Diaphragm Motion Control in fast MRI using Audiovisual Biofeedback

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Purpose: Involuntary respiratory motion can cause blur and ghost artifacts in body MRI. In clinic, respiratory gating and motion tracking methods for respiratory motion-compensation are practically useful, but respiratory gating increases scan time and non-rigid irregular motion limits motion tracking applications[1, 2]. The aim of this study is to develop a novel respiratory motion control system using audiovisual (AV) biofeedback combined with chest MRI to improve diaphragm motion reproducibility and reduce irregular respiratory motion, increasing respiratory gating efficiency and reducing motion artifacts in MRI.

Method and Materials: An AV biofeedback system has been developed to provide respiratory guidance during medical imaging[3] and treatment procedures. The real-time respiratory motion signals have been obtained by using the real-time position management (RPM) system (Varian) consisting of an infrared camera and a marker block on the abdomen (see Fig. 1). In respiratory guidance during MR scans, the system has been combined with an MR compatible AV system such as a projector, a screen and/or headphones. The AV biofeedback system utilized (1) the external position information of the abdomen using the RPM system to guide a human subject for regular breathing within the magnet and (2) a Fast GRE MR pulse sequence for chest imaging (512 images on coronal and sagittal planes): TR/TE 2.4/1 ms, FOV 480x384 mm^2, slice thickness 5 mm, and image matrix 96x96. The diaphragm motion control using the audiovisual biofeedback within the MRI system has been tested in six studies with five human subjects. All studies included a free breathing and an AV biofeedback session on the same day. A total of 46 measurements were acquired from the six studies.

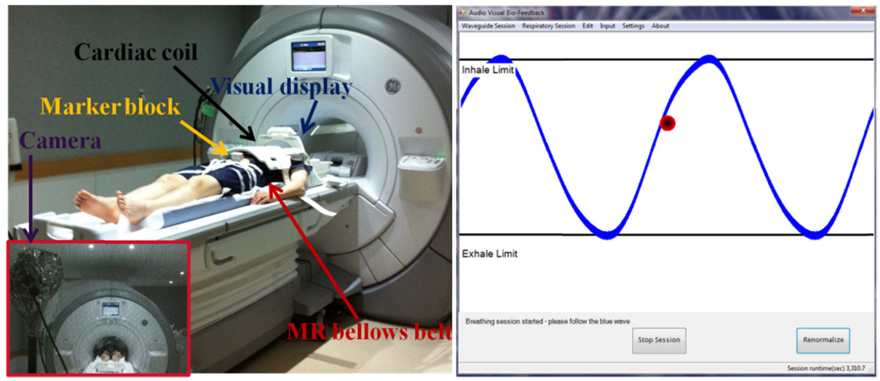

Fig.1. (left) Audiovisual biofeedback system in 3T MRI. Infrared camera and marker block on the abdomen. (right) Audiovisual respiratory waveguide (blue curve) with real-time abdominal position (red ball).

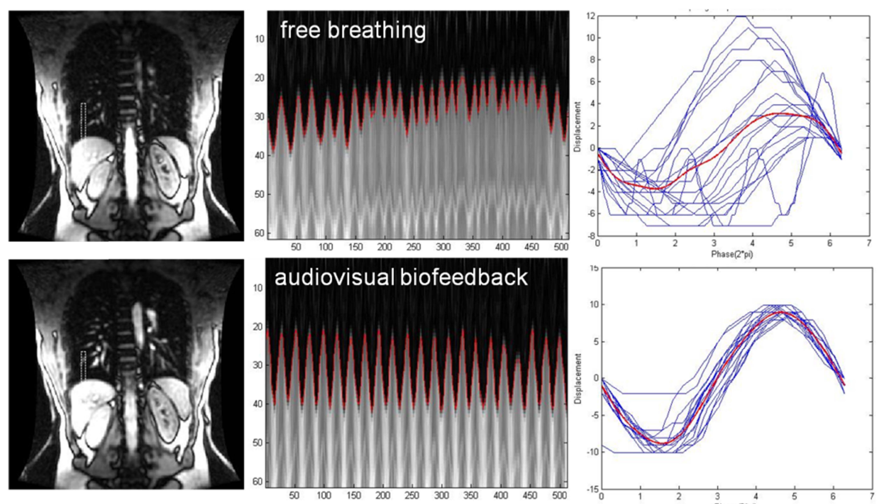

Fig. 2. (left) ROI boxes on coronal images. (middle) 1D signal profile of ROI over 512 images. Outline of diaphragm shown (red line). (right) Diaphragm motion cycles (blue) and average curve (red) shown in phase domain

Results and Discussion: By using the AV biofeedback system, the diaphragm motion reproducibility has been improved as shown in Fig. 2. In addition to qualitative evaluation of diaphragm motion reproducibility, the diaphragm motion regularity has been quantified using a spectral power dispersion metric in Fourier space, scaled by fundamental frequency[4]. A 1D signal profile of region of interest (ROI) including the diaphragm has been obtained from the images and the regularity metric was computed. For instance, in subject 5, average spectrum dispersion has been reduced from 10.36 for free breathing to 0.48 for AV biofeedback breathing. The average root mean square error (RMSE) of the breathing period has been reduced from 1.9s for free breathing to 0.17s using AV biofeedback, and the average RMSE of displacement changes from 2.7 mm for free breathing to 2.3 mm with AV biofeedback. Since the human subject's respiratory motion is fed back to the human subject during the MR scan using AV devices, the human subject can control the respiratory motion when they follow the guiding wave prepared from their own breathing patterns at the beginning of the scan.

Conclusion: The study demonstrated significant improvement of diaphragm motion control using AV biofeedback within the MRI system. This system provides clinically applicable diaphragm motion control in MRI scanning and can increase the efficiency of respiratory gating and reduce motion artifacts in MRI.

References:

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