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A treatment planning approach to spatially fractionated megavoltage grid therapy for bulky lung cancer

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ABSTRACT

The purpose of this study was to explore the treatment planning methods of spatially fractionated megavoltage grid therapy for treating bulky lung tumors using multileaf collimator (MLC). A total of 5 patients with lung cancer who had gross tumor volumes ranging from 277 to 635 cm^3 were retrospectively chosen for this study. The tumors were from 6.5 to 9.6 cm at shortest dimension. Several techniques using either electronic compensation or intensity-modulated radiation therapy (IMRT) were used to create a variety of grid therapy plans on the Eclipse treatment planning system. The dose prescription point was calculated to the volume, and a dose of 20 Gy with 6-MV/15-MV beams was used in each plan. The dose-volume histogram (DVH) curves were obtained to evaluate dosimetric characteristics. In addition, DVH curves from a commercially available cerrobend grid collimator were also used for comparison. The linear-quadratic radiobiological response model was used to assess therapeutic ratios (TRs) and equivalent uniform doses (EUD) for all generated plans. A total of 6 different grid therapy plans were created for each patient. Overall, 4 plans had different electronic compensation techniques: Ecomps-Tubes, Ecomps-Circles, Ecomps-Squares, and Ecomps-Weave; the other 2 plans used IMRT and IMRT-Weave techniques. The DVH curves and TRs demonstrated that these MLC-based grid therapy plans can achieve dosimetric properties very similar to those of the cerrobend grid collimator. However, the MLC-based plans have larger EUDs than those with the cerrobend grid collimator. In addition, the field shaping can be performed for targets of any shape in MLC-based plans. Thus, they can deliver a more conformal dose to the targets and spare normal structures better than the cerrobend grid collimator can. The plans generated by the MLC technique demonstrated the advantage over the standard cerrobend grid collimator on accommodating targets and sparing normal structures. Overall, 6 different plans showed 6 different dosimetric parameters. However, an optimal grid therapy plan selection from among these 6 types requires more information from clinical trials and radiobiological studies.

Introduction

The effectiveness of megavoltage grid therapy in treating bulky tumors has been recognized and clearly demonstrated in many references.[1-6] As reported by Zwicker *et al.*[6] and Zhang *et al.*,[7] grid therapy takes advantage of the fact that normal cells in general have superior repair capabilities over cancer cells. When normal tissue cells are spared by grid therapy, those underirradiated areas can serve as centers of regrowth for normal tissues. The cancer cell kill rate is maintained whereas the normal cell survival ratio is increased, thereby providing a clinical advantage. The latest study by Zhang *et al.*[8] demonstrated that grid therapy provided a pronounced therapeutic advantage in both hypofractionated and traditionally fractionated regimens as compared with the results seen with single-fraction, open debulking field regimens. However, the true therapeutic advantage (after separating the benefit of fractionation) exists only in hypofractionated grid therapy.[8] In addition, clinical outcomes and theoretical studies have indicated that a course of open-field radiotherapy is needed to fully control tumor growth after a large-fraction dose with grid therapy.[1,4,8]

Despite the complexity of grid fields, important knowledge has already been gained from clinical trials and radiobiological modeling. Nevertheless, much remains to be learned and improved

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upon, primarily with regard to 2 specific issues, which are discussed later.

First, the availability of various grid collimators that can take into account tumor shape and normal structures is limited. Commercially available grid collimators have only a limited number of hole sizes to select from. Additionally, there are too many closely arranged holes, and hole sizes are small and divergent. Thus, it is very difficult to put grid collimators into the treatment planning system (TPS) of a contemporary plan. In addition, in clinical applications, such devices are also very bulky (22 kilograms) and handling is labor intensive.

Second, the behaviors of cancer and normal cells in high-gradient radiation fields and bulky tumor locations remain largely unknown. As modeling beam data of the matrixlike grid holes is not easy, in most clinics, the dose-volume histogram (DVH) curves for both the tumor and the normal structures are not generated from the cerrobend collimator–based grid therapy treatments. In addition, the traditional grid therapy treatment is just a single-portal field radiotherapy; the tumor shapes and normal structures are not considered.

It is apparent that these issues need to be resolved before megavoltage grid therapy can be widely used in a clinic. A novel approach, which uses the existing technology of multileaf collimators (MLCs)—found in most modern radiotherapy linac machines and TPS for dosimetry—is explored in this study for creating grid therapy.

It should also be noted that the traditional cerrobend-based grid therapy takes much less time for both the dosimetry planning (10 minutes for cerrobend *vs* 2 hours for MLC by a skilled dosimetrist) and the treatment (5 minutes *vs* 20 minutes).

In the present study, we applied the TPS to make grid therapy plans, using electronic compensator and intensity-modulated radiation therapy (IMRT) techniques. Thus, the 3-dimensional (3D) dose distributions of grid therapy were obtained, and the dosimetric characteristics could be further analyzed. Because these grid therapy plans were achieved by MLCs, we named them MLC-based grid therapy plans. In addition, using Monte Carlo simulation we obtained the DVH curves from a cerrobend collimator–based (cerro-based) grid therapy plan for a 10-cm tumor with the same prescription dose. The DVH curves from an open-field therapy for the same spherical tumor with the same equivalent uniform dose (EUD) as the cerro-based plan were also obtained and were used to compare with the MLC-based plans. The geometry of the commercially available cerrobend grid collimator is reported elsewhere in the literature.[9] In this study, we used a single-fraction dose of 20 Gy to show the dosimetric properties of different grid therapy plans, simply because this fraction dose and regimen were widely used in various clinics.

Methods and Materials

Patient selection

A total of 5 patients with lung cancer with gross tumor volumes (GTVs) ranging from 277 to 635 cm^3 (median 398 cm^3) were retrospectively chosen for this study. The tumors were from 6.5 to 9.6 cm (median 7.6 cm) in the shortest dimension passing the tumor center in 3D measurement. A total of 6 plans for each patient were designed on the Eclipse TPS, version 10 (Varian Medical Systems, Inc, Palo Alto, CA). The prescription dose was calculated to the GTV. A prescription dose of 20 Gy was used for each plan. In cerro-based planning, this prescription dose represents the dose onto the central axis of the central hole at the tumor center. In MLC-based plans, this dose represents the maximum dose across the tumor volume. The MLC-based plans created in this study were called electronic compensation (Ecomp)-Tubes, Ecomp-Circles, Ecomp-Squares, Ecomp-Weave, IMRT, and IMRT-Weave based on the different techniques used.

MLC-based grid therapy plans

Ecomp-Tubes, Ecomp-Circles, Ecomp-Squares, and Ecomp-Weave plans

The Ecomp-Tubes plan was generated by contouring a structure of "Cold_Tubes." This was accomplished in the contouring mode with the grid tool set at 2.0 cm. Starting at the most superior slice of GTV, a Cold_Tube was contoured from anterior to posterior along the grid, through the GTV. The Cold_Tube continues inferiorly through the length of GTV. As the width of GTV increases, a new Cold_Tube is placed using the grid to allow 2.0-cm spacing between each cold tube laterally and contoured inferiorly as with the previous tube (Fig. 1). It is

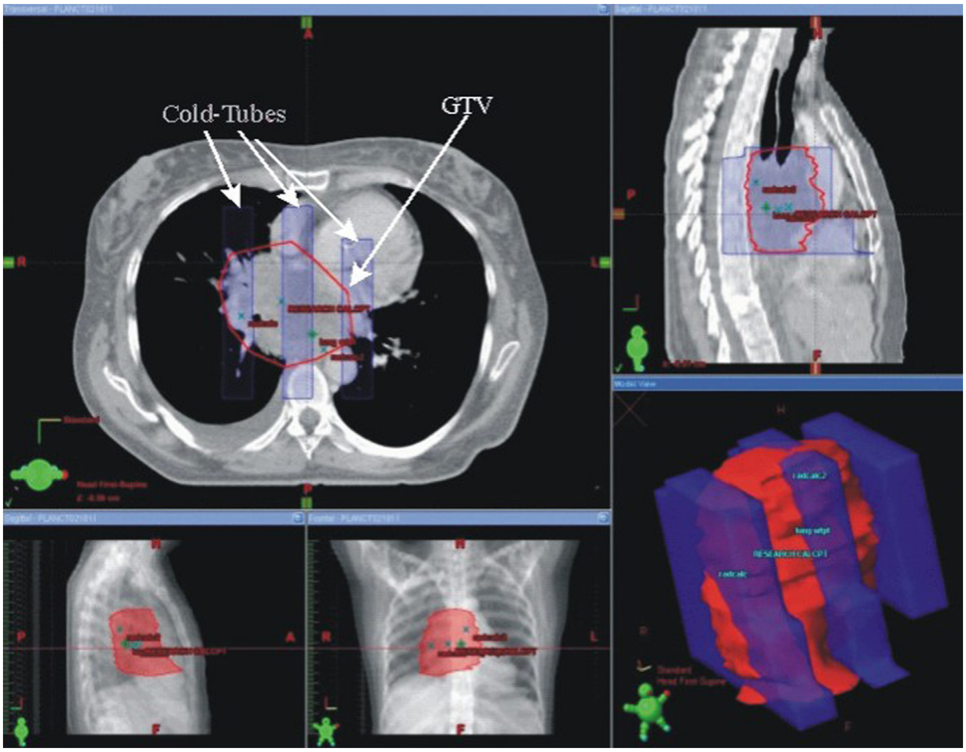

Fig. 1. View of Cold_Tubes contours. (Color version of figure is available online.)