Air-Bellow Belt and LED Display Based Compact Visual Biofeedback System Improves the Respiratory Regularities for Gated Radiation Therapy

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Purpose

Respiratory gating and voluntary deep inspiration breath hold (DIBH) strategies have been widely used to reduce the effect of organ motion in radiation therapy (RT) treatment. However, significant dose deviation can still occur if the patient's respiratory motion is not reproducible and/or predictable during simulation or treatment delivery. Here, we evaluate a novel air-bellows belt system, the Medspira Breathhold, which features a compact and mobile LED based visual biofeedback (VBF) system to improve the regularity of patient respiration.

Materials and Methods

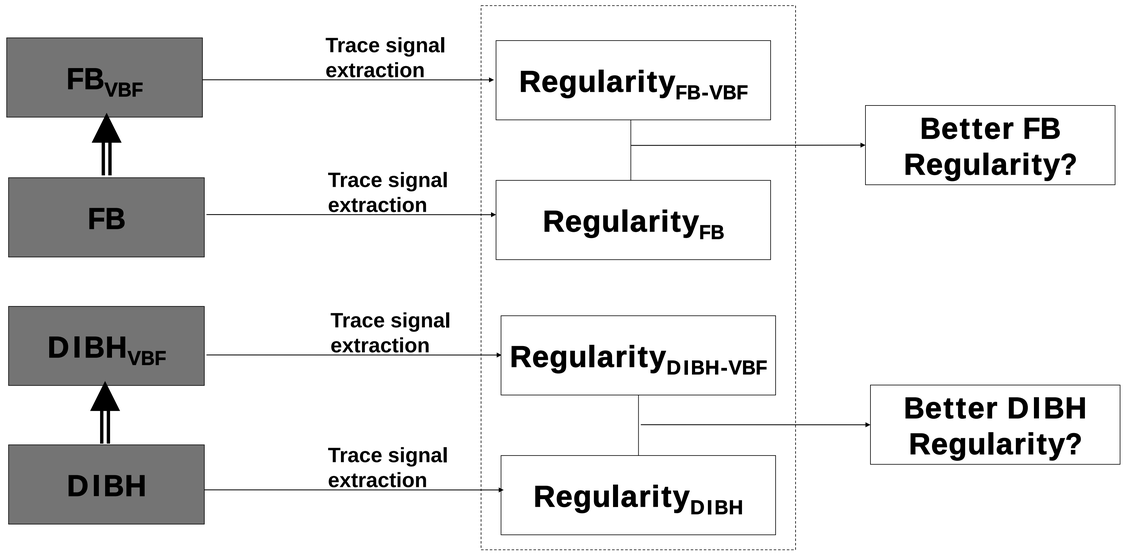

Fig. 1. The experiment setup and the trace signal processing diagram of the comparison between the regularity with and without the visual biofeedback (VBF). Shaded boxes indicate signal acquired and white boxes indicate the derived data.

Four healthy subjects enrolled in this study were fitted to wear the air-bellow belt for respiratory monitoring while lying supine on the flat CT couch overlay. A small LED display, designed to be used in a confined space, was attached to the CT couch and calibrated to provide visual biofeedback to the subjects of their respiratory signal from the pressure transducer in the air-bellow belt. An audio coaching signal was also used in all cases to assist the subject in maintaining a regular breathing frequency. Each subject had an initial training session to determine a comfortable free breathing pace for the audio coaching. The subject's breathing trace was recorded with the bellows system during 3 minute free breathing sessions and 20 second DIBH procedures. Multiple free-breathing sessions and breath hold procedures were recorded with the visual biofeedback both on and off to evaluate the effect of the biofeedback system. For free breathing, the regularity is quantified by the relative standard deviation of the inhale peak amplitude during the 3 minute monitoring period, which reflects the variability of the inhale at different cycles. For DIBH, the regularity metric is computed as the percent difference of the mean amplitude between any two consecutive breath holds.

Fig. 2. Examples of the novel air-bellows belt system, the Medspira Breathhold, which features a compact and mobile LED based visual biofeedback (VBF) system to improve the regularity of patient respiration. Left: respiratory signal acquisition system; Right: the compact LED VBF.

Results

Fig. 3. The setup for this study. The raw respiratory signal is acquired with the air-bellow belt and the subject is breathing following the audio coaching. The breathing trace is recorded by connecting the Medspira Breathhold to a standard laptop.

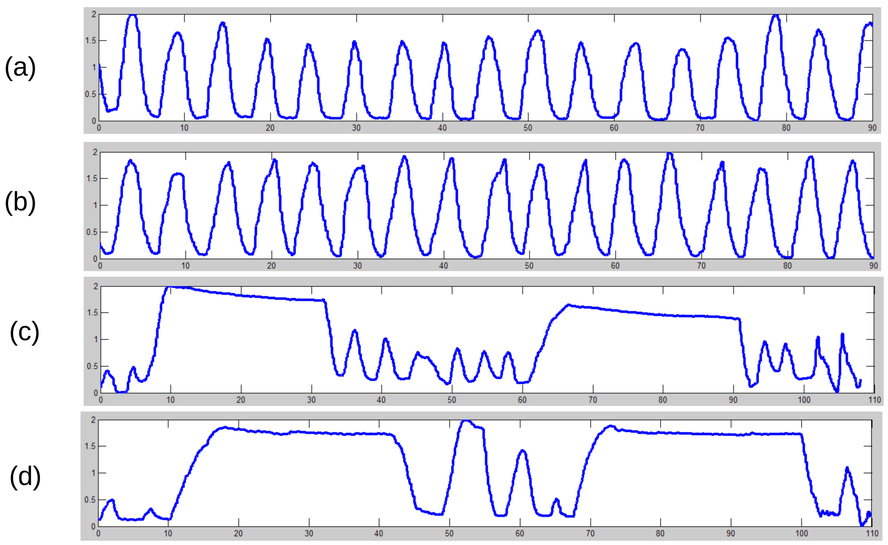

Fig. 4. Comparison of the respiratory signal with and without VBF from subject C. From top to bottom: (a) free breathing without VBF, (b) free breathing with VBF, (c) DIBH without VBF, (d) DIBH with VBF.

For free breathing, the average regularity metric among all subjects was 6.90 ± 1.39% and 12.79 ± 1.68% with and without the visual biofeedback, respectively, indicating less variation during respiration with the use visual biofeedback. The average DIBH regularity metric for all subjects was 2.48 ± 1.54% and 13.61 ± 10.53% with and without feedback, respectively, indicating that the breath hold is more consistent over the 20 second period when the subject is able to utilize the visual feedback system's LED display to control the breath hold.

Subject	Free breathing without VBF %	Free breathing with VBF %	DIBH without VBF %	DIBH with VBF %
A	13.31	6.15	3.10	2.24
B	10.43	7.44	24.77	2.54
C	14.41	8.57	15.43	1.16
D	13.01	5.43	11.16	4.00
Mean±SD	12.79±1.68	6.90±1.39	13.61±10.53	2.48±1.54

Conclusions

We demonstrated that the Medspira visual biofeedback system using the air-bellow belt and compact LED display can be utilized to improve the regularity of respiration during both free breathing and DIBH. Medspira is relatively inexpensive, compact, easy to position for simulation or treatment, and can be used in situations in which an infrared camera may be difficult to employ, e.g. in the bore of a Tomotherapy unit.

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