Free-Breathing T2 weighted liver Imaging using Retrospective Motion Compensation

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Introduction: T2 weighted magnetic resonance imaging is routinely used for the detection of focal hepatic lesions [1]. However, respiratory motion during the acquisition can cause severe artifacts which impede diagnosis. Breath-holding technique is usually applied to permit motion free acquisition, but it could be problematic for geriatric, pediatric and sick subjects. Alternatively, free breathing respiratory-triggered or navigator triggered technique [2, 3] only allows data acquisition at the relatively static mid-end expiration period. This prolongs scan and could lead to misregistration artifacts especially dealing with irregular respiration. To eliminate breath holding requirement and acquisition interruption, this work developed a novel retrospective motion compensation method. In addition, a selective coil combination scheme was proposed to preserve the signal noise ratio (SNR). In-vivo experiments demonstrated the proposed algorithm was robust and effective in reducing respiration artifacts in liver imaging.

Methods:

Iterative k-space convolution: Using GRAPPA [4] like *k*-space convolution introduced in data convolution and combination operation (COCOA) [5], motion induced error at each *k*-space location can be dispersed to its neighbors. If the acquired *k*-space is corrupted by continuous respiration motion, errors at different *k*-space locations are related to different motion states and hence inconsistent. Weighted combination of these incoherent errors in convolution will lead to error cancellation. However, due to the limitation of the convolution kernel size, errors dispersed to limited neighbors cannot be fully cancelled out by one single convolution. This work proposed to iteratively implement the *k*-space convolution with recalculated convolution kernel weights in each iteration. Owing to improved convolution kernel accuracy and further dispersing errors of a specific motion state to more *k*-space locations, the iteration theme is able to result in minimized motion artifacts. When the error level is similar with the noise level or residual errors are coherent, more iteration will not contribute to artifact reduction but amplify noise according to the parallel imaging theory [5]. In our work, convergence of difference between images from adjacent iterations D_n was adopted to adaptively terminate the iteration.

Selective coil update: Due to coil geometry, a coil element close to a moving object is more sensitive to the motion than a coil element with a longer distance. Therefore, the original data from the coil elements with low sensitivity to motion (such as the posterior coil element in abdominal imaging) might not be contaminated and should be kept to preserve SNR. More specifically, after each convolution with all *k*-space data, the degree of difference between image of every coil channel and its corresponding result of previous iteration was calculated respectively and ranked. For channels with difference degree much lower than average change level of all channels, data of previous iteration was retained.

In-vivo Experiments: Free breathing T2 weighted abdominal data were obtained on a 3.0T Philips Achieva scanner (Philips, Best, The Netherlands) using a 32-channel sense torso/cardiac coil (Invivo Corporation) without trigger or navigator technology. Four volunteers were scanned with a 2D multi-shot turbo spin echo (TSE) sequence (TR/ TE 3000/80ms). Each volunteer was scanned twice and asked to breathe normally and heavily respectively.

Image reconstruction: COCOA and the proposed motion compensation method were applied on acquired motion corrupted *k*-space respectively. D_n was calculated to indicate the quantitative change during iteration.

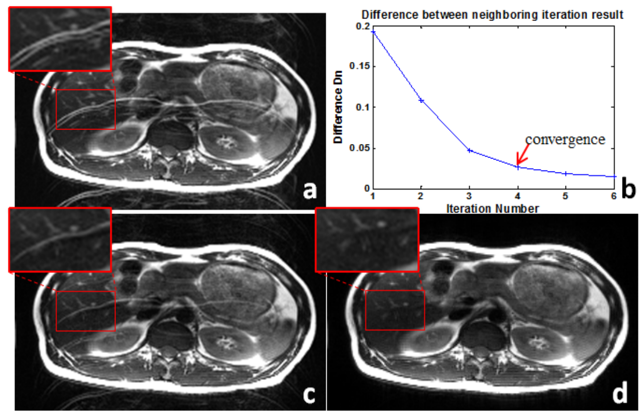

Fig.1. a) Original liver image corrupted by normal respiration. Motion corrected images using COCOA (c) and the proposed method (d). (zoomed out area for further comparison). b) *D*n curve indicated there was no significant difference between the result of the 3rd iteration and the following iteration.

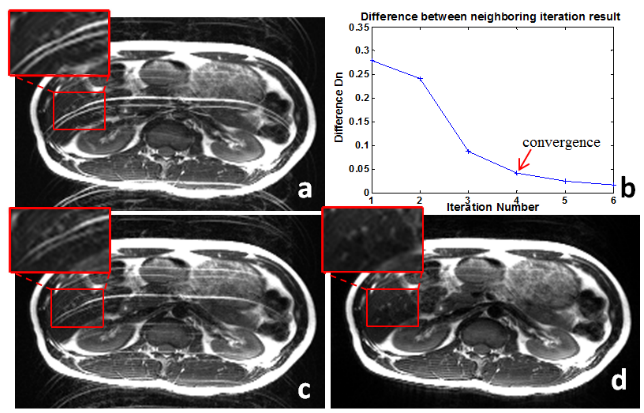

Fig.2. Heavy respiration motion compensation: a) motion corrupted image. c) COCOA processed image. d) The proposed method processed image. b) *D*n curve illustrated iteration number was 3.

Results: Figure 1 present the motion correction results for normal respiration while figure 2 is for heavy respiration. Original images were contaminated by different degrees of artifacts as shown in figure 1a and 2a. After iterative *k*-space convolution and selective coil combination processed, artifacts were dramatically reduced in figure 1d and 2d. As the indicated by the zoomed in images, residual artifacts could be observed and contaminated the visualization of blood vessel in the COCOA result (figure 1c and 2c), whereas they were removed by the proposed method. Corresponding D_n curves illustrated optimal motion compensated images could be adaptively achieved when the convergence was achieved.

Discussion and conclusion: An effective retrospective motion compensation method using iterative *k*-space convolution and selective coil combination was presented for free breathing T2 weighted liver imaging which is especially applicative on patients incapable of breath holding. The continuous data acquisition regardless of respiration obviously shortens scan time compared with triggered imaging. Even with heavy respiration, the proposed method can remarkably eliminate motion artifacts since it sufficiently utilizes the incoherence of *k*-space errors related to different respiration states. Distinct from conventional retrospective approaches, this work provided an adaptive motion compensation scheme by adaptively adjusting the iteration number. Therefore, it is advantageous for applications with variable degrees of motion including respiration. Moreover, the designed selective coil update effectively avoids unnecessary noise amplification due to convolution of relatively motion free data. Finally, the present technique has been carried out to compensate different types of patient motions. (e.g. swallowing). Combined with navigator technique to select severely corrupted data, further artifact reduction is realizable.

References: [1] Outwater EK., et. al. Radiology 1994;190:425-429 [2] Christian K., et. al. JMRI 2005; 21:567-582 [3] Sumire N., et. al. JMRI 2009; 30:321–326 [4] Griswold, M. A., et. al. MRM 2002;47:1202-1210 [5] Huang, F., et. al. MRM 2010;64(1):157-166