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Physics Contribution

Clinical Application of a Novel Hybrid Intensity-Modulated Radiotherapy Technique for Stage III Lung Cancer and Dosimetric Comparison With Four Other Techniques

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Summary

Planning delivery of >60 Gy can be challenging and time consuming for large stage III lung tumors. This study investigated which planning technique is optimal for fast planning, limiting total lung V_{20}, contralateral lung V_5, and hotspots. The novel hybrid-IMRT and hybrid-RapidArc techniques and full RapidArc fulfilled these criteria best. The hybrid techniques offer a simple and fast solution that can easily be implemented in the clinic.

Purpose: In large stage III lung tumors, planning delivery of doses exceeding 60 Gy can be challenging and time consuming. Intensity modulated radiation therapy (IMRT) can improve target coverage but may increase volumes receiving low-dose irradiation. We clinically implemented a novel hybrid IMRT (h-IMRT) technique that allowed plans to be produced quickly, and compared these plans with 4 other techniques.

Methods and Materials: h-IMRT was used to treat 14 consecutive patients with planning target volumes (PTVs) exceeding 500 cm^3 (average, 779 cm^3) with concurrent chemo-radiation therapy to 66 Gy. h-IMRT plans consisted of 2 components: an anterior-posterior/posterior-anterior/posterior-anterior (AP-PA-PA) oblique, open-field technique delivering an average dose of 58 Gy, plus a 3-field IMRT component optimized to achieve a final homogeneous dose of 66 Gy. Total lung V_{20} and contralateral lung V_5 were kept as low as possible but preferably less than 35% and less than 50%, respectively. All plans were retrospectively replanned using a 5- to 9-field 3-dimensional conformal technique, full RapidArc, 6-field full IMRT, and a hybrid RapidArc (h-RapidArc) technique similar to the h-IMRT.

Results: The h-IMRT, h-RapidArc, and full RapidArc plans could be generated in less than 2 h, with the first 2 plans achieving the lowest V_5 (36%) and V_{20} (30%) values together with the smallest hot spots. Both the 3-dimensional conformal and full IMRT plans occasionally led to unacceptable hot spots outside the PTV. Full RapidArc plans were fast and achieved comparable V_{20} values but led to slightly higher V_5 values.

Conclusions: Both h-IMRT and h-RapidArc permitted delivery of 66 Gy to large stage III lung tumors, and both were superior to either full IMRT or RapidArc plans for reducing lung doses. The clinical significance of small increases in V_5 during chemo-radiation therapy delivery are

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unknown, but the present study suggests that h-IMRT and h-RapidArc are preferable for treatment of large tumors.

Keywords: Stage III lung cancer, IMRT, RapidArc, Treatment planning comparison

Introduction

Concurrent chemo-radiation therapy (CT-RT) represents the standard of care for patients with stage III non-small cell lung cancer (NSCLC) (1). However, locoregional failure rates in phase III trials of CT-RT to doses of 60 Gy, range from 30% to 55% (2). Treatment of larger tumors has been reported to be associated with increased risks of pulmonary and esophageal toxicity (3, 4). Although our current protocol aims to deliver a dose of 66 Gy to the planning target volume (PTV), prescribed doses of 60 Gy or higher, and with at least 97% of the volume receiving 95% of the prescribed dose, were achieved in only 60% of patients (5). The latter was despite use of 4-dimensional computed tomography (4D-CT)-based involved-field radiation therapy with appropriate use of respiration-gated delivery to reduce lung volumes outside the PTV receiving doses greater than 20 Gy (TL-V_{20}), and volumes of contralateral lung receiving doses greater than 5 Gy (CL-V_5) (6).

Single-institution results suggest that the use of intensity modulated radiation therapy (IMRT) improves plan quality, reduces the toxicity, and may improve local control and survival rates (7). Some IMRT approaches have increased regions of low-dose radiation in lung tissue, leading to higher rates of radiation pneumonitis (8, 9). Also of concern are possible motion interplay effects arising when mobile tumors are treated using IMRT (10). These concerns may have limited the more widespread application of IMRT in stage III lung cancer.

A hybrid IMRT technique for treating esophageal and lung tumors was recently described, which used a 33% IMRT component (11). We developed, and clinically implemented, a modified hybrid IMRT (h-IMRT) technique that was based on the above, but that required a minimal IMRT contribution of on average 11%. The lower IMRT contribution will decrease the impact of motion interplay effects, and also reduce the likelihood of the plan optimizer increasing low-dose regions in the contralateral lung. The present study describes our technique and compares it with 4 other planning techniques, including full IMRT and RapidArc (Varian Medical Systems, Palo Alto, CA), for patients with much larger PTV sizes than were described previously (11).

Methods and Materials

Our h-IMRT technique was first implemented in 2008 for patients with stage III NSCLC undergoing concurrent CT-RT, whose PTVs exceeded 500 cm^3. The present report describes detailed planning studies in the first 14 patients treated with this approach, whose PTV averaged 779 cm^3 (range, 591-1258 cm^3). Clinical details are summarized in Table 1.

All patients underwent a 4D-CT scan, and 10 phases of the breathing cycle were reconstructed as described previously (12). The internal target volume (ITV) consisted of the primary tumor and regional lymph nodes that were considered to have metastatic disease on grounds of computed tomography (CT), fluorodeoxyglucose-positron emission tomography (FDG-PET), or pathology. The ITV (12) was copied to the average intensity projection of the 4DCT for treatment planning. A PTV was generated by expanding the ITV with a margin of 10 mm.

All 14 patients were originally planned to be treated to a prescription dose of 66 Gy in 33 fractions using h-IMRT. In the present comparative study, all cases were replanned using the same planning objectives. The 4 replanning techniques used were a 3D conformal plan, full fixed gantry IMRT, full RapidArc, and hybrid RapidArc (h-RapidArc). The comparative plans were generated by a dosimetrist in the Eclipse treatment planning program (v 8.6.15, Varian Medical Systems, Palo Alto, CA), and verified or improved by a medical physicist. Doses were calculated using the anisotropic analytical algorithm (AAA). Details of planning objectives are summarized in Table 2.

h-IMRT (clinical plan)

The plan consists of both a conventional and an IMRT component. The conventional component consisted of a 3-field plan to deliver an average PTV dose of 55 to 60 Gy, using a nominal fraction dose of 1.8 Gy. The field arrangement is mainly anterior-posterior to posterior-anterior (AP-PA) with an additional posterior oblique field that spares the spinal cord. Typically, 15-MV beams were used, occasionally combined with 6 MV, depending on the tumor location. An inhomogeneous dose distribution is permitted in the PTV at this stage, ranging from 47 to 66 Gy. An inhomogeneous dose distribution implies that no wedges are required in the fields, thereby allowing greater flexibility in the choice of collimator angles. The mainly AP-PA field arrangement ensures low doses to the contralateral lung. Field weights were selected such that the spinal cord doses remain at less than 45 Gy. Multileaf collimator (MLC) settings can be set as tight as 4 mm outside the PTV, as the IMRT component compensates for potential underdosage at the PTV borders. In cases in which the PTV includes contralateral mediastinal and/or supraclavicular lymph nodes, and in which oblique PA fields insufficiently limit spinal cord doses, both PA fields are split into 1 component that fully covers the PTV, and a second supplementary field where the cord is blocked by using leaves set parallel to the direction of the cord. The blocked segment generally consists of spinal canal plus margin of 2 to 3 mm.

The IMRT component consists of a nominal 0.2 Gy per fraction, delivered using 3 fields of 6 MV, 2 of which are angulated by 10 to 20° from AP and PA, and 1 lateral field. The IMRT beam directions were chosen such that the irradiation of contralateral lung was limited. For tumors in the left lung, typical field arrangements use gantry angles of 0°, 180°, and 140° for open fields, and 340°, 200°, and 90° for IMRT fields (Fig. 1a). For IMRT optimization, an additional organ-at-risk volume is created that contains most of the body in the planes of PTV, to prevent hot spots outside the PTV. The AAA-calculated dose distribution achieved using the 3-field conventional plan is used as a “base