Breathing control with a visual signal for aperture maneuver with controlled breath (AMC)

*Department of Radiation Oncology, Asan Medical Center, University of Ulsan College of Medicine,
† Department of Physics, Ewha Womans University

Yelin Suh*†, Byong Yong Yi*, Seung Do Ahn*, Jong Hoon Kim*,
Sang Wook Lee*, Seong Soo Shin*, and Eun Kyung Choi*

To appropriately control or compensate breathing motion of targets in thorax or abdomen during radiotherapy is still demanding. Our idea is that a visual signal may help regulate patient's breathing pattern, by controlling its amplitude and cycle. The system involving breathing control with a visual signal for aperture maneuver with controlled breath (AMC) has been developed. A thermocouple is used to detect the temperature change due to patient's breathing. The system also consists of a mask, in which the thermocouple is installed, an operational amplifier, a converter, etc. Patients were instructed to control their respiration by breathing following the visual signal, as watching a display that shows both patients' current breathing pattern and the signal. The patterns of patients' controlled breathing and the signals coincided well. Therefore, when AMC technique is applied, a target moves in the range that is 60 % less than the range of free breathing motion with the help of the system and so target margins can be reduced significantly. This study reveals that a visual signal is not only useful to control patient's breathing but also clinically effective.

Keywords: breathing control, respiratory motion, lung cancer, radiotherapy

INTRODUCTION

How to deal with target motion due to breathing is known to be one of the critical issues in radiation oncology field[1,2]. Advanced techniques such as breath-hold[3,4], gated[5,6], and 4D or tumor tracking[1,7-9] have been introduced and developed in order to take respiratory target motion into account during imaging and treatment. Breath-hold technique may be poorly tolerated by the patients with lung tumors, and respiratory gated technique may deliver dose to more normal tissues as the size of gating window expands and increase treatment time as beam on time decreases. The optimal solution is a beam adapting method among 4D techniques, which adapts radiation fields continuously to a moving target; it allows timesaving as well as comfort breathing. However, this technique is practical only when respiratory motion of internal anatomy is identified or predictable.

Although various methods are proposed to acquire respiration signal, none are proved to be the perfect answers for verifying complicated respiratory motion. Hence, this study diverts its interest to making patient's breathing regular and reproducible, instead of relying on respiration signal. If a patient can breathe regularly, the internal target motion due to respiration can be predicted. Then, applying beam adapting technique to clinic is possible.

Our idea is that a visual signal may help regulate patient's breathing pattern, by controlling its amplitude and cycle. Therefore, the system involving breathing control with a visual signal for aperture maneuver with controlled breath (AMC) technique[7] has been developed for investigating the effectiveness of visual stimulus to control breathing.

METHODS AND MATERIALS

The system for breathing control with a visual signal has been devised (Fig. 1). The system consists of a mask, a chromel-alumel thermocouple, an operational amplifier, and a converter. The mask, in which the thermocouple is installed, covers patient's mouth and nose, so that patient's breathing through both mouth and nose can be detected. The thermocouple, which is a key for this system, detects the temperature change due to patient's breathing inside the mask. The operational amplifier receives small voltage signal from the thermocouple and amplifies it. The signal is sent to analogue-to-digital converter and then analyzed.

A software that acquires a breathing signal, displays its pattern on a screen, and records the pattern was developed. As shown in figure 2, two curves are exhibited on the display: one is a curve indicating patient's current breathing pattern and the other is a visual signal, which reflects the patient's free breathing pattern. The visual signal, which shows the path that the patient will follow to breathe along, functions as a guidance of breathing. While the visual signal is moving on, patients are instructed to control their respiration by breathing following the signal, as watching the display that shows both curves.

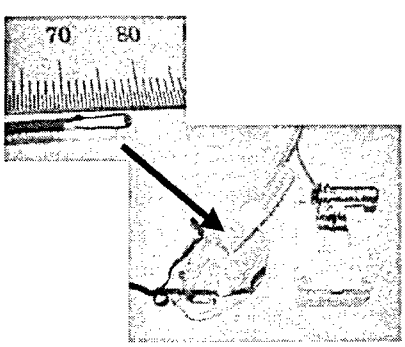

Fig. 1. System for breathing control with a visual signal: a mask, in which a thermocouple is installed, and an operational amplifier

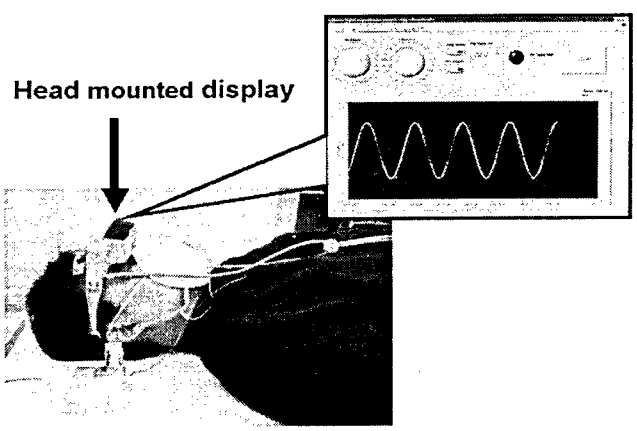

Fig. 2. Patient setup with the system for breathing control with a visual signal: patient lies down on a couch in treatment position, wearing a head mounted display, and breathes through a mask.

Five healthy volunteers were selected for regulating their breathing through the system. First of all, we monitored patients' free breathing to learn each patient's own breathing pattern. Patients used a head mounted display (HMD, Deocom, Korea) to see the above mentioned two curves (Fig. 2). After instruction and practice with the system was given, patient's controlled breathing pattern was recorded for analysis.

RESULTS

The patterns of a visual signal, controlled breathing of a patient by the system for breathing control with the signal, the visual signal, and their difference are shown in figure 3. Most of the patients could control their breathing through the system without difficulty, though some of them needed to practice more than others. The patterns of patients' controlled breathing and visual signal coincided well. Patients could maintain regular breathing to the extent that the differences from the signal were 60 % less than the displacement of free breathing.

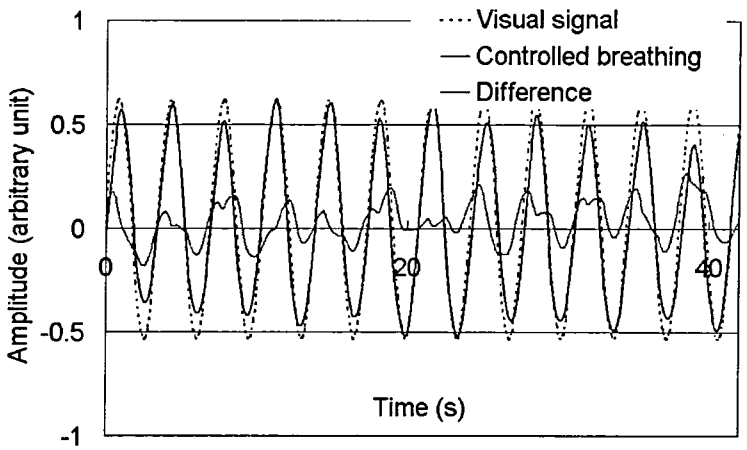

Fig. 3. Patterns of a visual signal, controlled breathing of a patient by the system for breathing control with the signal, and their difference

Conclusion

The effectiveness of breathing control with a visual signal using thermocouple is evaluated for regulating and reproducing patient's breathing pattern. Since it can be assumed that the motion of targets in abdomen or thorax is mostly due to breathing motion[1)], targets can be supposed to move regularly when breathing is controlled by the system. This makes it possible to predict target position and synchronizes radiation fields with a moving target, so that AMC technique is possible. It means that when AMC technique is applied, a target moves in the range that is 60 % less than the range of free breathing motion with the help of the system; therefore, target margins can be reduced significantly. This study reveals that a visual signal is not only useful to control patient's breathing but also clinically effective.

References

1. Ozhasoglu C and Murphy M J 2002 Issues in respiratory motion compensation during external-beam radiotherapy Int. J. Radiat. Oncol. Biol. Phys. 52: 1389-99
2. Langen K M and Jones D T L 2001 Organ motion and its management Int. J. Radiat. Oncol. Biol. Phys. 50: 265-78
3. Barnes E A, Murray B R, Robinson D M, Underwood L J, Hanson J, and Roa W H Y 2001 Dosimetric evaluation of lung tumor immobilization using breath hold at deep inspiration Int. J. Radiat. Oncol. Biol. Phys. 50: 1091-8
4. Wong J W, Sharpe M B, Jaffray D A, Kini V R, Robertson J M, Stromberg J S, and Martinez A A 1999 The use of active breathing control (ABC) to reduce margin for breathing motion Int. J. Radiat. Oncol. Biol. Phys. 44: 911-9
5. Kubo H D and Wang L 2002 Introduction of audio gating to further reduce organ motion in breathing synchronized radiotherapy Med. Phys. 29: 345 - 50
6. Vedam S S, Keall P J, Kini V R, and Mohan R 2001 Determining parameters for respiration gated radiotherapy Med. Phys. 28: 2139-46
7. Suh Y, Yi B, Ahn S, Kim J, Lee S, Shin S, Shin S, and Choi E 2004 Aperture maneuver with compelled breath

(AMC) for moving tumors: A feasibility study with a moving phantom Med. Phys. 31: 760-6
8. Neicu T, Shirato H, Seppenwoolde Y, and Jiang S B 2003 Synchronized moving aperture radiation therapy (SMART): average tumour trajectory for lung patients Phys. Med. Biol. 48: 587-98
9. Keall P J, Kini V R, Vedam S S, and Mohan R 2001 Motion adaptive x-ray therapy: A feasibility study Phys. Med. Biol. 46: 1-10