in the image reconstructed after the retrospective non-rigid motion correction (Fig. 2c).

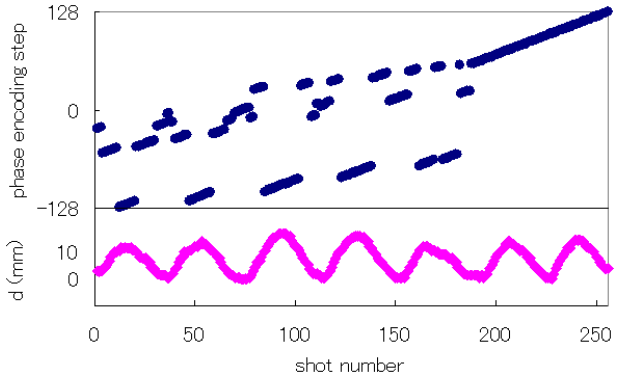

Fig. 1 Typical phase ordering of the eased MAG method. Central k-space data are acquired in early shots and scan time elongation is much smaller than the conventional MAG method.

Discussion

Combination of the eased MAG method and the non-rigid motion correction resulted in free-breathing abdominal scan with considerably less scan time elongation than conventional MAG approach. This technique reduces the whole MR examination time, and also enables various applications such as free-breathing dynamic contrast enhanced imaging. Further studies are necessary to optimize motion model and MAG gating thresholds to improve image quality.

Conclusion

Combination of the MAG method with the retrospective non-rigid motion correction reduced scan time remarkably compared to the conventional MAG approach. This technique can be applied to various abdominal applications such as free-breathing dynamic contrast enhanced imaging.

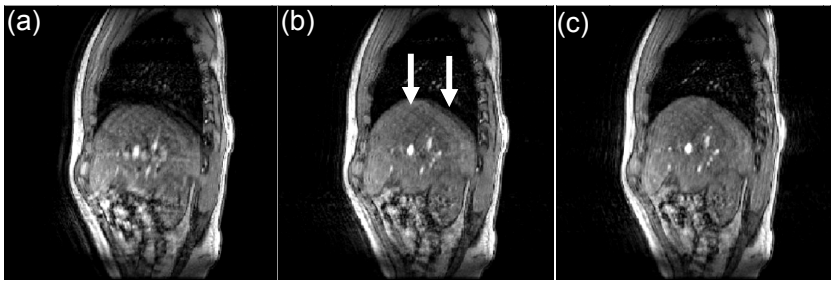

Fig. 2 Abdominal images obtained under normal respiratory conditions. In (a) no gating was performed; image (b) was obtained using the MAG algorithm; image (c) was reconstructed after non-rigid correction with the same data as (b).

References

1. Weiger et al., Mag Reson Med 38:322-333 (1997)