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A Study on the Feasibility of a Self-Monitoring System using a Laser Distance Sensor for a Deep-Inspiration Breath-Hold in Radiation Treatment of Breast Cancer

D. W. Kim [a], H. Jeon [a], J. H. Joo [a], Y. Ki [b*], W. Kim [b], D. Kim [b], D. Park [c], J. Nam [c]
[a]*Dep.of Radiat. Onc., Pusan Nat'l. Univ. Yangsan Hosp., Gyeonsangnam-do,Rep. of Korea, 50612*
[b]*Dep.of Radiat. Onc., Pusan Nat'l. Univ.School of Med., Gyeonsangnam-do,Rep. of Korea, 50612*
[c]*Dep.of Radiat. Onc., Pusan Nat'l. Univ. Hosp., Busan, Rep. of Korea, 49241*
[*]*Corresponding author: apex7171@hanmail.net*

1. Introduction

A deep-inspiration breath-hold (DIBH) with intensity-modulated radiation treatment (IMRT) is widely used to protect normal organs during radiation treatment (RT) in breast cancer [1-3]. In particular, as shown in Fig. 1, DIBH increases the distance between the left breast parenchyma and the heart, which reduces the irradiated heart volume [4-8]. Because prescribed RT doses are spread over several days, reproducibility of DIBH is essential to maintain the quality of RT. Therefore, we tried to develop a patient's respiration monitoring system using a distance-measuring laser sensor in this study. The absolute distance from the patient's skin on the sternum to the sensor was measured and transmitted in real-time to help improve the reproducibility of DIBH.

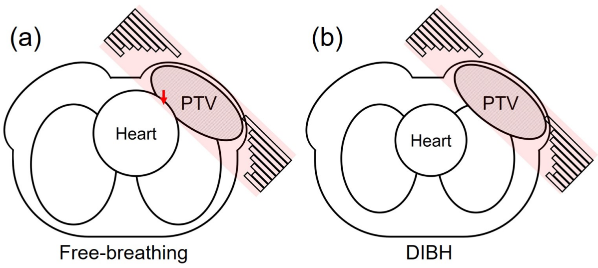

Fig. 1. Schematic diagram showing the distance between the left breast parenchyma and the heart according to FB and DIBH. (a) FB, and (b) DIBH.

2. Methods and Results

2.1 System design

A laser distance sensor (LDS) (ODSL 96B, Leuze Electronic Corp., Germany) can measure the absolute distance between the skin of a patient's sternum in real-time. The measurement range of LDS is 150 ~ 2000 mm, the spatial resolution is 1 mm, and the response time is less than 15 ms. Fig. 2(a) shows a schematic diagram of a device that measures the patient's thoracic breathing movement by attaching the LDS to a commercial breast board. It was designed so that the sensor mount and LDS do not interfere with movements or physical interference such as computed tomography or treatment devices.

Fig. 2(b) is the signal prediction for the patient's free-breathing (FB) and DIBH respiration. The signal obtained from LDS was divided into FB and DIBH sections using the PELT method [9, 10], and the FB signal before the first DIBH was selected as a reference value. In addition, the patient's DIBH amplitude was set using the reference value and the difference between the first DIBH signal and the FB signal. The set amplitude is sent to the monitor with a threshold range of 3 mm and displayed, and it is made available for reference during DIBH. It is designed to perform signal measurement and calculation simultaneously using in-house software.

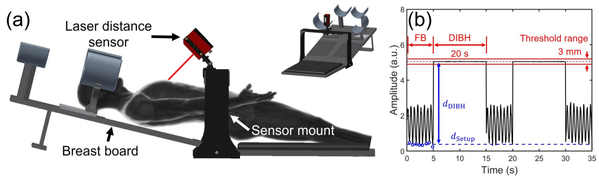

Fig. 2. (a) System design to monitor the breathing movement by using an LDS, and (b) the expected curve of measure signals in terms of the distance between the sternum and the LDS.

2.2 Experiments

In this study, for verfication of the developed system, measurement results were compared with commercial real-time position management (RPM), which is widely used for respiration measurement. A marker block of RPM was placed on the abdomen to observe the breathing movement of the abdomen. A total of five volunteers were requested to maintain FB for more than 20 seconds and DIBH for about 20 seconds, and DIBH was repeated four times. The above cycle was measured five times on different days depending on whether breathing was monitored.

2.3 Verification

Fig. 3 shows each volunteer's thoracic and abdominal movements measured by LDS and RPM for FB and DIBH. The curves measured using LDS and RPM were almost similar, with approximately 2.2% and 1.3% relative errors for FB and DIBH. In particular, the timing of the ascending (inhalation) and descending (exhalation) portions of the two DIBH curves was almost identical. The overall trends of the LDS and RPM curves were similar, but the amplitudes were slightly different. This is considered an error caused by the difference in the position of the chest and abdomen.

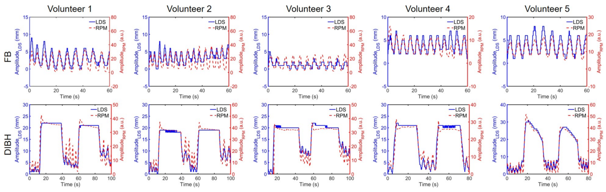

Fig. 3. Comparison of the LDS and the RPM measurements regarding FB and DIBH for each volunteer. Top: FB for about 120 s, and bottom: 4 repetitions of DIBH for about 20 s.

2.4 Shaping Amplifier Model

Fig. 4 shows the result of repeated DIBH depending on whether or not it is monitored. Fig. 4(a) shows the breath used for the initial DIBH amplitude measurement. Figs. 4(b), (c), and (d) showed the results when self-monitoring was not performed, and it can be confirmed that the reproducibility of DIBH is not achieved. Figs. 4(e), (f), and (g) are the results of self-monitoring, and it can be confirmed that the reproducibility of DIBH is well within the threshold range.

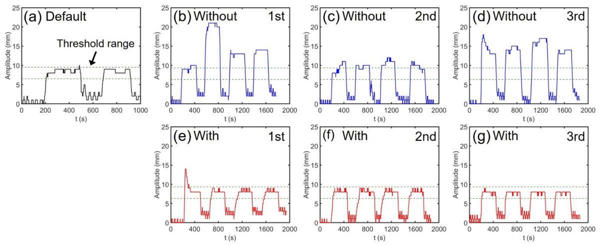

Fig. 4. DIBH results with or without self-monitoring. (a) DIBH reference value measurement, top: without self-monitoring, and bottom: with self-monitoring.

3. Conclusions

In this study, a distance measurement laser-based respiratory monitoring system for DIBH was fabricated. Verification with a commercial respiration measurement device showed a relative error of around 2%. In addition, the reproducibility of DIBH according to whether or not real-time self-monitoring was performed was confirmed. Because our system measures and uses only a small amount of data, the absolute distance between the sternum and sensor, it may be helpful when implementing breast RT with DIBH, which requires accurate and real-time respiratory monitoring.

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