

Effects of Interfractional Changes on Range in Charged Particle Radiotherapy of Lung Cancer

Shinichiro Mori, PhD, Hsiao-Ming Lu, PhD, John Wolfgang, PhD, Noah C Choi, MD, George TY Chen, PhD



Department of Radiation Oncology Massachusetts General Hospital, Harvard Medical School



INTRODUCTION

Charged particle beams are particularly affected by **intrafractional motion** because of their finite range and Bragg peak. Temporal variations in the water equivalent pathlength result in range changes, leading to overshoot or undershoot of heavy charged particle beams.

Other sources of range perturbations include **interfractional changes** such as tumor size, shape and tissue thickness etc. Tumor shrinkage has been observed over the course of treatment and its effect on dose has been evaluated. To our knowledge, however, a quantitative analysis of range fluctuation due to interfractional changes in charged particle therapy during treatment course has not been reported. We reported quantitative analysis of interfractional changes in charged particle lung therapy.

PATIENTS AND DATA ACQUISITION

The subject was a female patient aged 77 years old with non-small cell lung cancer. The tumor was located in the right middle lobe. Chemotherapy was administered. **Weight loss was 9.1 kg in five weeks.** A treatment planning CT scan (1st CT scan) was performed under free breathing conditions using a 4-slice CT scanner in 4DCT mode. Patient respiration was monitored by a Real-Time Position Management Respiratory Gating System. Five weeks after the initial CT scan, a conedown scan (2nd CT scan) was done.

DATA ANALYSIS

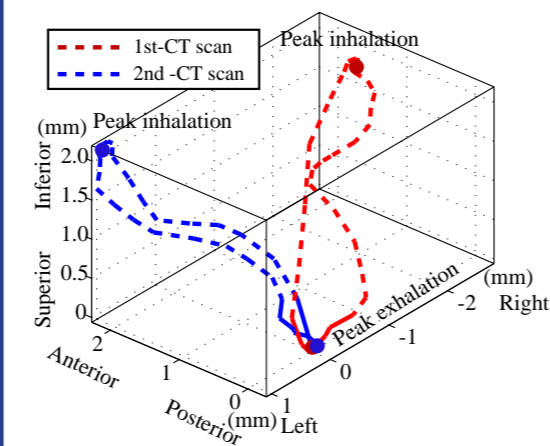
We evaluated range variations due to interfractional changes following four metrics. These results were compared between 1st- and 2nd-CT scans. Each respiratory cycle was subdivided into 10 phases (T0-90%).

(1) GTV and center of mass motion (COM)

To compute tumor GTV, all CT data were manually contoured on axial slices of both 1st and 2nd CT scan images.

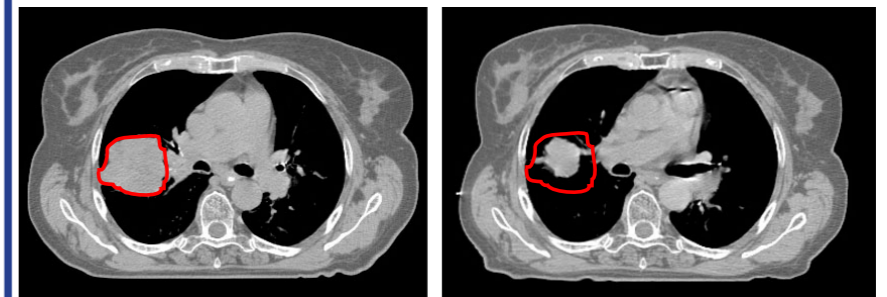
The COM trajectory for 1st and 2nd-CT scans is shown in **Fig. 1**. The solid lines correspond to the gating window (T40-60%). COM displacement is 3.5 mm (AP: 1.6mm, LR: 2.6mm, SI: 1.7mm) for the 1st-CT scan and 3.3 mm (AP: 2.3mm, LR: 1.1mm, SI: 2.1mm) for the 2nd-CT scan. The center of mass displacement and difference between both CT scans is relative small.

Figure 1



Center of mass trajectory for first and second CT scans in (a) 3D trajectory of tumor center of mass. The solid lines correspond to the gating window (T40-60%).

Figure 2



Axial images at peak exhalation (T50%). (a) First CT scan. (b) Second CT scan. The red contour represents the GTV at time of first CT scan.

for the 1st-CT scan and 39.2 cc for the 2nd-CT scan.

(2) WEL fluctuation

Water equivalent pathlength (WEL) is calculated. The calculation region is defined by two planes, one at the entrance surface the other just behind the target from a given beam direction. Same positions of the planes were adapted to the 2nd-CT scan image. The calculation direction is along the AP direction. A WEL difference image was calculated between the 2nd-CT scan from that of the 1st-CT scan at the same respiratory phase.

Several regions of the WEL difference image are noteworthy (**Fig. 3**). Alignment of the external contours and the contralateral lung are quite good. Greater than 20 mm-WEL change was observed at the edge of the breast due to **weight loss**. The periphery of the heart show negative WEL change (blue region) due to **cardiac motion**. There is a rim of positive WEL change near the inferior portion of the tumor due to **shrinkage**. To evaluate WEL changes at each respiratory phase, three circular

Although peak exhalation positions of the 1st-CT and 2nd-CT scans are close, **tumor trajectories differ**.

Axial images at the same cranio-caudal position for the 1st-CT and 2nd-CT scans at T50% were shown in **Fig. 2**. Tumor shape for 2nd-CT scan shows asymmetric shrinkage compared with that for 1st-CT scan.

The mean GTV volume from all respiratory phases is 115.2cc

