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Verification of the Grid Size and Angular Increment Effects in Lung Stereotactic Body Radiation Therapy Using the Dynamic Conformal Arc Technique

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The dosimetric effects of variable grid size and angular increment were systematically evaluated in the measured dose distributions of dynamic conformal arc therapy (DCAT) for lung stereotactic body radiation therapy (SBRT). Dose variations with different grid sizes (2, 3, and 4 mm) and angular increments (2, 4, 6, and 10°) for spherical planning target volumes (PTVs) were verified in a thorax phantom by using EBT2 films. Although the doses for identical PTVs were predicted for the different grid sizes, the dose discrepancy was evaluated using one measured dose distribution with the gamma tool because the beam was delivered in the same set-up for DCAT. The dosimetric effect of the angular increment was verified by comparing the measured dose area histograms of organs at risk (OARs) at each angular increment. When the difference in the OAR doses is higher than the uncertainty of the film dosimetry, the error is regarded as the angular increment effect in discretely calculated doses. In the results, even when a 2-mm grid size was used with an elaborate dose calculation, 4-mm grid size led to a higher gamma pass ratio due to underdosage, a steep-dose descent gradient, and lower estimated PTV doses caused by the smoothing effect in the calculated dose distribution. An undulating dose distribution and a difference in the maximum contralateral lung dose of up to 14% were observed in dose calculation using a 10° angular increment. The DCAT can be effectively applied for an approximately spherical PTV in a relatively uniform geometry, which is less affected by inhomogeneous materials and differences in the beam path length.

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I. INTRODUCTION

Arc-based radiation therapy (ART) using numerous beams has been used to achieve more conformal doses to the target volume and to disperse the dose weighting for sparing organs at risk (OARs) [1]. Dynamic conformal arc therapy (DCAT) can facilitate fast and effective

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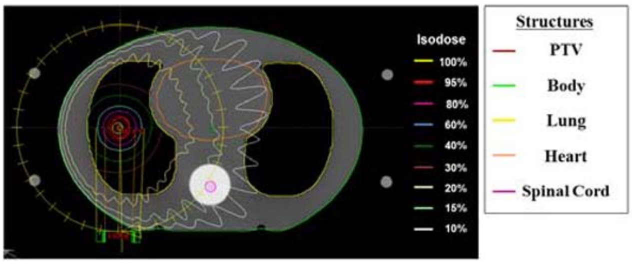

Fig. 1. (Color online) Dynamic conformal arc therapy (DCAT) plan for a spherical planning target volume (PTV) in a thorax phantom to verify the dosimetric effects of different grid sizes and angular increments. The PTV and the doses to organs at risk (OARs) for the ipsilateral and contralateral lung, spinal cord, and heart were verified using EBT2 films.

dose delivery for various cancers by using lower monitor units (MUs) [2–5]. As the intensity-modulated and the non-coplanar techniques are integrated with ART, more effective treatment method has been attempted to provide superior dose distributions [6,7]. For improved clinical outcome in lung stereotactic body radiation therapy (SBRT), ART using a dynamic multi-leaf collimator (MLC) was applied as a useful beam delivery method [8].

Although doses should be nearly identical because the same prescribed dose is delivered to the same planning target volume (PTV) under the definite treatment configuration of the DCAT, different discretizations with variable grid sizes and angular increments for dose calculations cause dose differences [9,10]. Because the predicted doses are delivered in a dynamic mode with gantry rotation and movement of the MLC leaf to an interpolated position between control points, dose discrepancies are inevitable in ART. Thus, even if an elaborate dose distribution can be obtained using the smallest grid size and angular increment in DCAT plans, selecting practical plan parameters is necessary to estimate the delivered dose distributions disturbed by the intrinsic dose errors in actual dose delivery.

In the present study, the dosimetric effects of grid size and angular increment in DCAT were verified using a thorax phantom and Gafchromic EBT2 films. We measured dose differences as functions of these two plan parameters in a relatively simple geometry, while minimizing the influence of the other factors that cause dose variations for lung SBRT. The evaluated dosimetric effects of grid size and angular increment can be considered when applying DCAT plan parameters to estimate the probable dose error.

II. MATERIALS AND METHODS

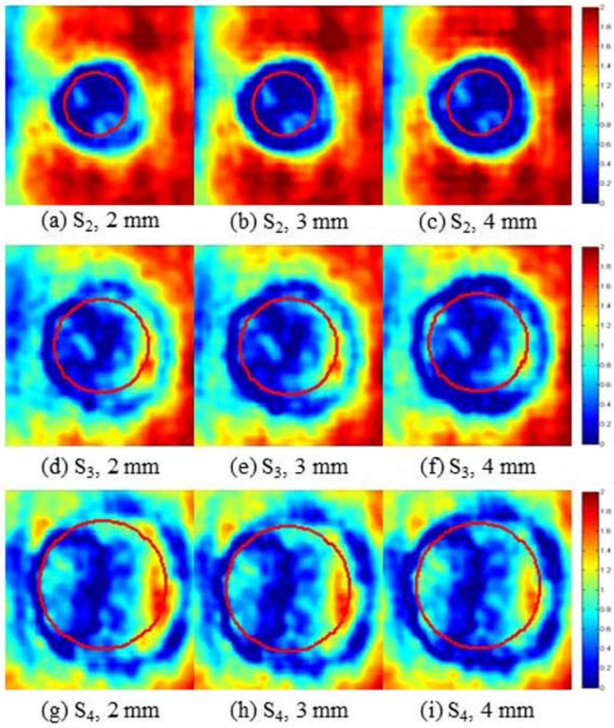

Fig. 2. (
Color online) Gamma distributions with different grid sizes (2, 3, and 4 mm) for spherical planning target volumes (PTVs) with diameters of 2 cm (S_2), 3 cm (S_3), and 4 cm (S_4). The smallest and the largest PTVs in the first and the third rows are S_2 and S_4, respectively. Each column shows the variation of gamma maps with grid sizes from 2 to 4 mm.

1. Dynamic Conformal Arc Treatment Plan

To evaluate the dose differences for various grid sizes and angular increments, we calculated doses for a thorax phantom (002LFC, CIRS, Inc., Norfolk, VA, USA) by using the Eclipse planning system (v. 8.6.17, Varian Medical Systems, Palo Alto, CA, USA) (Fig. 1). Three spherical PTVs with diameters of 2 (S_2), 3 (S_3), and 4 cm (S_4) were chosen to minimize other error factors, such as the interpolation of MLC segments between control points for irregularly-shaped PTVs. When a total dose of 48 Gy is to be delivered in four fractions for lung SBRT [11], 12 Gy per fraction can be delivered in two exposures by using coplanar double arcs because the Varian Clinac iX unit (Varian Medical Systems) allows a MU of less than 999 for each arc beam. Thus, the dose discrepancy in DCAT was evaluated in the measured dose distributions of 6 Gy, which is corresponded to the dose range of EBT2 films (International Specialty Products, Wayne, NJ, USA) in the red channel [12]. The dose was prescribed at the center of the PTV.

Predicted doses with different grid sizes (2, 3, and 4 mm) were calculated for a fixed angular increment of 2°