Phase Correction in Multi-Breath-Hold MRI with Tracking Using Information Entropy

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Introduction

The multi-breath-hold approach enables high resolution abdominal MRI that requires long scan time beyond a single breath-hold. The slice/slab tracking technique with navigator echo reduces motion-induced artifacts in multi-breath-hold studies by compensating displacements of the liver between the different breath-hold periods. However, artifacts derived from nonuniform receive coil sensitivity still remains since the moved organ experiences the different coil sensitivity. Several works have addressed this issue [1, 2], based on the pre-obtained coil sensitivity maps. With these methods, it is time and effort consuming to deal with the coil sensitivity change caused by inconsistent breath-hold condition. In this work, we developed a novel technique of residual motion artifact reduction that does not require the knowledge of the coil sensitivity map.

Methods

Data Acquisition: We conducted 3D FSPGR with flip angle of 12 degrees (TR/TE=3.8ms/1.8ms, FOV=340mm^2, matrix=256x256) with two breath-holds. The centric phase ordering scheme was used, where the first scan filled in the central lines of k-space in the phase-encoding direction. Navigator echo was incorporated at the beginning of each breath-hold scan and the excitation slab position of the second scan was modified according to the displacement value calculated with navigator echo signals. In phantom study, a phantom was manually moved by 20 mm in the SI direction between the two scan periods. We performed all scans on GE Signa 1.5T HDxt MR imaging systems (GE Healthcare, Waukesha, WI, USA) with a birdcage head coil (phantom study) and an 8-channel body array coil (volunteer study), and informed consent was obtained from a volunteer.

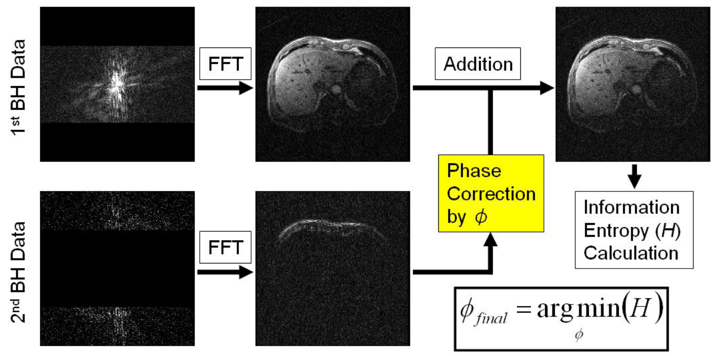

Fig. 1 Schematic description of image reconstruction for one of the coil elements. Phase correction and addition were repeated and the correction phase with the minimum entropy was finally selected (Φ_{final}).

Reconstruction: After the 1d FFT in the slice-encoding direction, the 2d FFT was performed separately for each breath-hold data set. The two data sets were added after zero-order phase correction was applied to the data acquired during the second breath-hold period (fig. 1). The phase correction was repeated in the range of 0-358 degrees with the step of 2 degrees. The image that produced the minimum information entropy was selected for each coil, based on the fact that image entropy increases with noise or blurring. With the 8-channel coil, the final image was synthesized by combining the selected images of all the channels in a sum-of-square manner.

Results

The phantom study showed that the correction phase with the minimum information entropy produced an image with reduced artifacts compared to the original (fig. 2). In the volunteer study, displacement of the diaphragm between the 1st and 2nd breath-hold scans was 0.8mm, as calculated from navigator echo signals. Fig. 3 shows the combined images without and with the phase correction, reconstructed from the same raw data. The information entropy of the combined image was reduced to 7.15 from the original 7.17, which is consistent with visual impression.

Discussion

The proposed method reduced artifacts derived from the inconsistent position of the subject in multi-breath-hold scan. The liver position was not still during each breath-hold period, as was seen from bellows signal in volunteer study, which also contributed to the artifacts in the original image. Our approach can address these motions during the scan because it doesn't use the explicit knowledge of the pre-obtained coil sensitivity. A limitation of this method is that it cannot deal with the large motion accompanying non-rigid deformation of organs. It may be possible to combine this method with non-rigid motion correction such as linear extension model technique [3] to address the limitation.

Conclusion

The phase correction with information entropy reduced artifacts in multi-breath-hold scan. It could deal with the several causes of artifacts without explicit knowledge of coil sensitivity.

References

1. Bammer et al., Mag Reson Med 57:90-102 (2007). 2. Odille et al., Mag Reson Med 60:146-157 (2008). 3. Tomoda et al., ISMRM 2010, p3070.

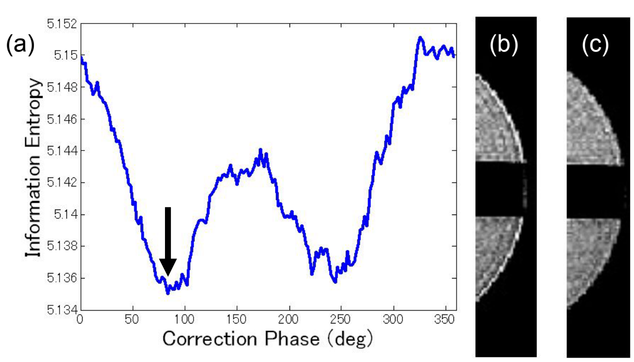

Fig. 2 Phantom results of (a) relationship between information entropy and correction phase, (b) original image, and (c) corrected image with the phase value (84 degrees) pointed by an arrow in (a).

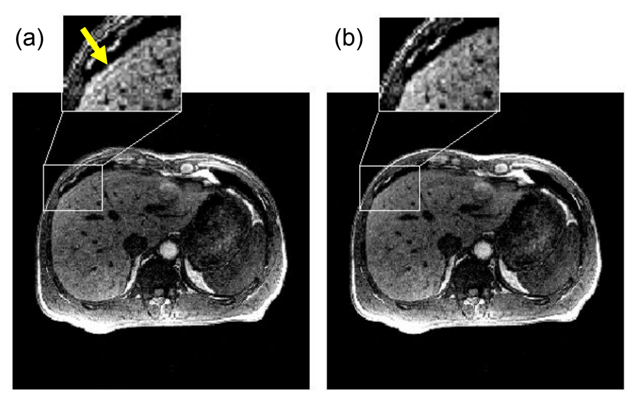

Fig. 3 Combined volunteer images (a) without and (b) with the phase correction. Ringing artifacts (arrow) was reduced remarkably.