Effects of Intrafractional Motion on Water Equivalent Path Length in Respiratory-gated Heavy Charged Particle Beam Radiotherapy

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INTRODUCTION

Current available multi-slice CT (MSCT) scanners utilize up to 64 segmented detector rings, with an effective slice thicknesses of 0.5 to 0.625 mm at the center of rotation. The 64MSCT therefore represents a significant improvement over conventional MSCTs. However, the cranio-caudal coverage of available scanners is typically 40 mm or less at a given couch position, and thus limits scan coverage for cine imaging. CT scanning in radiotherapy utilizes 4DCT to capture organ motion. In respiratory gated radiotherapy (RGRT), irradiation is often limited to that portion of the respiratory cycle at which motion is minimal and tumor position is typically exhalation. This technique leads to the potential of greater target dose conformity and normal tissue sparing Vs ungated treatment techniques. While respiratory gating controls breathing associated motion, cardiac motion can still cause range perturbations in RGRT of charged particle beam radiotherapy. This is due primarily to changes in heart shape and location during the cardiac cycle. Since high dose treatment beam is irradiated to heart in oesophageal or mediastinum cancer patient, the cardiac motion has been concerned in radiotherapy community.

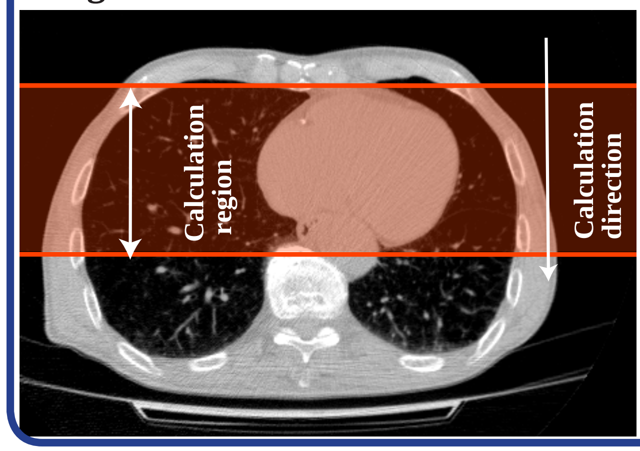
We have analyzed the water equivalent pathlength (WEL) fluctuations due to intrafractional motions (cardiac and respiratory motions) in RGRT using a 256MSCT scanner and present these variations in a beam's eye view (BEV) type format.

VOLUMETRIC CINE IMAGING

Subjects included seven in-patients (mean age, 76.7 y; S.D, 7.5 y) selected at random from patients with lung tumors (lung adenocarcinoma or carcinoma). All scans were performed under quiet free breathing conditions, with a respiratory sensing system. After several minutes' quiet breathing, volumetric cine scanning was initiated.

Scan parameters were: 120 kV, 220 mA, 0.5 s per rotation, 256 × 0.5 mm slice collimation and 6.0 s acquisition time. Effective temporal resolution is 250 ms.

Figure 1



WEL calculation regions for an AP field. Region 1 is defined by planes bounding the heart.

DATA ANALYSIS

The random phase of the end-diastole (ED) and –systole (ES) is in a respiratory gated window. Two specific cardiac phase images (ES and ED) occurring at respiratory exhalation were retrospectively identified. Range differences at these two cardiac phases are visualized in two forms: (i) an isopenetration plot, which displays contours of constant range from the entrance surface to a given range value and (ii) a WEL difference image (æ WEL), which is calculated by subtracting a WEL image acquired at ES from that at ED. The WEL difference image is calculated by mapping the physical length to the radiological water equivalent pathlength.

Since it is difficult to separate the cardiac and respiratory motions clearly in 4DCT under free breathing, even though two cardiac phase CT images are selected in gating window, two WEL calculation regions at "exhale" are specified. The calculating region is confined to the volume bounded by planes (perpendicular to the BEV angle) that encompass the heart to minimize the effect of respiratory motion as possible (**Fig. 1**); WEL calculations that are primarily impacted by cardiac motion. The rationale of the region is to quantify range perturbations in the "first half" of the thorax. Difference images calculated by subtracting the range images at ES and ED will include both heart motion as well as a small effect from different respiratory phases within the respiratory gate window.

The magnitude of the range fluctuations is dependent on beam direction. Twelve BEV angles (from 0º to 360º in 30 degree increments) were calculated. Since BEV angles d□ and d□ + 180□ are symmetric for transmission WEL calculations (assuming infinite SAD). WEL assessment was performed for the heart region by contouring it at ED at the selected BEV angles.