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A Half-Arc Multiple Deep-Inspiration Breath-Hold Volumetric Modulated Arc Therapy for a Lung Tumor with 10 MV Flattening-Filter-Free Beams and an Image Sensor Measuring a Distance Map to Thorax Surface: An Initial Clinical Experience

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Abstract

A technique for multiple deep-inspiration breath-hold (DIBH) volumetric modulated arc therapy (VMAT) for a lung tumor has been proposed with 10 MV flattening-filter-free beams and an image sensor measuring a distance map to thorax surface. Planning CT images were acquired under a DIBH condition and a clinical target volume (CTV) was contoured. This procedure was repeated five times and an internal target volume (ITV) among the multiple DIBHs was created by integrating the five CTVs. A planning target volume (PTV) was defined by adding an isotropic margin of 5 mm to the ITV. Immediately before treatment, a 30-second half-arc cone-beam computer tomography (CBCT) imaging was performed under another DIBH condition, and the couch was repositioned so that tumor may be located inside the PTV contours. An infrared distance measurement device having laser diodes and an image sensor was attached to the couch, and a distance map to the patient thorax surface was recorded as a reference during still another DIBH condition. A half-arc segmented VMAT beams with two beam interrupts were delivered to the patient under multiple DIBHs, where the delivery time of each of the three segmented beams was 30 seconds. During the beam delivery, the distance map was monitored in real time to confirm that the distance to the thorax surface remained unchanged. In-treatment CBCT images suggested that the tumor position at the time of tumor registration was accurately reproduced during the DIBH VMAT delivery.

Keywords

Deep Inspiration Breath-Hold, DIBH, FFF, VMAT, Kinect, Lung

1. Introduction

Deep-inspiration breath-hold (DIBH) technique has a long history to reduce position uncertainty of respiratory moving tumors or to reduce dose to heart for breast radiotherapy [1]. Spirometry was employed to reduce the position uncertainty of a lung tumor by assuming good correlation between the tumor position and a lung volume [2]. Another approach was to maintain the distance between surface reference marks and room lasers, or the distance between light field borders and the pre-marked field borders on the surface of a breast cancer patient [3]. Still another method was to employ a breath-hold monitor, which had two fulcrums each being placed on the abdomen and on the chest of a patient, and a pointer was mechanically connected to the two fulcrums thereby detecting breathing of a patient [4].

Although many techniques were reported, it is still not clear which method may provide the highest reproducibility of the tumor position among treatment planning CT imaging, pre-treatment tumor registration and beam delivery periods. We have proposed another DIBH technique using an infrared distance measurement device, where a reference distance map to the patient thorax surface is obtained at the time of tumor registration. During the DIBH beam delivery, the distance map is updated in real time to confirm that the breath-hold condition remains unchanged. The purpose of this study was to report our initial clinical experience of this DIBH workflow.

2. Methods

A patient having a respiratory tumor-motion amplitude of 17 mm was selected for this study. Written informed consent was obtained from the patient and it was held on medical records. DIBH was employed to minimize the dose to normal lung, whereas volumetric modulated arc therapy (VMAT) with 10 MV flattening-filter-free (FFF) beams were also used to minimize the number of breath-holds and thus the total delivery time. An Elekta research linac (Elekta AB, Stockholm, Sweden) equipped with on-board cone-beam CT (CBCT), X-ray Volume Imaging (XVI) version 5, was employed for this study, with a maximum dose rate of 2400 MU/min in 10 MV FFF mode.

Planning CT images were acquired under a DIBH condition and a clinical target volume (CTV) was contoured in Pinnacle treatment planning system (Royal Philips, Amsterdam, Netherlands). This procedure was repeated five times and an internal target volume (ITV) among the multiple DIBHs was created by integrating the five CTVs. In this way, the tumor position uncertainty among the multiple DIBHs was taken into account. A planning target volume (PTV) was defined by adding an isotropic margin of 5 mm to the ITV. A D95 dose of 55 Gy in four fractions was prescribed to the PTV.

Immediately before treatment, a 30-second half-arc CBCT imaging was performed under another DIBH condition, and the couch was repositioned so that the tumor may be located inside the PTV contours.

An infrared distance measurement device, Kinect version 2 (Microsoft, Washington, USA), was attached to the couch, and a distance map to the patient thorax surface was recorded as a reference immediately after the couch was repositioned under still another DIBH condition. The Kinect has three infrared laser diodes with an infrared image sensor, and detects phase differences between the three light beams with different modulations and the reflected image signals pixel by pixel thereby calculating the distance map [5]. A more detailed description of the Kinect application software will be separately published.

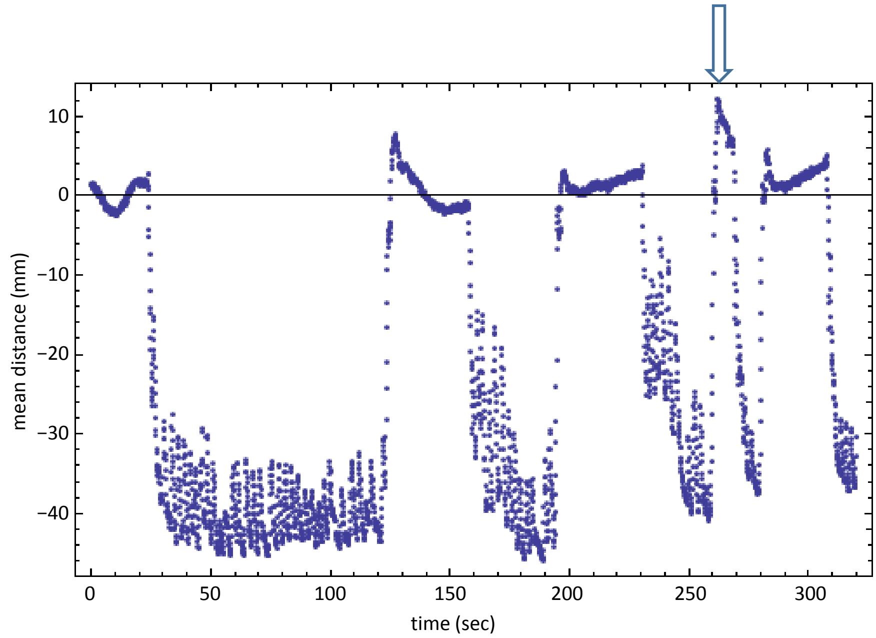
A 220˚-arc segmented VMAT beam, with two beam interrupts each having a period of at least 30 seconds, was delivered to the patient under repeated DIBH conditions, where the beam-on-time of each segmented beam was 30 seconds which is the maximum tolerable DIBH period for the patient. More accurately, the beam-on-time for the last segment may be less than 30 seconds depending on the total monitor units to be delivered. During the beam delivery, the distance map was updated in real time to confirm that the distance to the patient thorax surface remained unchanged. To simplify this evaluation, the reference distance map was subtracted from the updated distance map. Subsequently, a mean distance was calculated by spatial averaging within a region of large distance variations due to breathing. In-treatment CBCT imaging was further performed using the XVI version 5 to reconfirm the tumor position during the treatment.

3. Results

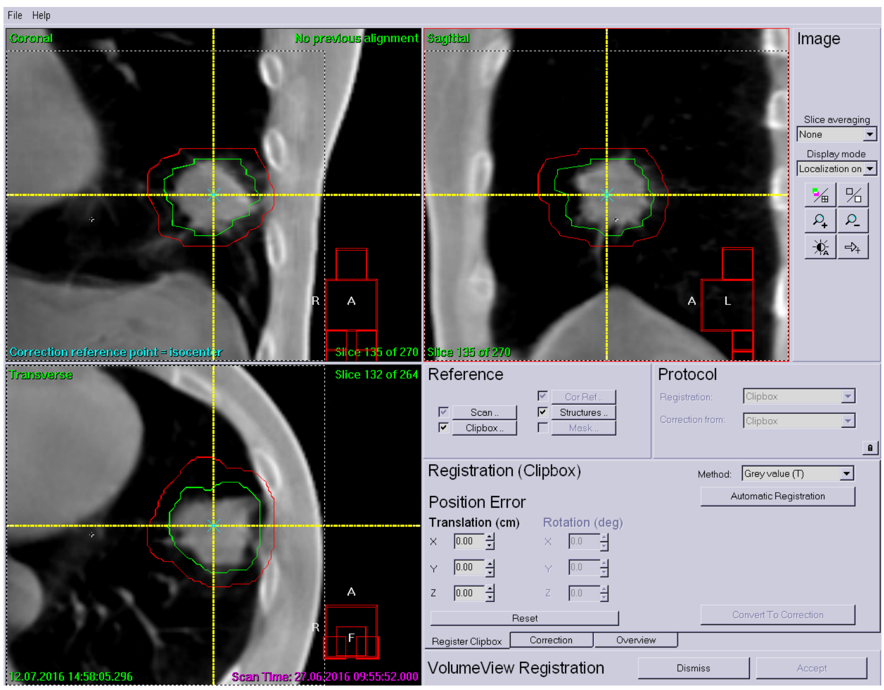
Figure 1(a) shows a plot of the mean distance during the pre-treatment CBCT imaging followed by the DIBH VMAT delivery with three segments, where the origin of the mean distance was given arbitrarily. The downward arrow shows a DIBH failure with a different mean distance and thus a different breath-hold condition, resulting in no treatment beam delivery. **Figure 1(b)** depicts the in-treatment 220˚-arc CBCT images of a lung tumor with green ITV and red PTV contours on the same day. It was confirmed that the tumor position at the pre-treatment registration was accurately reproduced during the treatment. The total VMAT delivery time including the beam interrupt periods was approximately three minutes. It was suggested that the distance map to the patient thorax surface was a promising index for reproducing the accuracy of the tumor localization.

4. Discussion

For breath-hold beam delivery, one of the most important aspects is reproducibility of the lung tumor position. As was mentioned in the introduction, it is still



(a)



(b)

Figure 1. (a) A plot of mean distance during pre-treatment CBCT imaging and DIBH segmented VMAT delivery. The downward arrow shows a DIBH failure with a different mean distance. (b) In-treatment half-arc CBCT images of a lung tumor with green ITV and red PTV.

unclear which method may provide the highest reproducibility of the tumor position among treatment planning CT imaging, pre-treatment tumor registration and beam delivery periods. We have proposed another DIBH technique using an infrared distance measurement device, where a reference distance map to the patient thorax surface is obtained at the time of tumor registration. By employing in-treatment CBCT imaging, we have confirmed that the tumor position at the pre-treatment registration was accurately reproduced during the VMAT beam delivery.

A limitation of this study was that this is a single case report, and more clinical data need to be collected so that PTV margin may be statistically calculated. Another limitation of this study was that the treatment beam interrupts were manually performed. Automatic control of the treatment beam delivery may increase the treatment efficiency.

5. Conclusion

In conclusion, a new multiple DIBH segmented VMAT technique with 10 MV FFF beams has been proposed using a Kinect distance sensor, where the distance map was compared to the reference map in real time so that the distance to the patient thorax surface between the pre-treatment registration and the treatment periods may remain unchanged. In-treatment CBCT imaging suggested that the tumor position at the time of tumor registration was accurately reproduced during the DIBH VMAT delivery.

References

[1] Boda-Heggemann, J., Knopf, A.C., Simeonova-Chergou, A., Wertz, H., Stieler, F., Jahnke, A., Jahnke, L., Fleckenstein, J., Vogel, L., Arns, A., Blessing, M., Wenz, F. and Lohr, F. (2016) Deep Inspiration Breath Hold-Based Radiation Therapy: A Clinical Review. *International Journal of Radiation Oncology * Biology * Physics*, **94**, 478-492. https://doi.org/10.1016/j.ijrobp.2015.11.049

[2] 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. *International Journal of Radiation Oncology * Biology * Physics*, **44**, 911-919. https://doi.org/10.1016/S0360-3016(99)00056-5

[3] Bartlett, F.R., Colgan, R.M., Donovan, E.M., Carr, K., Landeg, S., Clements, N., McNair, H.A., Locke, I., Evans, P.M., Haviland, J.S., Yarnold, J.R. and Kirby, A.M. (2014) Voluntary Breath-Hold Technique for Reducing Heart Dose in Left Breast Radiotherapy. *Journal of Visualized Experiments*, **89**, e51578. https://doi.org/10.3791/51578

[4] Onishi, H., Kawakami, H., Marino, K., Komiyama, T., Kuriyama, K., Araya, M., Saito, R., Aoki, S. and Araki, T. (2010) A Simple Respiratory Indicator for Irradiation during Voluntary Breath Holding: A One-Touch Device without Electronic Materials. *Radiology*, **255**, 917-923. https://doi.org/10.1148/radiol.10090890

[5] Sarbolandi, H., Lefloch, D. and Kolb, A. (2015) Kinect Range Sensing: Structured-Light versus Time-of-Flight Kinect. *Computer Vision and Image Understanding*, **139**, 1-20. https://doi.org/10.1016/j.cviu.2015.05.006