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PHYSICS CONTRIBUTION

A TREATMENT PLANNING ANALYSIS OF INVERSE-PLANNED AND FORWARD-PLANNED INTENSITY-MODULATED RADIATION THERAPY IN NASOPHARYNGEAL CARCINOMA

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Purpose: To compare dose–volume histograms of target volumes and organs at risk in 57 patients with nasopharyngeal carcinoma (NPC) with inverse- (IP) or forward-planned (FP) intensity-modulated radiation treatment (IMRT).
Methods and Materials: The DVHs of 57 patients with NPC with IMRT with or without chemotherapy were reviewed. Thirty-one patients underwent IP IMRT, and 26 patients underwent FP IMRT. Treatment goals were to prescribe a minimum dose of 66–70 Gy for gross tumor volume and 59.4 Gy for planning target volume to greater than 95% of the volume. Multiple selected end points were used to compare dose–volume histograms of the targets, including minimum, mean, and maximum doses; percentage of target volume receiving less than 90% (1-V90%), less than 95% (1-V95%), and greater than 105% (1-V105%). Dose–volume histograms of organs at risk were evaluated with characteristic end points.
Results: Both planning methods provided excellent target coverage with no statistically significant differences found, although a trend was suggested in favor of improved target coverage with IP IMRT in patients with T3/T4 NPC (p = 0.10). Overall, IP IMRT statistically decreased the dose to the parotid gland, temporomandibular joint, brain stem, and spinal cord overall, whereas IP led to a dose decrease to the middle/inner ear in only the T1/T2 subgroup.
Conclusions: Use of IP and FP IMRT can lead to good target coverage while maintaining critical structures within tolerance. The IP IMRT selectively spared these critical organs to a greater degree and should be considered the standard of treatment in patients with NPC, particularly those with T3/T4. The FP IMRT is an effective second option in centers with limited IP IMRT capacity. As a modification of conformal techniques, the human/departmental resources to incorporate FP-IMRT should be nominal. © 2007 Elsevier Inc.

Intensity-modulated radiation treatment (IMRT), Inverse planning, Nasopharyngeal carcinoma, Forward planning, Intensity modulation.

INTRODUCTION

The ability to modulate beam intensity in a simple manner is not new. Blocks produce binary intensity distributions (either present or absent), whereas wedges modulate a beam with a gradient of intensity along one plane. The upsurge in the clinical use of intensity-modulated radiation treatment (IMRT) was associated with delivery systems capable of creating automatic and random-intensity maps, as well as inverse-planning methods that can manipulate the tremendous added complexity associated with inverse-planned (IP) IMRT. The need for inverse-planning IMRT has led to major shifts in planning, delivery methods, and quality assurance measures. These changes can affect many aspects of a modern radiotherapy (RT) department (1).

Forward-planned (FP) RT does not preclude intensity modulation (IM), although practically, the degree of IM must be limited. As a relatively straightforward extension of conformal RT, FP with simple IM does not require many departmental changes and still allows an extra degree of planning freedom to create concave distributions. However, simple IM may not fully explore the dose-sculpting potential of IMRT and certainly from a forward planning perspective,

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even a limited degree of modulation along with other traditional planning factors (*e.g.,* beam number, beam angle, and beam shape) can create a very arduous planning process (2).

Recently, attention has shifted to the use of IMRT in patients with nasopharyngeal carcinoma (NPC) (3–5) and head-and-neck carcinomas (HNCs). Because RT is a primary treatment modality for patients with HNC and conventional RT often leads to target volume coverage compromises because of normal tissue tolerances, IMRT would appear to offer advantages over conventional methods. Previous studies (5, 6) showed the dosimetric superiority of IP IMRT compared with a combination of conventional field RT with a conformal boost.

Although the latter is one standard treatment, this combination does not represent the most sophisticated FP conformal technique available. Simple FP IMRT through a field-within-a-field technique and multiple beam angles can generate concave dose distributions (Fig. 1) that effectively treat patients with NPC while sparing critical tissues. Early clinical reports of IMRT (4, 7) were examples of simple FP IMRT. On an operational level, most radiation departments in the world could perform simple FP IMRT without a major resource upheaval within their departments.

Dose Distribution of a FP IMRT plan

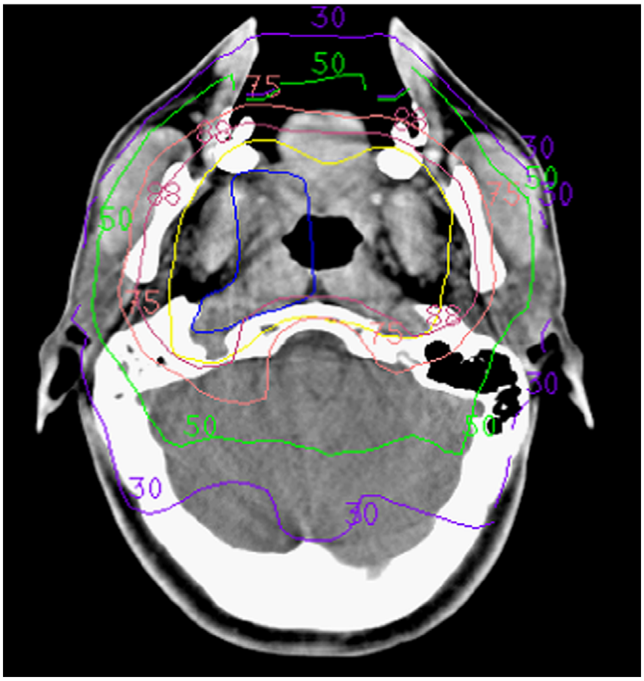

Fig. 1. A representative slice of a forward plan for a patient with nasopharyngeal carcinoma. FP IMRT = forward planned intensity modulated radiation treatment.

METHODS AND MATERIALS

Patient and staging evaluation

A total of 63 patients with primary NPC were treated with either FP IMRT or IP IMRT with or without chemotherapy: 31 patients with FP IMRT and 26 patients with IP IMRT. To accelerate the start of treatment, 4 patients started treatment by means of conventional opposed lateral RT fields initially and subsequently underwent IP IMRT for the remaining fractions when the plan was ready. Patients received the following doses from the opposed lateral fields: 1 patient with T3N2 received 720 cGy, 2 patients with T3N3 received 1,200 cGy, and 1 patient with T4N3 received 2,000 cGy. The conventional doses delivered were included in the analysis. The IP and FP IMRT were available during separate times, thereby limiting selection bias between the two groups. Six patients were excluded because treatment included both FP and IP IMRT. In total, the records of 57 patients were reviewed. Disease was staged according to the 1997 American Joint Committee on Cancer staging classification.

Treatment

FP IMRT. The FP IMRT used a three-dimensional (3D) planning system (U-M-Plan; University of Michigan Planning System, University of Michigan, Ann Arbor, MI) to the primary tumor only. Details of the planning process were previously described (5). Briefly, a plan with at least five coplanar angles was constructed while beam angles were adjusted manually to separate target volumes from the critical structures as much as possible. Two exposures with different multi-leaf collimator (MLC) shapes were delivered at each angle. From each beam angle, the entire target volume was treated with one subfield while the target volume was partially blocked in another subfield to shield the critical normal structures. Beam weightings and energy were also manually adjusted.

However, the FP IMRT plan could not be used for the entire treatment without exceeding the tolerance limit of the brain stem and spinal cord. When the tolerance limit of critical organs was reached, a cone-down plan was used for the remainder of the treatments, with portions of the target underdosed.

A split-beam technique was used to avoid divergence of these beams into the lateral opposed fields that treated the upper neck, for which the inferior border usually was at the top of the thyroid cartilage. The low neck and supraclavicular fossae were irradiated with a single anterior field, for which the isocenter was placed at the inferior border of the upper-neck fields. Potential hot or cold spots at the field junctions were smoothed out with an isocenter shift of 5 mm at least once during the treatment.

IP IMRT. Commercially available inverse treatment planning was used to generate IM plans with treatment delivered with either the MiMIC (Multi-leaf intensity Modulating Collimator, NOMOS Radiation Oncology, North American Scientific, Cranberry Township, PA) or MLC collimators. Details of the planning process were previously described (5). Briefly, the MiMIC is a dynamic multivane intensity-modulated collimator delivery system that irradiates in a slice-by-slice axial arc rotation approach, with slices 1.66 cm in width. The intensity pattern of the beam was modified every 5° of rotation through usually a 270° arc. Beam intensities were modulated with 10 nonzero steps. The treatment couch was moved between arcs craniocaudally, monitored by an indexing device. The second method used a conventional MLC collimator, in which beam intensity was modulated by the superimposition of a number of static segments of uniform radiation intensity (called step-and-shoot delivery).

Each treatment field was divided into 1 × 1-cm beamlets, and intensities of the beamlets were optimized by the inverse-planning process. Before the start of IM optimization, the number of beams, degree of IM, beam angles, and beam energy were selected at the discretion of the planner.

The primary tumor was irradiated by using either of these IMRT techniques described. The neck and supraclavicular lymph nodes